ENVIRONMENTAL RESEARCH PLAN
OF THE FEDERAL MINISTRY OF THE ENVIRONMENT,
NATURE CONSERVATION AND REACTOR SAFETY
- Environmental Planing/Ecology -

Sections of a
Research Project 108 02 085/01

Texte
84
97
ISSN
0722-186X

Wadden Sea Ecosystem Research
Sub-project Wadden Sea of Schleswig-Holstein

Salt-marsh protection in the Schleswig-Holstein Wadden Sea area

Basic principles, objectives and implementation

by

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By order of the Federal Environmental Agency and the
State of Schleswig-Holstein

Publications by the Federal Environmental Agency in the TEXTe series are available against advance payment of **DM 15,--** by bank transfer, crossed cheque or paying-in form to

Account number 4327 65 - 104 at the
Postbank Berlin (BLZ 10010010)
Fa. Werbung und Vertrieb
Ahornstraße 1-2
10787 Berlin

*Alongside the remittance, please send a written order naming the **volume number** from the TEXTE series, and the **name** and **address** of the orderer to the Firma Werbung und Vertrieb.*

Publisher: Federal Environmental Agency (Umweltbundesamt)
Postfach 33 00 22
14191 Berlin
Tel.: +49/30/8903-0
Telex: 183 756
Telefax: +49/30/8903 2285
Internet: http://www.umweltbundesamt.de

Editorial office: Section II 1.1/GÖW
Thilo Mages-Dellé

Charge: free of charge

Berlin, June 1998

Foreword

The Wadden Sea is a habitat in the transition zone between land and sea. The physicochemical environmental conditions prevailing in this zone are subject to strong variations, caused by the perpetual alternation of low tide and high tide, high temperatures in the summer and, in some years, ice formation in the winter, as well as variations in the salinity. The species living in these tidal flats are specially adapted to these conditions.

The high productivity of the Wadden Sea is the basis for the recruitment of North Sea fish stocks. It is also the prerequisite for its function as a point of convergence in bird migrations, thus linking the Wadden Sea to the Arctic and southern Africa.

The political desire to preserve these special characteristics is expressed in a number of agreements. For example, the Wadden Sea has gained recognition as a wetland of international significance (RAMSAR Convention) as well as a nature reserve under the EU Directive on the conservation of birds. The *Länder* Schleswig-Holstein, Lower Saxony and Hamburg have designated the German Wadden Sea as national parks, which have also been recognised as biosphere reserves under the UNESCO programme "Man and the Biosphere". Supranational protection and management measures have been adopted at Danish-Dutch-German governmental conferences held at regular intervals.

The efforts undertaken to protect the Wadden Sea are contrasted by anthropogenic pressures: inputs of nutrients and pollutants as well as manifold uses by fishery, shipping and tourism. Moreover, the natural dynamics have been restricted by securing the coastline (construction of dikes). These anthropogenic impacts increased to such an extent in the past that there is reason to fear that the ecosystem might sustain fundamental damage. Also, in many areas there was a lack of basic understanding of natural relationships and of the consequences of anthropogenic impacts. These shortcomings were investigated within the framework of the Ecosystem Research Programme of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), together with corresponding initiatives undertaken by the Federal Ministry for Education, Science, Research and Technology (BMBF).

The Wadden Sea Ecosystem Research programme consists of two separate sub-projects for the parts of the German Wadden Sea that belong to Schleswig-Holstein and Lower Saxony, as well as an overall synthesis. Each project consisted of an applied research part, funded by the respective *Land* and the BMU, and a basic research part, funded by the BMBF. Numerous universities and institutes participated in the more than 100 individual projects from fields as diverse as biology, geology, oceanography, hydrology, physics, chemistry, meteorology and sociology. By the end of 1998, the results of the individual projects will be combined and evaluated in an „Overall Synthesis of Wadden Sea Ecosystem Research" with consideration of scientific, methodological and environmental policy aspects, and taking into account further coastal research projects as well as the experiences gained in other joint ecosystem research projects. The synthesis is to provide an assessment of future research needs.

The aims of the joint interdisciplinary Wadden Sea Ecosystem Research programme were:

- to gain a basic understanding of the functioning of the system nature-man in the Wadden Sea,
- to provide a scientific framework for solutions to priority environmental problems in the Wadden Sea,
- to derive criteria for the assessment of the ecological status of the Wadden Sea,
- to develop monitoring strategies, and
- to provide instruments for the protection and management tasks of the national park administrations.

The basic research of the Lower Saxony project ELAWAT (*Elastizität des Ökosystems Wattenmeer* - elasticity of the Wadden Sea ecosystem) dealt with the question "stability through variability?". The research focused on such aspects as the mosaic-like pattern and temporal changes of sediment colonisation and chemistry, the distribution of birds as well as the recolonisation of areas devastated experimentally, or as a result of ice winters.

The applied research of the Lower Saxony project focused on the investigation of the subsystem mussel bank and on „black spots". Further areas included the development of monitoring strategies for the benthos, fish and crustaceans, investigations on pollutants in the food web, and the socio-economic situation of the fishery.

The basic research of the Schleswig-Holstein project SWAP (*Sylter-Wattenmeer-Austauschprozesse* - exchange processes in the tidal flats of Sylt) comprised transformations of matter and the transport of matter and organisms in the Wadden Sea as well as exchange with the North Sea, the terrestrial environment and the atmosphere.

The applied research of the Schleswig-Holstein project involved the mapping of numerous aspects, such as occurrence of fish, crustaceans, seals, birds and tourism. The establishment of a geographical information system allowed to process the information for use by the National Park authority for its planning and management tasks. Further aspects investigated included the impact of shrimp and mussel fisheries, the effects of disturbance on seals and on resting and nesting birds, the effects of intensive sheep grazing on the flora and fauna of salt marshes as well as the socio-economic system of the National Park region.

Results of the applied research part of the Schleswig-Holstein Wadden Sea Ecosystem Research project are presented in UBA-Texte 67/97 to 84/97.

Wadden Sea Ecosystem Research Secretariat

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4/1994 3. Wissenschaftliches Symposium Ökosystemforschung Wattenmeer, Norderney, 15. bis 18. November 1992 (Band 1 und 2)

1. Report No. UBA-FB 93-101	2.	3.

4. Report Title

Saltmarsh protection in the Schleswig-Holstein Wadden Sea area

5. Autor(s), Family Name(s), First Name(s)

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6. Performing Organisation (Name, Adress)

Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer, Schloßgarten 1, 25832 Tönning

7. Sponsoring Agencies (Names, Adresses)

Umweltbundesamt, Bismarckplatz 1, D - 14193 Berlin

Ministerium für Natur und Umwelt des Landes Schleswig-Holstein, Grenzstr. 1 - 5, D - 24149 Kiel

8. Report Date: August 1994

9. Publication Date:

10. UFOPLAN - Ref. No.: 108 02 085/01

11. No. of Pages: 55

12. No. of References: 111

13. No. of Tables: 8

14. No. of Figures and Diagrames: 25

15. Supplementary Notes

Final report of the project ÖSF-A 6.3 "Saltmarsh protection in the Schleswig-Holstein Wadden Sea area"

16. Abstract

The report presents a concept for saltmarsh protection in the Schleswig-Holstein part of the Wadden Sea area. The report is divided in seven chapters. After a short introduction an overview about the characteristics of saltmarshes in Middle Europe is given. Chapter three presents the most recent calculation of the total area of saltmarshes in the Schleswig-Holstein part of the Wadden Sea. Chapter four deals with the impact of human use on saltmarshes. Chapter five describes the trilateral recommendations and legislation about saltmarsh protection. Chapter six outlines the concept for saltmarsh protection in the Schleswig-Holstein Wadden Sea area. This chapter is divided in four parts. Part one describes the basic features for saltmarsh protection, part two formulates the protection aims and part three gives an owerview about the present status in Schleswig-Holstein. Part four tackles future problems and presents solutions.

17. Keywords

Wadden Sea of Schleswig-Holstein, National Park, Saltmarsh, Saltmarsh Protection, Coastal protection, Agriculture, Flora, Fauna, Management;

18. Price	19.	20.

1. Berichtsnummer UBA-FB 93-101	2.	3.

4. Titel des Berichts

Salzwiesenschutz im Schleswig-Holsteinischen Wattenmeer
Grundlagen, Zielsetzung und bisherige Umsetzung

5. Autor(innen), Name(n), Vorname(n)

Stock, Martin, Kiehl, Kathrin und Reinke, Hans-Dieter

6. Durchführende Institution (Name, Anschrift)

Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer, Schloßgarten 1, 25832 Tönning

7. Fördernde Institutionen (Name, Anschrift)

Umweltbundesamt, Bismarckplatz 1, 14193 Berlin

Ministerium für Natur und Umwelt des Landes Schleswig-Holstein, Grenzstr. 1 - 5, 24149 Kiel

8. Abschlußdatum
August 1994

9. Veröffentlichungsdatum

10. UFOPLAN - Nr.
108 02 085/01

11. Seitenzahl
55

12. Literaturangaben
111

13. Tabellen
8

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25

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Abschlußbericht des Teilprojekts ÖSF-A 6.3 "Schutz- und Managementkonzept für Salzwiesen"

16. Kurzfassung

In diesem Bericht wird ein Salzwiesenschutzkonzept für das Wattenmeer in Schleswig-Holstein vorgestellt. Der Teilprojekt-übergreifende Bericht ist in sieben Kapitel gegliedert. Einleitend wird eine kurze Charakterisierung der Salzwiesen Mitteleuropas vorgenommen. Im folgenden Kapitel werden die Ergebnisse der aktuellen Flächenermittlung der Salzwiesen an der Wattenmeerküste von Schleswig-Holstein vorgestellt. Das vierte Kapitel behandelt in einer kurzen Übersicht die Nutzung und Gefährdung der Salzwiesen. Kapitel fünf beschreibt die überregionalen Empfehlungen und gesetzlichen Vorgaben zum Salzwiesenschutz. Das sechste Kapitel stellt das eigentliche Schutzkonzept für die Salzwiesen im schleswig-holsteinischen Wattenmeer dar. Im ersten Teil werden ökologisch begründete Leitlinien für den umfassenden Schutz der Salzwiesen vorgestellt und diskutiert. Im zweiten Teil wird das Schutzziel formuliert, im dritten Teil wird der aktuelle Stand des Salzwiesenschutzes in Schleswig-Holstein dargestellt und im vierten Teil werden offene Probleme angesprochen und Lösungswege vorgestellt.

17. Schlagwörter

Schleswig-Holsteinisches Wattenmeer, Nationalpark, Salzwiese, Salzwiesenschutz, Küstenschutz, Landwirtschaft, Flora, Fauna, Management

18. Preis	19.	20.

Acknowledgement

The implementation of the project would not have been possible without the kind help and assistance of many colleagues and friends, to whom we would like to express our particular gratitude.

Doris Timm was responsible for producing several drawings as well as for the planimetry of the vegetation maps and various aerial photographs. She also helped us with many other assorted tasks. Katja Pautzke performed the necessary preparation of maps and aerial photographs. Reimert Neuhaus from the University of Kiel assisted with the interpretation of the aerial photographs of the saltmarshes on Sylt. Bernd Hälterlein, David M. Fleet and H.U. Rösner provided valuable bibliographic references.

The Departments of Agriculture and Water Resources (ALW) in Husum and Heide supplied the foreshore maps required. The surveying offices of the two ALW were responsible for surveying the research areas in the Sönke-Nissen-Koog and on the Friedrichskoog foreshore. They also provided the materials. The ALW in Husum made the CIR aerial photographs from the research areas in the Sönke-Nissen-Koog taken in 1993 available to us. Mr. Wieland and Mr. Christiansen from the Büsum hydrography office of the ALW Heide gave us access to old aerial photographs of Trischen and allowed us to use them for evaluation.

We also thank our colleagues in the National Park Office and in the working for their friendly and helpful cooperation during our work. Special mention must go to the members of the "Saltmarshes" working group for the many fruitful discussions held.

I am particularly grateful to Eckart Schrey, Detlef Hansen and Kirsten Boley-Fleet for enabling me (Martin Stock) to work on this protection concept within the scope of the project work at the National Park Office. Many thanks also to K. Dierssen for his critical appraisal of the concept. With the benefit of his vast knowledge and the necessary impartiality he was able to help us thoroughly revise the manuscript shortly before its completion.

Our work was sponsored by the German Federal Environmental Agency within the framework of the Environmental Research Plan of the Federal Ministry of the Environment, Nature Conservation and Reactor Safety (Project 108 02 085/21) and by the State of Schleswig-Holstein.

Abstract

Salt-marshes in the Schleswig-Holstein Wadden Sea

Salt-marshes are found in the supralittoral zone of the Wadden Sea between Den Helder in The Netherlands and Esbjerg in Denmark along the mainland coast, on the Wadden Sea islands and on the Halligen (low salt-marsh islands). This zone forms the transition between the Wadden Sea and the adjoining mainland marshes or dunes. The numerous dykes and embankments in the Wadden Sea have split what used to be an unbroken strip of salt-marshes along the mainland coast into isolated sections. Salt-marshes are now one of the most rare habitat types in continental Europe. They are acutely threatened by a wide range of anthropogenic influences, even within the borders of the national parks, and are in need of special protection.

This report is intended to provide the basis for a protection and management concept for the salt-marshes in the Schleswig-Holstein Wadden Sea National Park and was compiled within the framework of the "Schleswig-Holstein Wadden Sea" ecosystem research project.

Ecological significance

Coastal salt-marshes develop in areas which are flooded periodically by seawater. The animal and plant communities living there can be divided into zones on the basis of the frequency and duration of inundation, which affect the salinity and aeration of the soil. Below the mean high tide level pioneer vegetation such as *Salicornia europaea* can become established, followed by *Puccinellia maritima* further up the shore and by *Festuca rubra*. Particularly the violet flowers of *Aster tripolium* and *Limonium vulgare* attract attention.

Many of the organisms resident here could not survive in the long term in other habitats. In addition to halophytes these organisms are primarily many invertebrate species (arachnids and insects), which are dependent upon the salt-marshes of the Wadden Sea for their survival. Of the vertebrates, birds in particular make use of the salt-marshes as breeding, feeding and roosting grounds, e.g. Brent Geese, Avocets, Black-headed Gulls and terns.

Salt-marsh areas in the Schleswig-Holstein Wadden Sea

Wadden Sea salt-marshes develop naturally in calm areas in which sediment is transported and deposited by the sea. Once the mud flats have reached an appropriate level in relation to the mean tidal high water mark, sufficient aeration takes place during the periods of exposure and pioneer plants such as Salicornia and Spartina can become established; a salt-marsh starts to form. Technical measures to promote sedimentation and thus to accelerate the development of salt-marshes have been implemented for decades throughout the Wadden Sea region. Most of today's foreland salt-marshes are the result of land reclamation and are characterised by an artificial, regular drainage system. There are only few examples where the boundary to the seaward side is formed by a natural, non-developed transition zone with erosion features.

In Schleswig-Holstein the salt-marshes extend over a total area of roughly 10,000 hectares. 58 % of all salt-marshes lie within the boundaries of the National Park. These include many of the foreland salt-marshes and the natural Wadden Sea island and mainland salt-marshes. However, only 5 % of the Hallig salt-marshes lie within the National Park.

Impact of sheep grazing

Decades of intensive sheep grazing have led to the development of structurally simple, grass-dominated vegetation forms in the Schleswig-Holstein foreland salt-marshes. Typical salt-marsh plant species that are sensitive to grazing have become scarce. Grazing experiments within the Ecosystem Research Project showed, that salt-marsh vegetation suffers greatly from intensive grazing and trampling by sheep, that grazing prevents most plants from flowering and that species sensitive to grazing are severely restricted in both their vegetative and their generative development and are usually absent in intensively grazed areas. If grazing is discontinued typical salt-marsh species such as *Aster tripolium*, *Artemisia maritima* and *Halimione portulacoides* establish themselves and the plants flower and propagate again.

Grazing leads to changes, for example in the vegetation structure, microclimate and soil structure, which in turn influence the species composition and dominance structure of the fauna. These changes are mainly a result of cropping, trampling and the intro-

duction of faeces. Numerous invertebrate species suffer a significant population decline as a result of grazing, particularly those specialised in herbs that are sensitive to grazing and those utilising flowers or pollen.

Coastal protection

Despite their ecological significance salt-marshes were regarded as a dyke protection structure in the past. They cushion the wave energy to which dykes are exposed during storm surges. Surface erosion of the salt-marshes must be prevented if this function is to be maintained. From the point of view of coastal protection it is therefore desirable to have sheep compact the salt-marsh soil with their feet and keep the turf closely cropped. According to present knowledge there is no longer a basic demand for salt-marsh grazing for coastal protection reasons. Taller ungrazed vegetation can promote sedimentation and lead to an accelerated horizontal growth of the salt-marsh.
The artificial drainage channels have a positive effect on low-lying salt-marshes by improving soil aeration, however, grazing neutralises this effect. On higher lying salt-marshes there was no detectable effect of artificial drainage on soil development. In areas with a positive sedimentation salt-marshes can develop in the shelter of land reclamation dykes even without a ditch building and maintenance.
These results permit the following conclusions to be drawn: Thanks to their protective plant growth, foreland salt-marshes are sufficiently resistant to large-scale erosion even without ditch building/maintenance and grazing. They may, however, be at risk from erosion to the seaward edge. This can be adequately counteracted by constructing protective brushwood groynes. Management measures in foreland salt-marshes should be limited to the protection of eroding edges using brushwood groynes and the drainage of the foot of the dyke using narrow ditches close to the dyke and a main drainage channel. Systematic management measures covering the entire salt-marsh area are not necessary for coastal protection.

Basic principles for the salt-marsh protection

At the Sixth Trilateral Governmental Conference on the Protection of the Wadden Sea in 1991 in Esbjerg the environment ministers of the Wadden Sea states declared that the Wadden Sea should be protected as a natural, self-preserving ecosystem in which

natural processes can take place undisturbed. This should involve further harmonisation of the interests of nature conservation and coastal protection, with the safety of the population being acknowledged as a matter of prime importance. Certain aspects of the ministerial declarations were implemented in Schleswig-Holstein in the form of the State Nature Conservation Law (LNatSchG). This law places salt-marshes under special protection and bans foreland salt-marsh management work and grazing in the National Park. These can, however, be allowed under a special permit.

The internationally acknowledged overriding objective for salt-marshes in the Wadden Sea is their conservation. It forms the basis for the ban on further embankment work in the region and the aim of increasing the total salt-marsh area, for example by way of opening summer dykes.

The undisturbed course of natural processes is declared as a prime objective of the Schleswig-Holstein, Hamburg and Lower Saxony National Park Laws. The guiding principle for the protection of the salt-marshes is that they should be largely free from human influence, with tidal channels left to meander, a geomorphological structure typical of the habitat and a distribution of flora and fauna governed by natural dynamic processes.

From the point of view of nature protection the cessation of sheep grazing and the reduction of coastal protection measures, particularly a discontinuation of the maintenance of artificial drainage channels, is recommended in Schleswig-Holstein.

Implementation of the protection concepts

The implementation of the concepts for salt-marsh protection is a long-term process. A first step in this process is the large-scale cessation of agricultural usage. The second stage involves the implementation of coastal protection activities more compatible with nature. In parallel with these measures, a comprehensive concept is to be developed dealing with the control of the flow of visitors to the Wadden Sea. In the long term, all salt-marshes should be integrated into the National Park within the framework of an amendment to the National Park Law. This will apply in particular to the salt-marshes in the 150 m wide strip between the border of the National Park and the dyke, the estuarine salt-marshes at the mouth of the Elbe and in the Godel marsh on Föhr as well as to the salt-marshes on the Wadden Sea islands.

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1. Introduction

Salt-marshes are found in the supralittoral zone of the Wadden Sea between Den Helder in The Netherlands and Esbjerg in Denmark along the mainland coast, on the Wadden Sea islands and on the Halligen (low salt-marsh islands). Marine and terrestrial biotic communities intermingle in this transition zone between the Wadden Sea and the mainland marshes or dunes. Its special environment gives rise to the development of characteristic flora and fauna. The salt-marshes of the Wadden Sea are at the same time the scene of an extreme conflict of interests between coastal protection, agriculture, tourism and nature conservation (c.f. for example KEMPF et al. 1987, OEVESEN 1990, KIEHL & STOCK 1994, STOCK et al. 1995).

The numerous dykes and embankments in the Wadden Sea have split what used to be an unbroken strip of salt-marshes along the mainland coast into isolated sections. Salt-marshes are now one of the most rare biotope types in continental Europe. They are acutely threatened by a wide range of anthropogenic influences, even within the borders of the national parks, and are in need of special protection (SSYMANK et al. 1996).

This report which is intended to provide the basis for a protection and management concept for the salt-marshes in the Schleswig-Holstein Wadden Sea National Park was compiled within the framework of the "Schleswig-Holstein Wadden Sea" ecosystem research project. It describes the usage of and threats to the salt-marshes, specific problem areas and the present status of salt-marsh protection. These are then taken as the basis for the development and discussion of guiding principles for the protection of the salt-marshes in the Schleswig-Holstein Wadden Sea.

The interdisciplinary ecosystem research project in the Schleswig-Holstein Wadden Sea was conceived with a view to establishing and analysing the intricate, reciprocal relationships existing between natural processes and anthropogenic influences in the Wadden Sea and with the aim of protecting the Wadden Sea over the long term in

the interests of both mankind and nature (LEUSCHNER 1988, LEUSCHNER & SCHERER 1989).
Part A of the project was mainly concerned with structural ecosystem analysis and applied research, whereas Part B concentrated on functional ecosystem research, processes and material balance. In addition to research necessary to fill in gaps in the existing knowledge about the Wadden Sea ecosystem, many of the projects from Part A also developed strategies for dealing with major environmental problems in the Wadden Sea. It was possible to present the nature conservation authorities with advice on practical courses of action even while the study was still in progress.

Within the framework of sub-project A 6.3 this report was compiled with the close co-operation of the ecosystem research working group on salt-marshes, who contributed data and information towards the development of the salt-marsh protection concept. The work of HÄLTERLEIN et al. (1991) was taken as a basis for the area reference system used. The concept covers all salt-marshes on the North Sea coast of Schleswig-Holstein including those on the Wadden Sea islands and Halligen. Data on coastal protection were gathered and evaluated in the course of co-operation between the National Park Office and the relevant coastal protection authorities.

In this protection concept, attention is focused on agriculture and coastal protection as major factors of influence. Tourism and control of the flow of visitors are only dealt with superficially. These aspects are treated in detail in KNOKE & STOCK (1994). A more extensive, spatial protection concept was developed in the synthesis phase of the Wadden Sea ecosystem research and will be incorporated into a National Park plan (STOCK et al. 1996).

2. Characteristic features and ecological significance of salt-marshes

2.1 Characteristic features of the salt-marshes of North West Europe

Coastal salt-marshes develop in areas which are flooded periodically by seawater. The animal and plant communities living there can be divided into zones on the basis of the frequency and duration of inundation, which affect the salinity and aeration of the soil.

The classification of salt-marshes as defined by CHAPMAN (1974) takes account of both floristic and phytosociological aspects. Accordingly, salt-marshes throughout the world can be subdivided into nine geographic groups (Tab. 1). In contrast to CHAPMAN (1974), ADAM (1990) proposes classification highlighting the parallels between the geographically delimited regions. He differentiates between salt-marshes in the Arctic, the Boreal zone, the temperate zone in Europe, Western and North America, Japan, Australia and South Africa, the West Atlantic region, the dry coastal zone and in the Tropics. DIJKEMA (1984) suggested a geographic differentiation of the salt-marshes in Northern Europe, which GÉHU & RIVAS - MARTINEZ (1984) subdivided into smaller areas (Fig. 1). This subdivision is based on the distribution of the salt-marsh flora.

The salt-marsh vegetation of the European, North American and Siberian Arctic forms a phytogeographic unit with species of circumpolar distribution. The most common plant community is the *Puccinellietum phryganodis* with *Puccinellia pryganodes* as dominant species. Generally speaking, Arctic salt-marshes are not rich in species and support only a few plant communities (e.g. DIJKEMA 1984, ADAM 1990).

The characteristic features of the salt-marshes of Western Scandinavia and the Baltic region are essentially governed by the salinity levels of the seawater. The

salinity decreases from 27 – 34% around the Norwegian coast to 3 – 5% in the inner Baltic. A particular feature of the coastal zone in this region is the rise in land level, which may be as much as 1cm per year. As a consequence of this, the vegetation zones are
constantly shifting seawards (DIJKEMA 1984). A wide range of species and different vegetation types can be found on account of the sometimes considerable variation in abiotic factors in this geographic area.

Tab. 1 Classification of salt-marsh types according to CHAPMAN (1974)

1. Arctic group
2. Northern European group
   - Scandinavia
   - North Sea coast
   - Baltic coast
   - Channel coast
   - SW Irish coast
3. Mediterranean group
   - W. Mediterranean coast
   - E. Mediterranean coast
   - Caspian Sea
4. Western Atlantic group
   - Bay of Fundy type
   - New England type
   - Coastal Plains type
5. Pacific - American group
6. Sino - Japanese group
7. Australian group
   - Australia
   - New Zealand
8. South American group
9. Tropical group

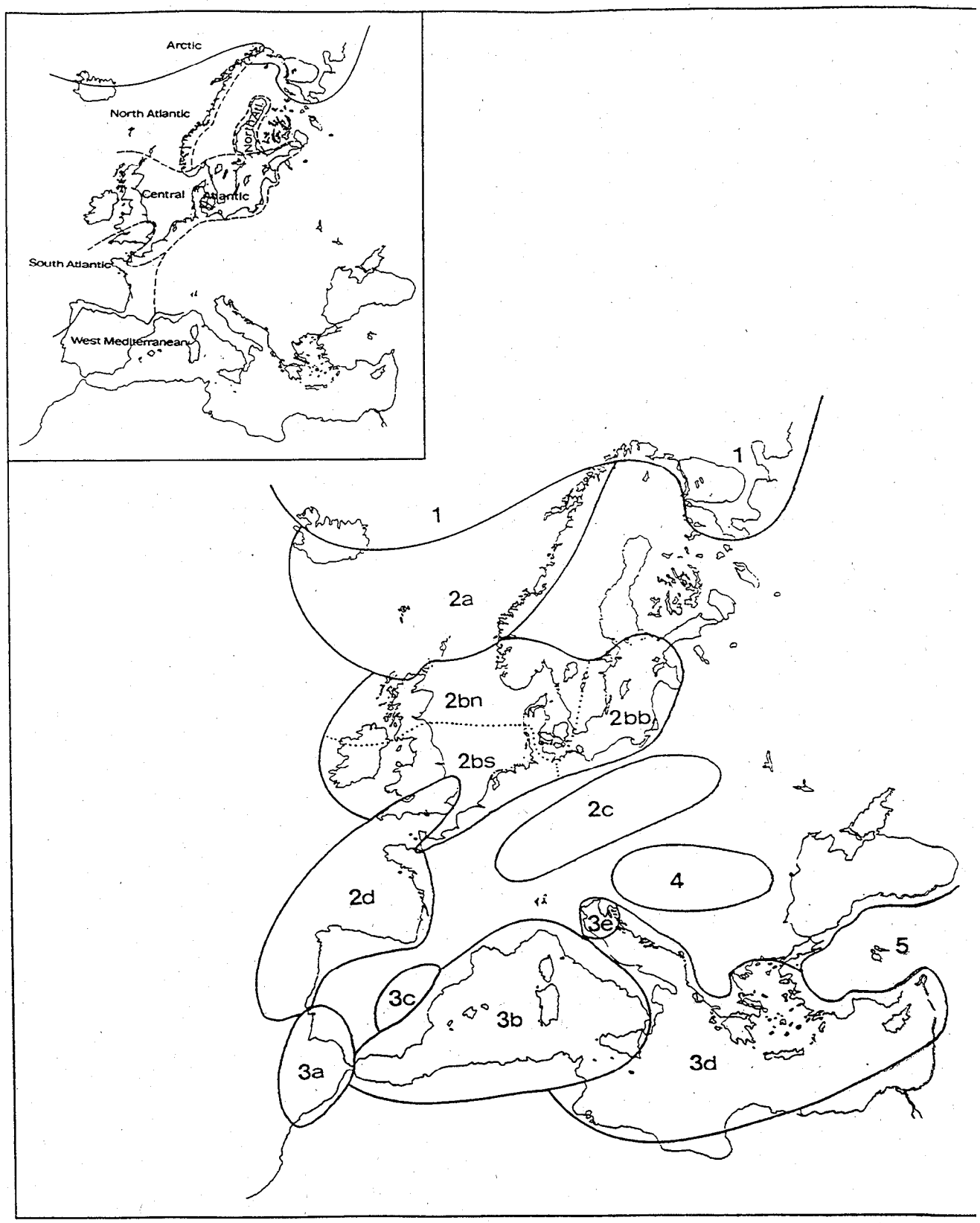

Fig. 1 Boundaries and subdivision of the Atlantic coasts in the Euro-Siberian region based on the distribution of coastal plant species. According to DIJKEMA (1984) and GÉHU & RIVAS - MARTINEZ (1984).1 Arctic region, 2 Euro-Siberian region, 2a Boreal - Atlantic region, 2b North Atlantic - Baltic, 2c Sub-Atlantic, 2d Cantabrian - Atlantic, 3 Mediterranean region, 4 Pontic region, 5 Iranian - Turkish region.

Although phytogeographic similarities exist between the Scandinavian salt-marshes and those of the British Isles and the Wadden Sea, there are also certain differences. In Scandinavia, for example, plant communities with *Spartina anglica* and *Halimione portulacoides* do not occur. The northern boundary of the distribution of *Halimione portulacoides* lies on the Skallingen peninsula in Denmark. To the south of Skallingen this species often dominates the vegetation of natural salt-marshes in the temperate European climate zone, thus distinguishing such salt-marshes from related types in other temperate regions. Plant communities with *Limonium vulgare*, *Artemisia maritima* and *Parapholis strigosa* only occur in the transition zone of the geographic gradient mentioned (BEEFTINK 1959, DIJKEMA 1984, ADAM 1990).

The salt-marsh vegetation of the Western European coasts and in particular that of the Wadden Sea is described in detail by BEEFTINK (1977), DIJKEMA & WOLFF (1983), DIJKEMA (1984), DOODY et al. (1984) and GÉHU (1984). The vegetation of the Wadden Sea salt-marshes in Schleswig-Holstein is described by RAABE (1981), HAGGE (1989, 1990) and DIERSSEN et al. (1991).

2.2 Characteristic features of the Wadden Sea salt-marshes

2.2.1 Differentiation of salt-marsh types according to geomorphological aspects

Extensive coastal salt-marshes can only form in areas where a shallow shelf exists with a sufficient supply of sediment. They develop either on sediments deposited by tidal action or on peat deposits. DIJKEMA (1987) produced a classification system for European salt-marsh types which takes into consideration the nature and origin of the substrate, the geological and hydrological features of the location and the geomorphology of the salt-marshes in relation to the ecological conditions.

According DIJKEMA (1987), three different types of salt-marsh can be identified in the Wadden Sea region: Coastal sand salt-marshes form in the shelter of dunes, beach ridges, sandy beaches and shingle beaches. These are characterised by a thin layer of clay on a sandy substrate. The majority of sand salt-marshes have a natural morphology. They are found in Schleswig-Holstein on the leeward side of the sandy islands and in several sites on the mainland. They frequently develop on the edge of dunes. Extensive natural sand salt-marshes occur on the islands of Sylt, Amrum and Trischen as well as on the west coast of the Eiderstedt peninsula. The sand salt-marshes on Eiderstedt alternate between low sandy beach ridges with primary dune vegetation and sandy salt-marsh areas (Fig. 2) (EHLERS 1988, DAUMANN 1990).

Foreland salt-marshes form on coastlines where sedimentation is sufficient. They only develop naturally where sedimentation areas are protected by a chain of islands and sands which form a barrier to wave action. Most of the existing foreland salt-marshes are the result of land reclamation and are characterised by an artificial, regular drainage system. The seaward boundary and transition zone to terrestrial habitats of existing foreland salt-marshes is rarely natural.

Fig. 2: With adequate sedimentation, naturally structured salt-marshes form in the shelter of beach ridges and spits as well as on the leeward sides of the islands. These salt-marshes are drained by meandering tidal channels but also feature salt pans, sometimes with a covering of water (from STOCK et al. 1995).

Almost all of the salt-marshes in the National Park are of the foreshore type. Naturally accreted foreland salt-marshes only occur in the Schleswig-Holstein Wadden Sea on the northern coast of the island of Föhr and in Königshafen on Sylt. The salt-marshes occurring on the Nordfriesian Halligen are also of the foreland type, with some still featuring near-natural geomorphological structures.

Estuarine salt-marshes form in sheltered locations in the brackish waters of river estuaries. Salt-marshes of this type develop on soils which are rich in nutrients and

contain fine sediments. Upstream the vegetation gradually changes to tidal reed beds and carr. Most estuarine salt-marshes are confined by dykes or separated from the Wadden Sea by tidal barrages. A few remaining fragments of this salt-marsh type still occur in Schleswig-Holstein on the Neufeld foreshore at the mouth of the Elbe, in the embanked Eider estuary and in the Godel marsh on the island of Föhr.

To summarise, salt-marshes with natural or near-natural morphological structures, with a natural drainage system and without artificial coastal protection structures in the form of brushwood groynes or stone revetments are rare in the Schleswig-Holstein Wadden Sea (Fig. 3). They now only occur on the islands of Sylt and Trischen, on the northern coast of the island of Föhr and on the west coast of Eiderstedt in St. Peter-Ording. With the exception of Föhr, these are sand salt-marshes. The western and central sections of the salt-marshes on Föhr are naturally accreted foreland salt-marshes. Salt-marshes with near-natural drainage and without brushwood groynes only occur on Amrum and in the Neufeld foreshore area at the mouth of the river Elbe. Salt-marshes with near-natural drainage but influenced by coastal protection measures in the form of brushwood groynes and stone revetments occur on the small Halligen and in a few restricted areas along the mainland coast. Most of the large Halligen also feature near-natural morphology with near-natural drainage, however, with erosion protection in the form of a revetment. The remaining salt-marshes which are not specifically marked in Fig. 3 have been influenced to a great extent by coastal protection measures.

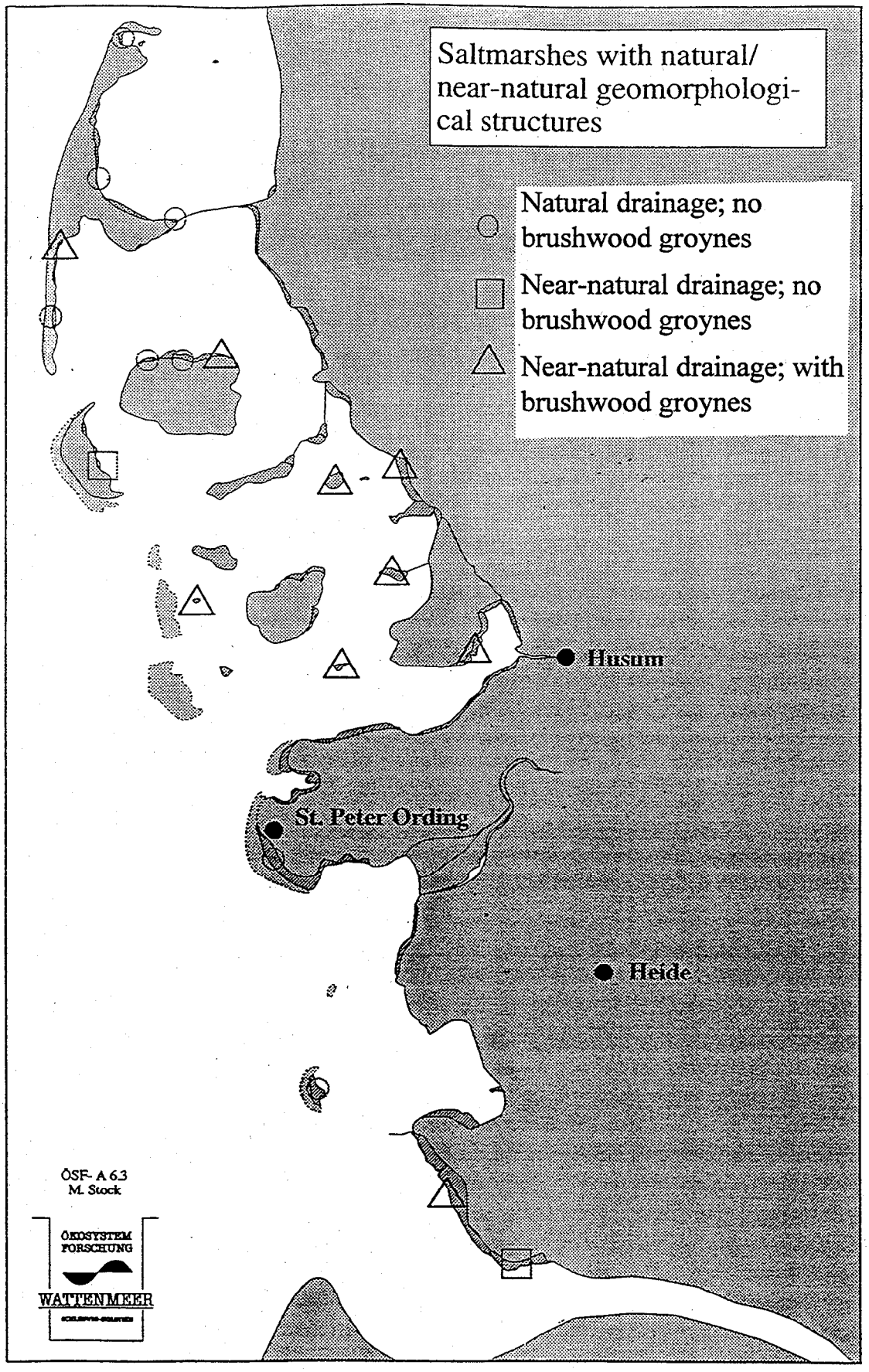

Fig. 3: Salt-marshes (dark shaded areas) with natural/near-natural geomorphological structures in the Schleswig-Holstein Wadden Sea.

2.2.2 Salt-marsh formation and morphology

2.2.2.1 Natural salt-marsh formation

Wadden Sea salt-marshes develop naturally in calm areas in which sediment is transported and deposited by the sea. Once the mud flats have reached an appropriate height above the mean tidal high water mark, sufficient aeration takes place during the periods of exposure and pioneer plants such as Glasswort *Salicornia spp* and Cord Grass *Spartina spp* can established themselves (c.f. DIJKEMA 1987). With increasing density of pioneer-plants, the first small drainage channels start to form at ebb tide. This enhances soil aeration and creates the necessary conditions for the growth of Common Salt-marsh Grass *Puccinellia maritima*. In the mean high water zone Common Salt-marsh Grass grows densely and enhances sedimentation and prevents erosion of existing sediment deposits. The sedimentation rates in these stages of development are higher than at any other stage of salt-marsh formation. The patchy covering of *Puccinellia maritima* in the initial stage of salt-marsh genesis promotes the formation of tidal channels and thus helps to improve drainage of the site. This in turn creates favourable habitat conditions for the establishment of further plant species (Fig. 4) (WOHLENBERG 1933, DIJKEMA et al. 1988).

Today such processes take place naturally on the leeward side of the Wadden Sea islands or in the shelter of beach-ridge systems and offshore sands, for example in St. Peter-Ording and off Westerhever. The particles transported with the water on the incoming tide are deposited at a rate governed by the speed of the current and the weight of the particles. Sandy, coarser and heavier particles are deposited on the seaward edge of the salt-marsh or tidal channels, whereas the water transports the finer, usually clay particles further towards the land before they are deposited. Due to their structure, sandy particles tend to be more loosely packed and can not be compressed. The finer clay constituents, on the other hand, dry out and shrink. Furthermore grazing can compact and compress them mechanically. Accordingly, salt-marshes rise in height from their landward to their seaward side. Erosion due to wave action occurs at the seaward edge of salt-marshes. Under certain

circumstances multiterraced salt-marshes are created when new salt-marsh formation occurs in front of the seaward erosion edge (JAKOBSEN 1954).

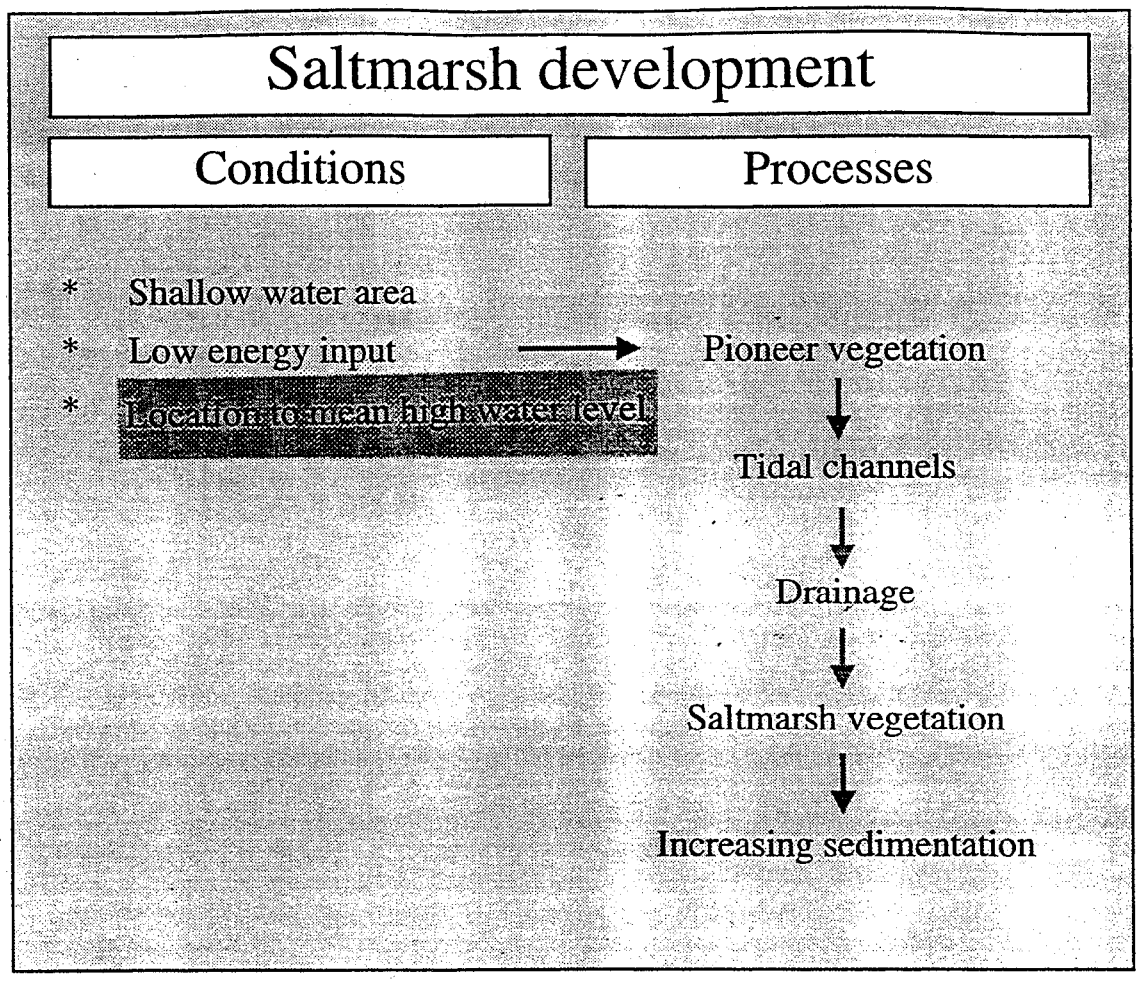

Fig. 4: The process of salt-marsh formation: Salt-marshes form in the Wadden Sea in shallow water in the vicinity of the mean high water level, where energy input is low. Following the establishment of pioneer vegetation, small tidal channels form which help to drain the site. This promotes the establishment of permanent salt-marsh vegetation which can then collect more sediment. According to DIJKEMA (unpublished).

2.2.2.2 Technically assisted salt-marsh formation

Technical measures to promote sedimentation and thus to accelerate the development of salt-marshes have been implemented for decades throughout the Wadden Sea region. The oldest method was to drain existing salt-marshes with

ditches every 5 to 15 metres at right angles to the coastline and extending into the mud flats. The ditches were dug out regularly. The main aim was to drain and aerate the sediment in order to create the necessary conditions for the permanent establishment of plants. This practice enabled the aerated soil area to be extended relative to the mean high water level and the size of the plant-covered salt-marsh zone to be increased. This method dates back to 1740 in the Dollart region (STRATINGH & VENEMA (1855) in DIJKEMA et al. 1990).

Active and systematic creation of salt-marshes employing sedimentation fields made of brushwood groynes has been practised in Schleswig-Holstein since the turn of the century (HINRICHS 1931, KÖNIG 1987). Brushwood groynes are erected at intervals of 200 to 400 m at right angles to the coastline. Further groynes are then built at right angles to these at approximately 200 m intervals, producing sedimentation fields covering areas of between 200 x 200 m and 200 x 400 m. The size of the sedimentation fields depends on the degree of exposure of the coastline and thus on the extent to which the corresponding stretch of coast is subject to erosion or sedimentation. Traditionally three rows of sedimentation fields, each field with a size of 200 x 200 m, are created in front of an existing foreshore (Fig. 5).

The brushwood groynes themselves normally consist of double rows of posts filled with brushwood and secured with wire. The top of the groynes may be as much as 30 cm above the mean high water level. The size, type and construction materials used for the groynes vary from region to region. In Schleswig-Holstein spruce posts and spruce brushwood are used; in The Netherlands deciduous trees are generally employed, although experiments have recently been conducted with various other types of wood (HEKHUIS & DE VRIES 1994). Some of the groynes in Schleswig-Holstein and Niedersachsen have also been filled with PVC tubing or PVC sheeting or made from pre-fabricated concrete sections or rubble (e.g. ERCHINGER 1970). In the 1930s, groynes were also constructed in Dithmarschen by the so-called Gabion-method using wire baskets filled with gravel. Except where groynes are made of prefabricated concrete sections, ditches are created on both sides of the groynes immediately following their completion and are maintained at regular

intervals. The excavated material is used to protect the groynes against current-induced erosion damage and floating ice in winter.

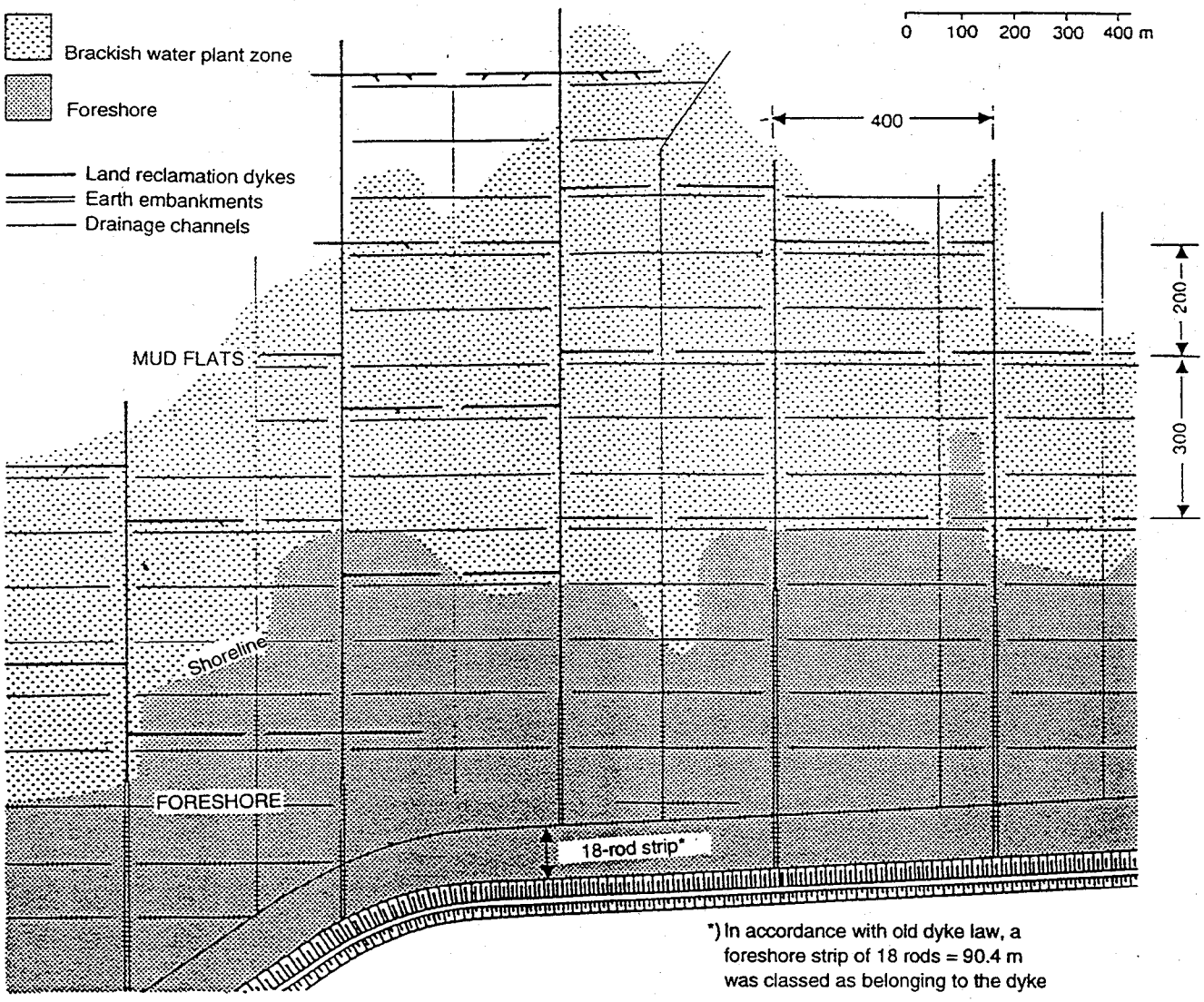

Fig. 5: Layout of brushwood groyne sedimentation fields. From STADELMANN 1981.

The brushwood groynes are primarily intended to lessen the water current and thus to enhance sedimentation. Sedimentation is at its peak in the first year and may be as much as 20 cm/year. Thereafter the sedimentation rate decreases in the vegetation free fields and only attains higher levels again after lasting vegetation has become established (DIJKEMA et al. 1988). To assist drainage, ditches are dug in the sedimentation fields and maintained at regular intervals. Whereas this used to be done manually, almost exclusive use is nowadays made of machines. An amphibious excavator with a bucket width of 3 m removes the sediment from

the ditches and deposits it on the ridges between them.

This procedure creates a regular system of ditches and ridges. Ditch excavation is repeated until the accumulation of silt and the improved aeration of the sediment has enabled the establishment of a dense vegetation cover. From this time onwards ditches with a width of roughly 1 m are dug in the plant-covered areas. The systematic creation of drainage ditches produces a pattern of ridges, ditches and broad channels within the sedimentation fields. Nearly all foreland salt-marshes are subdivided by this process into beds with an area of approximately 10 x 100 m. The dense network of artificial ditches prevents the formation of a natural drainage system. Foreland salt-marshes thus feature a regular morphological structure. There are no natural edges to tidal-channels with shallow gradual slopes and steep abrupt slopes, no old flooded creeks that have been cut off from the natural drainage system and no salt pans.

3. The size of salt-marshes in the Schleswig-Holstein Wadden Sea

Wadden Sea salt-marshes are presently restricted to the leeward side of the islands and the Halligen and a narrow, broken strip along the mainland coast (c.f. Fig. 3). Data published so far on the size of the salt-marshes in the Schleswig-Holstein Wadden Sea and in the Schleswig-Holstein Wadden Sea National Park are highly divergent and no precise information has been given on the method of area determination used, and on which types of vegetation were included in the calculation; furthermore there was no differentiation between areas inside and outside the boundaries of the National Park.

In 1980 HEYDEMANN & MÜLLER-KARCH presented a first analysis of the area covered by salt-marshes on the west coast of Schleswig-Holstein. The measurements, which were carried out in 1978, related solely to the salt-marshes along the mainland coast. No consideration was given to the salt-marshes of the islands and Halligen or to the salicornia zone. Their studies revealed a total of 3,456 hectares of salt-marshes on the mainland coast of Nordfriesland. A further 1,664 hectares were measured on the mainland coast of Dithmarschen, thus resulting in an overall size of 5,120 hectares for the mainland salt-marshes on the west coast of Schleswig-Holstein.

An in-depth study of the area covered by and the anthropogenic utilisation of the salt-marshes in the Schleswig-Holstein Wadden Sea was conducted by KEMPF et al. (1987). All the salt-marshes in the Wadden Sea region were recorded together with a brief description of their characteristics. Information was provided on size, breadth, ownership, intensity of agricultural utilisation and the extent of technical management. The salt-marshes are classified as either sand salt-marshes, foreland salt-marshes, estuarine salt-marshes, lagoon salt-marshes or Halligen. KEMPF et al. (1987) arrived at a total area of 7,801 hectares of salt-marsh on the west coast of Schleswig-Holstein.

The measurements were carried out on maps with a scale of 1:10,000/ 1:25,000. The most recent maps were from 1986. No further details are, however, available on the maps used. The vegetation boundary in the maps was used as the boundary for measurement. All areas above mean high water level (i.e. all green areas, however, excluding the salicornia zone) were incorporated. No field work was carried out and the maps were not compared with aerial photographs.

DIECKMANN (1988) conducted a study to determine the extent of the foreland salt-marshes in Nordfriesland, defining these as the plant-covered zone between the coastline (foot of the sea dyke) and shore line (mean high water level). According to his findings from 1979 the total expanse of all foreland salt-marshes and comparable Hallig salt-marshes in Nordfriesland amounted to 6,500 hectares, with the foreland salt-marshes of the mainland coast of Schleswig-Holstein covering 4,030 hectares. No information is, however, given on the methods used to determine these areas. DIECKMANN (1987, 1988) further investigated the extent of the Nordfriesian foreland salt-marshes in the period between 1870 and 1979 (Fig.6).

DANKERS et al. (1991) quote a total figure of 5,100 hectares for the entire salt-marsh area in Schleswig-Holstein. If the summer polders (Halligen) are also included, the total increases to 6,300 hectares. The figures are from 1987, however, no source is quoted. The authors probably obtained these from HEYDEMANN & MÜLLER-KARCH (1980). The International Wadden Sea Secretariat adopted the data of DANKERS et al. (1991) and KEMPF et al. (1987) and integrated them into the report on the 6th. Trilateral Wadden Sea Conference in Esbjerg (CWSS 1992). Summarising the published data reveals a total of 5 different sets of information on the extent of the salt-marsh areas (not including summer polders) in the Schleswig-Holstein Wadden Sea and in Nordfriesland (Tab. 2).

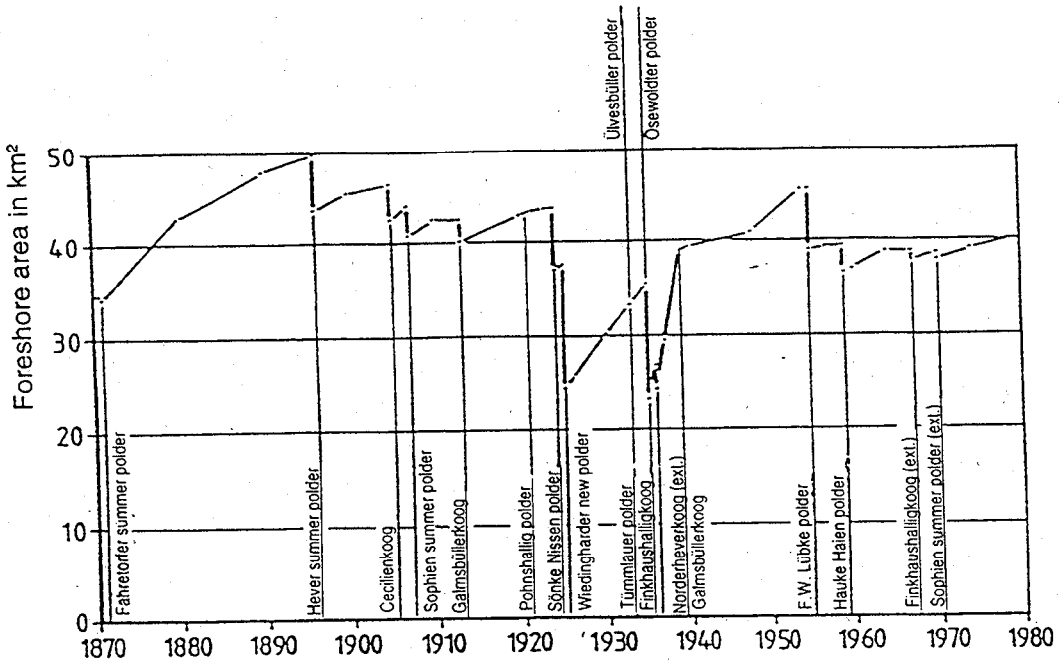

Fig. 6: Development of the total size of salt-marshes on the Nordfriesian mainland coast from the Danish border to Nackhörn (Tümlauer Bay) between 1870 and 1979. According to DIECKMANN 1988.

Tab. 2: Salt-marsh area (ha) on the west coast of Schleswig-Holstein according to the published literature

Source	Region	Area
KEMPF et al. (1987)	S-H Wadden Sea	7,801
DANKERS et al. (1991)	S-H Wadden Sea	5,100
DIECKMANN (1988)	S-H foreshore & Halligen	6,500
HEYDEMANN & M‹LLER-KARCH (1980)	S-H foreshore West coast	5,120
DIECKMANN (1987)	S-H foreshore West coast	5,100

The most recent survey of the extent of the salt-marshes on the mainland coast of Nordfriesland and Dithmarschen was presented by HAGGE (1989) as part of the ecosystem research work. HAGGE mapped the actual salt-marsh vegetation. Topographic vegetation maps were produced with the help of CIR aerial photographs (map scale approx. 1:5000, aerial survey 1988). The salicornia zone was not measured. Measurement of the size of the salt-marshes from vegetation maps revealed a salt-marsh area of 6,317 hectares on the mainland coast of Schleswig-Holstein. This figure does not include either the St. Peter-Ording salt-marshes or those on the Wadden Sea islands and Halligen. Addition of these omitted areas using the data from KEMPF et al. (1987) gives a total of 8,478 hectares. This is 677 hectares, or roughly 8.4 % more than published by KEMPF et al. (1987).

Table 3 compares the size of salt-marshes measured for Nordfriesland and Dithmarschen in three different studies. The values given for the size of the salt-marsh areas on the mainland coast of Nordfriesland are quite similar. The increase in area can be attributed to real growth. There are conspicuous differences in the values given for salt-marshes in Dithmarschen. The results obtained by HEYDEMANN & MÜLLER-KARCH (1980) and KEMPF et al. (1987) largely agree. HAGGE (1989) quotes considerably larger expanses for the foreland salt-marshes of Dithmarschen. It is impossible to say whether these differences correspond to the growth in area over the last 10 years. Re-measurement of the vegetation maps drawn up by HAGGE, however, confirmed her values. It can therefore be assumed that the data presented by HAGGE are a true reflection of the situation in 1988.

Tab. 3: The size of mainland salt-marshes (ha) according to HEYDEMANN & MÜLLER-KARCH (1980), KEMPF et. al. (1987) and HAGGE (1989). NF = Nordfriesland, DTM = Dithmarschen

Region	HEYDEMANN et al. (1980)	KEMPF et al. (1987)	HAGGE (1989)
NF	3,456	3,656	3,723
DTM	1,664	1,635	2,595
Total	5,120	5,291	6,318

Because the differences in the size of the salt-marshes published by different authors was considerable, and so great that they cannot be attributed to methodological errors, all the salt-marsh areas on the west coast of Schleswig-Holstein were re-surveyed.

3.1 Map materials and method

The size of the salt-marshes was measured from existing vegetation maps of the mainland salt-marshes and of mapped Wadden Sea island and Hallig salt-marshes (from HAGGE 1989, 1990; scale 1:5,000), and B/W and CIR aerial photographs of the salt-marshes not recently mapped. Tab. 4 gives a list of the maps and aerial photographs used.

Transparencies were made of each vegetation map and aerial photograph showing the current boundaries on the basis of the foreshore maps of the Departments of Agriculture and Water Resources (scale 1:5,000/1:10,000). This enabled the maps to be updated to incorporate salt-marsh losses which have occurred as a result of embankment and dyke construction. The seaward foreshore boundary corresponded to the visible vegetation limit of the respective map sources. In certain instances the transparencies of the CIR aerial survey were used for

interpretation of the photographs. In the majority of areas the landward boundary was the foot of the sea dyke. The aerial photographs of the islands of Sylt and Amrum proved more difficult to interpret as the salt-marsh vegetation on these islands gradually merges with other types of vegetation and the dyke, as a distinct boundary, is absent.

The areas specified and delimited on the basis of the above criteria include all types of vegetation with the exception of the salicornia zone. Areas with Spartina were determined separately. Small areas of beach-ridge vegetation scattered among the sand salt-marshes of St. Peter-Ording and on the foreshore of the island of Föhr were included in the measurements. A distinction was also made between the salt-marshes inside and beyond the boundaries of the National Park (salt-marshes in 150 m strip between the dyke and the National Park boundary). On the islands such a distinction was only possible where the salt-marshes are delimited on the landward side by a dyke. This was not possible where salt-marshes bordered on to dune vegetation or other vegetation types because the National Park boundary is defined by the mean high water level + 150 m, which cannot be seen in the aerial photographs. The vegetation free areas within the salt-marshes, such as those covered by drainage channels and smaller salt pans as well as those recently used for clay extraction, were also included in the totals. The area covered by major drainage channels and natural tidal channels was not included in the totals. The measurements were made on the transparencies by hand using a Haffs Digital Polar Planimeter to the scales given in Tab.4.

Tab. 4: Materials used for determining salt-marsh area on the west coast of Schleswig-Holstein

Region	Aerial photo	Scale	Year
Foreland salt-marshes	CIR aerial photo	1:5,000	1988
St.Peter-Ording	B/W aerial photo	1:5,000	1993
Sylt	B/W & CIR aerial photo	1:10,000	1989
Pellworm	CIR aerial photo	1:5,000	1988
Föhr	CIR aerial photo	1:5,000	1988
Amrum	CIR aerial photo	1:5,000	1988
Trischen	B/W aerial photo	1:5,000	1993
Langeness Hallig	CIR aerial photo	1:5,000	1988
Oland Hallig	B/W aerial photo	1:10,000	1989
Oland foreshore	CIR aerial photo	1:5,000	1988
Hooge Hallig	B/W aerial photo	1:10,000	1989
Gröde Hallig	B/W aerial photo	1:5,000	1990
Nordstrandischmoor Hallig	B/W aerial photo	1:5,000	1990
Südfall Hallig	B/W aerial photo	1:5,000	1990
Süderoog Hallig	B/W aerial photo	1:5,000	1990
Habel Hallig	B/W aerial photo	1:5,000	1990
Norderoog Hallig	B/W aerial photo	1:5,000	1990

3.2 Results

In line with the maps dated as indicated in Table 4 (1988/89 - mainland coast, 1990 - Halligen and 1993 - Trischen and St. Peter-Ording) the salt-marshes extend over a total area of roughly 10,000 hectares (Fig. 7), corresponding to 3.5 % of the total area of the Schleswig-Holstein Wadden Sea. 58 % of all salt-marshes lie within the boundaries of the National Park. The different types of salt-marsh which can be distinguished geomorphologically (see DIJKEMA 1987) are represented to differing degrees within the National Park.

Tab. 5: Areas covered by various salt-marsh types on the west coast of Schleswig-Holstein. All figures in hectares.

Type of salt-marsh	Total area	Within the National Park
Foreland salt-marsh - mainland	6,152	4,832
Foreland salt-marsh - Wadden Sea islands	374	72
Foreland salt-marsh - Halligen	218	ñ
Hallig salt-marsh *)	2,093	111
Sand salt-marsh - mainland	735	559
Sand salt-marsh - Wadden Sea islands	439	240
Total area	10,011	5,814

*) Hallig salt-marsh area not including foreshores

Altogether 73 % of the foreland salt-marshes and 68 % of the natural island and mainland salt-marshes, but only 5 % of the Hallig salt-marshes lie within the National Park. Table 5 shows the proportions of the various types of salt-marsh in the overall total and within the National Park.

Most of the salt-marshes are located in the Nordfriesian part of the Schleswig-Holstein Wadden Sea, namely 4,510 hectares on the mainland coast, 720 hectares on the Nordfriesian islands and 2,300 hectares on the Halligen. In Dithmarschen salt-marshes cover 2,320 hectares along the mainland coast, with a further 90 hectares on the island of Trischen. The salt-marshes of the former Helmsand Hallig have been assigned to the foreland salt-marshes of the mainland coast.

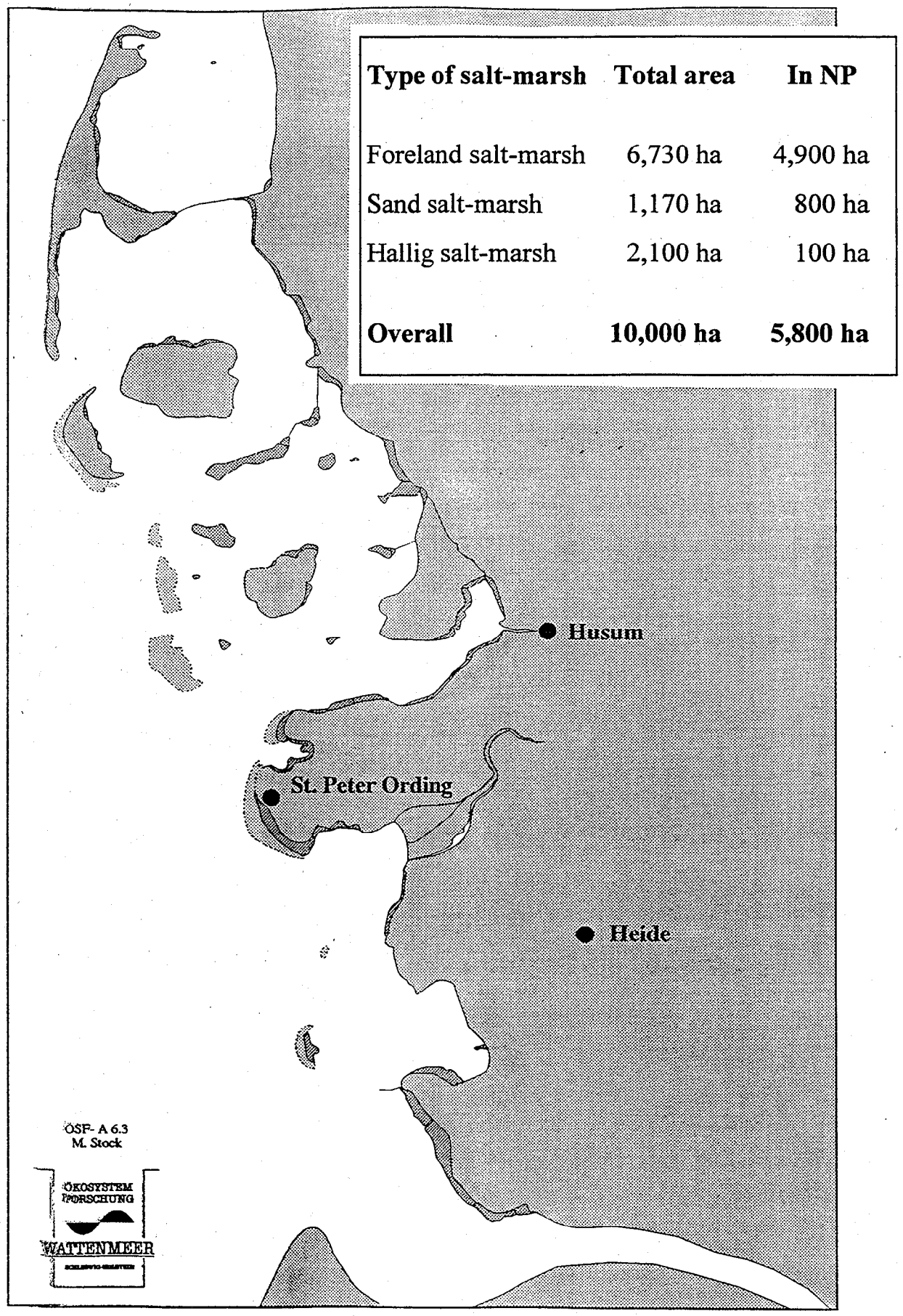

Fig. 7: Location and size of salt-marshes (dark shaded areas) on the west coast of Schleswig-Holstein.

4. Utilisation of and threats to the salt-marshes

Salt-marshes have been used by man for a number of traditional purposes for many centuries (e.g. KÖNIG 1987, BAKKER 1989, BAKKER et al. 1993). From an historical point of view their uses for agricultural and coastal protection purposes have always been of great importance. Hunting played a role in the salt-marshes for a long time, however, it was banned in the National Park of Schleswig-Holstein in 1989 (CONRADY 1989, ANDRESEN 1989). Tourism in its modern form is on the other hand a relatively recent development. The increase in recreational activities has been accompanied by larger areas being devoted to leisure pastimes for longer periods. Such pastimes include water sports, amateur aviation, hiking and cycling as well as intensive use of beaches, dunes and salt-marshes for tourism. All these anthropogenic activities make their presence felt on the salt-marsh habitat and its flora and fauna. A detailed description of the utilisation of and the threats to the Wadden Sea and in particular the salt-marshes is given by HEYDEMANN (1981), WOLFF et al. (1982), WOLFF (1983), BUCHWALD (1990), PROKOSCH et al. (1991), LOZAN et al. (1994), and STOCK et al. (1994).

A detailed temporal and spatial description of various types of human activities in the areas of tourism, leisure-boating, excursion shipping and air traffic is summarised in the final report "Human activity in the Schleswig-Holstein Wadden Sea and its influence on bird life" (KNOKE & STOCK 1994). In this context we refer readers to the above report. The emphasis in the following Sections will be on the aspects of agriculture and coastal protection.

4.1 Agricultural utilisation of the salt-marshes

In Schleswig-Holstein the main form of agricultural utilisation of the salt-marshes along the mainland coast and on the islands has been sheep grazing. Cattle grazing has always been a secondary aspect. Even today the salt-marshes on the mainland coast of Dithmarschen are still used for the grazing of domestic geese. Salt-marshes on the mainland coast are not mown for hay, however, reed cutting

still takes place in the sandy salt-marshes of the islands in the freshwater-influenced transition zone to the dunes (c.f. KEMPF et al. 1987).

The salt-marshes have always been crucially important to the agriculture of the Halligen, as no crops can be grown there. The salt-marshes on the Halligen are traditionally used for the grazing of cattle and sheep, although few farmers keep sheep nowadays. Over the past few years, horse grazing has become more widespread on some of the Halligen. A further use for the salt-marshes in these areas is the production of hay for winter fodder.

Classification of grazing intensity is based on KEMPF et al. (1987). Moderate grazing refers to salt-marshes on which a maximum of 1 head of cattle or 3 sheep (including lambs) are kept per hectare. Intensive grazing is used to denote salt-marshes on which more than 1 head of cattle or more than 3 sheep (including lambs) are allowed to graze per hectare.

Agricultural subsidies have led to an intensification of grazing on salt-marshes to such an extent over the last thirty years that many examples of large-scale overgrazing and trampling damage can be observed, particularly on the Hallig salt-marshes.

DIJKEMA (1984) and KEMPF et al. (1987) provide a complete analysis of the agricultural exploitation of salt-marshes and Halligen and its ecological impact. The ecological consequences of salt-marsh grazing for the vegetation and its invertebrate fauna have been investigated in depth as part of the ecosystem research work and are briefly summarised in the following. The effect of grazing on bird life is described by HÄLTERLEIN (1996).

4.1.1 The influence of sheep grazing on the salt-marsh vegetation

Decades of intensive sheep grazing have led to the development of structurally simple, grass-dominated vegetation forms in the Schleswig-Holstein foreland salt-marshes.
Where intensive grazing takes place, the lower salt-marsh zone is dominated by *Puccinellia maritima* and annual herb species such as *Salicornia europaea* agg. and *Suaeda maritima* (Fig. 12, HAGGE 1989, DIERSSEN et al. 1994 b). The sparse vegetation brought about by grazing and trampling provides good germination conditions for these species. Perennial herb species typical of near-natural salt-marshes are severely restricted in both their vegetative and their generative development and are not usually present.

Due to intensive grazing of almost all the foreland salt-marsh areas in Schleswig-Holstein *Halimione portulacoides*, a typical lower salt-marsh species, had become so rare by the beginning of the 1990s that it is now listed as an endangered species in the Red Data Book of pteridophytes and spermatophytes in Schleswig-Holstein (MIERWALD & BELLER 1990). The sea aster *Aster tripolium* is grazed selectively by sheep. Isolated examples of this species are found on intensively grazed salt-marshes, however, these tend to exhibit little vitality and only flower occasionally (DIERSSEN et al. 1991, 1994 b).

The dominant species in the upper salt-marsh zone of intensively grazed salt-marshes is often red fescue grass (*Festuca rubra* agg.). Other species occurring in this zone are short, rosette-forming herbs such as thrift (*Armeria maritima*). Taller species typical of the upper salt-marsh, for example *Artemisia maritima*, suffer greatly from grazing and trampling and only occur singly.

Experimental grazing plots were established during the Schleswig-Holstein Wadden Sea ecosystem research project. Studies on these plots reveal that if grazing is reduced or discontinued in the lower salt-marsh zone, even after decades of intensive sheep grazing, the establishment and renewed propagation of

typical plant species affected by grazing, such as *Halimione portulacoides* (Fig. 8), is a relatively rapid process (KIEHL 1997). In intensively grazed areas the density of species sensitive to grazing increases with increasing distance from the dyke, as the sheep stay predominantly in the vicinity of the dyke. The survey of flowering sea aster *Aster tripolium* shows that this plant can only flower in a normal way on non-grazed plots, as it is selectively cropped by sheep.

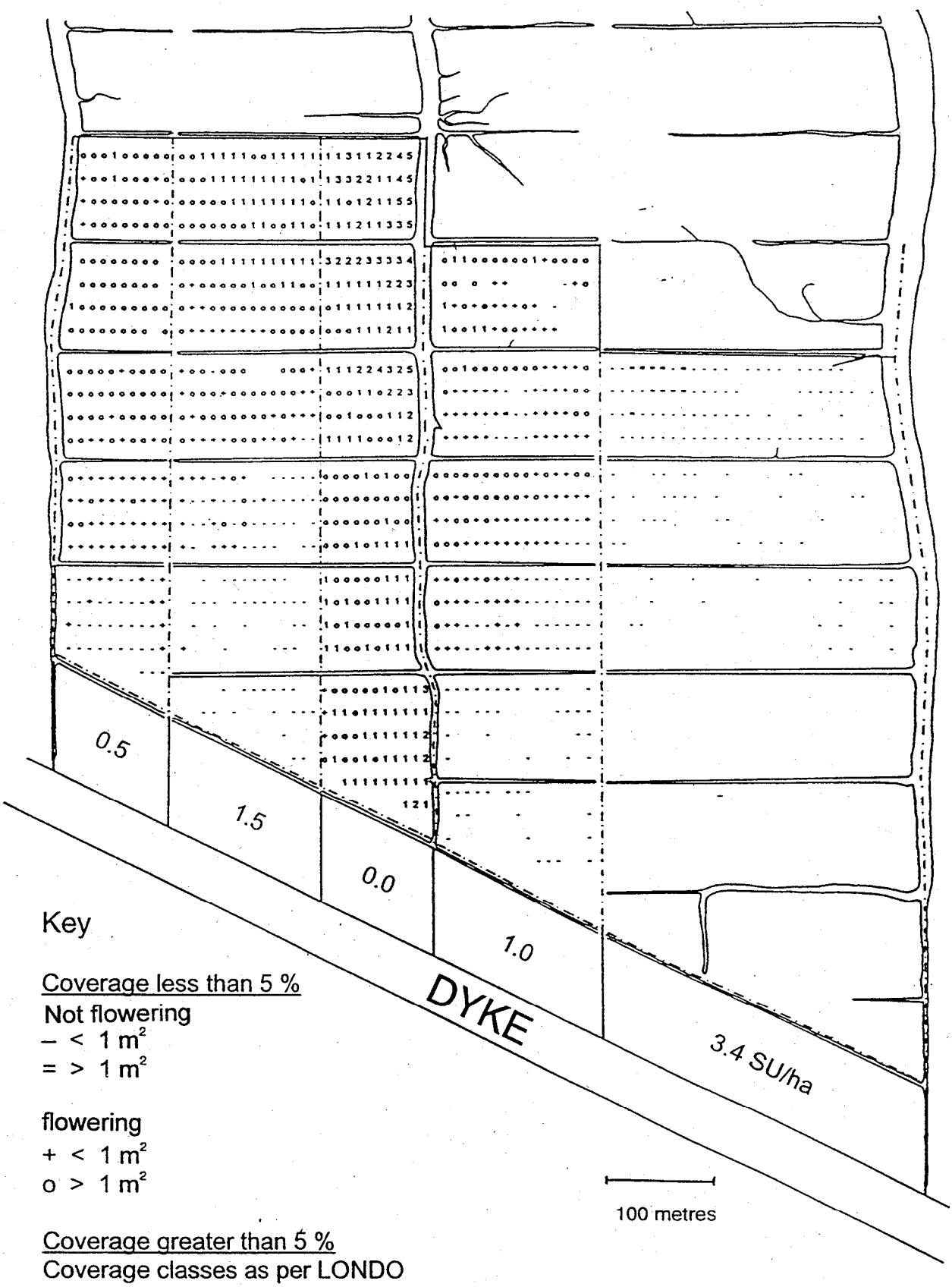

Fig. 8: Distribution of sea purslane (*Halimione portulacoides*) on the Sönke-Nissen-Koog foreshore, 1992 (from DIERSSEN et al. 1994 b).

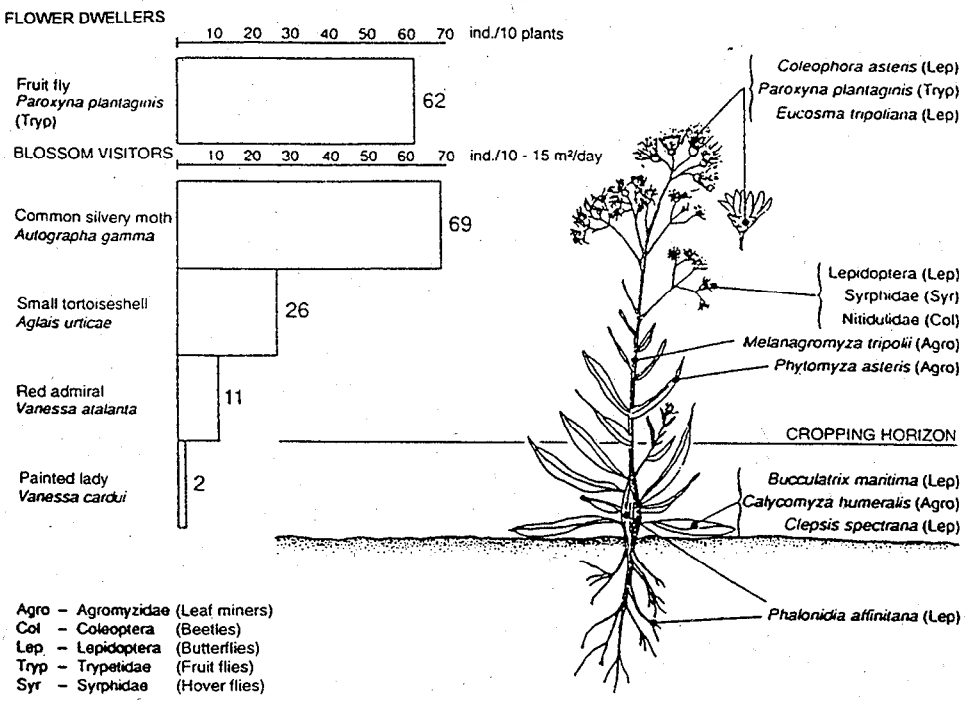

Fig. 9: Distribution of various insect species on *Aster tripolium*. The distribution of the various species living on a non-grazed and, in the lower section (cropping horizon), a grazed sea aster plant (from TISCHLER et al. 1994).

There is a sharp decrease in the number of flowering plant of this species as grazing becomes more intense. A large number of invertebrate species are dependent on fully developed sea aster plants. In addition to visitors to the flower heads (Fig. 9) a number of phytophagous species live in and on the stems and heads of sea aster.

Moderately grazed and non-grazed areas also differ in terms of their vegetation structure. The diversity of vegetation height is considerably more pronounced on non-grazed plots than in areas which are grazed (Fig. 10). In addition to this, when grazing is discontinued a mosaic of dominant stocks of various plant species develops over an area of a few metres (Fig. 11). This is typical of near-natural salt-marshes, whereas the distribution of species on grazed plots is far more homogeneous (Fig. 12).

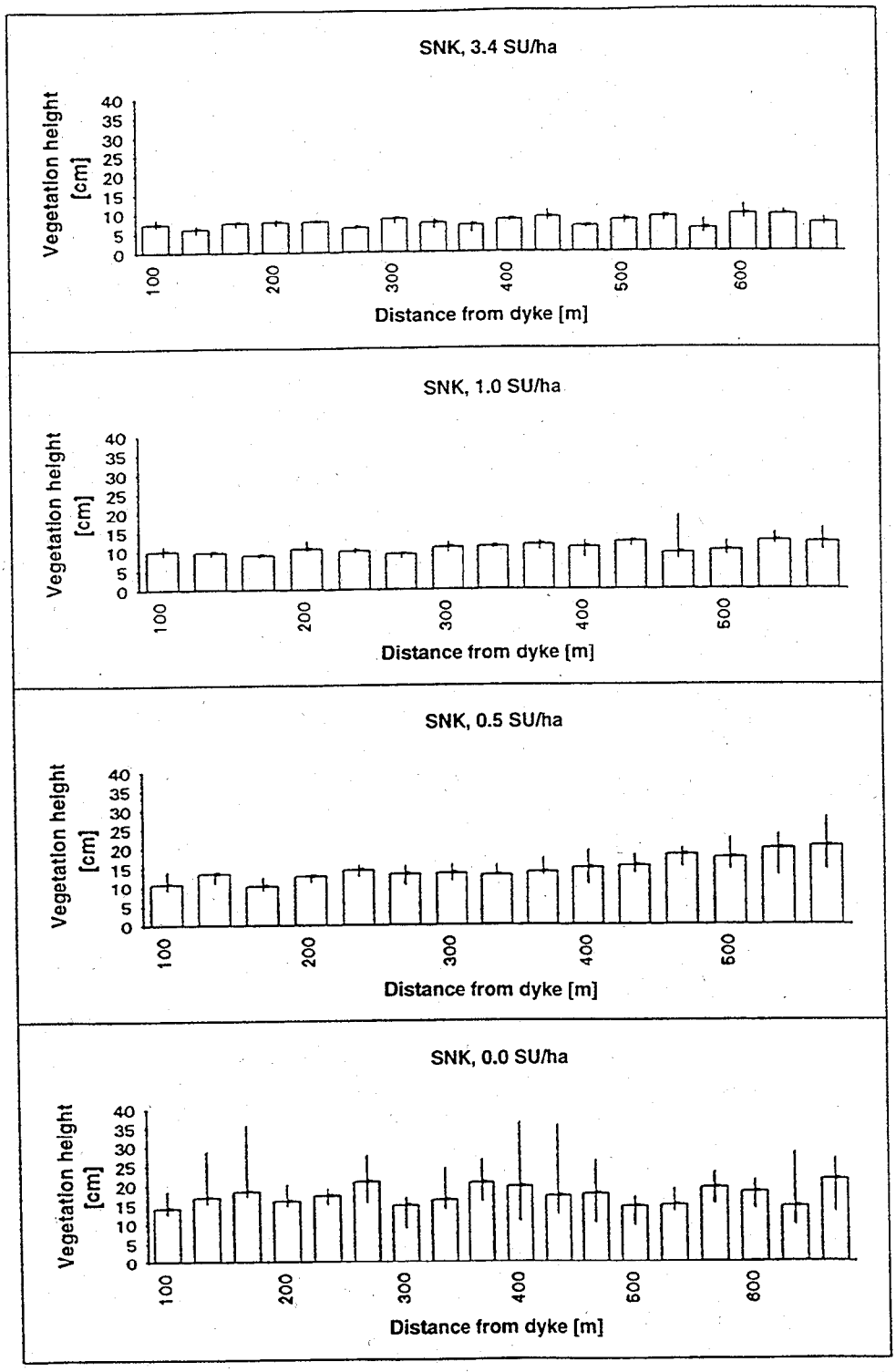

Fig. 10: Vegetation height (minimum, maximum and median) with differing grazing intensity on the Sönke-Nissen-Koog foreland salt-marshes along a transect from the dyke to the mud flats (from DIERSSEN et al. 1994 b).

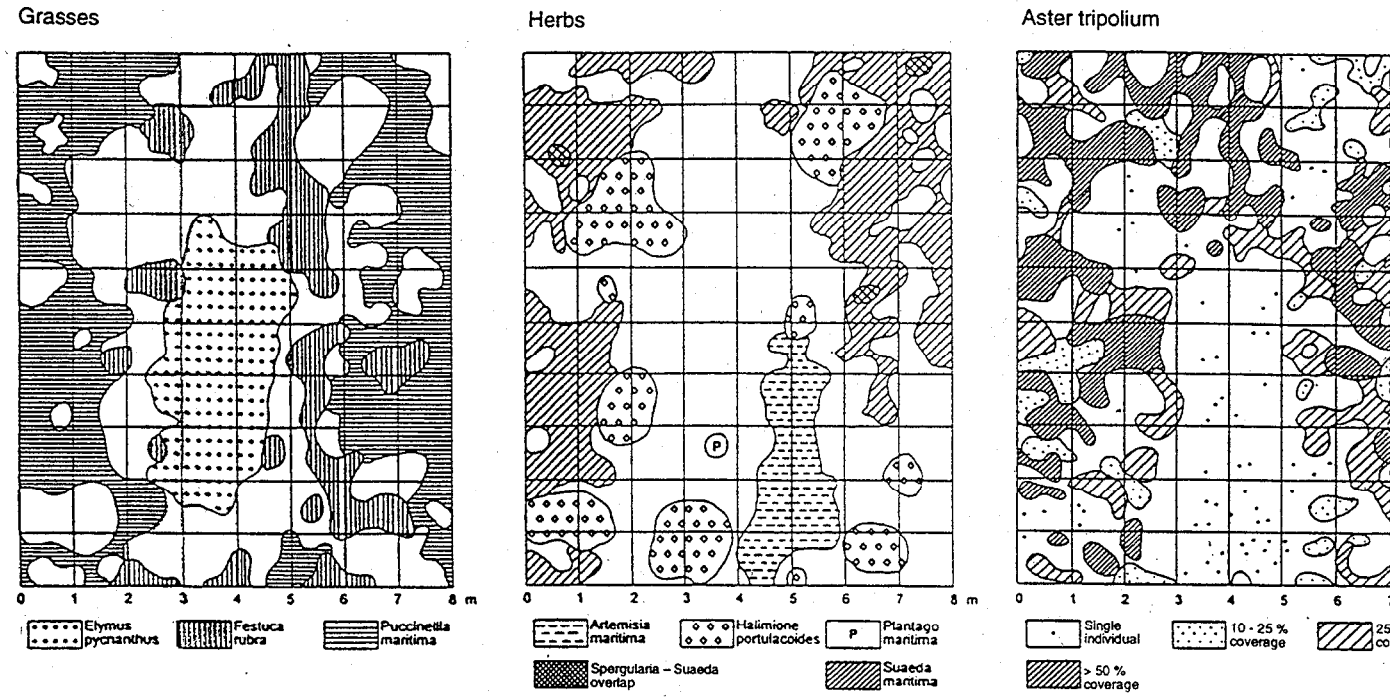

Fig. 11: Spatial distribution pattern of grasses and herbs with more than 50% coverage on a non-grazed plot of the Sönke-Nissen-Koog foreland salt-marsh, five years after cessation of grazing. The grazing-sensitive species *Aster tripolium* was mapped in 4 coverage classes (from DIERSSEN et al. 1994 b).

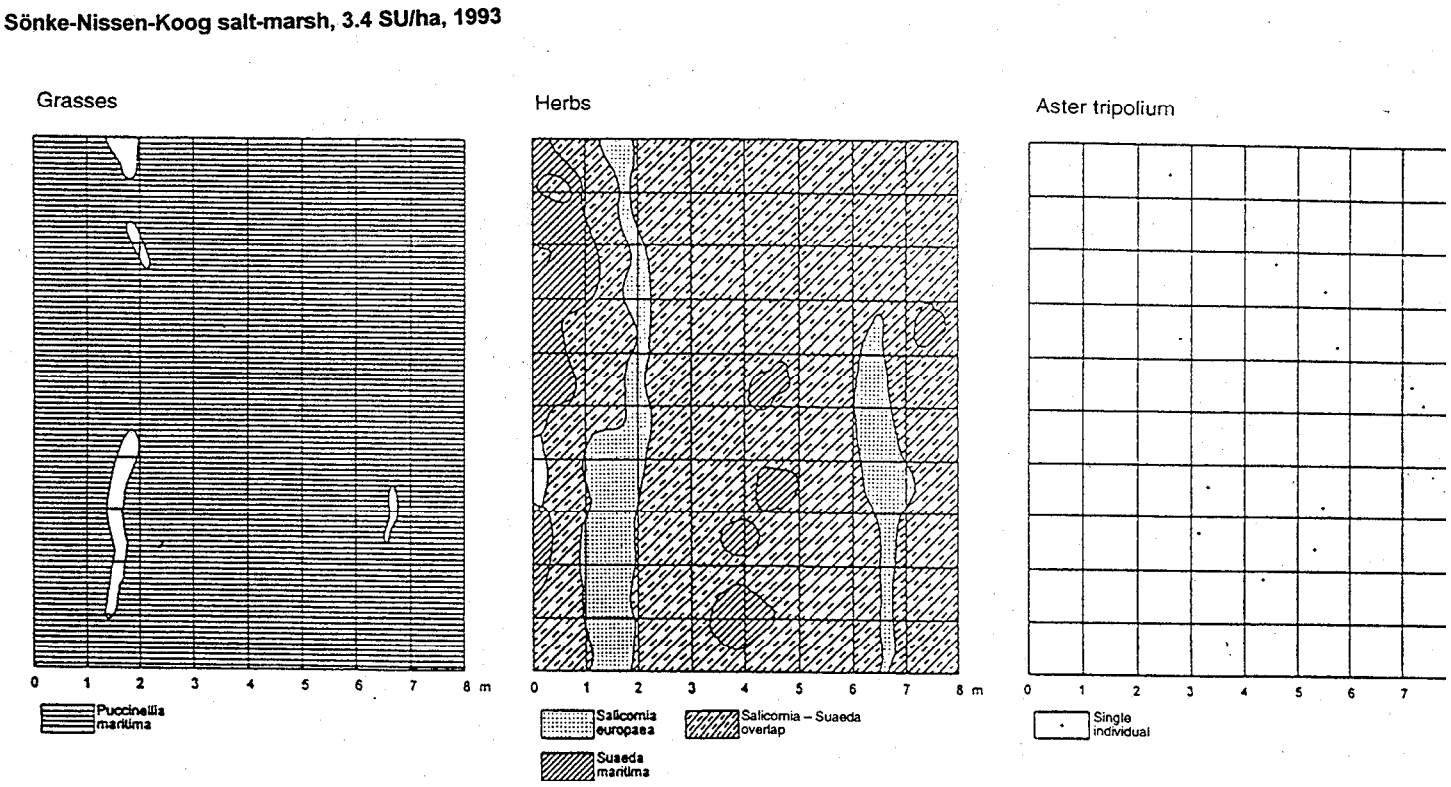

Fig. 12: Spatial distribution pattern of grasses and herbs with more than 50% coverage on the intensively grazed plot of the Sönke-Nissen-Koog foreland salt-marsh. The grazing-sensitive species *Aster tripolium* was mapped in 4 coverage classes (DIERSSEN et al. 1994 b).

In the upper salt-marsh zone the propagation of plant species sensitive to grazing such as *Aster tripolium* or *Artemisia maritima* takes place more slowly following reduction or the cessation of grazing in areas which were previously intensively grazed. On the experimental plots in the Friedrichskoog salt-marshes such species are slower to become established on account of the dominance of red fescue grass (*Festuca rubra*). The results obtained by DIERSSEN et al. (1994 b) show that both *Aster tripolium* and *Artemisia maritima* become established almost exclusively on non-grazed plots. Their propagation on all grazed plots is obstructed through selective cropping by the sheep.

4.1.2 Impact of sheep grazing on the salt-marsh fauna

The effects of sheep and cattle grazing on the invertebrate fauna in salt-marshes along the Wadden Sea coast have been investigated in Niedersachsen by ANDRESEN et al. (1990), IRMLER & HEYDEMANN (1986) and RAHMANN et al. (1987); and in Schleswig-Holstein by GÖTZE (1992), GRELL (1992) and MEYER et al. (1995). This latter study makes reference to the findings of DIERSSEN et al. (1994 a,b,1997) within the Ecosystem Research Project in the Schleswig-Holstein Wadden Sea. This project concentrated on the short-term and medium-term influence of different degrees of sheep grazing on the invertebrate fauna.

Grazing leads to changes in the vegetation structure, microclimate and soil structure, etc., which in turn influence the species composition and dominance structure of the fauna. This is above all a result of cropping, trampling and the input of faeces. Whereas grazing is beneficial to certain species and others exhibit scarcely any or no reaction, many invertebrate species suffer a significant population decline as a result of grazing. Some examples are listed below:

- The amphipod *Orchestia gammarellus* reacts to moderate, and especially to intensive grazing with a distinct decline in the number of individuals as trampling greatly diminishes the coarse pores in the soil in which this species lives (Fig. 13).

- Numerous phytophagous species can no longer exist in grazed salt-marshes due to the absence of certain plant species or structural components.
- Insects which utilise flowers as a food source can only exist in non-grazed areas, as the salt-marsh plants only flower there (Fig. 9).

Grazing can cause changes in the dominance structures of the invertebrate fauna. The money spider *Erigone longipalpis* (Fig. 14) dominates clearly in intensively grazed silt salt-marshes, whereas *Baryphyma duffeyi,* a salt-marsh spider, that within Schleswig-Holstein has only been found on North Sea coast, dominates in salt-marshes with no or little grazing. *Erigone longipalpis* occurs also on the Baltic coast and in inland habitats, such as farmland and meadows (REINKE & IRMLER 1994).

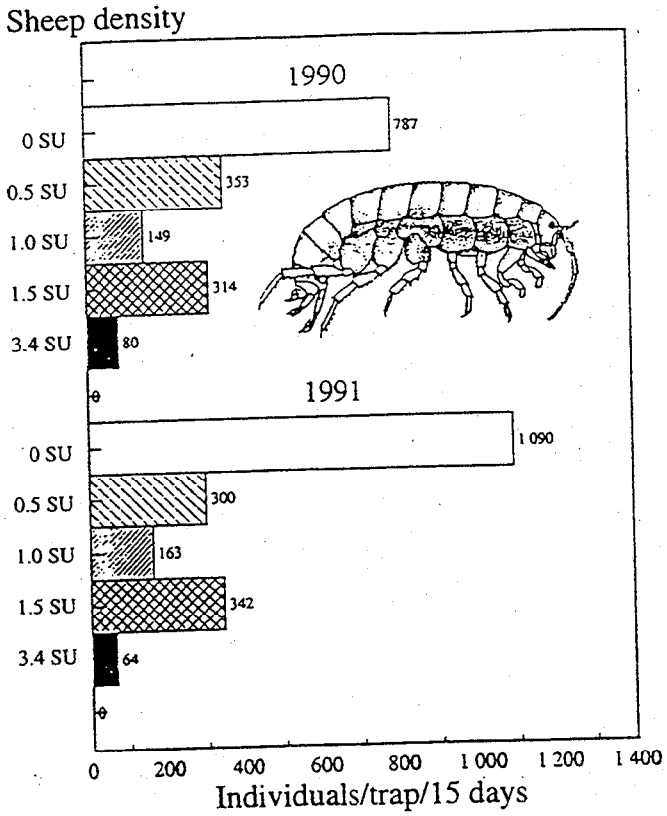

Fig. 13: Influence of sheep grazing on population density of the amphipod *Orchestia gammarellus* on the Sönke-Nissen-Koog salt-marshes (TISCHLER et al. 1994).

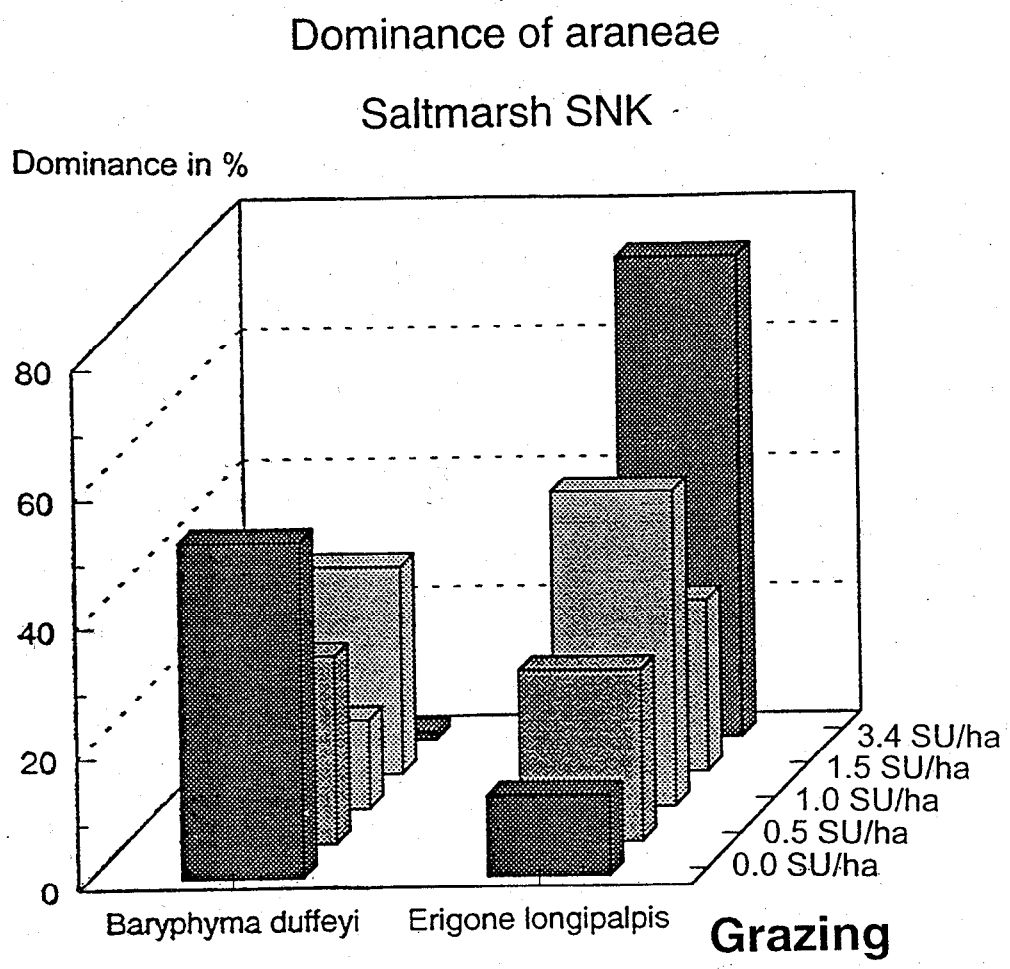

Fig. 14: Sensitivity of the dominant money spider species *Baryphyma duffeyi* and *Erigone longipalpis* to grazing in the Sönke-Nissen-Koog salt-marshes (TISCHLER et al. 1994).

The population density of other salt-marsh spider species such as *Pardosa agrestis* and *Pachygnatha clercki* is reduced significantly by grazing. The typical coastal species *Enoplognatha mordax* may even completely disappear as a result of intensive grazing. In contrast, widespread spider species such as *Bathyphantes gracilis*, *Erigone atra* and *Porrhomma microphthalmum* dominate on intensively and heavily grazed salt-marshes. *Baryphyma duffeyi* no longer occurs in the sandy to silty salt-marsh off Friedrichskoog. However, a shift in dominance can be observed here, away from *Erigone longipalpis*, which achieves large numbers of individuals on heavily grazed salt-marshes, towards *Oedothorax fuscus* (Fig. 15). *Oedothorax retusus*, *Pachygnatha degeeri* and other species also favour moderately grazed and non-grazed areas, whereas here again various common

euryoecious spider species benefit from grazing (MEYER & REINKE 1996).

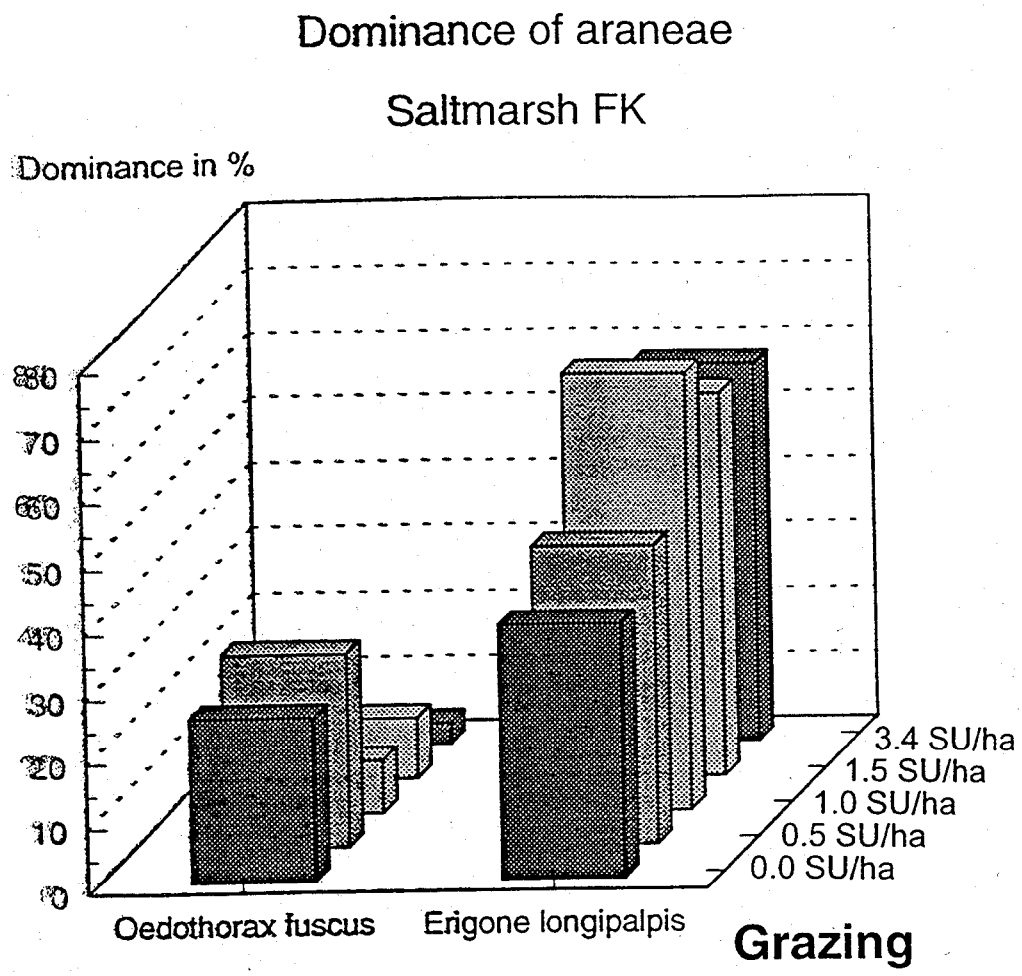

Fig. 15: Influence of grazing on dominance structure of spiders in the Friedrichskoog salt-marshes (TISCHLER et al. 1994).

4.1.3 Effects of grazing on sedimentation

Salt-marshes act as wave breakers absorbing wave energy and thus protecting the dykes during extremely high tides. Surface erosion of the salt-marshes must be prevented if this function is to be maintained. From the point of view of coastal protection it is therefore desirable that the salt-marsh soil is compacted by the trampling of the grazing sheep and that the turf is kept dense through close cropping (ERCHINGER 1995). The elevation of the salt-marsh is crucial to the reduction in wave energy. Net sedimentation governs the accretion rate. The

greatest amounts of sediment are transported onto the salt-marshes by the storm surges in winter. The net sedimentation rate in salt-marshes is influenced to a considerable degree by the grazing intensity. ANDRESEN et al. (1990) provided evidence of higher sedimentation rates (2.3 cm/year) in the *Puccinellia maritima* zone of the Leybucht area in non-grazed areas than in those where grazing took place (1.7 cm/year). Conversely, there was no dependence of sedimentation rates on grazing in either the red fescue or *Salicornia* zones. The average annual sedimentation rates were 1.6 cm and 1.8 cm for the red fescue and *Salicornia* zones respectively.

As part of the Schleswig-Holstein Wadden Sea ecosystem research, the Departments of Agriculture and Water Resources in Husum and Heide measured the height of salt-marshes in the research areas at Sönke-Nissen-Koog and Friedrichskoog.

Permanent plots were used to measure the effects of sheep grazing on the net sedimentation rate in the two salt-marshes, which differ in terms of age and location. This made it possible to measure the change in elevation of the salt-marsh over time with the aid of a measuring frame. Measurements were taken on the Friedrichskoog salt-marshes in 1991, 1992 and 1993 and on the Sönke-Nissen-Koog salt-marshes 1991 and 1993 (Fig. 16). The measurements were taken in July/August of each year. For measurement purposes on the Friedrichskoog salt-marshes four squares were marked out on each grazing plot along a transect from the dyke towards the tidal flats. Only three squares were created on each plot on the Sönke-Nissen-Koog salt-marshes and these were not representative of the region. The results from the latter area are, therefore, only of limited use.

In the Friedrichskoog salt-marshes the greatest increase in height occurred on the non-grazed or only slightly grazed plots. Irrespective of grazing intensity, the maximum net sedimentation rate was found in the *Pucinellia maritima* zone in the areas close to the mud flats. In contrast to the results obtained for the Leybucht area, the Friedrichskoog salt-marsh was, however, also characterised by a decline

in the net sedimentation rate.

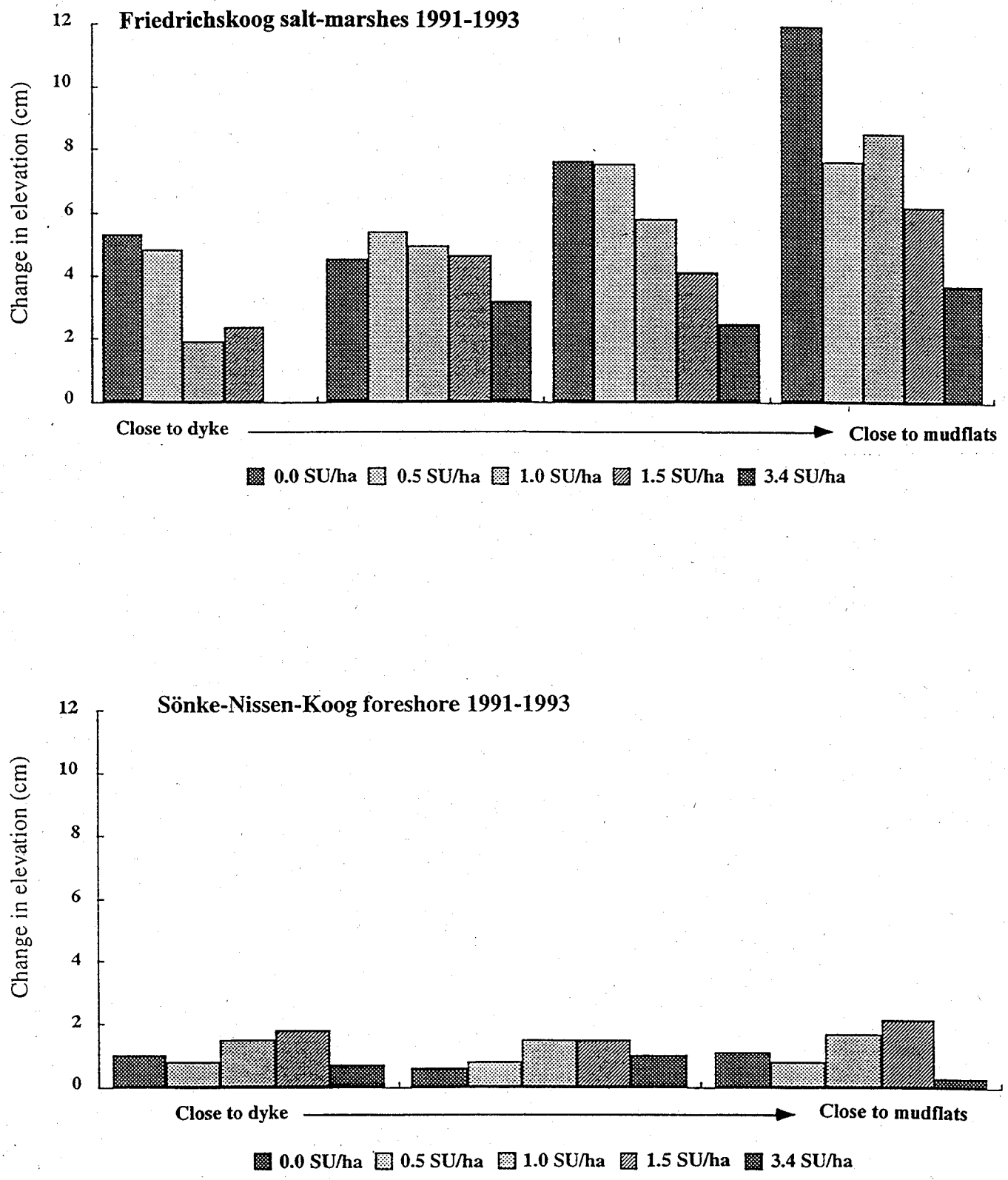

Fig. 16: Results of elevation measurements on permanent plots in the salt-marshes of Friedrichskoog and Sönke-Nissen-Koog. The figure shows the change in elevation of the salt-marsh between 1991 and 1993 as a function of the intensity of sheep grazing and distance from the dyke.

with increasing grazing intensity in the red fescue zone close to the dyke.

In the Friedrichskoog salt-marsh the average change in elevation over the course of the two-year period was 5.1 ± 2.8 cm, corresponding to an annual difference in height of roughly 2.6 cm. The value obtained in the Sönke-Nissen-Koog salt-marshes was considerably smaller, amounting to 1.2 ± 0.5 cm for the two years or an annual change in elevation of approximately 0.6 cm. These results are similar to the sedimentation rates found by DIECKMANN (1988), who quotes between 0.6 and 2.5 cm per year. Comparable values can be found for the Netherlands in DIJKEMA et al. (1990).

The change in elevation of the Sönke-Nissen-Koog salt-marshes was far less pronounced. No correlation was found between the net sedimentation rate and the intensity of grazing or the distance from the dyke. Whether this was due to less transportation of sediment in this area or a poor choice of study plots remains unclear.

The results indicate that there are salt-marsh areas in which, even close to the dykes, the sedimentation rate on non-grazed salt-marshes is higher than on grazed sections of the same area. In the Friedrichskoog salt-marshes the average change in elevation in two years on the non-grazed plot close to the dyke was more than twice that measured on the moderately to intensively grazed plots.

4.2 Use of the salt-marshes for coastal protection purposes

Land reclamation has been a feature of the Wadden Sea and thus also of the salt-marshes since the first dykes were constructed more than 1,000 years ago (KÖNIG 1987). More than 40,000 hectares of mud flats and salt-marshes have been embanked throughout the Wadden Sea region during the relatively short period of the last 30 years. By far the largest area of salt-marshes has been lost due to embankment measures in Schleswig-Holstein (CWSS 1992). DRIJVER (1983) gives a history of dyke construction in the Wadden Sea since 1570.

As over the course of time technology improved, dykes were built further and further out into the mudflats. This not only caused the loss of large areas of salt-marsh, but also hindered the formation of natural salt-marsh in front of the new dykes. A good deal of work is necessary (construction of brushwood groynes and large-scale ditching work) to create new salt-marshes for agricultural and coastal protection purposes in front of dykes built on mudflats. The methods employed for salt-marsh reclamation are described in detail in WOHLENBERG (1938), KÖNIG (1948), KAMPS (1962) and ERCHINGER (1970). A brief summary is given in Section 2.2.2.2 of this report.

The constant intensification of coastal protection measures in the Wadden Sea, along with increased mechanisation, has created a situation today where the majority of salt-marshes are used intensively for coastal protection purposes and salt-marshes with a natural or near-natural geomorphological structure have become a rarity (c.f. Section 2.2).

The most significant effects of coastal protection measures, from an ecological point of view - in particular dyke construction and the use of salt-marshes for coastal protection - are summarised below (CWSS 1991):

- The embankment of mudflats and salt-marshes means an irreversible loss of these habitats.
- The construction of new sea dykes or their reinforcement has a negative influence on abiotic and biotic parameters in the Wadden Sea, affects the natural dynamics of the Wadden Sea and creates an artificial fixed landward boundary to the ecosystem.
- Coastal protection measures to create new and/or safeguard existing salt-marshes influence natural processes and eliminate the variety in the geomorphological structure of the salt-marshes.

Even allowing for the fact that there has been a shift of priorities in the field of coastal protection over the past few years - away from land reclamation towards the safeguarding of existing man made salt-marshes - the human impact on salt-marshes associated with coastal protection still remains.

4.2.1 Erosion resistance of salt-marshes as a function of grazing as well as ditch building and maintenance

The major criteria with regard to future salt-marsh management can be found in the results of the KFKI project "Erosion resistance of salt-marshes" (ERCHINGER et al. 1994). The aim of the research project was to analyse the hydrodynamic impact on the salt-marshes, to quantify the sedimentation and erosion processes and to document the protective effect of brushwood groynes. In order to be able to determine the influence of soil and plant development, elevation, ditch building/maintenance and grazing of the salt-marshes on erosion resistance, both field studies and wave simulation experiments were performed. The principal results of the project are outlined below.

- In conjunction with the long-term rise in mean high water level and extreme high water levels during storm surges, there has been severe erosion of exposed and unprotected foreland salt-marsh edges in Niedersachsen since the mid 1980s. The greatest erosion rate (up to 2.5 m/year) has been observed on foreland salt-marshes that are not protected by brushwood groynes and on low-lying mud flat areas. The construction of a protective groyne with a height of 30 cm above the mean tidal high water mark helped to subdue the wave action and resulted in increased sedimentation. Consequently there was a sharp decline in the rate of erosion of the foreshore edge.

- The aggradation of foreland salt-marshes is essentially governed by the frequency and duration of flooding. It is influenced by grazing intensity and is most pronounced on non-grazed plots. Ditch building and maintenance only slightly increased the rate of increase in the height of the salt-marsh.

- The development of foreland salt-marsh soil is primarily characterised by the type of soil, elevation, ditch building/maintenance and grazing practice. Adequate soil aeration as the result of ditch building/maintenance has a positive influence on low-lying salt-marsh areas. This effect is, however, neutralised by grazing. Ditch building/maintenance does not appear to have any effect on soil development in upper salt-marsh areas. The aggregate stability is more or less the same regardless of whether ditch building/maintenance takes place or not.
- There are considerable seasonal differences in the growth of salt-marsh root systems. Ditch building/maintenance does not effect root growth. Greater root growth occurs in the winter months. There are also more roots to be found in the deeper soil layers at this time of year. The resistance of the soil to erosion increased significantly with increasing subterranean biomass on non-grazed experimental plots. The reverse was true of grazed areas.
- The impact of the water current and the wash of the waves on the strength of the salt-marsh surface and its edge was determined experimentally using various simulation methods in a wave tunnel. The results showed that surface erosion due to the water current can virtually be ignored. The sole danger to the salt-marshes is local erosion of its edge caused by the impact of the waves.

ZHANG (1993) and HORN & ZHANG (1994) investigated the effects of agricultural activities on the physical properties of salt-marshes in the experimental grazing plots of Sönke-Nissen-Koog.

According to their results, sheep grazing affects the physical properties of the soil down to a depth of 30 cm. The trampling action of the animals compresses the top layer of soil. This influences the water saturation of the topsoil and inhibits oxygen diffusion into the horizon below. Grazing also alters the soil formation, as can be seen from the structure of the soil profile. Kneading effects can reduce the shear strength of the soil in moist areas. On the other hand, grazing of the surface phytomass creates close-cropped plant cover and thus promotes evaporation.

Consequently the soil becomes drier and gains in strength. The concentration of plant roots in the topsoil observed with increasing grazing intensity enhances the shear strength. Irrespective of seasonal fluctuations, this shear strength becomes greater with increasing grazing intensity and reaches its peak at a grazing intensity of between roughly 1.0 and 1.5 sheep units/hectare (Fig. 17). As the grazing sheep tend to remain in the close proximity of the dyke, the effect of grazing on shear strength is more pronounced in this area than further away from the dyke.

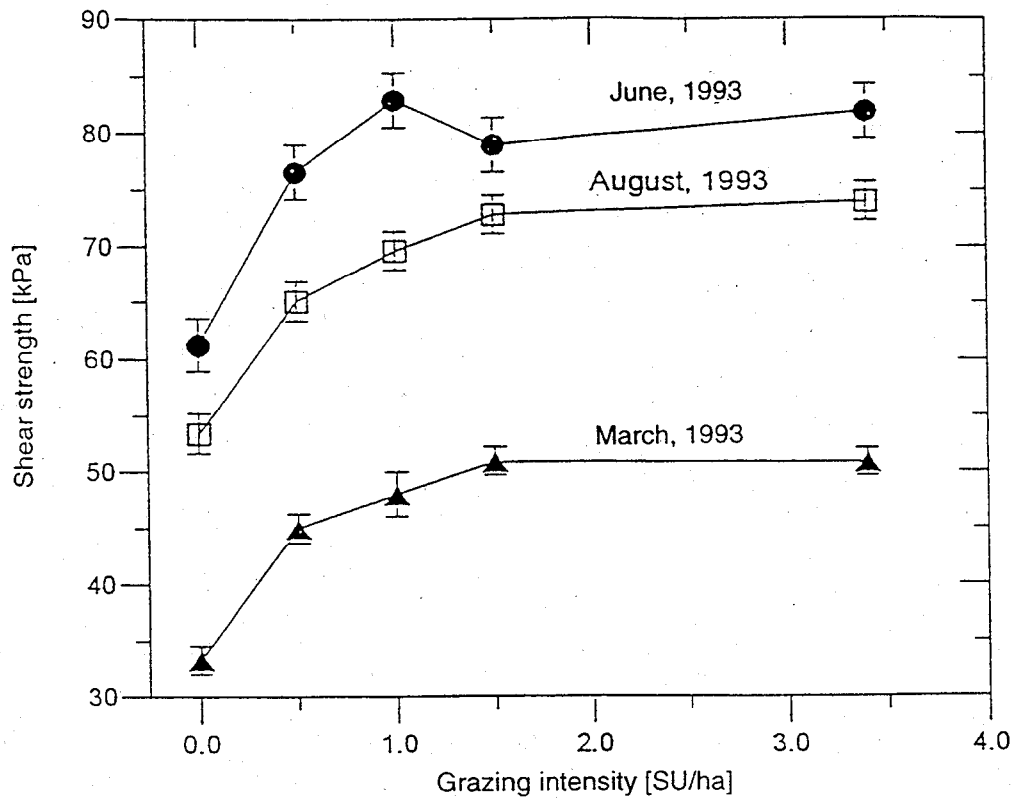

Fig. 17: The shear strength of the Sönke-Nissen-Koog salt-marshes as a function of grazing intensity. According to HORN & ZHANG (1994).

On the basis of the results of their studies into the physical properties of the soil, the authors recommend moderate grazing with 1 sheep unit per hectare (HORN & ZHANG (1994), although no erosion phenomena were observed on soil monoliths of non-grazed areas in the experimental wave tunnel. The shear strength of non-grazed foreland salt-marshes is thus adequate and is merely increased by moderate grazing.

These results permit the following conclusions to be drawn: Thanks to their protective plant growth, foreland salt-marshes are sufficiently resistant to large-scale erosion even without ditch building/maintenance and grazing. They may, however, be at risk from edge erosion. This can be adequately counteracted by brushwood groynes. Eroding foreshore edges can be protected by brushwood groynes and narrow ditches close to the dyke and a main drainage channel are sufficient for drainage of the foot of the dyke. Systematic measures covering the entire salt-marsh area are not necessary.

4.2.2 Influence of ditch building and maintenance on salt-marsh formation in the shelter of brushwood groynes

The influence of ditch building and maintenance on salt-marsh formation in the shelter of brushwood groynes was investigated in the Sönke-Nissen-Koog foreland salt-marshes. A small salt-marsh area which is protected by brushwood groynes, where no ditches have been built and cleaned for decades and which is characterised by a finely branched tidal-channel system with shallow, water filled old creeks and salt pans exists in this area. Colour infrared photographs were taken of these salt-marshes in 1988 (Fig. 18) and 1993 (Fig. 19) on a scale of 1:10,000 and 1:5,000 respectively. Figs. 18 and 19 both show the outer limit of the area covered by vegetation. Comparison of the two photographs clearly shows the increase in the extent of the salt-marshes in the shelter of the brushwood groynes constructed in 1989 (c.f. Fig. 18). Intensive ditch building and maintenance work had taken place in the southern area, whereas the northern zone had been allowed to develop without such intervention.

In the ditched sector the horizontal foreshore growth over the 5 year period was roughly 80 - 90 m, corresponding to an annual rate of between 16 and 18 m. In the adjacent area where no such measures had been taken, the foreshore boundary had advanced seawards by approximately 40 - 80 m in the same period, or by 5 - 16 m per year. The somewhat greater growth in area in that part of the salt-marsh where ditches had been built and maintained can probably be attributed to the position of the brushwood groynes.

sedimentation. According to DIECKMANN (1988)

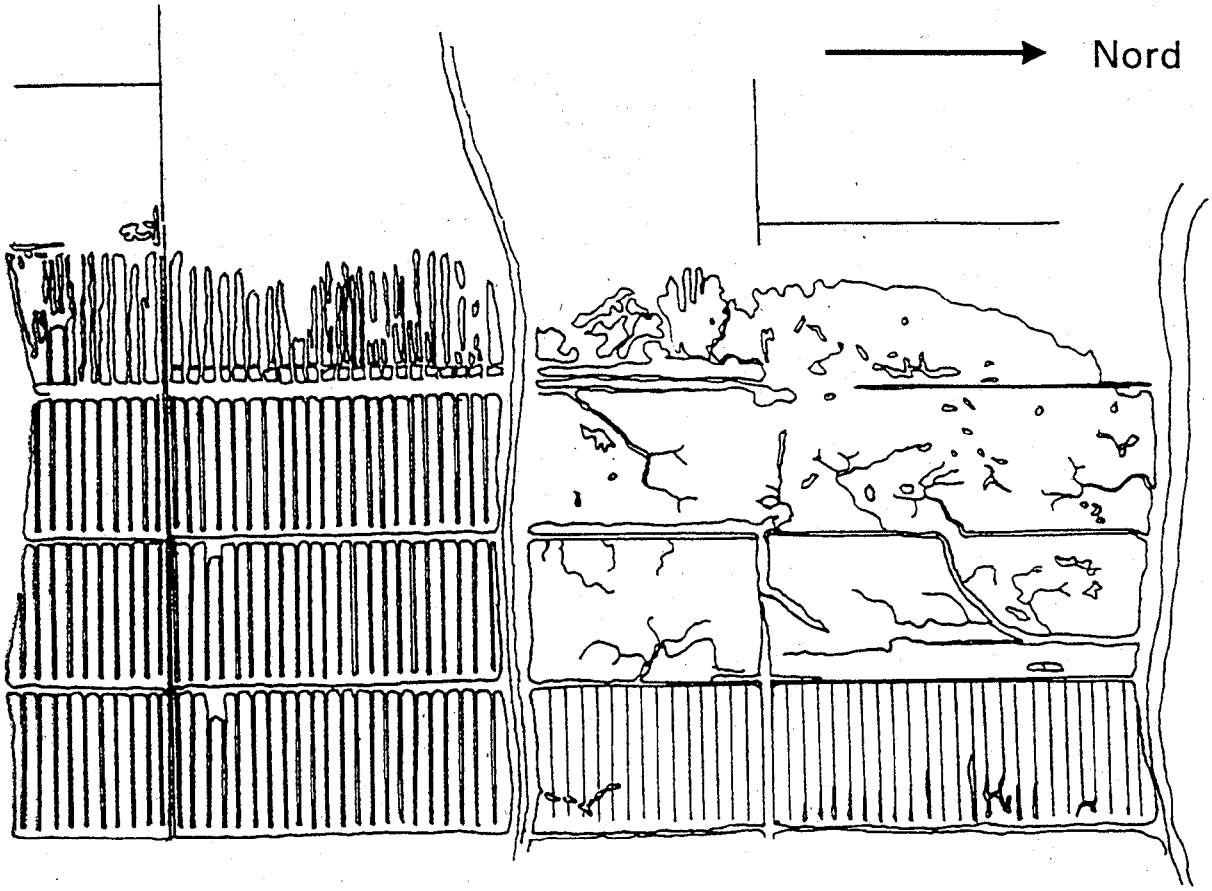

Fig. 18: Salt-marsh development in the shelter of brushwood groynes, Sönke-Nissen-Koog, CIR photograph, May 1988.

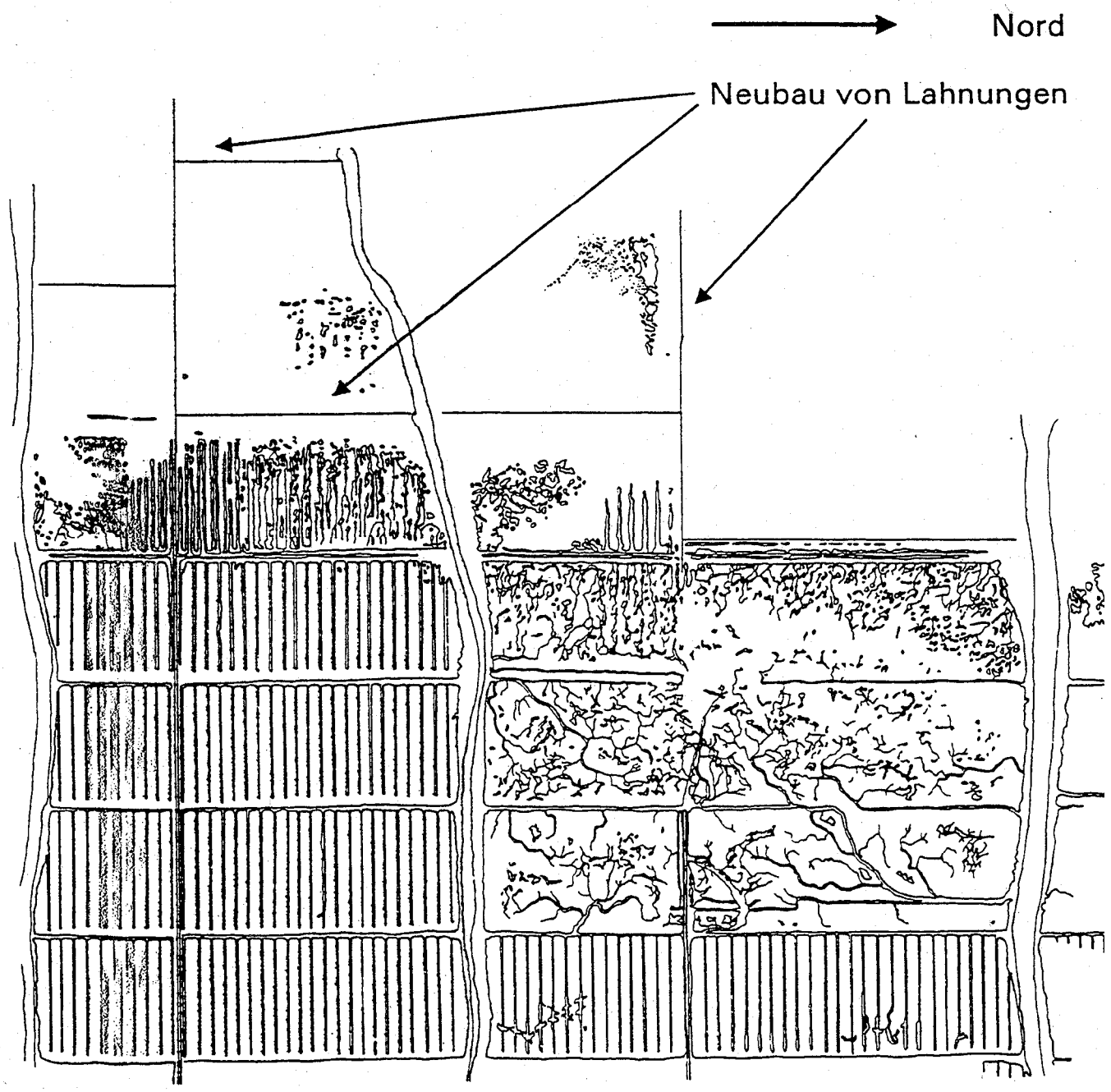

Fig. 19: Salt-marsh development in the shelter of brushwood groynes, Sönke-Nissen-Koog, CIR photograph, August 1993. Ditch building/maintenance work had been performed in the left section, but not in the right section of the brushwood groynes.

the average annual growth rate of salt-marshes in the Nordfriesian part of the Wadden Sea for the period between 1830 and 1978 was 7.1 m, but only 4.7 m in the period 1940 to 1979. DIJKEMA et al. (1988) indicate an average annual growth rate of 4.7 to 8.2 m for the Dutch foreland salt-marshes in the period 1960 to 1987. According to ADAM (1990) the horizontal growth of salt-marshes may, however, fluctuate greatly within small areas and over the course of time. He stresses that the sedimentation conditions are directly dependent on the position of tidal channels and mud flats further seaward, which are highly dynamic in character.

A comparison of the morphological structures in salt-marsh accreted over the last five years (Fig. 20) shows that the area without ditches is rich in geomorphological structures, with meandering tidal channels and salt pans. A smaller percentage of this area is covered with water than is the case in areas where intensive ditch building and maintenance work has taken place. On the basis of the assessment of aerial photographs roughly 30 % of the area is covered by water in salt-marshes where ditches are built and maintained, as opposed to only 10 % in salt-marshes with a near-natural geomorphological structure (KOHLUS, pers. comm., REENTS 1995).

This clearly shows that salt-marshes can develop in the shelter of brushwood groynes without extensive and sustained use of mechanical ditch building and maintenance. Accordingly, "natural" foreshore development is possible in areas featuring positive sedimentation conditions even without the construction of brushwood groynes.

4.2.3 "Re-naturalisation" of foreland salt-marshes

If the ditches in the foreland salt-marshes are not maintained - particularly in the low-lying areas – the ditches begin to meander and the rigid pattern of ditches breaks up. Depending on the current, gradual or steep slopes form on the sides of the channel. The tidal channels become narrower and generally deeper. Following the collapse of ditches, submerged areas or salt pans may occur.

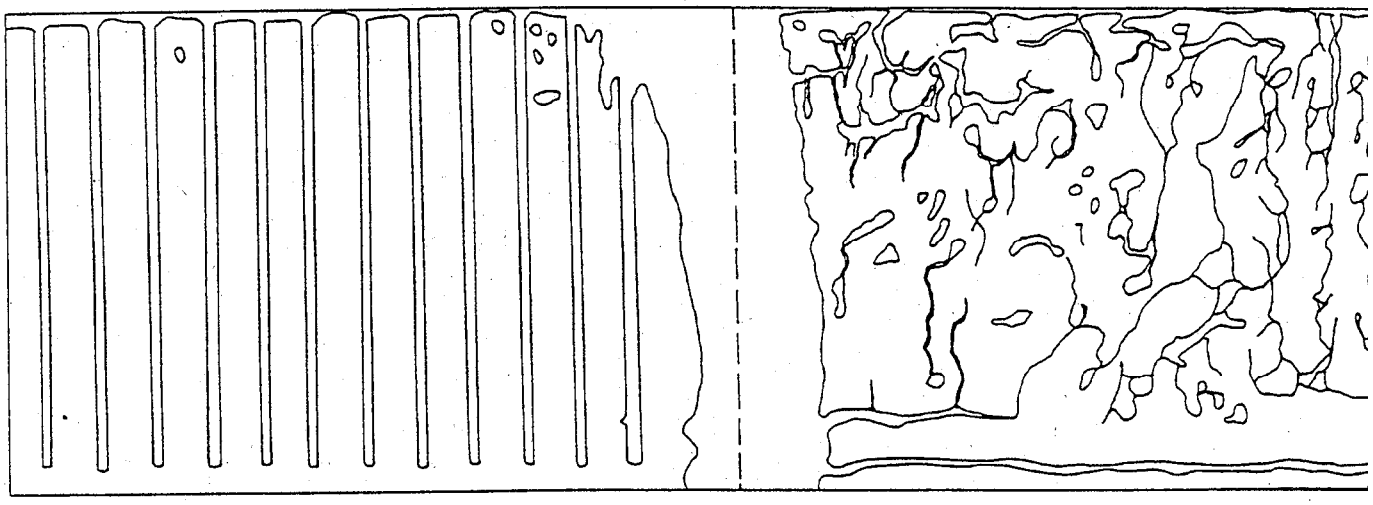

Fig. 20: A natural geomorphological structure develops in salt-marshes where ditch building/maintenance is abandoned. Where ditch building/maintenance is continnued there is little structural diversity. Sönke-Nissen-Koog salt-marshes, CIR photograph, August 1993.

This can take several years depending on the elevation and degree of exposure of the salt-marsh. Break-up of the rigid ditch profiles is, however, very rapid and can be seen in many salt-marsh areas (Fig. 21). The process takes longer in the higher salt-marshes.

The island of Trischen is an example of how dynamic this process can be. The polder area of the island, which was still being cultivated in the 1940s and the brushwood groyne sediment fields in the eastern part with the foreland salt-marshes were left to develop naturally after the brushwood groynes were abandoned in 1943 (TODT, pers. comm.). Fig. 22 shows the contours of the island of Trischen according to aerial photographs taken in 1935, 1973 and 1991 on a scale of 1:10,000. The island is drifting slowly eastward and it has moved over the polder area which now lies to the west in the mudflats. Parts of the former foreland salt-marsh are to be found in the inner, western sector of the current salt-marsh.

The salt-marsh spit in the eastern part of the island is the result of natural growth. The eastern boundary of the salt-marsh scarcely developed between 1973 and 1991. There is, however, evidence of salt-marsh accretion in the northern sector. All other areas have become covered with sand in the course of time (TODT, pers. comm.). The aerial photograph taken in 1973 reveals the break-up of the ditch structure. The harbour tidal channel, which already existed on the foreshore in 1935, has developed over the years and today still forms the main tidal channel in the south-eastern part of the salt-marsh (Fig. 22).

Even now - 50 years after the salt-marshes were abandoned - it is possible to make out the original pattern of ditches and ridges of what used to be the foreland salt-marsh, although a great deal of changes have taken place. In the topography, however, this structure has almost completely disappeared with the exception of the former embankments. The salt-marsh on the leeward side of the island of Trischen is without doubt an exceptional feature, but this example nevertheless shows the sort of development which can occur when nature is left to run its dynamic course.

Fig. 21: The profile of a drainage ditch gradually disintegrates over the years, Hamburger Hallig.

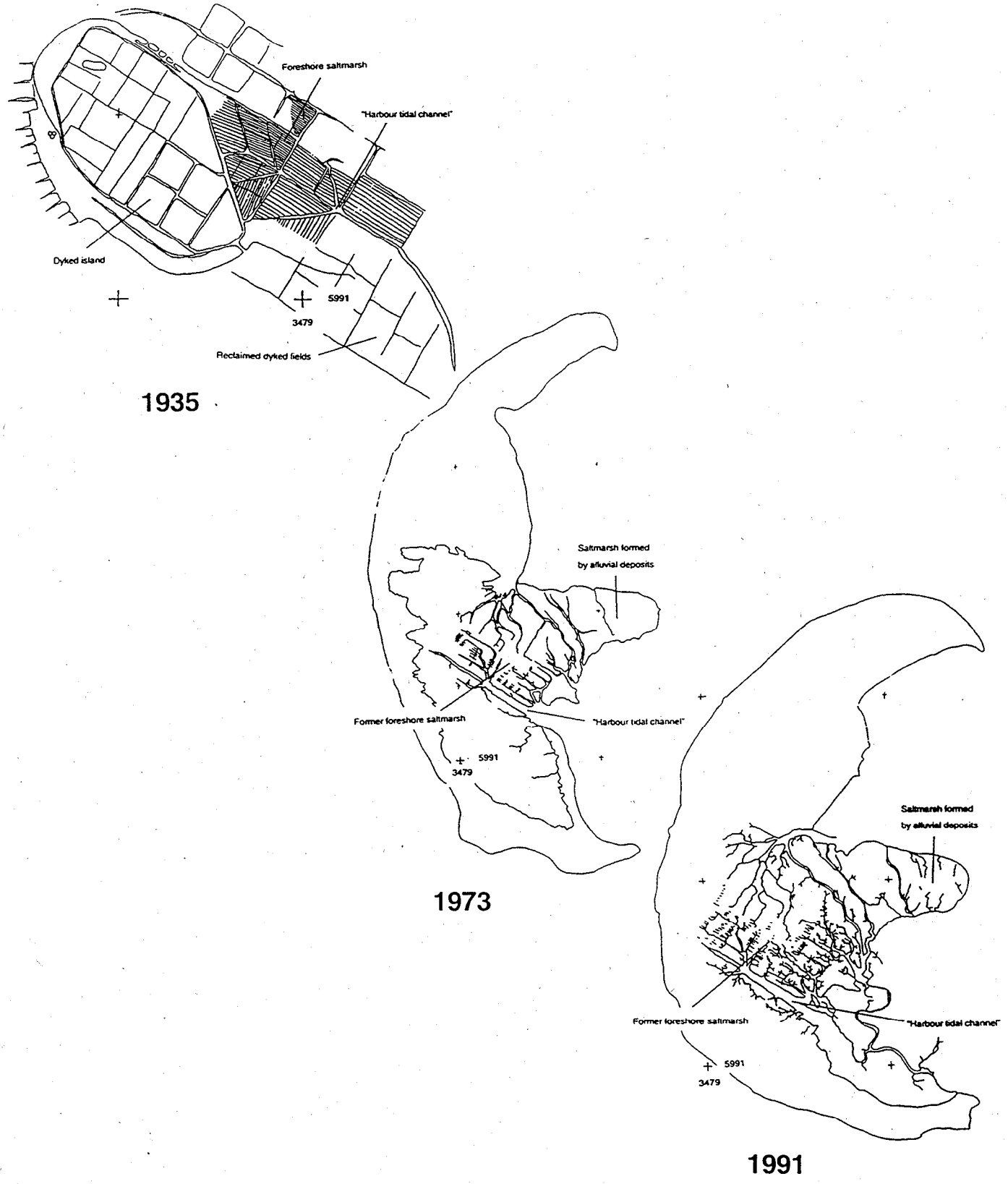

Fig. 22: The foreshore of the island of Trischen in 1935, 1973 and 1991. Drawn from B/W aerial photographs to a scale of 1:10,000. The Gauss-Krüger co-ordinates are plotted to aid orientation. Note the eastern drift of the island over the years.

5. Basic principles for the development of a salt-marsh protection concept

The conservation and development of man's natural environment requires certain habitats to be preserved in their original condition or transformed such that they are subject to less intervention. There may be many reasons for such a course of action: To conserve biological diversity, to preserve genetic resources, to maintain the original condition of areas considered to be of particular scenic beauty and aesthetically appealing, or to provide an opportunity for familiarisation and contact with nature in its original form.

Some biotops require management measures to recreate near-natural conditions or to maintain a specific, desired status. Large-scale natural habitats do not require such management activities. They can be left to develop naturally and to undergo the dynamic processes characteristic of each particular habitat.

Opinions differ among the various Wadden Sea states as to the nature and scope of management measures to be taken in the Wadden Sea salt-marshes. The viewpoints of the Dutch and German nature conservationists have recently been presented and discussed (DIJKEMA 1992, BAKKER 1993, STOCK 1993, ZANDER 1993). The Danish views on salt-marsh protection are explained by VOIGT (1990) and GRAVESEN (1990).

Whereas species diversity is the main nature-conservation objective in The Netherlands, priority is given in the German Wadden Sea national parks to ensuring that natural processes remain undisturbed. In line with the respective targets set and the resultant management measures, the central issues are thus grazing of the salt-marshes as well as differing ideas on nature management and the scope of coastal protection measures (BAKKER 1989, BAKKER et al. 1993, DIJKEMA 1994, KIEHL & STOCK 1994).

5.1 Inter-regional recommendations

Initial impetus for salt-marsh protection in the Wadden Sea resulted from a conference organised by the WWF (KEMPF et al. 1987). Under the heading of "Salt-marshes: The product of coastal protection, agriculture or nature ?" representatives of various specialist disciplines outlined requirements for the Wadden Sea salt-marshes and held discussions on the various objectives to be set for salt-marsh protection. On the basis of the results of this conference, the WWF then drew up recommendations for salt-marsh protection in the Wadden Sea:

> "The fundamental aim is to preserve the remaining salt-marshes. Above all, no further losses resulting from dyke construction, land reclamation, construction measures or uses not compatible with nature can be accepted in the entire Wadden Sea area. No artificial land reclamation work whatsoever should be performed in salt-marsh zones where there is a natural tendency for sedimentation to occur. In the protected salt-marshes, all human activities and measures must serve, or at least not be detrimental to, the purposes of nature conversation.
>
> Various protection strategies and goals are to be developed and implemented in the form of a regionally and internationally co-ordinated, differentiated salt-marsh protection and maintenance programme."

The recommendations for salt-marsh protection in the international Wadden Sea were translated into concrete terms at the international salt-marsh conference in Rømø in 1989 (OEVESEN 1990). These reflect the progress of discussions in 1989 in the three Wadden Sea states and contain the compromises reached on various aims and concepts. This means that certain recommendations are contradictory or unspecific. Thus, for example, protection by law and natural development were declared to be principal objectives, whilst at the same time there was considered to be a need for management measures (e.g. grazing) to preserve the diversity of the natural salt-marsh biotopes.

For the agriculture and salt-marsh management sector, detailed recommendations were made with regard to vegetation management involving the grazing of cattle and/or sheep. These recommendations, though, are only applicable if vegetation management is compatible with the fundamental protection objectives. Salt-marsh management and natural development are, however, mutually exclusive.

The recommendations of the Rømø Conference formed the basis for the Sixth Trilateral Governmental Conference on the Protection of the Wadden Sea in Esbjerg, where the environment ministers of the Wadden Sea states declared that the Wadden Sea should be protected as a natural, self-preserving ecosystem in which natural processes can take place undisturbed (CWSS 1992). This should involve further harmonisation of the interests of nature conservation and coastal protection, with the safety of the human population living behind the sea dykes being acknowledged as a matter of prime importance.

The ministerial declaration covered, for example, a ban on embankment of saltmarshes and mudflats, the possibility of opening summer dykes to recreate salt-marshes and a ban on the use of fertilisers and pesticides on salt-marshes.

These objectives were again emphasised at the 7th Conference of Environment Ministers in Leeuwarden (CWSS 1994b). The ministerial declarations, however, only become binding once they have been implemented in the form of laws, regional ordinances or other legally binding directives, regulations or programmes.

Above and beyond these measures the Common Wadden Sea Secretariat is currently co-ordinating work on the development of a management plan for the entire Wadden Sea, one aspect of which will be recommendations for Wadden Sea salt-marsh management (c.f. CWSS 1994a).

5.2 Legislation

5.2.1 State Nature Conservation Law

Certain aspects of the ministerial declarations made in Esbjerg in 1991 were implemented in Schleswig-Holstein in the form of the State Nature Conservation Law (LNatSchG). This law places numerous biotopes such as mud flats, tidal channels, sandbanks, coastal dunes and salt-marshes under special protection. These areas are expressly designated as being "top-priority nature conservation areas" in which any action which could destroy, damage, severely impair or bring about a change in the characteristic nature of the protected biotopes is banned (c.f. §15a (2) LNatSchG).

§15a (5) LNatSchG further bans foreland salt-marsh management work (ditching and brushwood groyne construction) and grazing within the National Park. These are only permitted within the national park if the stipulations of §15a (5), no. 1 and 2 are satisfied. Management measures in specially protected biotopes (§15 LNatSchG) lying in the 150 m strip between the national park boundary and the sea dyke are exempt from this regulation.

This is a consequence of the constitutional stipulation that the Federal Nature Conservation Law (§20c BNatSchG) must be implemented at state level. This means, for instance, that future plans for coastal protection measures in the salt-marshes of the National Park must observe the legal priority of nature conservation in the National Park in accordance with §20c (BNatSchG) (Schleswig-Holstein State Parliament, publication 13/1369). During the process of implementation of federal law at state level, the legislator was aware that the exclusion of the mud flats and salt-marshes between the sea dyke and landward boundary of the National Park does not fully correspond to the provisions of the Federal Nature Conservation Law.

As a more recent and more specific regulation, §15a LNatSchG supersedes §2 (3) of the National Park Law (Schleswig-Holstein State Parliament, publication 13/1369), according to which there were no restrictions on coastal protection measures which included safeguarding of the foreland salt-marshes, land reclamation and drainage of inland areas. This provision also permitted sheep grazing insofar as this served the purposes of coastal protection.
Exemptions from this ban can be granted on application if

1 exemption is necessary on grounds of the public welfare and if the associated detrimental effects on the balance of nature or to the landscape is rectified in line with §8 and §8b (LNatSchG) or

2 the measure is necessary for nature conservation purposes.

This provision guarantees that any necessary coastal protection measures can take place.

The coastal protection concepts in Schleswig-Holstein which have to satisfy the stipulations of the State Nature Conservation Law and State Water Act have been produced by a working group consisting of representatives of the ministries of agriculture and the environment as well as the subordinate nature conservation and coastal protection authorities (MELFF 1995).

5.2.2 National Park Law

In addition to the regulations contained in the State Nature Conservation Law, the National Park Law provides the legal framework for the protection of the Schleswig-Holstein Wadden Sea. §2 (2) describes the objective of the law as follows:

"The establishment of this National Park serves to protect the Schleswig-Holstein Wadden Sea and to preserve its particular characteristics, its beauty and its natural state. Its wide range of species of both flora and fauna is to be protected and natural processes are to be allowed to take place with a minimum degree of disturbance" (MELF 1985).

The stipulations of the National Park Law and the State Nature Conservation Law thus create the legal basis for a salt-marsh protection concept in which "natural processes are to be allowed to take place with a minimum degree of disturbance" in the salt-marshes as well.

6. Protection concept for the salt-marshes in the Schleswig-Holstein Wadden Sea

6.1 Ecology-based guiding principles for salt-marsh protection

6.1.1 Importance of the salt-marshes for the Wadden Sea ecosystem

The Wadden Sea between Esbjerg and Den Helder is considered to be the longest unbroken stretch of tidal mud flats in the world and is also known as Europe's greatest wetland area (OEVESEN 1990). Within the Wadden Sea as a whole, the salt-marshes are classed as the largest single example of this type of ecosystem in Europe. Embankment has, however, repeatedly caused the loss of considerable salt-marsh areas, with the result that the once continuous salt-marsh strip along the mainland coast of the Wadden Sea is broken at numerous locations.

The salt-marshes along our coasts are today one of the biotops most in need of protection in Central Europe. Many of the organisms resident here could not survive in the long term in other biotops. In addition to plants adapted to live in a saline environment (halophytes) these organisms mainly include a large number of invertebrate species (arachnids and insects), which are dependent on the salt-marshes of the Wadden Sea. More than 250 species, subspecies and ecotypes are classed as being endemic to the Wadden Sea (DE JONG et al. 1993). The conservation of the salt-marshes with their specialised fauna and flora thus serves to protect irreplaceable genetic resources.

Of the vertebrates, birds in particular make use of the salt-marshes as breeding, feeding and roosting grounds. In late summer more than 3 million coastal birds can be observed at any one time in the Wadden Sea roosting on the salt-marshes at high tide (PROKOSCH 1988, MELTOFTE et al. 1994). There are around 20 species of birds for which the salt-marshes and surrounding land represent a major breeding ground (FLEET et al. 1994). Salt-marshes are also an important feeding

area for geese and ducks (BERGMANN et al. 1994).

Sediment is deposited and exchanged in salt-marshes, thus cleaning and filtering the North Sea (ASJES & DANKERS 1994). The salt-marshes are important in terms of coastal and dyke protection, as they absorb wave energy and thus protect the sea dykes (DIJKEMA 1984). This function is of significance with regard to the rising sea level (DIJKEMA et al. 1990, DIJKEMA 1994).

Not least, the salt-marshes provide irreplaceable resources for research, study and instruction. Furthermore, the natural landscapes of the Wadden Sea and the natural salt-marshes are extremely important as recreational areas.

6.1.2 Diverse protection objectives

From the nature conservation standpoint various protection objectives can be formulated for the Wadden Sea salt-marshes, with the significance and weighting of each individual aim and the resultant recommendations being the subject of controversial discussion. The various objectives are presented and assessed in the following.

Objective: Conservation of salt-marshes

The internationally acknowledged overriding objective is the conservation of the salt-marshes. This goal was established for example in 1986 at the WWF Wadden Sea Conference (KEMPF et al. 1987) and in the recommendations made by the Rømø Conference (OEVESEN 1990, c.f. Section 5.1). It is also emphasised in both the State Nature Conservation Law and the National Park Law. It forms the basis for the ban on further embankment work and the required increase in the salt-marsh area, for example by way of opening the summer dykes (CWSS 1992).

Apart from preservation or extension of the salt-marsh area, there are further objectives of relevance to nature conservation, on which - in accordance with the weighting they are given - various management recommendations depend.

Objective: Species diversity

Dutch scientists in particular regard the species diversity of the salt-marshes as being the most important objective (c.f. WESTHOFF 1985, BAKKER 1989). With a view to preserving the greatest possible diversity of species, the authors call for moderate grazing of the salt-marshes. Especially in upper salt-marsh areas with uniform habitat conditions, the discontinuation of grazing can lead to the dominance of individual plant species such as the *Elymus pycnanthus* and thus to a reduction in the diversity of plant species. In the opinion of BAKKER et al. (1993), natural salt-marshes which have never been grazed should, however, remain so in order to give priority to natural succession.

In comparison to other biotops, salt-marshes tend to have relatively few species, as the organisms to be found here are "specialists" adapted to extreme living conditions. According to TISCHLER (1979), a small number of animal species exhibiting a large number of individuals is typical of extreme habitats. The results of vegetation studies reveal that individual plant species may compete with others to become dominant in non-grazed areas (BAKKER 1989, DIERSSEN et al. 1994 a, b). Alternation of dominant stands of different plant species is, however, characteristic of near-natural salt-marshes. When viewed over a small area, near-natural non-grazed salt-marshes may only have a small number of species, however, on a larger scale it becomes apparent that individual plant species are not endangered and that species diversity is similar to or even greater than that found in grazed areas (DIERSSEN et al. 1994 a, b).

Intensive sheep grazing on the other hand may endanger individual plant species as, in contrast to cattle, sheep are very selective when choosing their food plants and specific plant components (DIERSSEN et al. 1994 a,b). Consequently even if, after decades of intensive grazing, grazing pressure is reduced on the foreland salt-marshes of Schleswig-Holstein, sheep may in the long-term slow down the process of permanent establishment and propagation of the plant species which are susceptible to grazing.

The recommendation made by BAKKER (1989, 1993) in favour of moderate salt-marsh grazing is based on studies on the effects of cattle grazing, which has less impact than sheep grazing on the establishment and propagation of plant species susceptible to grazing.

The number of species in a plant community does not provide any information on the development status and vitality of the individual species. As grazing severely damages many plant components, in particular generative organs, the ecological function of a species - for example as a habitat and food source for specialised animal species - is not guaranteed simply by its presence. HEYDEMANN (1984) and MEYER et al. (1995) for instance refer to the significance of the flower horizon. Already in moderately grazed salt-marshes insects that visit the flowers of the sea aster are absent, as few of the plants actually ever blossom in such areas.

The number of animal species registered on the non-grazed and moderately grazed plots of the Sönke-Nissen-Koog and Friedrichskoog salt-marshes in Schleswig-Holstein was only slightly higher than in intensively grazed areas. However, further analysis of the data shows that species which are particularly characteristic of salt-marshes can only become established in areas where little or no grazing takes place. Furthermore, an unbalanced dominance structure was registered in the intensively grazed plots for the majority of taxa investigated.

Objective: Structural diversity

The term "structural diversity of salt-marshes" is often mentioned in the course of discussions on objectives and recommendations, but is hardly ever precisely defined. It is widely used to refer to the following aspects:

Diversity of geomorphological structures

Salt-marshes with a wide variety of geomorphological structures are ones with a natural drainage system, featuring for example tidal channels with both shallow gradual slopes and steep abrupt slopes, raised channel edges, salt pans and non-

draining old arms. As a result of the numerous microhabitats, the diversity of species may be somewhat greater than in salt-marshes with few morphological structures (DIERSSEN et al. 1987). Artificially created salt-marshes, on the other hand, with their regular channel system, feature a uniform morphological structure and therefore more evenly balanced habitat factors. There are no special habitats. In areas where ditches have not been maintained for many years, the diversity of geomorphological structures increases again when ditches start to meander, steep ditch edges wear down or non-draining old arms are formed by the collapse of ditch edges and sedimentation.

Structural richness of vegetation

BARKMAN (1979) describes the horizontal and vertical distribution of morphological vegetation elements as the vegetation structure. Structural richness can be defined as the alternation of different single structures, such as individual plant species (DIERSSEN et al. 1991), various growth forms or higher and lower parts of plants (BAKKER 1989).

Phytosociological studies reveal that it is not possible to give a generally valid description of structurally rich vegetation, as the structural diversity depends on the scale under consideration.

In lower salt-marsh zones, the greatest small-scale variation in vegetation height is to be found in non-grazed areas, which can thus be classed as possessing a wealth of vegetation structures. In areas of moderate sheep grazing, the small-scale differences are less pronounced in the lower salt-marsh zone. When considered on the scale of several hundred metres, however, gradients can be observed between low vegetation in areas close to and high vegetation further away from the dyke. In upper salt-marsh areas, on the other hand, moderate grazing is accompanied by small-scale alternation between high and low *Festuca rubra* vegetation (BERG & GROENEWEG 1994, BERG et al. 1997).
Cattle and sheep grazing have different impacts on the vegetation structure. Generally speaking, areas grazed by sheep are more evenly cropped over a small

area and thus exhibit fewer structures than those on which cattle graze.

Habitat diversity

A diversity of geomorphological structures and vegetation structures promotes the development of the rich invertebrate fauna characteristic of salt-marshes. Various salt-marsh animal species are dependent on special structures and microhabitats. Thus, for example, numerous phytophagous insects are directly dependent on the formation of specific structural elements of vegetation such as stems or flowers (DIERSSEN et al. 1994 b).

The above examples illustrate that both used and unused salt-marshes can be described as having a wealth of structures depending on the parameters and scales chosen for consideration. The use of the term "structural diversity" therefore has to be clearly defined in the context of discussions on objectives.

Objective: "Natural dynamics" or "undisturbed course of natural processes"

The undisturbed course of natural processes is the declared prime objective of the Schleswig-Holstein, Niedersachsen and Hamburg Wadden Sea National Park laws. Against this background, the discontinuation of sheep grazing and a considerable reduction in coastal protection measures, particularly with regard to the building and maintenance of ditches in foreland salt-marshes, are recommended for nature conservation reasons (STOCK 1993, KIEHL & STOCK 1994).

Natural salt-marshes largely free from human influence are worthy of protection in the Wadden Sea region on account of their small total area and special features (c.f. WESTHOFF 1985, DIJKEMA et al. 1990, BAKKER 1993).
Despite having been created by coastal protection measures, foreland salt-marshes subjected to ditch building and maintenance can be largely given over to natural sedimentation and erosion processes (KIEHL & STOCK 1994, CWSS 1994b). This means that coastal protection measures such as the construction of

brushwood groynes and ditch building/maintenance should be greatly reduced. As the preservation of the salt-marshes is the uppermost objective, the construction of brushwood groynes cannot be avoided in areas at risk from erosion. This in turn restricts their natural character.

If ditch building/maintenance is considerably reduced and grazing discontinued, foreland salt-marshes will develop into more natural ecosystems. They can, however, never become natural salt-marshes.

By contrast, the cessation of anthropogenic activities in areas with a high sedimentation rate allows new natural salt-marshes to form. The enhancement of sedimentation by way of brushwood groynes can also promote the development of near-natural salt-marshes in areas with lower sedimentation rates, if ditch building/maintenance is dispensed with and a natural drainage system allowed to form.

6.2 Objectives for salt-marsh protection

The particular desirability of and necessity for protection of the salt-marshes along the Wadden Sea coast are reflected in the corresponding laws and recommendations (§20c BNatSchG; §15a LNatSchG; National Park Law; OEVESEN 1990; Trilateral Ministerial Declaration, Esbjerg and Leeuwarden). Consequently, any future-oriented protection concept should incorporate all salt-marshes irrespective of their current protection status.

Salt-marsh protection in the Schleswig-Holstein Wadden Sea is governed by the guiding principle of "natural dynamic processes" and relates to all salt-marshes. An exception is only made for the salt-marshes of the Halligen which lie outside the National Park (c.f. Section 6.4.3.1).

Guiding principle of "natural dynamic processes"

The guiding principle for the protection of the salt-marshes is that a salt-marsh should be largely free from human influence, with tidal channels left to meander, a geomorphological structure typical of the habitat and a distribution of flora and fauna governed by natural dynamic processes.

The implementation of this guiding principle corresponds to the international nature conservation requirements applicable to a National Park. It should be stressed that there are no fixed goals, for example with respect to the establishment of plants and wildlife. Salt-marshes should be able to form and develop in line with the characteristic features of the biotops.

A first step in the implementation process is the large-scale cessation of agricultural usage. The second stage involves more or less complete discontinuation of the maintenance of the artificial drainage channels in salt-marshes. Coastal protection activities to safeguard the existing foreshore are to be reduced to a minimum and are to become more compatible with nature. In parallel with these measures, a comprehensive protection concept is to be developed and a concept for the control of recreational activities in order to ensure that selected salt-marsh areas remain accessible to humans for recreational purposes and as natural history study areas.

When implementing this guiding principle it is absolutely essential to give continued priority to the protection of the coastline and the human population living behind the dykes. If natural dynamic processes are allowed to take their course, a monitoring programme will be necessary to observe the future development of the Wadden Sea salt-marshes, both with regard to the establishment of flora and fauna and with respect to changes in the morphological structure due to sedimentation and erosion (MELFF 1995).

6.3 Implementation of the salt-marsh protection concept

6.3.1 Implementation problems in the past

For decades, coastal protection requirements have determined the outward appearance of the Wadden Sea salt-marshes. The foreshores of Schleswig-Holstein were primarily viewed as being coastal-protection "structures":

"A foreshore cushions the force of the waves during flooding, prevents the bases of dykes being washed away by encroaching tidal channels, supplies soil and turf for dyke maintenance, provides a substitute for extremely expensive stone revetments at the base of the dyke and serves as an alternative grazing area for sheep which, for animal health reasons, cannot be grazed solely on the dykes" (MELFF 1990).

Intensive salt-marsh grazing was considered an essential element of coastal protection in the past. Even as late as 1990, the following statement was made in a MELFF brochure "Coastal Protection in Schleswig-Holstein" on the maintenance of coastal-protection features, including the foreland salt-marshes of the mainland coast as well as the Wadden Sea islands and Halligen:

"The most important and at the same time most natural means of maintaining dykes and foreland salt-marshes is to let sheep graze on them. This guarantees a firm turf, keeps the turf short and provides the necessary fertilisation" (MELFF 1990).

There are no comparable demands with regard to grazing of salt-marshes of neighbouring countries. In The Netherlands, no demands are made on the agriculture usage of the salt-marshes in the context of coastal protection. The Dutch dykes are, however, provided with strong revetments at their base. Grazing and grass-cutting take place in the Dutch salt-marshes, within the scope of management measures and in line with nature-conservation stipulations. The Danish foreshores are still intensively grazed in many areas, however, not for coastal protection reasons, but rather in the economic interest of the sheep

farmers.

For years, European agricultural policy failed to recognise the ecological significance of non-grazed salt-marshes. State compensation payments and subsidies led to a large intensification of sheep grazing on salt-marshes in Schleswig-Holstein over the past 30 years, that was not experienced on salt-marshes in the rest of the Wadden Sea area. This is illustrated by the sheep stock figures for Schleswig-Holstein: In 1986 a total of 33,000 ewes (not including their lambs) were counted on the dykes and foreland salt-marshes of the West coast of Schleswig-Holstein. 12,500 ewes were grazing on the salt-marshes in the National Park. This corresponds to a grazing intensity of almost 4 ewes per hectare of salt-marsh. If the lambs and young ewes are included, this gives a total of up to 12 sheep grazing on each hectare of salt-marsh on the mainland coast of Schleswig-Holstein.

Findings obtained from ecosystem research and above all growing awareness of the importance of non-grazed salt-marshes, have led to a situation where the coastal protection authorities no longer categorically demand foreland salt-marsh grazing for coastal protection reasons.

Initially, the reduction of agricultural usage of salt-marshes in the National Park was a slow process. The stipulation made by the National Park Law that "unreasonable impairment of the interests and customary practices of the local population is to be avoided when implementing protection measures" (§2 (2) NPG) hindered efforts to reduce or discontinue sheep grazing.

A working group "dyke sheep-farming" was formed in 1986 from representatives of the sheep farmers, the coastal-protection authorities and nature conservationists. Over the course of several years, this working group formulated the following agreement on the basis of available information and on the basis of the present the political situation:

- On expiry of its lease, each sheep farm should reduce its stock by 20 %

within a 3-year period without compensation, provided that such a course of action does not endanger the economic livelihood of the farmers.

- Instead of a 20 % reduction in stocks it was agreed to stop grazing completely on the area of salt-marshes needed for grazing 20 % of the stock., as the 20% reduction did not have a noticeable effect on the salt-marshes.
- New leases are not to be granted for those given up on account of retirement.
- The following preamble will be incorporated into new lease contracts:

  "As a North Sea protection measure and to prevent eutrophication the salt-marshes - as coastal margin zone - must be allowed to develop naturally. This will involve large-scale restrictions on salt-marsh grazing in the National Park. Moderate grazing is permitted provided that it complies with nature conservation requirements. On the other hand, intensive grazing must be continued on the sea dykes, a salt-marsh strip directly in front of the dykes and the areas needed for turf for dyke maintenance. The discontinuation or restriction of salt-marsh grazing must not be allowed to endanger the livelihood of the tenants."

In addition to the steps taken by the working group to reduce sheep grazing, success was achieved in 1989 in reducing grazing from an intensive to a moderate level in a large area of the natural sand salt-marsh in St. Peter - Böhl. On a smaller scale, it also proved possible, within the scope of the ecosystem research studies started in 1987, to stop or reduce usage of small salt-marsh areas. A large-scale reduction in the number of sheep and therewith the intensity of salt-marsh grazing was, however, impossible because it would have endangered the livelihood of the sheep farmers (§2. 2 National Park Law). It was not until the coastal margin zone programme was launched in 1991 that the necessary steps could be taken to achieve an effective reduction in use of the National Park salt-marshes for grazing (BOLEY 1991).

6.3.2 The coastal margin zone programme as an important implementation aid

Since its introduction in 1991, the coastal margin zone programme (KURP) of the Schleswig-Holstein State Government has met with a resounding response; it pursues the following goal:
"As North Sea protection measure and to prevent eutrophication, the salt-marshes - as a coastal margin zone - must again be allowed to develop naturally. This will involve a large-scale reduction and in many areas even the discontinuation of grazing in the National Park salt-marshes."

Within the framework of the objectives pursued by its coastal margin zone programme, the State of Schleswig-Holstein grants financial compensation, corresponding to the level of previously earned profits, if sheep farmers give up sheep farming on foreland salt-marshes and dykes. This promotes the reduction of salt-marsh grazing in the National Park, as the leased dyke areas relinquished are then offered for lease to neighbouring sheep farmers, who in turn then have to proportionally reduce the number of sheep they keep on the salt-marshes.

A one-off payment of 200.- DM is awarded for each ewe less kept on the foreshore or dyke, with the maximum total per farm being set at 100,000.- DM. These funds are granted in the form of fixed-sum allocations in the context of project subsidisation as set out in the KURP guidelines (OFFICIAL GAZETTE for SCHLESWIG-HOLSTEIN 1991). The sum available in each of the first two years was 264,000.- DM, with 150,000.- DM being provided in both 1993 and 1994 and a further 75,000.- DM in 1995. Table 6 outlines the measures made possible to date by the coastal margin zone programme.

Tab. 6: Measures carried out by the State of Schleswig-Holstein within the coastal margin zone programme for the reduction of the number of ewes on salt-marshes. Situation at the end of December 1994.

Year	Number of Ewes taken off the salt-marshes	Area of dyke where grazing was stopped (ha)	Area of foreland salt-marsh where grazing was stopped (ha)	Costs (DM)
1991	1303	85.3	329.4	260,600
1992	1230	97.8	148.5	246,000
1993	374	4.7	* 69.6	74,800
1994	295	8.4	** 74.5	59,000
Total	3202	196.2	622.0	640,400

*) additionally the number of ewes has been reduced on 261 ha of foreland salt-marsh on the Hamburger Hallig

**) Partly estimated figures, as payments were not always made for the entire sheep stock of a tenant.

6.3.3 The present situation of salt-marsh protection

In 1986 approximately 80% of all the salt-marshes along the mainland coast of Schleswig-Holstein were grazed very intensively, 13% moderately and only 7% were not grazed at all (KEMPF et al. 1987). Only 4% of the total salt-marsh area can be classed as long-term non-grazed and these constitute the only reference areas in Schleswig-Holstein for salt-marshes not subjected to agricultural influence over the long term (Fig. 23).

By 1989 90 % of all foreland salt-marshes were intensively grazed, 9% moderately

grazed and 1% ungrazed. Grazing in Nordfriesland only involves sheep, whereas in Dithmarschen domestic geese are also kept. For the most part abandonment of or reduction in grazing took place along the mainland coast in the foreland salt-marshes.

Since the early 1990s it has proved possible to reduce the proportion of intensively grazed foreland salt-marshes along the mainland coast to a level of 54% in 1994. The number of moderately grazed salt-marshes increased slightly to 10%, whereas the proportion of non-grazed salt-marshes rose from 1% to 36% (Fig. 24).

Table 7 outlines the size of the various types of salt-marsh, the area they cover within the National Park and the extent of agricultural utilisation of the respective salt-marsh areas. The figures quoted for the sizes of the variously grazed salt-marsh areas refer to the status in December 1994.

Tab. 7: Salt-marshes and their agricultural utilisation on the West coast of Schleswig-Holstein (December 1994). All figures in ha. NP = National Park.

Salt-marsh type	Total	In NP	Int. grazing	Mod.. grazing	Non-grazed
Foreland salt-marsh - mainland 1)	6125	4832	3262	268	2623
Foreland salt-marsh - Wadden Sea islands	374	72	336	19	19
Foreland salt-marsh - Halligen	218	0	0	0	218
Sand salt-marsh - mainland	735	559	0	278	457
Sand salt-marsh - Wadden Sea islands	439	240	170	0	269
Hallig salt-marsh	2093	111	0	1942	151
Total foreland salt-marsh	6744	4904	3598	287	2860
Total sand salt-marsh	1174	799	170	278	726
Total Hallig salt-marsh	2093	111	0	1942	151
Overall area	10011	5814	3768	2507	3737

1) Including Neufeld estuarine salt-marsh

Of the 10,000 hectares of salt-marsh, 37 % were not being put to any agricultural use at the end of 1994, 25 % were being grazed moderately and 38 % intensively. At the same point in time, 42 % of the foreland salt-marshes in the Wadden Sea were non-grazed, 11 % grazed moderately and 47 % intensively.

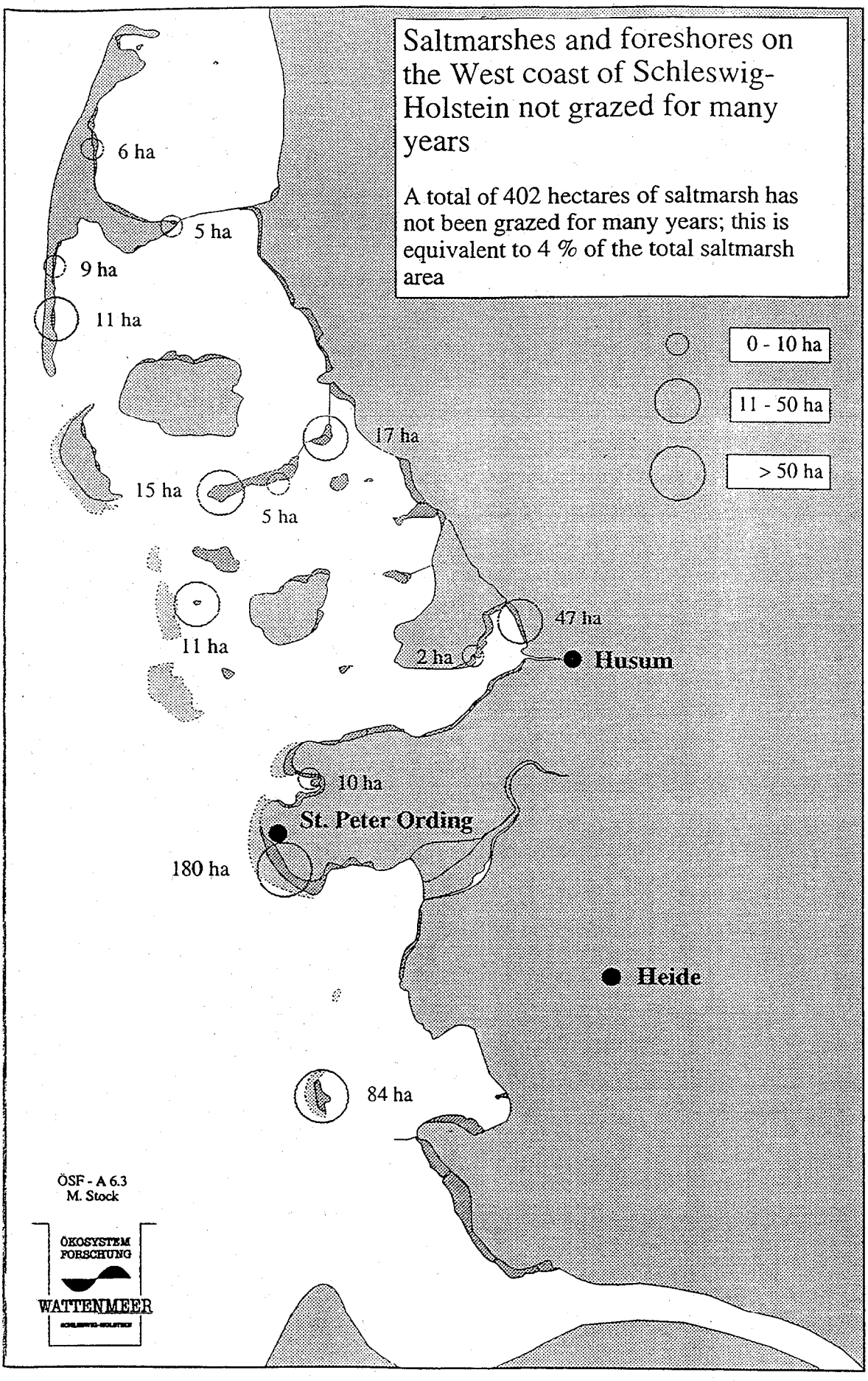

Fig. 23: Salt-marshes on the West coast of Schleswig-Holstein that have not been grazed for many years.

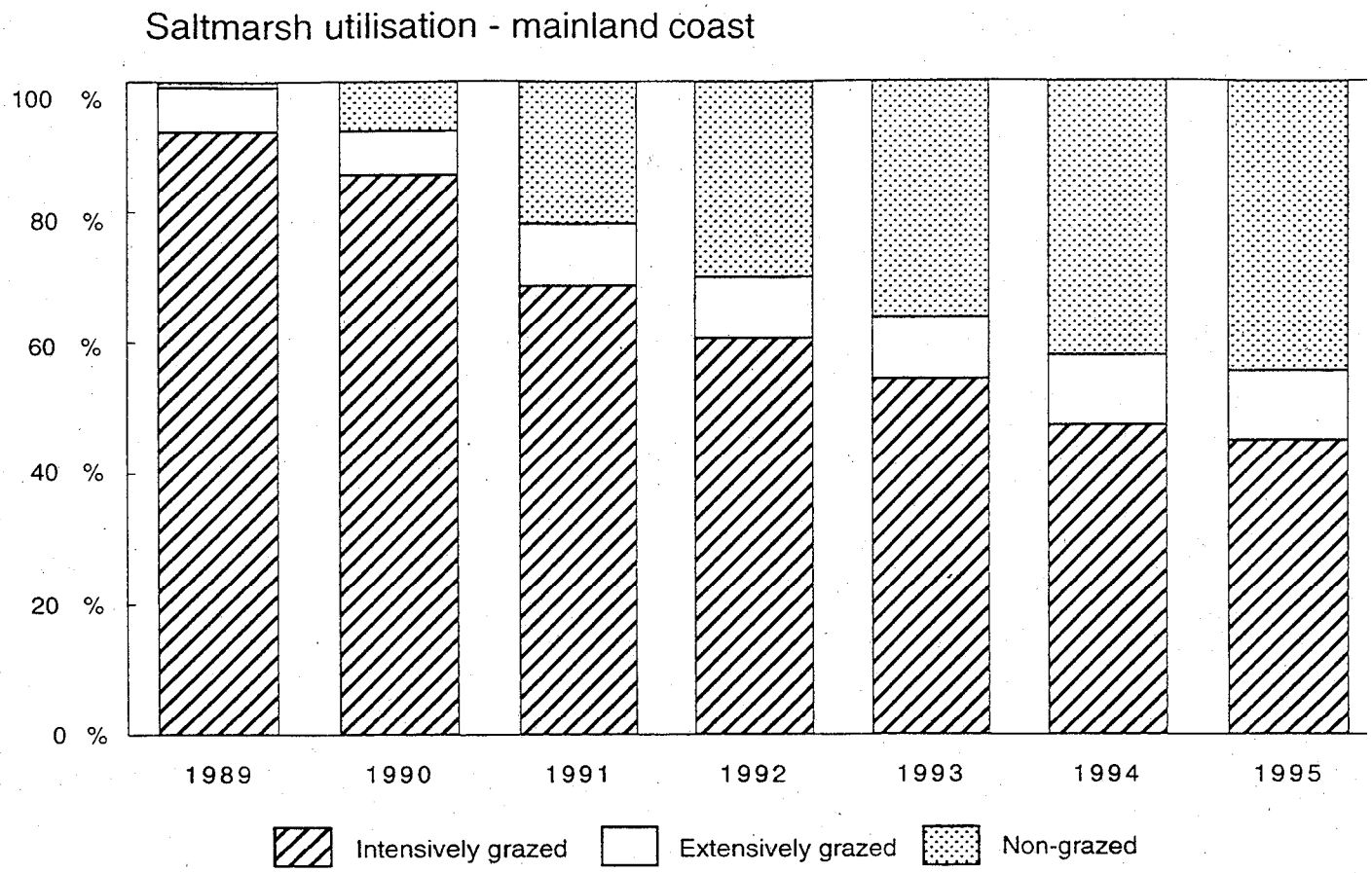

Fig. 24: Utilisation of foreland salt-marshes for sheep grazing on the mainland coast.

At the end of 1993, 62 % of the sand salt-marshes were non-grazed, whereas 24 % were being grazed moderately and 14 % were being used intensively or for other purposes. The sand salt-marshes of the mainland coast occur exclusively in St. Peter - Ording and are grazed by cattle and horses. Most of the sand salt-marshes on Sylt are grazed by cattle, with some being cut or used for example as recreational areas,.

The majority of the salt-marshes on the Halligen are moderately grazed (93 %), only 7 % are non-grazed. Agricultural utilisation has been discontinued completely on the Langeness foreland salt-marshes and to a great extent (82.5 %) on those of Oland and Nordstrandischmoor. Moderate grazing on the Halligen is subsidised as part of the "Hallig Programme". Grazing on the Halligen is mainly with cattle, though horses and sheep are kept in some areas.

Table 8 provides an outline of the size, intensity of usage and type of utilisation of the Wadden Sea island and Hallig salt-marshes in Schleswig-Holstein.

Tab. 8: Extent, utilisation intensity and type of utilisation of Wadden Sea island and Hallig salt-marshes (December 1994). Areas given in ha. C = cattle, H = horses, s = Sheep. The foreland salt-marsh areas are not included in the data for the Halligen.

Region	Area	Int. grazing	Mod. grazing	Non-grazed	Type of utilisation
Sylt	296	264	0	32	C/H/S
Amrum	57	23	19	15	C/H/S
Föhr	221	73	0	148	S
Pellworm	145	145	0	0	S
Trischen	94	0	0	94	0
Langeness	1006	0	933	73	C/H/S
Hooge	580	0	564	19	C/H/S
Oland	204	0	117	87	C/S
Gröde	230	0	197	33	C/S
Nordstrandischmoor	180	0	132	48	C/S
Südfall	40	0	8	32	S
Süderoog	54	0	23	31	C/H/S
Habel	6	0	6	0	S
Norderoog	11	0	0	11	0

Fig. 25 gives a summary of the status of salt-marsh grazing intensity along the West coast of Schleswig-Holstein in December 1993. The illustration shows the percentage grazing intensity in each sub-area as defined by HÄLTERLEIN et al. (1991). It should be noted that the various sub-areas differ greatly in size.

Moderate grazing is mainly to be found on the Halligen and in small areas on the island of Amrum as well as on the Hamburger Hallig and in St. Peter - Ording.

Larger intensively grazed areas occur on Sylt, on the mainland coast to the North of Dagebüll, on Pellworm, in the eastern part of the North coast of Eiderstedt and in Dithmarschen.

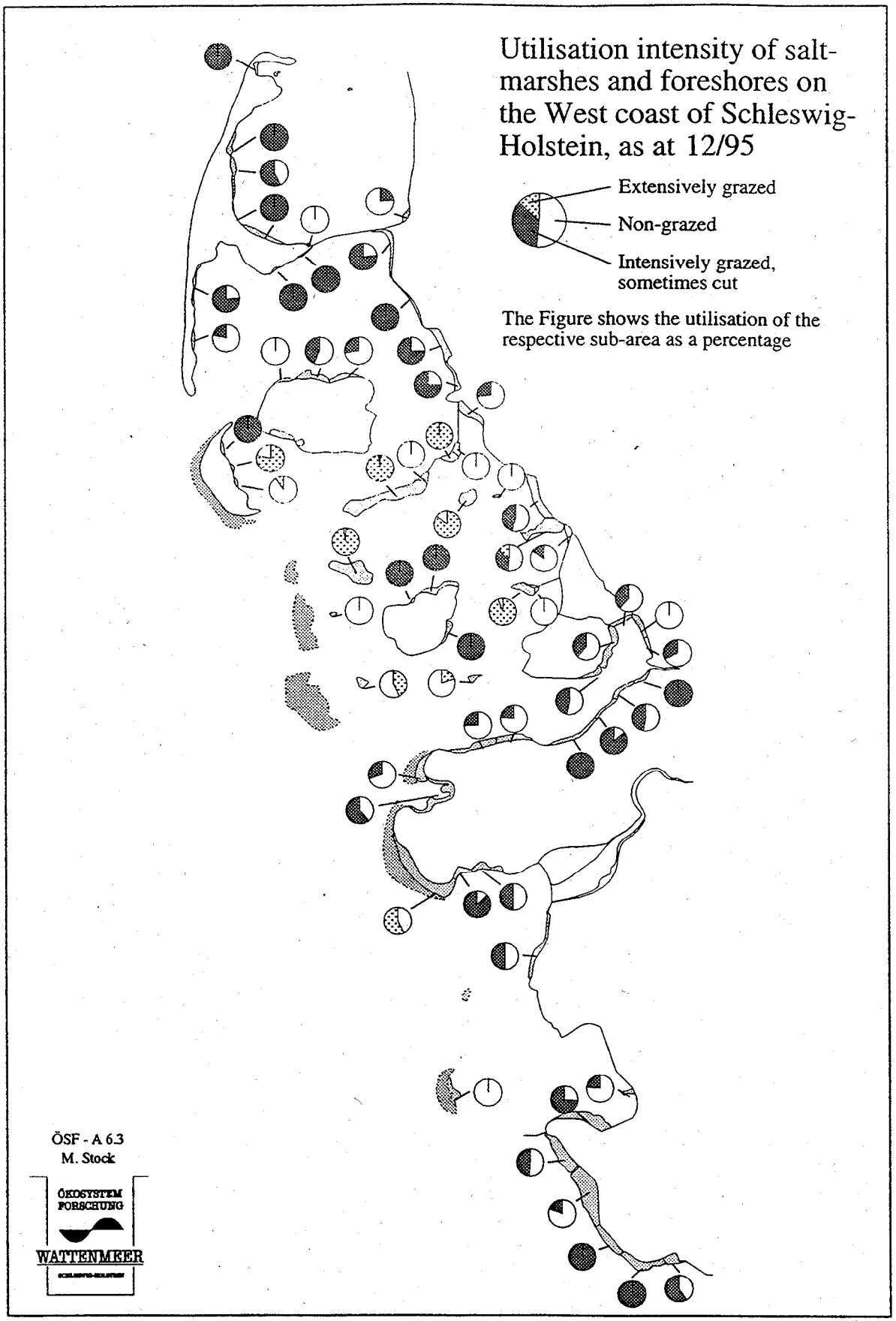

Fig. 25: Utilisation intensity of salt-marshes on the West coast of Schleswig-Holstein (December 1993).

6.4 Problem areas

The legislative provisions, ecological factors and nature-conservation policy targets presented in Sections 5 and 6 provide the framework for salt-marsh protection in the Schleswig-Holstein Wadden Sea. Implementation is, however, hindered by various factors and can only be achieved over a lengthy period of time and in several stages. A first step was to reduce agricultural usage of the salt-marshes, this was followed by efforts to make coastal protection compatible with nature. This has been accompanied by small-scale measures to control the flow of visitors for limited periods, for example to protect breeding colonies as well as roosting and feeding grounds of birds.

Regardless of the success in salt-marsh protection and reduction of grazing already achieved, medium and long-term solutions and strategies for their implementation will have to be developed for the problem areas; protection area boundaries, tourism and control of visitor flow, agriculture, coastal protection and also educational and public relations activities.

6.4.1 National Park boundaries

According to §15a LNatSchG salt-marshes are protected biotopes. This applies to all salt-marshes both within and outside the boundaries of the National Park. §15a (2) (LNatSchG) prohibits all activities which "... result in ... serious impairment of or a change in the characteristic state" of §15a biotopes. Grazing of the salt-marshes by sheep leads to their serious impairment and a change in their characteristic state (c.f. Section 4.1). However, with regard to salt-marsh grazing, the LNatSchG only contains a provision covering the areas within the National Park. §15a (5) LNatSchG states that grazing is prohibited in these areas. Existing contracts with sheep farmers retain their validity for an interim period up until 1998.

The distinction between salt-marsh areas inside and outside the National Park and the associated differences in their treatment cannot be justified on ecological

grounds and is a political compromise. The consequence of this distinction is that the various saltmarsh areas are currently treated in different ways, both with regard to grazing and coastal protection aspects (c.f. Sections 6.4.3 and 6.4.4). In the long term, all salt-marshes should be integrated into the National Park within the framework of an amendment to the National Park Law. This will apply in particular to the salt-marshes in the so-called 150 m strip, the estuarine salt-marshes at the mouth of the Elbe and in the Godel marsh on Föhr as well as to the salt-marshes on the Wadden Sea islands (c.f. STOCK et al. 1996).

6.4.2 Tourism

Due to the increasing number of visitors to the National Park and the surrounding areas the impact of tourism on Wadden Sea habitats has reached an alarming level in recent years. As there is no full-time ranger system in the National Park, the flow of tourists within the National Park is relatively uncontrolled, particularly in the salt-marshes and shore areas (c.f. KNOKE & STOCK 1994, STOCK 1992). Isolated solutions to this problem have been found at local level over the last few years. There is, however, no overall, spatial concept aimed at directing the course of, and where necessary concentrating, new developments and plans from their instigation onward, or aimed at rectifying existing shortcomings. One aspect of great importance in this respect is the incorporation of the areas surrounding the national park within the national park boundaries.

Such a concept for the salt-marsh areas is to be drawn up in the synthesis phase of the ecosystem research project on the basis of spatial surveys of tourism, leisure activities (visitor control, e.g. cycling, horse-riding, dog-related problems, windsurfing, kite-flying etc.), harbour locations, leisure-craft, excursion traffic and air traffic over the National Park, with consideration also being given to ornithological data.

6.4.3 Agriculture

Grazing of the salt-marshes in the National Park is generally prohibited, except in cases where grazing is necessary for nature conservation reasons (§15a LNatSchG).
In line with the objectives for salt-marsh protection in Schleswig-Holstein, the guiding principle is to maintain natural dynamic processes. Management measures, for example in the form of vegetation or grazing management for breeding birds, can only be justified in exceptional circumstances on nature-conservation grounds.

Small areas of the National Park are currently being moderately grazed by sheep and cattle. On the mainland this involves two areas, namely the sand salt-marshes of St. Peter-Ording and part of the foreland salt-marsh on the Hamburger Hallig. Use has been made of this situation on the Hamburger Hallig to investigate the effects of the different grazing levels on the vegetation and birdlife.

6.4.3.1 Agricultural utilisation of the Halligen

With the exception of the mainland salt-marshes indicated above, moderate grazing occurs only on the Halligen. Within the National Park this relates to small areas on the Halligen of Habel, Süderoog and Südfall, and outside the park boundaries, to the salt-marshes of the large Halligen.

The moderate grazing currently practised on the Halligen in the National Park should be completely stopped, as it is not necessary from the point of view of nature conservation. Südfall and Süderoog are good examples of the dynamic processes which develop in abandoned salt-marsh areas. These two Halligen also provide evidence of the fact that non-grazed salt-marshes are also used intensively by Brent Geese (RÖSNER & STOCK 1994).

The Halligen outside the National Park boundaries are used for low intensity farming within the framework of the "Hallig" programme (OFFICIAL GAZETTE for

SCHLESWIG-HOLSTEIN 1987, 1992). Whereas in the beginning this programme concentrated on securing the livelihood of the local population, its amendment (OFFICIAL GAZETTE for SCHLESWIG-HOLSTEIN 1992) gave greater weight to landscape preservation aspects and also subsidises the conservation of salt-marshes in their natural condition.

According to the recommendations made by STOCK et al. (1992), the cessation of agricultural utilisation in certain areas is more beneficial than a general reduction in grazing intensity of the whole area. This should not, however, give rise to a situation where specific areas are used more and more intensively, while others are not used at all. Abandonment of agricultural activities should concentrate on low-lying areas and those exhibiting a wealth of geomorphological structures. In the long term agricultural usage should also cease in broad strips along the edges of tidal channels and ditches, as in such areas cattle frequently trample down the turf. The aim must be to achieve a pattern of moderately grazed and unused salt-marsh areas, a demand which is also reinforced by the latest findings of an accompanying study (PETERSEN & DEMUTH 1994).

6.4.3.2 Grazing management in sand salt-marshes

The recommendations for protection of salt-marshes that are based on the results of the ecosystem research relate to foreland salt-marshes, as the studies concentrated exclusively on such areas (DIERSSEN et al. 1994 a,b, 1997). It is not possible to apply these results directly to the situation found in sand salt-marshes. Investigations into sand salt-marsh have, however, been performed, especially in The Netherlands, and appropriate grazing management recommendations made (c.f. BAKKER 1989, 1991, 1993).

In the Schleswig-Holstein Wadden Sea, large sand salt-marshes are only found on the mainland coast in St. Peter-Ording and on the island of Sylt. Some moderate grazing is practised in both these areas. Generally speaking, the objectives formulated in Section 6.2 should also apply to these salt-marshes and consequently grazing should be discontinued.

Implementation of the objective "natural dynamic processes" is, however, hindered in St. Peter-Ording by the fact that this salt-marsh is the main breeding site of the southern Dunlin (*Calidris alpina schinzii)* within the salt-marshes of the Schleswig-Holstein Wadden Sea (HELDT 1966, SÜDBECK & HÄLTERLEIN 1994).

The reasons for the decline in the southern Dunlin population, which has its southern boundary in this area, are not known. There is, however, evidence that the breeding population of this subspecies is generally declining (PIERSMA 1986). FRIKKE (1991) and JÖNSSON (1991) suspect that the main reason for this decline is the discontinuation of grazing in many former breeding grounds. This is not the case in St. Peter-Ording, as there have not been any major changes in grazing management and the breeding population now breeds for the most part in non-grazed areas (SCHULZ, pers. comm.). One important factor responsible for the move from grazed to non-grazed areas could well be the accessibility of the former areas to predators (JÖNSSON 1991).

The sand salt-marshes influenced by freshwater in St. Peter-Ording and on Sylt are also characterised by rare plant communities which have adapted to the prevailing habitat conditions (DIERSSEN et al. 1988). These include sites with the communities *Ononido-Caricetum distantis*, *Sagino-Cochlearietum* and *Blysmetum rufi*. Moderate cattle grazing is recommended to safeguard these stocks (DIERSSEN pers. comm., SCHERFOSE 1993).

Whether or not moderate grazing in certain areas of the St. Peter-Ording salt-marsh should be maintained on species-conservation grounds is still a matter of discussion.

6.4.3.3 Grazing of domestic geese on foreland salt-marshes

The foreland salt-marshes in Dithmarschen have traditionally been used for grazing domestic geese. This form of use is not practised to any comparable degree in other Wadden Sea salt-marshes. In line with existing lease contracts, there are

currently some 4,000 domestic geese grazing in the Dithmarschen foreland salt-marshes. This corresponds to 260 sheep units. Sheep-proof ditches are not an obstacle to geese, which means that these are also to be found in areas where officially grazing has been stopped. There are no findings as yet on the effect of such grazing on the salt-marsh flora and fauna.

6.4.4 Coastal protection

6.4.4.1 Creation of an unbroken salt-marsh margin to the Wadden Sea

The formerly extensive salt-marsh margin to the Wadden Sea in the transition zone between land and sea has been vastly reduced by embankment (KÖNIG 1987). Although land reclamation measures have created many new foreland salt-marshes, there are now gaps in what used to be an unbroken salt-marsh margin. The creation of foreland salt-marshes in front of dykes where they are not present aims to re-establish this unbroken margin. From the nature conservation point of view there is no need for the formation of a continuous salt-marsh margin using technical foreland creation measures. It is also questionable whether technical means could even be used to build up a foreland salt-marsh on low-lying and exposed mud flats in front of the present dyke. It is not possible to say at this point whether or not isolated salt-marsh fragments suffer from their island-like character. No published data is available on this subject.

6.4.4.2 Management in the 150 m strip

The National Park boundaries established in 1985 lead to differences in the way in which salt-marshes, which are protected under the State Nature Conservation Law, are treated (c.f. Section 6.4.1). Coastal protection measures in the 150 m strip are generally exempt from the stipulations of the State Nature Conservation Law (§15a (5) LNatSchG). As a consequence, they are still subject to intensive and systematic drainage including ditch building/maintenance activities. On coastal protection grounds intensive sheep grazing is necessary in the 150 m salt-marsh strip as well.

In the future, the coastal protection measures and grazing practised in the 150 m strip will have to be adjusted to the extent actually required to protect the dykes and should take a form more compatible with nature than has been the case to date. This will mean giving consideration not only to the results of the KFKI research projects, but also to the findings obtained from ecosystem research. The evidence that this has provided of high sedimentation rates on non-grazed areas close to the dyke is to be seen in a positive light from the point of view of coastal protection.

Coastal protection measures in the 150 m strip should be restricted to drainage of the foot of the dyke. Drainage work of this nature in the existing salt-marsh areas close to the dyke should only be performed using a ditch cutter or by hand and then only when required to maintain narrow drainage channels. The optimal distance between the ditches is to be determined experimentally. In the long term, systematic manual ditch work involving the digging of channels with widths of up to 1 m as little as 10 m apart, where the excavated material is thrown into the centre of the beds to raise the level of these, should be avoided. The latest findings of the KFKI project "Erosion resistance of foreland salt-marsh areas" reveal that this method does not guarantee the desired success (ERCHINGER et al. 1994). Moreover, the massive creation of this foreland salt-marsh strip is unnecessary, as turf extraction is not planned in this area which lies close to the dyke.

6.4.4.3 Turf extraction and soil removal

"Foreland salt-marsh work on the seaward side of the dykes is only performed for the purpose of coastal and dyke protection. ... foreland salt-marshes ... supply soil and turf for dyke maintenance..." (MELFF 1990).

The extraction of turf and, to a lesser extent soil, is still practised today in the salt-marshes of the National Park. Salt-marsh turf is required for dyke repair after storm damage has occurred, for new coverings during dyke construction and for repair of large areas where sheep or large numbers of visitors have damaged the turf by

trampling. Soil is required for dyke repair work and other uses. Soil extraction should be stopped except during natural catastrophes. Alternative sites for soil extraction are available on the landward side of the dykes.

The many years of experience gained by the coastal-protection authorities indicate that in the long term 650 hectares of turf must be maintained for the approximately 360 km of land protection dykes on the west coast of Schleswig-Holstein. The coastal-protection authorities are of the opinion that these areas must be intensively grazed, drained and tended. Nearly all the turf extraction areas lie within the National Park. From a coastal protection viewpoint in Schleswig-Holstein, soil extraction in the 150 m strip close to the dyke should not be allowed. By contrast, in Niedersachsen there are demands that precisely this strip should be managed and used for turf extraction (ERCHINGER et al. 1994).

Against the background of the special ecological significance of the salt-marshes and their protection status, the provision and management of turf areas to the extent stated above presents a problem. The coastal-protection concept should therefore be geared to reducing the use of salt-marsh turf to the absolute minimum required. The demand for turf is to be constantly re-assessed. Consistent use should be made of turf from non-salt-marsh areas wherever possible. This applies to all areas that lie 3 m and more above sea-level (approx. 1.5 m above mean high water level). Where salt-marsh turf is extracted, the areas involved are to be worked to ensure rapid re-growth of salt-marsh vegetation and re-use of the same areas at shorter intervals. Furthermore, investigations should be made into alternative sites for the production of salt-marsh turf which lie outside the National Park and outside the salt-marshes e.g. on inland meadows treated with saltwater, as well as into alternative methods for the cultivation of salt-marsh turf.

6.4.4.4 Demarcation of salt-marshes set aside from agricultural usage

The demarcation of salt-marshes set aside from agricultural usage is mainly through ditches, which wherever possible follow the course of existing drainage ditches. New ditches have only been dug in a few areas. In some places

demarcation fences have also been erected instead of using ditches.

The demarcation ditches have a width of 3 – 4 m and a depth of 1 - 1.5 m and are dug by an excavator. Maintenance work has to be performed at regular intervals. The excavated material is deposited on the seaward side of the ditch. Particularly in the case of repeated ditching, the material removed forms banks parallel to the dykes. Pioneer vegetation initially develops on these embankments, to be succeeded in all probability in the course of time by a vegetation characteristic of high-lying, well-drained locations. Experience from comparable areas shows that *Elymus pycnanthus* becomes more abundant in such situations. This form of ditching leads to a change in the natural composition of the vegetation.

In future, demarcation ditches should only be dug and maintained where ditches already exist and are known not to silt up quickly on account of high sedimentation rates. The excavated soil should be placed on the dyke side of the ditch and levelled. A side effect of this would be that the material would then rapidly raises the level of the salt-marsh areas close to the dyke.

Ditches are also unsuitable for demarcation purposes in sandy areas. Use should be made instead of fences in areas where ditches do not already exist, where there are high sedimentation rates or where sandy soil predominates. In many cases a careful check should be made on whether it is possible to create the demarcation immediately at the foot of the dyke. For practical reasons, fencing parallel and close to the dyke must be designed to allow for dismantling in winter. This means additional maintenance work and thus extra costs. It is proposed that compensation be paid for these measures.

6.4.4.5 Access ridges

The maintenance of so-called access ridges (banks of soil allowing for access to the salt-marshes and providing escape routes for sheep during high tides) in salt-marshes set aside from agricultural usage is comparable with the problems mentioned above. Their necessity is justified by the need to transport materials and

machines to the edge of the foreshore for the maintenance and building of brushwood groynes. Such transport is, however, of only secondary significance, as the material needed for brushwood groynes is generally transported by sea on barges. The movement of machines on the foreshore is more a technical matter. For instance in The Netherlands tracked vehicles and vehicles with balloon tyres have been developed which exert less pressure per unit of area than humans do with their feet. The use of these types of vehicles would ensure accessibility of the foreshore for vehicles in exceptional circumstances.

In ecological terms, the maintenance of access ridges also affects the salt-marsh habitat and the long-term creation of ridges with different ecological conditions. Such banks act for example as watersheds and therefore have a considerable influence on the hydrological conditions in the surrounding salt-marsh. They do not comply with the objective of allowing natural dynamic processes to take place. The maintenance of existing ridges in order to allow for access to the edge of the foreshore in an emergency (e.g. oil and chemical spillage) should thus be reduced to an absolute minimum. New access ridges should not be created in extensive foreland salt-marsh areas.

6.4.5 Educational and public relations activities

National Parks have to be accessible to visitors and ought to be a source of edification, education and recreation as well as providing a cultural experience. In the light of the above, visitors have to be made aware of the tasks and objectives of the National Park, but also of the typical appearance of the various habitats in the natural landscape. With this in mind, the system of information centres, information kiosks and boards and nature trails already existing in the National Park should be further developed. Furthermore slide shows, guided walks and other such information events are to be offered in conjunction with nature conservation associations. As far as salt-marshes are concerned, the range of activities is limited to nature trails and guided walks designed to explain the unique nature of this habitat to visitors and the importance of its conservation.

If, however, a visitor enters the National Park without making use of these options, he is confronted, after crossing the dyke on the mainland coast, with foreland salt-marshes which are not only uniform in appearance but are also intensively used for sheep grazing. With the exception of St. Peter-Ording there are hardly any areas where visitors can experience a natural, non-grazed salt-marsh with an appearance typical of this habitat. In the tourist centres such as Westerhever and the Hamburger Hallig the non-grazed salt-marshes are a long way from the dyke. There is thus an urgent need - in these areas at least - to place non-grazed areas along the paths in the immediate vicinity of the dyke as well. How else can National Park visitors be made to appreciate the objectives of salt-marsh protection other than by experiencing for themselves the pleasure of strolling alongside a salt-marsh in full bloom?

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