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BD. 204 • NR. 2

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WITH 25 FIGURES AND 3 TABLES

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Abstract

At seven localities along the coasts of Disko and Nûgssuaq the vegetation and soil conditions of salt marshes have been analysed by means of gradient analyses.

In a number of sample plots along transects, which represent the change in vegetation with increasing elevation, the species composition was quantified by frequency and cover determinations, soil samples were taken at depths of 0–5 and 5–15 cm, and the relative elevation was established as the height of the plot above the lower salt marsh limit in percentage of the vertical range of the salt marsh.

The number of species pr. m^2 in each plot and the species similarity between the plots along each transect were calculated.

The soil samples were analysed for actual water content, cation exchange capacity, organic matter, specific conductivity, pH, water-extractable and NH_4Ac-extractable Ca, Mg, K and Na, water-extractable Cl, H_2SO_4-extractable P and EDTA-extractable Cu, Pb, Zn and Ni. From these data a number of derived soil data were computed.

From the soil data in total, mean and standard deviation for each soil factor within six classes of relative elevation, and correlation coefficients between the soil factors mutual and between the soil factors and relative elevation, were computed.

The vegetation and soil conditions of each locality are described, and the general trends in the vegetation structure and edaphic conditions of the salt marshes in relation to the height above the lower salt marsh limit, which seems to correspond to the mean high water level, are pointed out.

It is shown, that the salt marshes form ecoclines from lower to upper marsh limit, composed by vegetational and environmental gradients. The ecocline has been divided into a lower and an upper salt marsh, dominated by *Puccinellia phryganodes* and *Carex glareosa* respectively; the vegetational and environmental characteristics of these marsh parts are described.

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Contents

Introduction

The coastal salt marsh vegetation in the Arctic is characterised by a rather high degree of circumpolar homogenity, arising from the occurrence of certain widely distributed species like the arctic *Carex ursina* as well as the arctic subartic *Puccinellia phryganodes*, *Carex glareosa*, *C. subspathacea*, *Stellaria humifusa* and *Potentilla egedii* (HULTÉN, 1962 and 1968). The number of species is generally lower than in temperate salt marshes; a gradual transition, however, exists between temperate and arctic marshes.

Generally, the arctic salt marshes are restricted to protected localities along the coastline, often in connection with river outlets and developed on fine-grained sediments supplied by the rivers.

The literature on arctic salt marsh vegetation is not very extensive. Reviews have been published by CHAPMAN (1960) and MOLENAAR (1974). Best known outside Greenland are the arctic marshes on Svalbard (WALTON, 1922; DOBBS, 1939; HADAC, 1946, and HOFMAN, 1969), in Northern Alaska (HANSON, 1953) and in Northern Canada (THANNHEISER, 1975), and the arctic-subarctic marshes in Northern Fennoscandia (KALELA, 1939; NORDHAGEN, 1954; GILLNER, 1955; THANNHEISER, 1974), in Western Alaska (HANSON, 1951) and in Hudson Bay (KERSHAW, 1976).

The salt marshes in Greenland are generally not extensive in area. The floristics and phytogeography of their vegetation is well known from regional studies on the vegetation of Greenland, published through the years, mainly in *Meddelelser om Grønland*. Recently salt marsh vegetation has been included in a monograph on littoral vegetation of the Angmagssalik district, published by MOLENAAR (1974). The environmental conditions of the Greenlandic salt marshes as well as arctic salt marshes on the whole are, however, only sparsely investigated.

The dominating environmental factor in salt marshes in general is the temporary inundations by water of high salinity, which partly determines the floristic composition of the vegetation and partly differentiates the vegetation within the marsh. Within the vertical range of the salt marsh the decreasing frequency and duration of tidal inundation with increasing elevation forms a continuous environmental gradient. Along such a gradient the species, according to WHITTAKER (1970)

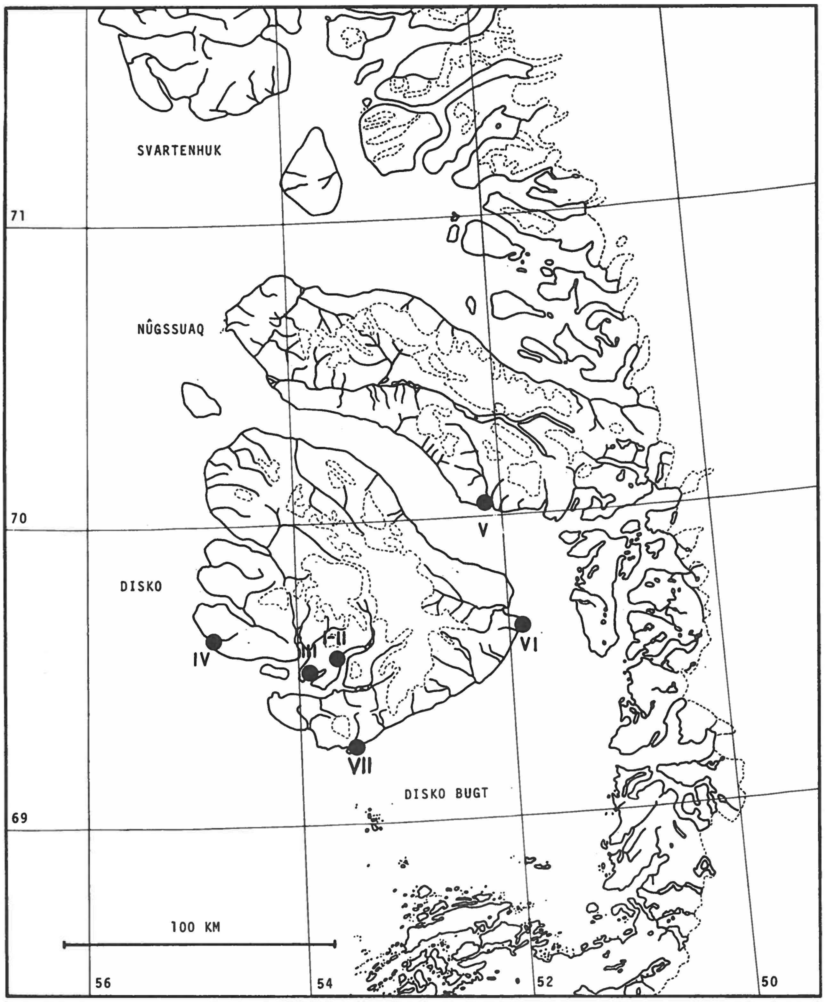

Fig. 1. Situation of the localities investigated.

I: Eqalúnguit, Disko Fjord, 69°33′N, 53°36½′W.
II: Eqalúnguit, Disko Fjord, 69°33′N, 53°37½′W.
III: Evqigtoq, Disko Fjord, 69°30′N, 53°51½′W.
IV: Eqaluit, 69°38′N, 54°47′W.
V: Sarqaq, 70°2½′N, 52°7½′W.
VI: Nûk, Flakkerhuk, 69°38½¹N, 51°52′W.
VII: "Sorte Sand", Godhavn, 69°15′N, 53°31½′W.

replace one another with greater or lesser overlap, according to their specific relations to abiotic and biotic factors and their specific life-cycles characteristics. However, the vegetation appears more or less zonally arranged, the zones being determined by the dominating species.

At the arctic coasts the tendency of zonal arrangement of the salt marsh vegetation is often less marked, as the local physiographic conditions may allow only small patches to be covered by salt marsh species (e.g. Molenaar op. c.). In West Greenland, however, where at certain localities more extensive areas are covered by salt marsh, several examples of zonal structure have been described (Berggren, 1871; Porsild, 1902; Böcher, 1963; Böcher & Lægaard, 1962; Nielsen, 1969).

This paper reports investigations on salt marsh vegetation within the Disko area in West Greenland. The aim of the work has been to investigate the vegetation structure and the soil conditions of the marshes in relation to the height above some hydrographically well-defined level, and from this to point out edaphic gradients reflecting the tidal influence and of possible importance to the plant distribution within the salt marshes.

The localities investigated are situated partly on the Disko island and partly on the peninsula of Nûgssuaq (fig. 1). This area is well investigated from a general botanical point of view, and it has therefore been possible from the literature as well as through personal communications to gather information on salt marsh localities within the area before beginning the field work.

The field work was carried out during a stay at the Arctic Station at Godhavn, Disko, belonging to the University of Copenhagen, July–August 1972, with assistance of Inge Vestergaard. The station's boat "Porsild" was put at our disposal during the stay and made it possible to visit rather scattered localities.

A similar study was carried out in Northern Norway in 1971 (Vestergaard, 1972).

Field methods

At each locality the vertical range of the salt marsh was established. The lower limit (L.L.) was defined by the lowermost level of salt marsh phanerogams, in every locality represented by *Puccinellia phryganodes*, on gently sloping ground. The hydrographical characteristics of this level, which was used as a zero-point in the height-determinations, are discussed on p. 37. The upper limit (U.L.) was defined as the level where the salt marsh phanerogams, commonly *Carex glareosa*, are replaced by epilittoral species, and may furthermore be marked by a lower limit of black lichens on rocks within the marsh area. It was possible to establish the lower and upper salt marsh limits with an accuracy of ± 2 cm and ± 5 cm respectively.

The epilittoral vegetation differs from locality to locality: *Salix glauca* scrub, *Empetrum hermaphroditum* heath, *Elymus mollis* dune or, locally, fresh-water marsh (not included in transects).

At each locality a transect was established from a point below the L.L.-level to a point in the epilittoral. The transect represents the vegetation gradient characteristic for the locality. Where the conditions were very regular, with the vegetation zones running parallel to the coastline, the transect was placed at right angles to the zones. Where the conditions were more complex a transect-line was chosen which best represents the vegetation gradient characteristic to the locality.

Along the transect a number of sample plots, small areas 2–3 m^2, of approximately floristic homogenity (Braun-Blanquet, 1964), were established. The intervals between the plots varied relative to the width of the vegetation zones.

Supplementary sample plots from vegetation desired to be included in the material, but not appropriately included in transects, were established at several localities. In total 83 sample plots were analysed.

For each plot 1) the height above the lower salt marsh limit was established, 2) the vegetation was analysed, and 3) soil samples were taken.

1) The height above the lower salt marsh limit was determined as the vertical distance from the sample plot to a wire fixed at a point at the upper salt marsh limit and stretched horizontally over the sample plots, subtracted from the vertical distance between the lower and upper salt marsh limits.

2) Vegetation analyses. The species composition was quantified by determination of frequency and cover degree of the species.

The frequency determinations were based upon the frequency method of RAUNKIÆR (RAUNKIÆR, 1909 and 1916). Within the homogenious vegetation, represented by the sample plot, ten circles of 0,1 m^2 were placed. Where the transect runs at right angles to the vegetation zones, the circles were placed with intervals of 0,5 m along a line at right angles to the transect; in other cases the circles were placed at random within the sample plot. In each circle the rooted species as well as species represented only by a shoot were recorded, and the "area-frequency"-$^0/_0$ (AF-$^0/_0$) (RAUNKIÆR, 1916) of the species was calculated. This value is somewhat better correlated to cover degree than the frequency-$^0/_0$ (F-$^0/_0$), which is based on recording species rooted or with aboveground, perennial parts within the circle (RAUNKIÆR op.c.).

Cover degree. Within each of the frequency circles the cover degree of the species was estimated with the Hult-Sernander-Du Rietz cover scale (DU RIETZ, 1921):

Part of area covered	Degree of cover	Area value (Middle of cover class)
<1/16	1	1/32
1/16–1/8	2	3/32
1/8–1/4	3	6/32
1/4–1/2	4	12/32
>1/2	5	24/32

To obtain one cover value for each species in each plot, the mean cover degree (D) was calculated. Due to the logarithmic character of the Hult-Sernander-Du Rietz scale, the cover degrees were transformed into area-values (middle of cover class, in the table above) before the calculation (cf. SJÖRS, 1954); afterwards the mean area-value was transformed again to Hult-Sernander-Du Rietz cover degree.

The area used for the cover determinations in each plot, 1 m^2 in total, is in general well above the minimal area (GREIG-SMITH, 1964) of the salt marsh vegetation in question.

Species which could not be identified with certainty in the field, including all mosses and lichens, were marked with a code and collected for later identification.

3) Soil sampling. In each plot two soil samples were taken: one from the depth 0–5 cm and one from 5–15 cm. Each sample was composed of several sub-samples taken at random within the plot. The samples were kept in paper bags.

Supplementary soil samples for determination of actual water content were taken in a similar way and kept in plastic cups.

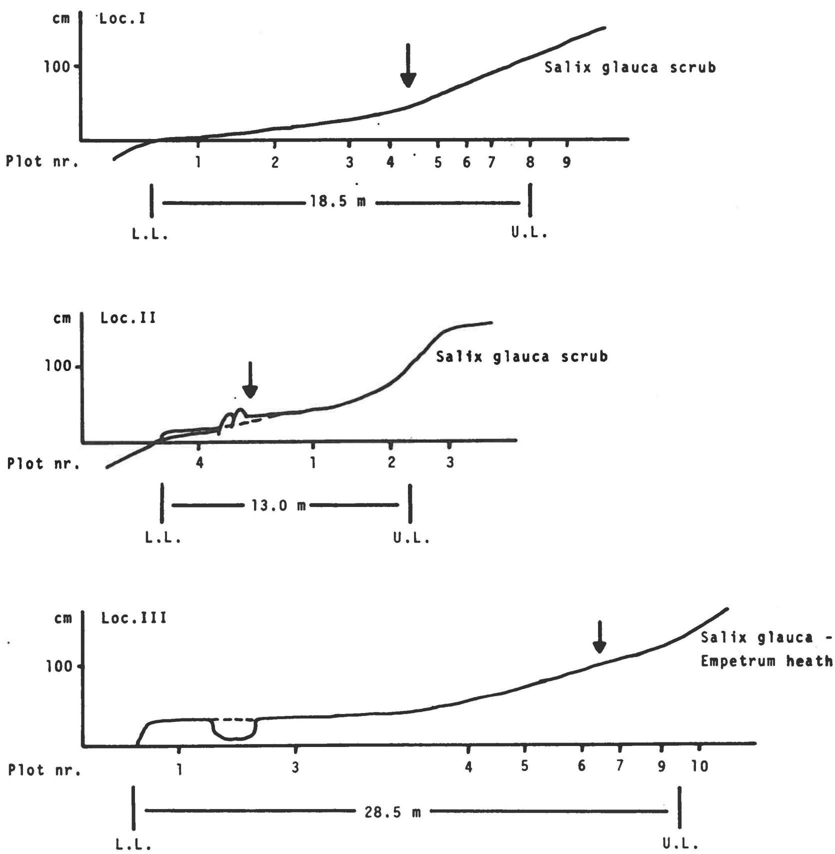

Fig. 2A. The salt marsh transects investigated, showing the marsh profiles and the vegetation of the epilittoral. L.L. = lower salt marsh limit; U.L. = upper salt marsh limit; the arrows mark the limit between lower and upper salt marsh.

Laboratory methods

Treatment of the field data

Relative elevation.

The vertical range of the salt marsh is determined by the inundation range characteristic of the locality, and differs therefore from locality to locality (fig. 2). To compare the soil conditions and the vegetation structure between the localities, the relative elevation (R.E.) of each sample plot was calculated as the height of the sample plot above the lower salt marsh limit as a percentage of the vertical difference between the lower and upper marsh limits of the locality in question. Thus the relative elevation of the L.L.-level and the U.L.-level equals 0 and 100 respectively.

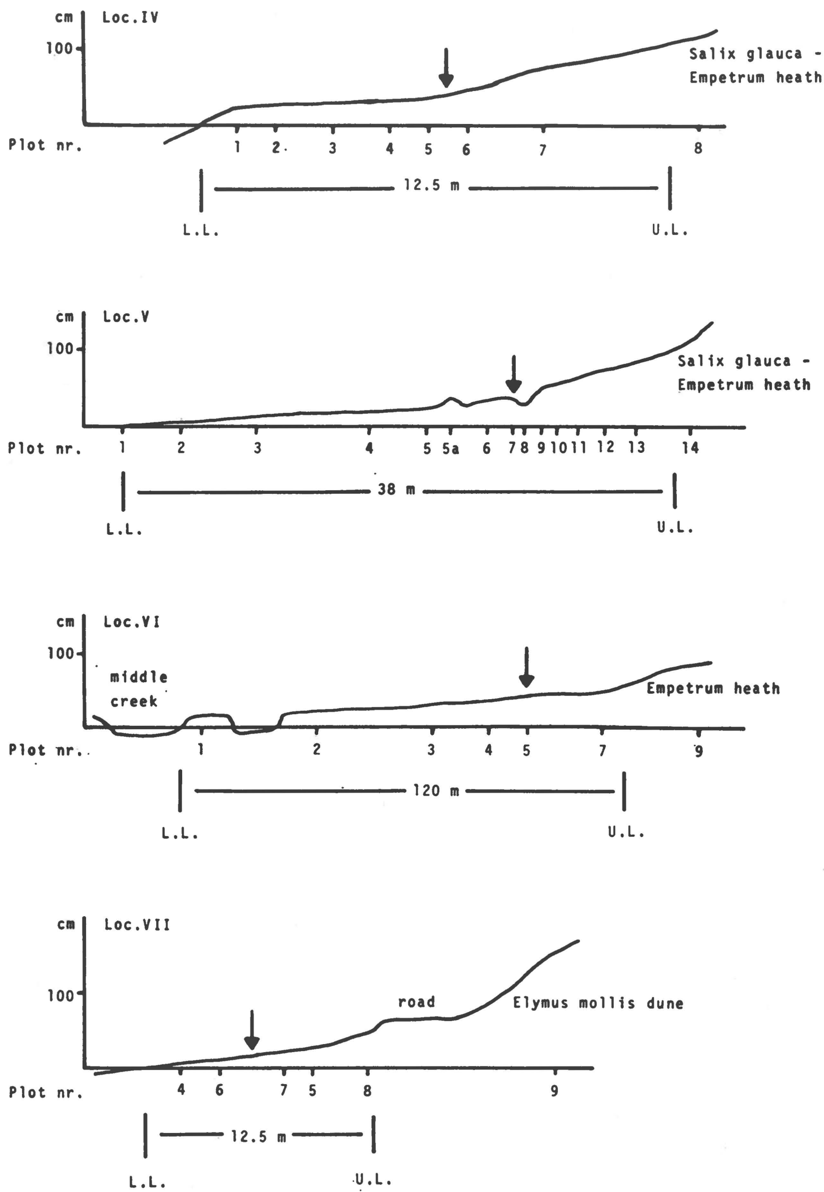

Fig. 2B. See fig. 2A.

The vegetation data.

To express the "importance" of each species in each sample plot by one value, a combination of the frequency and cover values has been attempted. In fig. 3 the correlation between frequency (AF-%) and cover (D) for the total material is shown. It is seen that species with a frequency lower than 90 % generally have low cover values. These

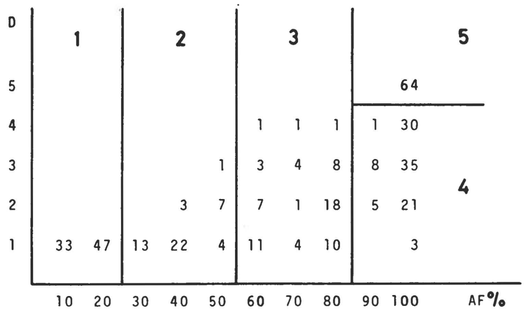

Fig. 3. The correlation between frequency (AF-%) and cover (D), shown by number of records per combination. The numbered compartments represent the steps in a combined frequency-cover scale.

species are most effectively differentiated by the frequency values. On the contrary species with frequencies of 90–100 % are better differentiated by the cover value .In accordance with this the following combined scale (AF-%-D) from 1 to 5 has been constructed:

AF-%	D	AF%-D
10–20		1
30–50		2
60–80		3
90	}	
100	1–4 }	4
100	5	5

The vegetational structure along the transects is described by the floristic variation, the species similarity and the variation in species number.

a. The floristic variation. In fig. 19 the distribution of eight important species in relation to relative elevation is compared for the transects.

b. Species similarity. The similarity in species composition between the plots along the transcets has been calculated according to the Sørensen quotient of similarity (qs) (SØRENSEN, 1948):

$$qs = \frac{2\,c}{a + b},$$ where a = number of species within the one plot, b = number of species within the other plot, c = species common to the plots. The qs-values varies between 0 and 1. In this way a similarity matrix has been obtained for each transect. In fig. 20 the similarity between the lowermost and the uppermost plots respectively and the other plots along each transect is shown in relation to relative elevation.

c. Species number. In each plot the number of species represented within the area covered by the circles (1 m^2 in total) has been summed (fig. 20).

A complete list of species is given in table III (see p. 28). The identification of species has been undertaken by:
Mosses: lic. scient. Gert Mogensen
Lichens: cand. scient. Eric Steen Hansen
Fungi: cand. mag. Peter Milan Petersen
Puccinellia: dr. phil. Bent Fredskild, who has also checked the identification within certain other genera.

Soil analyses

The soil samples have preliminarily been dried at the Arctic Station before transportation to the laboratory in Copenhagen. After supplementary drying at 60° C. the samples were comminuted, sieved through a 2 mm sieve and analysed for the following factors:

pH, specific conductivity, water-extractable metals and Cl.

20 g soil was extracted in 50 ml destilled water for 24 hrs. After filtering, the extracts were analysed for

pH – potentiometry; pH meter 26, Radiometer.

specific conductivity – Conductivity-meter CDM 3, Radiometer, corrected to 20° C, expressed in μS

Ca and Mg – atomic absorption spectrophotometry; Perkin Elmer 403, expressed in milliequivalents (meq)/100 g soil.

K and Na – emission photometry; Spectralphotometer Bechman DU, expressed in meq/100 g soil.

Cl – potentiometry; specific Cl-electrode, Orion 96–17, specific Ion Meter, Orion 407, expressed in meq/100 g soil.

NH_4Ac-extractable metals.

20 g soil was extracted in 80 ml 1 N NH_4Ac, pH7, for 24 hrs. After washing the soil with a further 120 ml NH_4Ac, the extracts were filtered and analysed for Ca, Mg, K and Na – as the water-extractable fractions.

Cu, Zn, Pb and Ni.

10 g soil was extracted in 50 ml 0.02 m Na-EDTA for 24 hrs. After filtering, the extracts were analysed by means of atomic absorption spectrophotometry; Perkin Elmer 403, expressed in ppm/soil.

Cation exchange capacity (CEC).

The quantity of Na^+ necessary to saturate the colloids in a quantity of the soil were analysed by emission photometry; Spectralphotometer Bechman DU (Jackson, 1958); expressed in meq/100 g soil.

Table 1. *Texture of soil samples from 5–15 cm depth at the lower salt marsh limit. The weight of the grain size fractions as a percentage of the sample total.*

locality	gravel	coarse-medium sand	fine sand coarse silt	medium fine silt-clay
	≧ 2 mm	2–0.2 mm	0.2–0.02 mm	< 0.02 mm
I	59	26	11	4
II	6	15	50	29
III	0	17	67	16
IV	6	12	52	30
V	0	2	23	75
VI	0	3	15	82
VII	27	60	9	4

Organic matter.

Wet combustion of a quantity of the soil in chromic and sulphuric acid (Walkley-Black method), according to JACKSON (1958). Excess oxidant was titrated potentiometrically with Fe^{++}, by means of a Titrator 11, Radiometer, an Autoburette ABU 11, Radiometer, connected to a potentiometer pH-meter 26, Radiometer. Expressed as a percentage of the soil.

Phosphorus.

1 g soil was extracted in 200 ml 0.2 N sulphuric acid for 24 hrs. After filtering, the extracts were analysed for P by measurement of the colour intensity of a P-molybdate complex (JACKSON, 1958); spectrophotometer Spectronic 20, Bausch & Lomb; expressed in ppm/soil.

Soil water content.

Measured gravimetrically by drying the fresh soil at 120°C to constant weight; expressed as percentage of the dry soil.

The texture of the soil in the depth 5–15 cm at the lowermost sample plot from each transect was analysed by sieve analyses, in connection with determinations of the mineral composition of the samples, carried out at the Laboratory of Sediment-petrography, Institute of General Geology, Copenhagen University (Table I).

Treatment of the soil data

Soil salinity (the concentration of soluble salts in the soil solution) is estimated from 1) soil water content and water-extractable Na, assuming that the percentage of Na in the soil solution equals that in the sea water, 2) soil water content and specific conductivity, according to JACKSON (1958). The soil salinity is expressed in $^0/_{00}$. The correlation between salinity$_{Na}$ and salinity$_{\mu S}$ was highly significant (r = 0.99).

By means of the IBM 370/165 computer of the Northern Europe University Computing Center (NEUCC) at the Technical University of Denmark and with the assistance of cand. stat. SUSANNE MØLLER, the following calculations and procedures have been undertaken:

1) Based upon the basic soil data from the transect samples (N =112) the following derived data have been obtained: Sum of water-extractable metals; adsorbed metals (NH_4Ac-extr.water extr. metals); sum of adsorbed metals; water-extractable Ca/Mg/K/Na respectively as percentage of sum of water-extractable metals; adsorbed Ca/Mg/K/Na respectively as percentage of sum of adsorbed metals; water-extractable and adsorbed Ca/Mg, Ca/K, Ca/Na, Mg/K, Mg/Na, Na/K.

2) To elucidate general relations between the soil factors and the relative elevation, all the transect plots have been distributed in six classes of relative elevation: 0–19, 20–39, 40–59, 60–79, 80–100 and above 100, with 6, 17, 11, 9, 4 and 9 observations respectively. In each class the mean ($\bar{x}$) and standard deviation (s) of each soil factor have been calculated, holding the two soil depths apart. Some of these data are shown in the fig. 21–25.

3) Calculation of mutual correlation coefficients between the soil factors as well as correlation coefficients between each soil factor and relative elevation. N = 56. Degrees of freedom: 54. Levels of significance: * $P<0.05$,**$P<0.01$***$P<0.001$, corresponding to r-values of 0.26, 0.34 and 0.42 respectively (FISHER & YATES, 1957). $P>0.05$ were regarded as non-significant (ns) (Table II).

The localities

General features

Geology. The localities I–IV and VII are situated within the tertiary basalt area of West Greenland, and the salt marshes are developed in connection with locally occurring, low rocks of precambric gneiss (loc. II and III) or on marine and/or fluviale deposits (loc. I, IV, VII). The localities V and VI are situated in areas of cretacious or tertiary sediments (ESCHER, 1971; WEIDICK, 1971).

Climate. According to BÖCHER (1975) the area investigated is situated at the transition between the low-arctic/oceanic and the high-arctic/oceanic parts of West Greenland. The precipitation is rather low; in the period 1962–1971 values of 464, 244 and 203 mm/year were

Table 2. *Correlations between 14 soil factors and relative elevation. Levels of significance* *fican*

	relative elevation	pH	specific conduc- tivity	organic matter	cation exchange capacity	actual water
rel.elev.	–	ns	–*	ns	–ns	–***
pH	–	–	–ns	–ns	–**	–***
spec.cond.	–	–	–	*	ns	**
org.matter	–	–	–	–	***	ns
CEC	–	–	–	–	–	*
act.water	–	–	–	–	–	–
sal_{Na}	–	–	–	–	–	–
w.-ext.Cl	–	–	–	–	–	–
Σ w.-ext.metals	–	–	–	–	–	–
Σ ads.metals	–	–	–	–	–	–
P	–	–	–	–	–	–
Pb	–	–	–	–	–	–
Cu	–	–	–	–	–	–
Zn	–	–	–	–	–	–
Ni	–	–	–	–	–	–

measured at the stations Godhavn, Jakobshavn and Qutdligssat respectively (data, provisionally published by the Danish Meteorological Institute 1967–73).

Permafrost has been described from loc. VI (NIELSEN, 1969), but seems to occur only sporadically within the investigation area as a whole (A. WEIDICK, personal communication). Compared with the salt marshes at Hudson Bay, studied by KERSHAW (1976), where permafrost is an important factor in the development of the vegetation, the role of permafrost at the present localities is supposed to be a minor one.

Hydrography. The pattern of sea water level fluctuations is determined by periodic tidal movements as well as by aperiodic, meteorologically conditioned fluctuations, and varies further with local topography. Within the investigation area tidal ranges from 2.2 to 3.0 metres have been recorded (NIELSEN, 1969). The vertical range of the salt marshes varies between 50 and 135 cm; thus the salt marsh vegetation is developed in the geolittoral exclusively — probably between mean high water level and mean high water level at spring-tide (p. 37).

Salinity. As the salt marshes investigated are found either along more or less closed lagoons and estuaries or near river outlets, the salinity of the inundating water varies with time and locality between full-strength ocean salinity (about 33 $^0/_{00}$) and salinities near that of freshwater, caused by interaction of river water supply, especially important in spring and early summer, and the sea water level fluctuations.

*** *P<0.001 (r=0.42)*, ** *P<0.01 (r=0.34–0.41)*, * *P<0.05 (r=026–0.33)*, *ns (non-signi-*
r<0,26).

salinity Na	water-extr. Cl	water-extr. metals	adsorbed metals	P	Pb	Cu	Zn	Ni
−ns	−ns	−*	−***	−ns	ns	−***	−**	−ns
−ns	−ns	−ns	ns	−ns	−ns	−*	−**	ns
***	***	***	−ns	ns	ns	ns	ns	ns
ns	*	*	ns	−ns	***	−ns	ns	−ns
ns	ns	*	***	ns	*	ns	ns	ns
−ns	ns	*	ns	ns	ns	***	***	*
–	***	***	−ns	ns	−ns	−ns	−ns	−ns
–	–	***	−ns	ns	ns	−ns	ns	−ns
–	–	–	−ns	ns	ns	ns	ns	ns
–	–	–	–	ns	−ns	***	ns	**
–	–	–	–	–	−ns	ns	ns	−ns
–	–	–	–	–	–	ns	ns	ns
–	–	–	–	–	–	–	***	***
–	–	–	–	–	–	–	–	***
–	–	–	–	–	–	–	–	–

Ice conditions. The water is covered by local winterice, occasionally supplied by floes of the drifting West-ice, from December–January to May–June and is free of ice during the rest of the year (apart from the presence of icebergs from the productive glaciers of the inner Disko Bugt (H. Valeur, personal communication); the shallow lagoons, however, may be ice-covered for an even longer period.

Locality I Eqalúnguit, Disko Fjord

Salt marsh of varying width (max. 20 metres) along the northern coast of a short, shallow, east-west running creek in the inner part of the Disko Fjord system (Kuánerssuit suvdluat) (fig. 4).

Epilittoral vegetation: luxuriant *Salix glauca* scrub rich in lichens and mosses, more or less characterised by numerous small streams. Transect: 9 sample plots (fig. 2A).

The lower part of the marsh is dominated by *Puccinellia phryganodes*, accompanied by *Carex subspathacea*, which is restricted to this part, *Stellaria humifusa*, *Potentilla egedii* and, at a slightly higher level, *Bryum* sp. In the upper part of the marsh the number of species is only a little higher; dominant is *Carex glareosa;* other species are *Stellaria humifusa*, *Potentilla egedii*, *Bryum* sp., *Puccinellia phryganodes* and, at higher levels, *Drepanocladus uncinatus*. *Puccinellia* is often fertile in this part is contrast to the lower part. Near the upper limit of the marsh *Mertensia maritima* is found on stony substrate together with scattered epilittoral species.

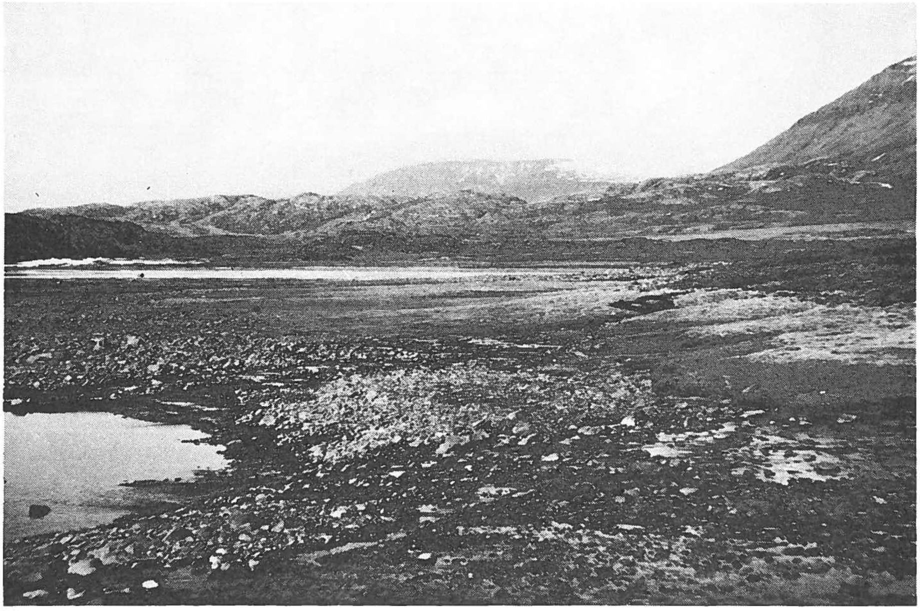

Fig. 4. Salt marsh at the inner Disko Fjord (loc. I). To the right *Salix glauca* scrub. July 20, 1972.

Soil conditions (fig. 16–18). Texture: Mainly gravel and coarse sand. The soil organic matter was nearly entirely restricted to the upper 5 cm of the soil; the values were highest in the middle part of the marsh (about 30 $^0/_0$) and declined towards the lower as well as the upper marsh limits. The water content was rather high in the lower part of the marsh (100–200 $^0/_0$), and low (20–40 $^0/_0$) in the upper part, caused by low organic content and good drainage conditions. Below 5 cm soil depth the water content was low everywhere in the marsh. The electrolyte concentration of the soil, measured as specific conductivity, was remarkably low everywhere and only a little higher in the upper soil layer compared with the soil below.

Locality II Eqalúnguit, Disko Fjord

Salt marsh among low gneiss-rocks near the bottom of the same creek, where loc. I is situated (fig. 5).

Epilittoral vegetation: partly species-rich freshwater marsh, dominated by *Carex rariflora*, *C. stans*, *Equisetum arvense*, *Salix glauca*, *Polygonum viviparum*, and partly, on the gneiss, *Salix glauca* scrub rich in mosses.

Transect through the salt marsh into the *Salix* scrub: 4 sample plots (fig. 2A); further two plots were analysed in the freshwater marsh.

The vegetation is very similar to that of loc. I. Near the upper

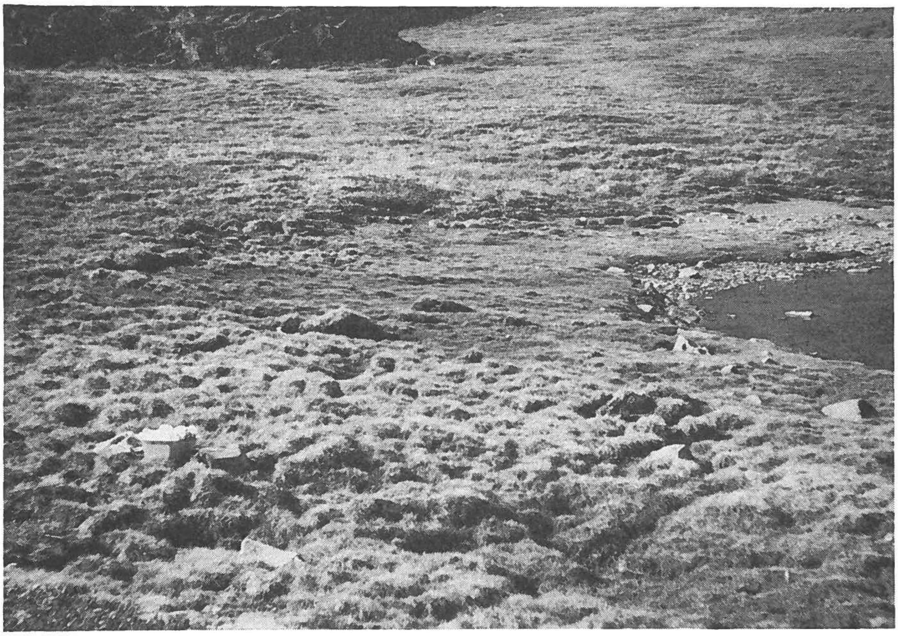

Fig. 5. Salt marsh at the inner Disko Fjord (loc. II). In the middle lower salt marsh dominated by *Puccinellia phryganodes;* in the middle left freshwater marsh; in the foreground upper salt marsh with *Carex glareosa* tufts. July 21, 1972.

marsh limit *Carex stans* and, in small open patches between the *Carex glareosa* tufts, *Cochlearia groenlandica* was found.

In spite of the similarity in vegetation, the soil conditions were rather different from those found in loc. I (fig. 16–18). Texture: mainly fine sand, silt and clay. Organic matter and water content increased from lower to upper marsh, with maximum values of about 50 $^0/_0$ and 200 $^0/_0$ respectively in the *Carex glareosa* vegetation. The specific conductivity was very variable along the transect, but declined generally from lower to upper marsh. The soil was rather homogeneous from the surface to 15 cm depth.

Locality III Evqigtoq, Disko Fjord

Rather extensive salt marsh covering a part of a low gneissic peninsula at the Kangerdluarssuk, a part of the Disko Fjord system, near the village of Disko Fjord. On the peninsula an abandoned village, Evqigtoq. The locality is described by Porsild (1902) and seems unchanged since that time.

Epilittoral vegetation: sparsely developed heath with *Salix glauca, Empetrum hermaphroditum, Pyrola grandiflora, Festuca brachyphylla, Papaver radicatum* between bare rocks.

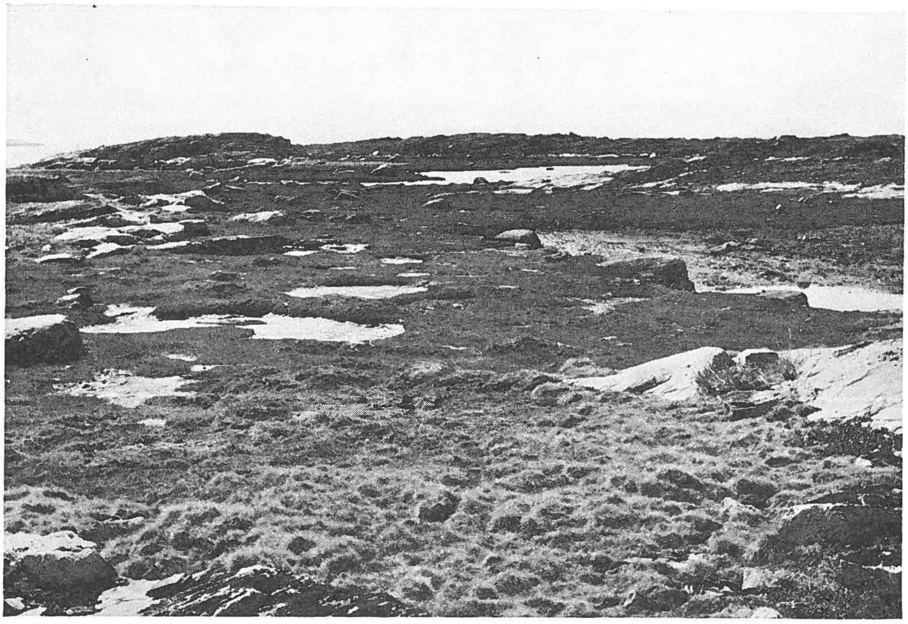

Fig. 6. The salt marsh at Evqigtoq, Disko Fjord (loc. III). Dark flats dominated by *Puccinellia phryganodes* interrupted by erosion hollows; in the foreground *Carex glareosa* vegetation. July 22, 1972.

The salt marsh is not regularly zoned. The greatest part is occupied by flats with *Puccinellia phryganodes* sward, interrupted by rocks and vegetation-free erosion hollows (fig. 6).

Transect: 8 sample plots (fig. 2A).

The number of species is extremely low in the lower part of the marsh; *Puccinellia phryganodes* is the only species up to R.E. 30–35. Above this level *Stellaria humifusa* is co-dominant. In the higher part, at R.E. above 70, *Carex glareosa* is dominant; other species are *P. phryganodes*, *Stellaria humifusa* and *Bryum* sp. Near the upper marsh limit the number of species increases by scattered occurrences of epilittoral species, including small patches of *Elymus mollis*.

Soil conditions. Texture: mainly fine sand and silt. The soil conditions were more heterogeneous than expected from the homogeneous vegetation, especially in the soil below 5 cm depth (fig. 16–18). In the upper soil layer the content of organic matter and water were high everywhere along the transect, except in the sample plot just below the upper marsh limit; the conductivity was high up to R.E. 70. In the deeper soil layer the values were very variable, but the correlation between the three soil factors was closer in this layer. The decline in conductivity in both soil layers above R.E. 70 coincides clearly with the *Carex glareosa* vegetation at this level.

Fig. 7. View of the Eqaluit kûgssuat-estuary, west coast of Disko (loc. IV). The estuary is protected from the sea by a narrow, sandy barrier. July 22, 1972.

Locality IV Eqaluit, the west coast of Disko

Narrow salt marshes on marine and fluviale deposits along the coast of the estuary of the river Eqaluit kûgssuat, protected from the sea by a sandy barrier (figs. 7 and 8).

Epilittoral vegetation: Heath with scattered vegetation dominated by *Empetrum hermaphroditum* and *Salix glauca.*

Transect: 8 sample plots (fig. 2B).

The lower part of the marsh is dominated by *Puccinellia phryganodes* and partly, in a narrow belt at R.E. about 30, by *Carex subspathacea.* Subordinate is *Stellaria humifusa.* In the upper part the number of species is higher; in addition to the dominant, *Carex glareosa,* species from the lower part and *Potentilla eqedii, Triglochin palustre* and *Bryum* sp. were found.

Soil conditions (fig. 16–18). Texture: mainly fine sand, silt and clay. Organic matter was rather low (about 10 $^0/_0$) and fairly constant along the gradient. Water content and specific conductivity were highest in the lower part (max. 150 $^0/_0$ and 7500 μS respectively) and declined through the *Carex glareosa* vegetation. The three soil factors reached in general the highest values in the upper soil layer.

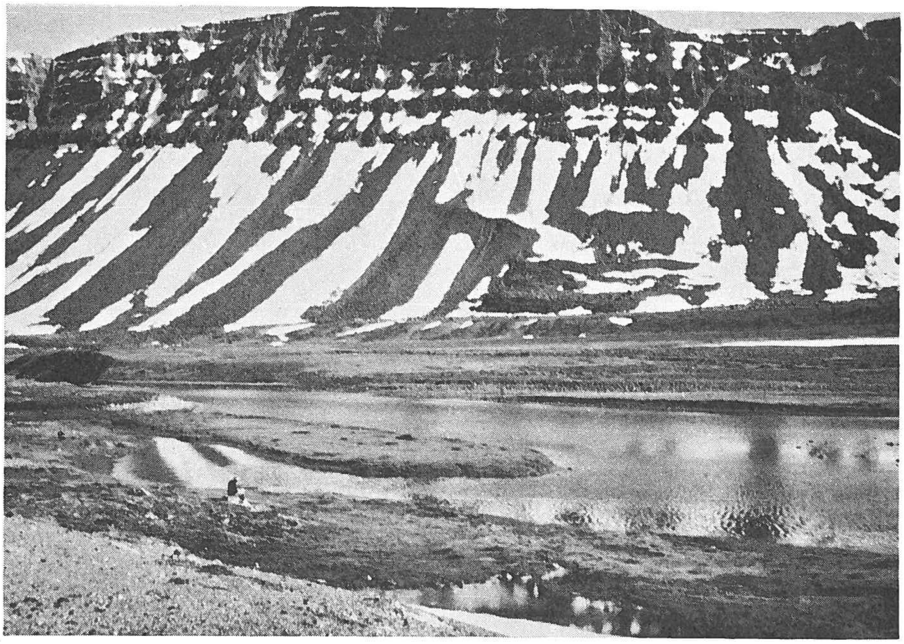

Fig. 8. Salt marsh flats along the Eqaluit kûgssuat estuary. July 22, 1972.

Locality V Sarqaq, south coast of Nûgssuaq

Rather extensive salt marsh along the western coast of a bay about 6 km west of the town of Sarqaq, near the outlet of the river Kûgssuaq (fig. 9).

Epilittoral vegetation: Heath with *Empetrum hermaphroditum*, *Salix glauca*, *Polygonum viviparum*, *Vaccinium uliginosum*, *Tofieldia pusilla*, *Cassiope tetragona*, *Dryas integrifolium*. Below the salt marsh, extensive sandy tidal flats, locally colonised by *Puccinellia phryganodes*.

Transect: 15 sample plots (fig. 2B).

The lower part of the marsh is characterised by bad drainage conditions, caused by very weak slope and very fine-grained soil; the vegetation consists of *Puccinellia phryganodes* and, from R.E. about 10, *Carex subspathacea* in mosaic with *Puccinellia* (fig. 10). From a somewhat higher level the dominants are accompanied by *Triglochin palustre*, which is an important component in the marsh as a whole. This vegetation continues up to R.E. about 35; in its upper part, however, a system of low ridges, on the average $^1/_2$ metre wide and 10 cm high, run parallel to the coast, apparently formed by the action of packing ice (fig. 9). The vegetation on these ridges is quite different from the surroundings; dominant is *Carex ursina*, apparently conditioned by the better drainage conditions. In the upper part of the marsh, at R.E. above 45, the vegeta-

Fig. 9. Salt marsh near Sarqaq, south coast of Nûgssuaq (loc. V). In the middle ice-pressed ridges in the lower salt marsh; in the background epilittoral heath vegetation. July 28, 1972.

Fig. 10. Mosaic of *Puccinellia phryganodes* (light) and *Carex subspathacea* (dark) in the lower marsh at loc. V. July 28, 1972.

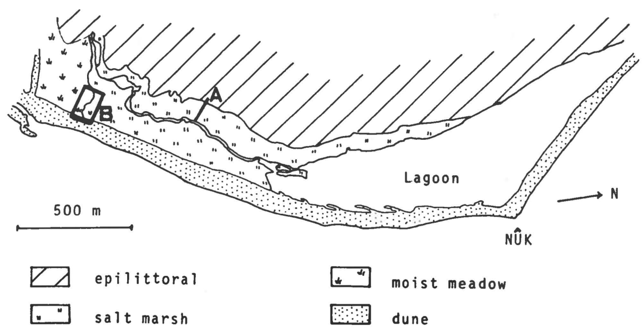

Fig. 11. Map of loc. VI, Nûk at Flakkerhuk, east coast of Disko. A marks the transect, B marks the salt-fresh transition area investigated. Redrawn from NIELSEN, 1969, fig. 17.

tion is rather complex; the lower levels are dominated by *Carex stans*, which is especially associated with a water-filled "ditch", running parallel to the coast. At higher levels, up to R.E. 70, the vegetation is dominated by *Carex glareosa*, *C. stans*, *Stellaria humifusa*, *Puccinellia phryganodes* and locally *Carex ursina*. At levels between R.E. 70 and the upper salt marsh limit the vegetation is rather open; greater parts of the ground are covered by *Bryum* sp.; important phanograms are *Cochlearia groenlandica*, *Carex stans*, *Equisetum arvense* and locally *Salix glauca*. *Carex glareosa* is only of minor importance.

Scattered over the salt marsh, bird feathers are found, possibly from the White-fronted Goose (*Anser albifrons*), which, according to SALOMONSEN (1971), is known to feed on *Puccinellia phryganodes* on salt marshes in middle west Greenland.

Soil conditions (fig. 16–18). Texture: mainly fine sand, silt and clay. In the lower marsh (R.E. 0–45) organic matter, water content and conductivity were generally high, especially in the upper soil layer. The ice-pressed ridges and the *Carex stans* "ditch" differed, however; in the former the water content and conductivity were rather low; in the latter the conductivity was low. At levels R.E. above 45 the values of the three soil factors were low.

The importance of species like *Triglochin palustre* and *Carex stans* as well as the presence of the water-filled "ditch" of low salinity indicate a rather high degree of freshwater influence of the locality.

Locality VI Nûk, Flakkerhuk, east coast of Disko

Barrier beach, consisting of a system of lagoons protected by a long sand barrier, sparsely covered by dune vegetation (mainly *Elymus mollis* and *Honckenya peploides*). The lagoons are more or less surrounded by extensive salt marshes, which at the southern end of the area change

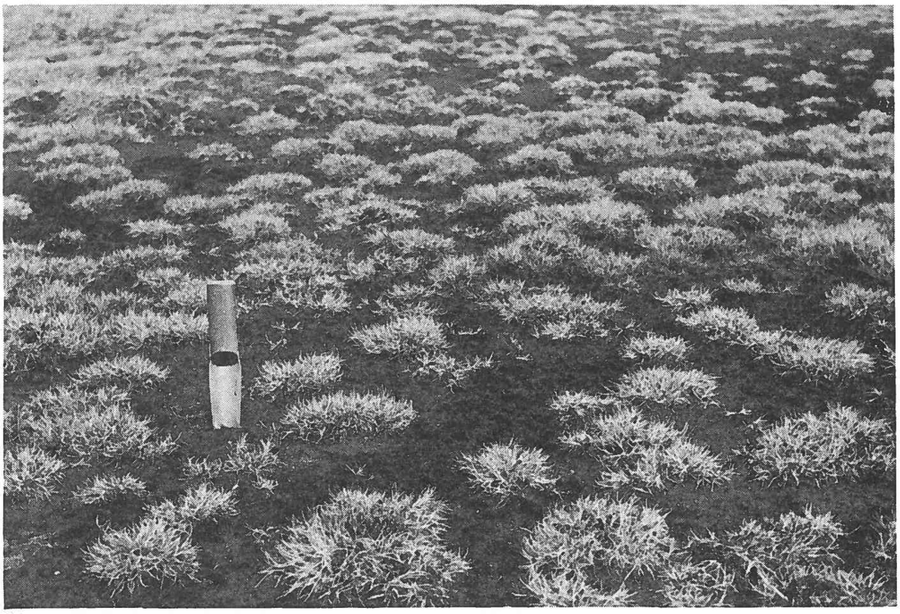

Fig. 12. Sandy flat, covered by *Carex ursina* tufts, at Nûk (loc. VI B). July 31, 1972.

into freshwater marshes. The geomorphology, hydrography and vegetation of the locality has been described by NIELSEN (1969).

The area investigated is that of salt marshes at the southern end of the southern lagoon (fig. 11). In total 18 sample plots were analysed: 7 along a transect from the middle creek to the landward side of the lagoon (at A in fig. 11) and 11 plots from the salt-fresh transition area (at B in fig. 11).

The vegetation of the transition area is alternately dominated by *Carex subspathacea*, *C. glareosa*, *C. ursina* (figs. 12 and 13), *C. rariflora*, *C. stans*, *Stellaria humifusa*, *Juncus arcticus*, *Festuca rubra* (especially on pals, small elevations caused by ice pressure from below (NIELSEN op.c.)) and *Empetrum hermaphroditum* (on sandy epilittoral patches), according to the elevation, texture, water and electrolyte content of the substrate. Other species, see table III. In general the electrolyte content of the soil in this part of the area was low, due to strong freshwater influence.

Transect (fig. 2B): The lower marsh limit is formed by the lowermost level of *Puccinellia phryganodes* along the middle creek. The vegetation of the lower part of the marsh, which stretches from the creek about 80 meter landward, is very uniform (fig. 14). Dominant is *Puccinellia phryganodes*, at higher levels accompanied by *Stellaria humifusa* *Carex subspathacea* (locally dominant) and *Triglochin palustre*. The species form a rather dense sward, broken only by small vegetationfree

Fig. 13. *Carex ursina* tuft with *Bryum salinum* and leaves of *Triglochin palustre*. Nûk, loc. VI B. July 31, 1972.

hollows scattered over the marsh. In the upper part of the marsh, from R.E. about 65 to the epilittoral, the number of species is higher, but the vegetation more open (fig. 15). Dominants are *Carex glareosa*, *C. subspathacea*, *Stellaria humifusa* and *Bryum* sp. Just below the upper marsh limit species such as *Festuca rubra*, *Cochlearia groenlandica* and several epilittoral species occur. Epilittoral vegetation: Heath with sparse, but rather species-rich vegetation dominated by *Empetrum hermaphroditum*.

Soil conditions along the transect (fig. 16–18). Texture: mainly silt and clay, at higher levels more sandy. Organic matter, water and electrolyte contents were high in the lower part, where the soil seems rather homogeneous, declined within the interval R.E. 50–70 and were low in the upper part of the marsh. The highest values were found in the upper soil layer.

Locality VII "Sorte Sand" at the Arctic Station, Godhavn, Disko

Patches of salt marsh vegetation around the lagoon protected from the sea by a barrier of basalt sand ("Sorte Sand").

Epilittoral vegetation: *Elymus mollis-Honckenya peploides* dune at the barrier side of the lagoon, on the other sides *Salix glauca* scrub or heath covering low gneissic rocks.

13 sample plots were analysed: 6 plots along a transect at the barrier side of the lagoon; the other plots from various vegetation around the

Fig. 14. Salt marsh dominated by *Puccinellia phryganodes* at Nûk, Flakkerhuk (loc. VI A). In the background the middle creek and farther away the sandy barrier, which protects the salt marsh from the sea. July 31, 1972.

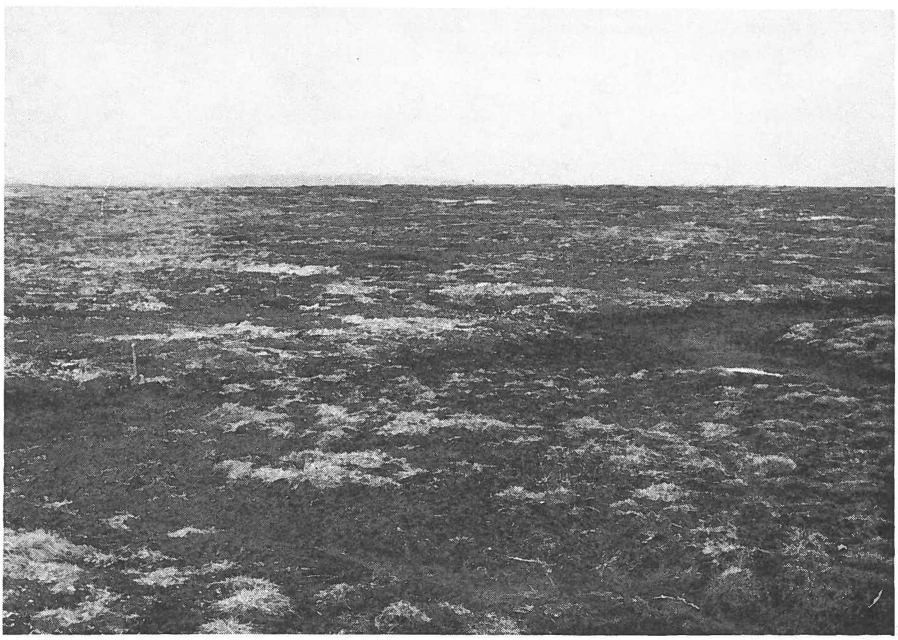

Fig. 15. Limit between upper salt marsh with tufts of *Carex glareosa* (foreground) and epilittoral heath (background) at locality VI A. July 31, 1972.

lagoon, including plots with *Calamagrostis neglecta*, *Carex rariflora* and *Dupontia psilosantha*. The species are shown in table III.

Transect (fig. 2B): The lower part of the marsh is rather different from the lower marshes at the other localities, apparently conditioned by the brackish water in this very closed lagoon. The dominants are *Triglochin palustre* and *Drepanocladus exannulatus*, at higher level with *Carex subspathacea* as co-dominant. *Puccinellia phryganodes* is present but of minor importance. The occurrence of the moss *Drepanocladus exannulatus* is interesting, as this species is also found in salt marshes at Hudson Bay

Table 3. *Species found at the localities investigated.* +: *salt marsh*, +°: *epilittoral and upper salt marsh*, +°°: *epilittoral. Nomenclatur according to phanerogames*: BÖCHER, HOLMEN & JACOBSEN, *1966*, *mosses*: GROUT, *1928–1940*, NYHOLM, *1954–1969*, *lichens*: LYNGE, *1937*, *fungi*: GULDEN & LANGE, *1971.*

Locality No.	I	II	III	IV	V	VI A	VI B	VII
Phanerogames								
Alopecurus alpinus		+						
Armeria scabra						+°°		
Betula nana		+°°			+°°	+°°		
Calamagrostis neglecta							+	+
Carex glareosa	+	+	+	+	+	+	+	+
– *rariflora*		+°				+	+	+
– *stans*		+°			+°		+°	+
– *subspathacea*	+	+		+	+	+	+	+
– *ursina*					+	+	+	+
Cassiope tetragona					+°°			
Cochlearia groenlandica		+			+	+		
Dryas integrifolia					+°°			
Dupontia psilosantha								+
Elymus mollis			+°		+		+°°	+°°
Empetrum hermaphroditum	+°		+°	+°	+°	+°	+°°	
Eriphorum angustifolium							+	
– *scheuchzeri*							+	+
Equisetum arvense		+°			+°		+°°	+°
Festuca brachyphylla			+°°					
– *rubra*						+	+	
Honckenya peploides			+°			+	+°°	+°°
Juncus arcticus				+			+	
– *castaneus*							+	
Luzula confusa						+°°		
Mertensia maritima	+						+°°	
Pedicularis hirsuta		+°°			+°°	+°°		
Poa pratensis		+°°	+°°					+°

Continued

Locality No.	I	II	III	IV	V	VI A	VI B	VII
Polygonum viviparum		+°°		+°	+°			
Potentilla egedii	+	+	+	+			+	
Puccinellia andersonii							+	
– *phryganodes*	+	+	+	+	+	+	+	+
– *vaginata*			+					
Pyrola grandiflora			+°°					
Sagina intermedia						+°	+°	
Salix glauca	+°°	+°	+°	+°	+°	+°°	+°	+°
– *herbacea*		+°°				+°°		
Saxifraga rivularis			+°			+°		+
Silene acaulis						+°°		
Stellaria humifusa	+	+	+	+	+	+	+	+
Tofieldia pusilla					+°°			
Triglochin palustre				+	+	+	+	+
Vaccinium uliginosum					+°°			
Mosses								
Aulacomnium palustre	+°°							
– *turgidum*		+°°						
Bryum cfr. *salinum*	+	+	+	+°	+	+	+	+
Calliergon sarmentosum							+	
Campylium stellatum	+				+°°		+	
Ditrichum flexicaule		+°°						
Distichium capillaceum					+°°			
– *hagenii*					+		+	
– *unclinatum*					+			
– sp.							+	
Drepanocladus exannulatus ..							+	
– *uncinatus*	+°	+°	+				+	+
Meesia uliginosa		+°°			+°°			
Oncophorus wahlenbergii	+°°	+°°					+	
Paludella squarrosa		+°°						
Pohlia longicolla							+	
Polytrichum alpinum	+°	+°°	+°	+°°		+°		+°
Pottia heimii					+			
Tomenthypnum nitens		+°°						
Lichens								
Cetraria delicei		+°°				+°°		
Cladonia gracilis			+°°					
– *gracilis* var. *cordalis*	+°°							
– *mitis*	+°°					+°°		
Peltigera spuria	+°°							
Psoroma hypnorum	+°°							
Stereocaulon alpinum	+°°							
Fungi								
Inocybe dulcamara								+
Omphalina rustica								+

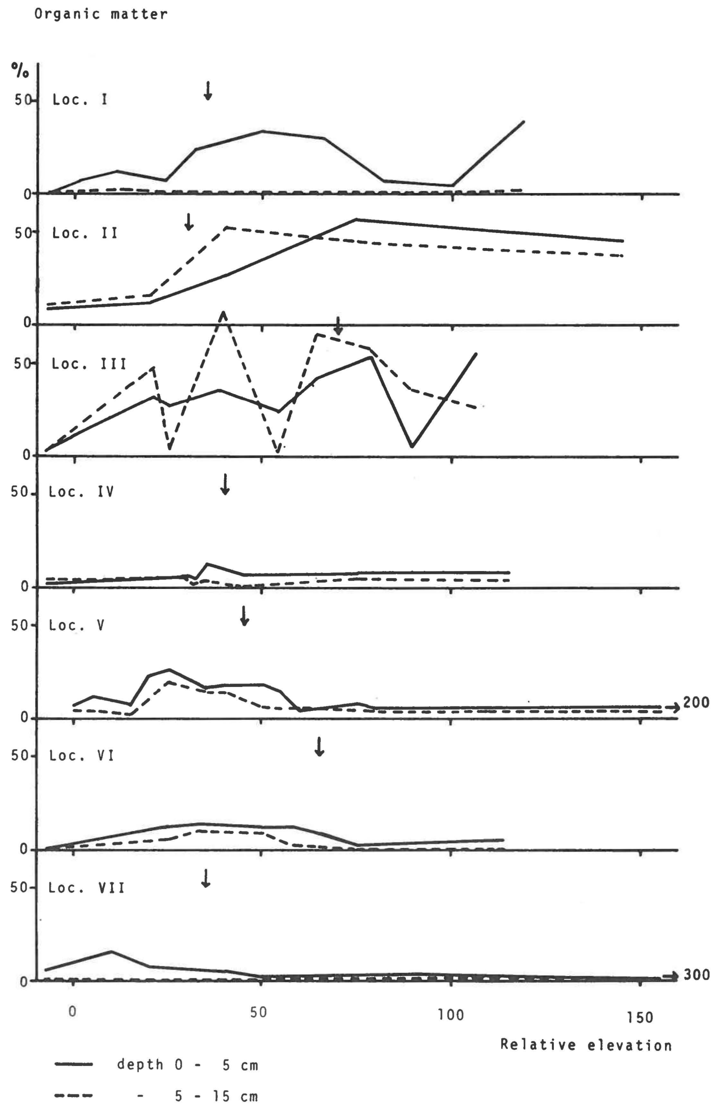

Fig. 16. Soil organic matter at a depth of 0–5 cm and 5–15 cm in relation to relative elevation, along the transects of loc. I–VII. The arrows mark the limit between lower and upper salt marsh.

(KERSHAW, 1976). The upper part of the marsh, which occupies the interval from R.E. 35 to the epilittoral, is typically developed, dominated by *Carex glareosa* and *Drepanocladus uncinatus;* other species are *Stellaria humifusa*, *Bryum* sp. and at higher levels *Polytrichum alpinum*, *Saxifraga rivularis* and *Puccinellia phryganodes* (fertile).

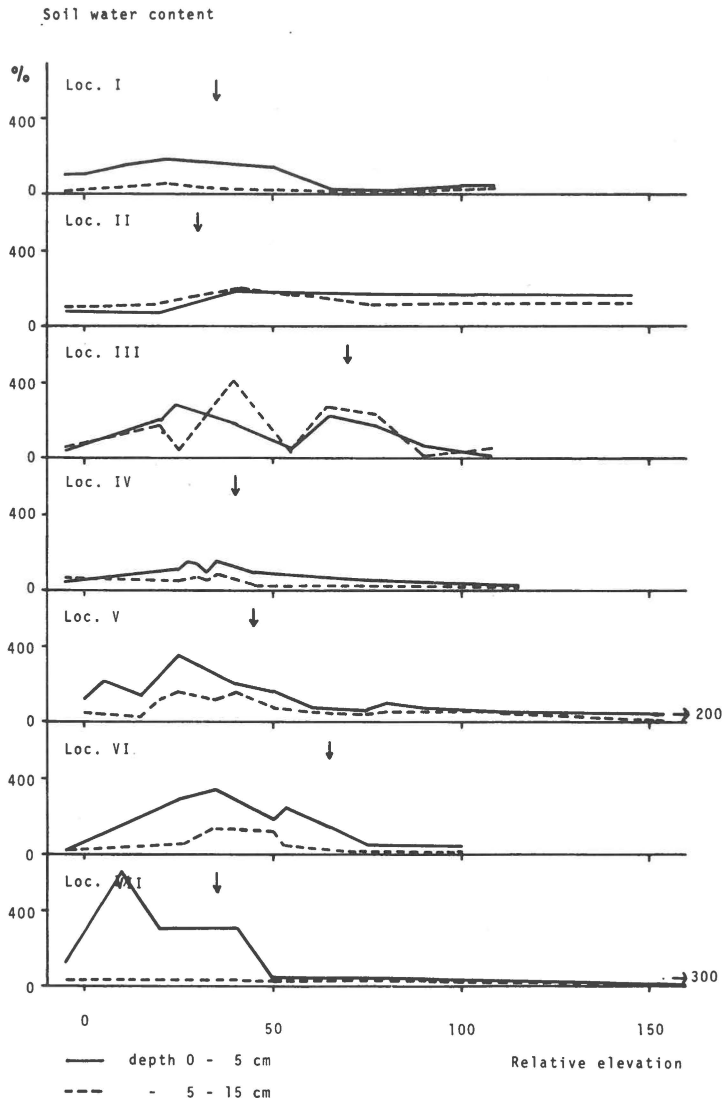

Fig. 17. Soil water content at the depth of 0–5 cm and 5–15 cm in relation to relative elevation along the transects of loc. I–VII. The arrows mark the limit between lower and upper salt marsh.

Soil conditions (fig. 16–18). Texture: mainly sand and gravel. The content of organic matter and electrolytes in the soil was relatively high in the lower part of the marsh and low elsewhere. The water content was high up to R.E. about 45 and thus high in the lower marsh as well as in the lower part of the *Carex glareosa* vegetation.

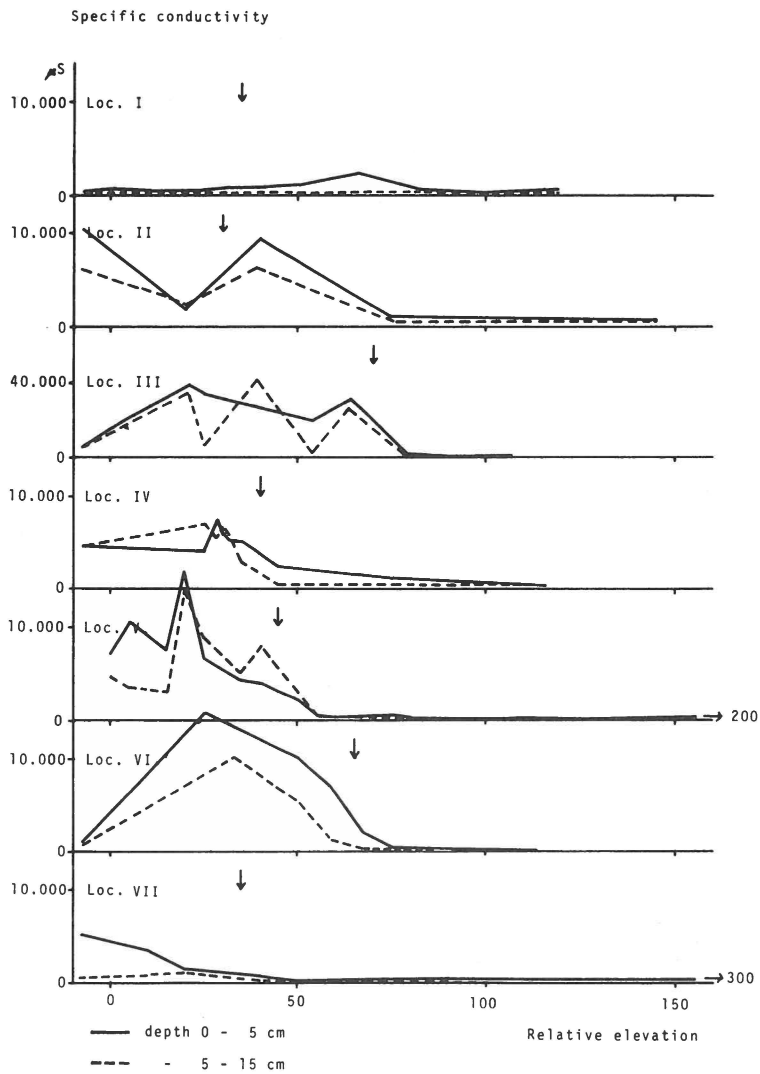

Fig. 18. Specific conductivity of the soil at the depth 0–5 cm and 5–15 cm i relation to relative elevation, along the transects of loc. I–VII. The arrows mark the limit between lower and upper salt marsh.

Vegetational structure of the salt marshes

Distribution of the species within the salt marsh

Fig. 19 shows the distribution of eight important species in relation to relative elevation at each locality.

In general the most important species are *Puccinellia phryganodes* and *Carex glareosa.* On the basis of the degree of dominance of these species, the salt marshes can be divided vertically in a lower marsh, at relative elevation from zero to about 45 (30–70), dominated by *Puccinellia phryganodes*, and an upper marsh at relative elevation from about 45 to the epilittoral, dominated by *Carex glareosa.* The two species are not sharply separated, however, but overlap broadly. It is characteristic, that *P. phryganodes* declines gradually throughout the upper marsh and has numerous occurrence on open patches in the upper marsh, whereas *C. glareosa* declines more sharply in the lower marsh with no occurrence on open patches in the lower marsh. This indicates that the upper limit of *P. phryganodes* is determined by declining competitive power of the species at higher levels, whereas the lower limit of *C. glareosa* is determined by hydrographic or edaphic factors.

The division of the marshes into two parts on the basis of the dominating species, however, is not definitely confirmed by any of the other species. Even though some species show preference for one part, the species in general replace one another, with broad overlaps, in sequences along the slope from the lower to upper marsh limits, characteristic of a continuous vegetational gradient. Therefore, the two parts of the marshes cannot strictly speaking be regarded as distinct plant communities, each with a specific composition. Similar vegetational gradients in arctic salt marsh have been described by Dobbs (1939) from Svalbard and by Kershaw (1976) from Hudson Bay. Nevertheless it may be advantageous, for the sake of clarity and comparision with other authors, to maintain the two subdivisions of the salt marshes.

Similarity in species composition

The degree of similarity in species composition along the transects supports the existence of continuous vegetational gradients in the salt marshes. Fig. 20 shows the similarity in species composition between the lowermost sample plot and the other plots for each transect (graph 1); the curve declines gently throughout the marshes, without very marked discontinuities. Graph 2 compares the epilittoral with the other plots. In general this curve has declined to zero at the transition from upper to lower marsh, in accordance with the presence of some epilittoral species in the upper marsh, but none in the lower marsh.

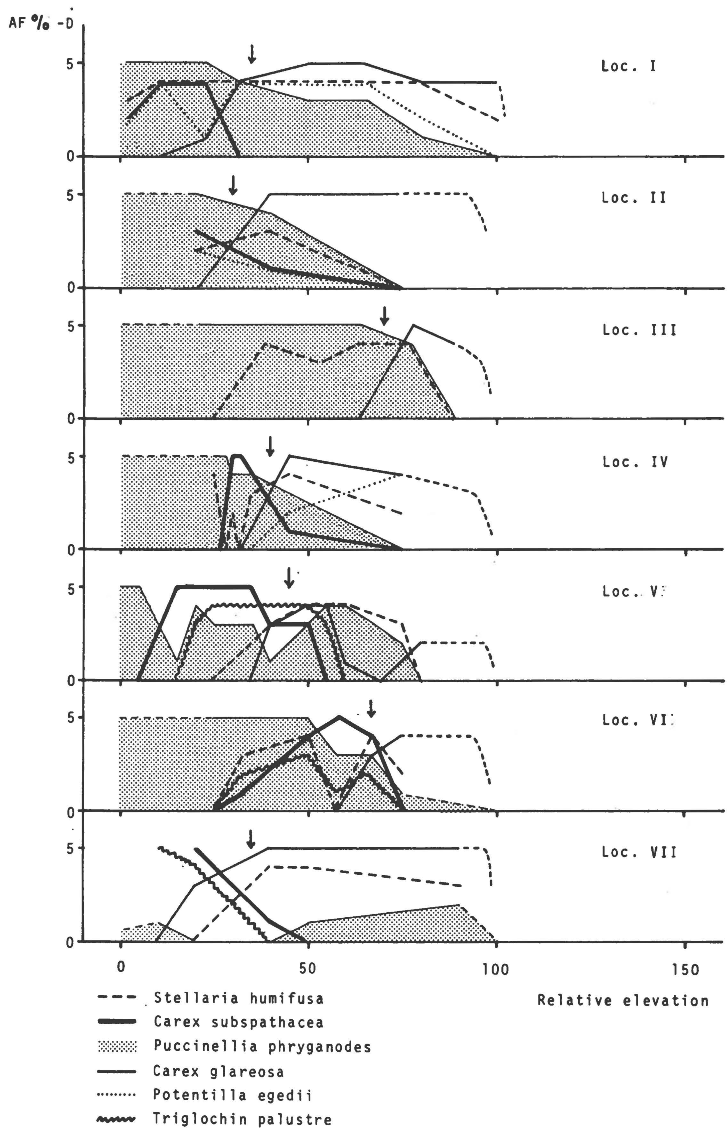

Fig. 19A. The distribution of some important species in relation to relative elevation along the transects of loc. I–VII.

Species number

In general the number of species per m^2 increases from the lower to the upper salt marsh limit (fig. 20). At most localities only one species (*Puccinellia phryganodes*) reaches to the lower limit. Throughout the lower marsh the number of species is low, generally below 5. In loc. III and VI where the lower marsh forms uniform and extensive flats, interrupted only by small hollows and creeks, the number of species is constant

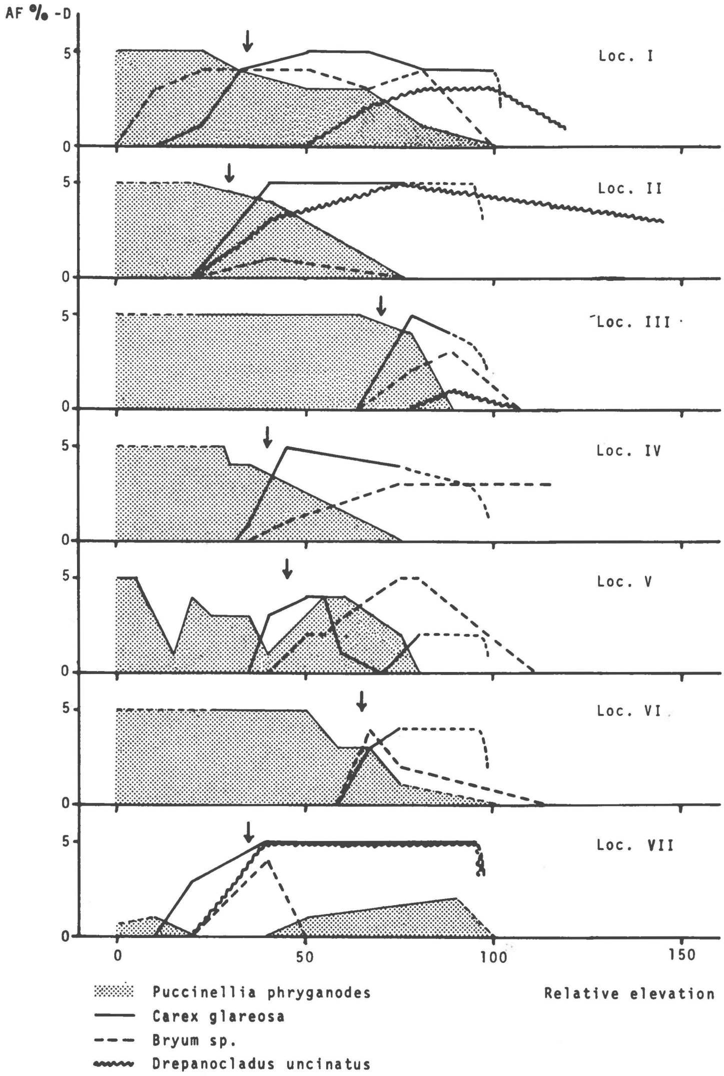

Fig. 19B See fig. 19A.

throughout the lower marsh. In other localities, however, where the ground slopes constantly, the species number increases gently with height.

In the upper marsh the number of species is higher and generally increases along the transect. The highest number of species is found in the uppermost marsh at the transition to the epilittoral.

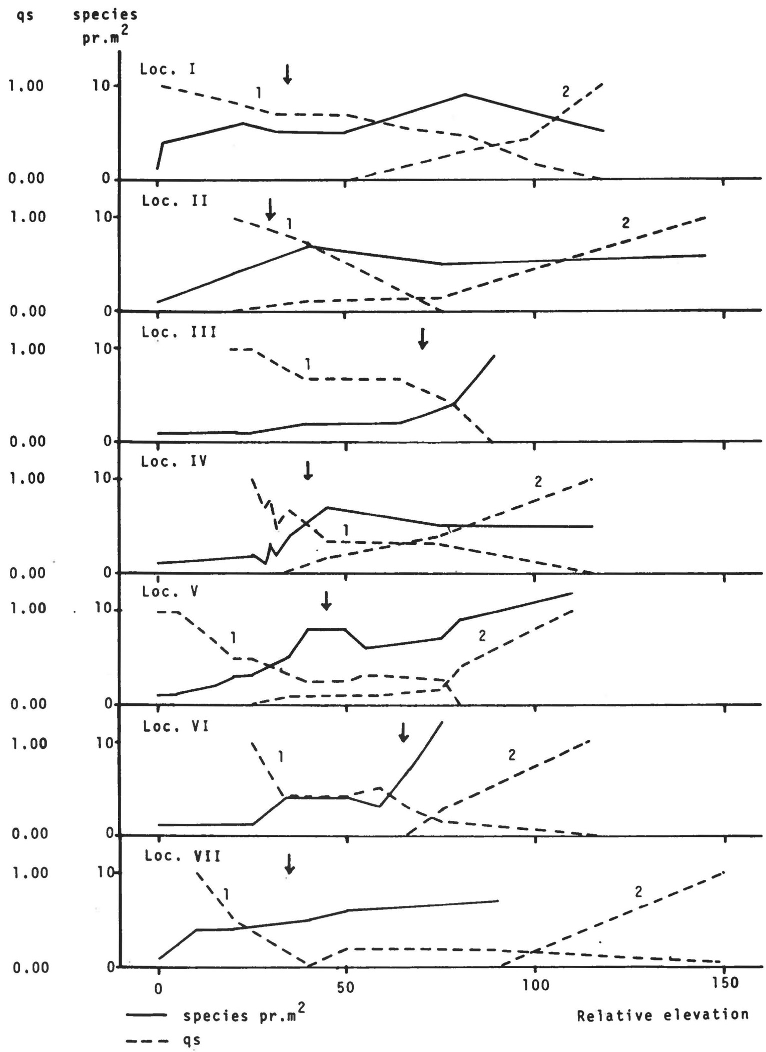

Fig. 20. Number of species per m² and species similarity (qs) along the transects of loc. I–VII, in relation to relative elevation. The graphs 1 and 2 represent the similarity between the lowermost sample plot and the epilittoral respectively and the other plot along the transect.

The lower salt marsh

Vertical range: relative elevation zero to 30–70, varying with locality.

Dominant at most localities is *Puccinellia phryganodes*, which forms blue-green-reddish rather dense, low swards of sterile, but effectively vegetative propagating individuals. The number of species is low in accordance with the extreme hydrographic and edaphic conditions. Most important along with *P. phryganodes* is *Carex subspathacea*, which may suppress *Puccinellia* at some localities, especially at higher levels. Other species are *Stellaria humifusa*, *Potentilla egedii*, which is found only at loc. I, II and IV and which, in spite of being represented often by scattered individuals only, is a very characteristic physiognomical feature with its large yellow flowers, *Triglochin palustre* and *Bryum* sp. (loc. I only). Of these *C. subspathacea* is the only one, which is found almost exclusively in the lower marsh.

The lower salt marsh is clearly exposed to frequent tidal inundation, and the lower marsh limit must coincide with some hydrographical limit. This has been discussed in some detail by several authors, but very few exact data exist. According to NORDHAGEN (1954), levels dominated by *Puccinellia phryganodes* seem to be inundated by "normal" high-tide; according to MOLENAAR (1974), *Puccinellia phryganodes* is found in East Greenland from about half a metre below the mean high-water level and is subjected to regular flooding at each tide. NIELSEN (1969) has attempted to establish the exact lower limit of *P. phryganodes* at Nûk on the east cost of Disko (loc. VI). NIELSEN shows that *P. phryganodes* occurs from a level about + 0.4 metre above mean water level and supposes, that this level is critical limit for the vegetation. At Nûk + 0.4 metre corresponds to the level flooded by half the high tides (= mean high water level). In temperate tidal marshes the lower limit of *Puccinellia maritima* lies at about the mean high-water level (CHAPMAN, 1960), thus the arctic *P. phryganodes*-vegetation seems to correspond to the temperate *P. maritima*-vegetation. According to NORDHAGEN (op.c.), however, the *Puccinellia phryganodes* vegetation corresponds to the *P. maritima* + the *Salicornia* vegetation of temperate marshes. In this connection it can be mentioned that there seems to be no vegetation found in the Arctic, which is similar in structure and function to the temperate *Salicornia* marsh.

Phytosociologically, the lower marsh at the localities investigated corresponds to the alliance *Puccinellion phryganodis*, described by HADAC (1964) from Svalbard as well as to the associations *Puccinellietum phryganodis* + *Caricetum subspathaceae*, described by NORDHAGEN (op.c.) from Northern Norway. From more southern parts of West Greenland, BÖCHER & LÆGAARD (1962), BÖCHER (1963) describe similar vegetation (*Puccinellia phryganodes*-soc., *Puccinellia-Stellaria humifusa*-soc., *Carex subspathacea*-soc., *Carex subspathacea-Stellaria humifusa*-soc.).

The upper salt marsh

Vertical range: relative elevation 30–70 to the epilittoral, varying with locality. The upper limit is supposed to correspond to the mean high water level at spring-tide.

At the transition to the upper marsh the conditions gradually become less extreme, the number of species increases and the vegetation becomes more dense.

Generally in the upper marsh *Carex glareosa* is dominant, forming a dense, tufted, yellow-green sward, in sharp contrast to the lower marsh. Species found together with *Carex glareosa: Stellaria humifusa*, *Potentilla egedii* and *Puccinellia phryganodes*, which are also found in the lower salt marsh; *Bryum* sp. and *Carex ursina*, which are found almost exclusively in the upper marsh; *Mertensia maritima* and *Cochlearia groenlandica* at levels near the upper salt marsh limit; a number of epilittoral species, which appear at different levels in the upper marsh: *Drepanocladus uncinatus*, *Polythricum alpinum*, *Carex rariflora*, *C. stans*, *Polygonum viviparum*, *Equisetum arvense*, *Salix glauca*, *Empetrum hermaphroditum*, *Saxifraga rivularis*, *Elymus mollis* and others.

The large number of species in the uppermost part of the salt marsh is due to the fact that sea water influence is only slight at this level. This seems to enable less salt-tolerant salt marsh species as well as several epilittoral species to compete. In general, however, the vegetation-cover in this transition zone is sparse, even if rich in species, possibly due to soil water contents being below the optimum for many salt marsh species, caused by inadequate water supply combined with effective drainage, and soil salinities above the optimum for epilittoral species. The transition zone is densely covered by vegetation only at places where the water supply is plentiful due to freshwater influx from the landward side.

Phytosociologically the upper salt marsh may correspond to the association *Festuceto-Caricetum glareosae* described by NORDHAGEN (1954) from Northern Norway, to the association *Caricetum glareosae* described by MOLENAAR (1974) from the Angmagssalik-district, East Greenland, as well as to the *Carex glareosa*-sociation described by BÖCHER and LÆGAARD (1962) and BÖCHER (1963) from several localities further south in West Greenland. The upper salt marsh in the Disko area differs, however, by the almost complete absence of *Festuca rubra*, which has its northern distribution limit in West Greenland at Nûgssuaq (HULTÉN, 1962).

Soil conditions

Texture

The salt marsh vegetation requires a substrate with a rather high content of fine grained particles (sand, silt, clay) to develop. The actual percentage of fine particles in the soil seems, however, unimportant. This is demonstrated in table I, (see p. 14) where soil samples from the lower salt marsh at depth 5–15 cm are compared. In spite of a rather similar vegetation there are great differences in texture between the localities.

Within the individual localities only minor differences in texture are found. In general, however, the content of silt and clay increases from

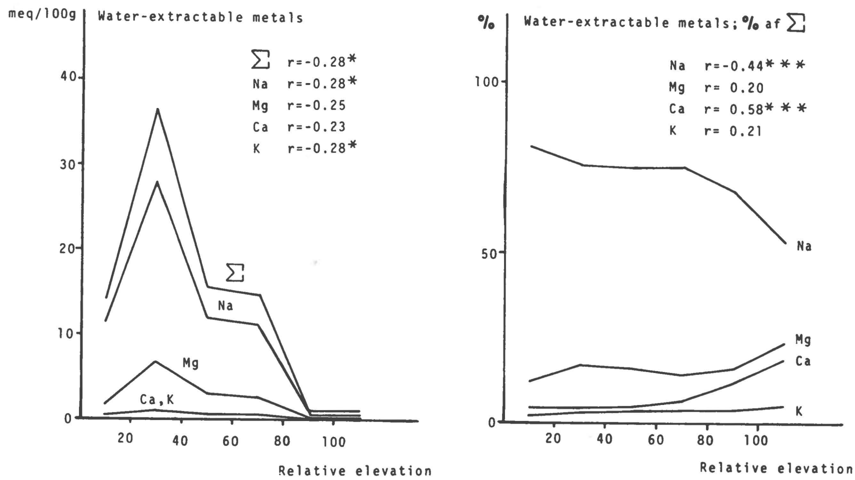

Fig. 21. Water-extractable metals in meq/100 g soil and as percentage of the sum, in relation to relative elevation, with correlation coefficients (r).

upper to lower marsh, apparently as a result of sedimentation from inundating water.

Edaphic factors

In the description of the localities it was shown that, in spite of the rather similar vegetational gradients found, the variation in soil organic matter, water content and specific conductivity were considerable (fig. 16–18). Comparisons of the soil analysis results show that this variation generally exists in the edaphic factors.

While some factors, such as organic matter and cation exchange capacity, are more or less constant throughout the year; other factors, including those of special importance in salt marshes, are subjected to considerable variation with time, conditioned by variation is sea water level, freshwater supply, evaporation and precipitation. In the sampling of the salt marshes it was not possible to adjust the sampling-dates to these hydrographical and meterological factors. It seems therefore reasonable to ascribe some of the edaphic variation between the localities to the difference in the time of the sampling.

In the following it has been attempted to gather information of possible general trends in the variation of the edaphic conditions in relation to the height above mean high-water level, by means of statistical treatment of the whole transect material, in order to uncover any edaphic gradients of potential importance to the distribution of the species along the height gradient.

The statistical procedure is described on p. 15. In fig. 21–25 the mean values of the edaphic factors in each class of relative elevation are

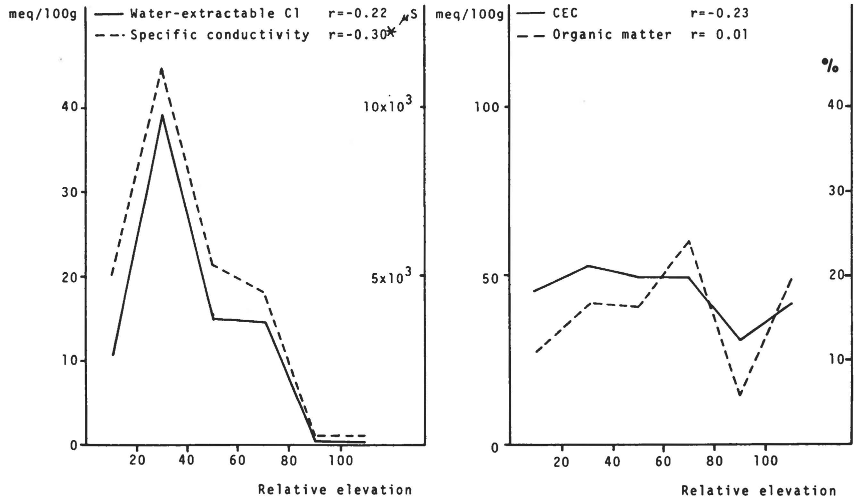

Fig. 22. Water-extractable Cl (meq/100 g soil), specific conductivity (μS), cation exchange capacity (CEC) (meq/100 g soil) and soil organic matter (°/₀) in relation to relative elevation, with correlation coefficients (r).

shown. The variation between the individual values from which the means are calculated, is in general, large and the standard deviations correspondingly considerable; the standard deviations are, however, omitted in the figures for the sake of clarity. In table II, (see p. 16) correlation between some important edaphic factors and relative elevation is shown.

Water-extractable Na, Mg, Ca, K and Cl. Specific conductivity

Na + Mg + Ca + K (fig. 21): Compared with the epilittoral the values were high everywhere in the salt marsh, except at levels above R.E. 80, that is in the uppermost *Carex glareosa* marsh, where scattered occurrences of epilittoral species are found. Maximum values were found in the upper part of the lower marsh: mean 36.4 meq/100 g. The possible reason for this maximum is discussed in connection with soil salinity (p. 43). The magnitude and distribution of the values correspond well with data obtained from subarctic marshes in Northern Norway (VESTERGAARD, 1972). In spite of the maximum near the middle of the marsh, Na + Mg + Ca + K is significant negatively correlated with relative elevation.

Na, Mg, Ca and K individually (fig. 21) were highly significant, positively inter-correlated (r = 0.93–0.98). The ratios between the metals, however, change throughout the marsh. At the lower limit the ratio between Na, Mg, Ca and K in meq was about 80:12:4:2, which expressed as mg/l extract (83:7:3:6) corresponds well with the ratio of these metals in sea water (TUKERIAN, 1969). This ratio was fairly stable throughout

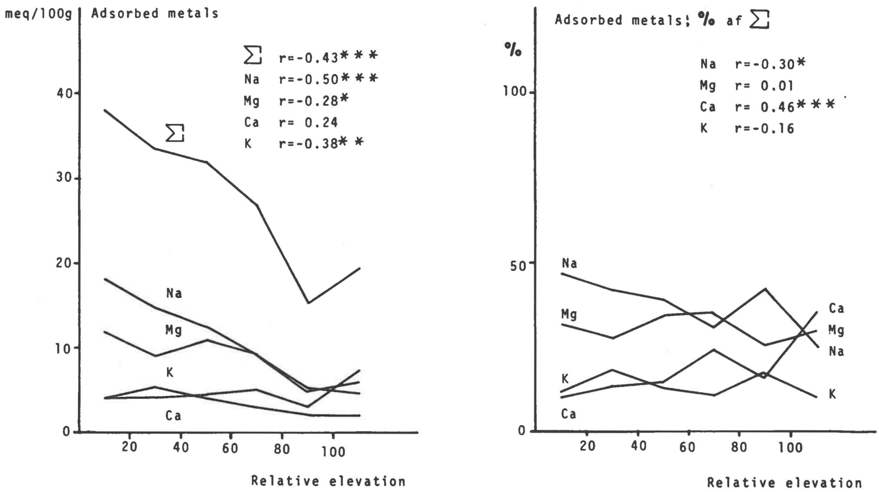

Fig. 23. Adsorbed metals in meq/100 g soil and as percentage of the sum, in relation to relative elevation, with correlation coefficients (r).

the lower salt marsh, corresponding with the rather frequent sea water inundation of this part. Throughout the upper marsh the ratio gradually changed as especially Na declined and Ca increased. Even in the near epilittoral, however, the quantitative order of the metals was the same as in the lower marsh; the dominance of Na at the near epilittoral indicates a sea water influence by air-borne spray and/or extremely rare inundation even at this level.

The ratio of Na/Ca was about 20 at the lower marsh limit and about 3 in the epilittoral; the correlation of this ratio with relative elevation was significant (r = – 0.52). Siira, in the Bothnian Bay (1970) has found Na/Ca-values in presswater from the lower geolittoral and epilittoral of about 10 and 5 respectively.

Cl (fig. 22) was highly significant, positively correlated with water-extractable Na (r = 0.98).

Specific conductivity (fig. 22) was highly significant, positively correlated with water-extractable Na + Mg + Ca + K (r = 0.98).

Adsorbed Na, Mg, Ca and K (fig. 23)

The difference between the fraction of Na, Mg, Ca and K extractable with 1 N NH_4Ac, pH 7, and the fraction extractable with water is taken as giving a fairly good estimate of the fraction of these metals adsorbed to the soil colloids (cf. Tyler, 1968).

Na + Mg + Ca + K: Highly significant, negatively correlated with relative elevation; the values declined from the lower marsh limit (mean 38 meq/100 g) throughout the marsh and increased again in the epilittoral, mainly due to an increase in Ca. Thus, the picture was quite different from that of the water-extractable metals.

Na, Mg, Ca and K individually were generally not well inter-correlated. The ratios between the metals changed more or less irregularly throughout the marsh. The ratios of Na, Mg, Ca and K at the lower marsh limit equalled about 47:32:10:12, which compared with the ratio of the water-extractable fraction indicates the stronger adsorptive power of Ca, Mg and K compared with that of Na. In the epilittoral the ratio changed to 25:30:35:11. The ratio of Na/Ca is about 4.7 at the lower marsh limit and about 0.7 in the epilittoral; the correlation of this ratio with relative elevation was significant at the 5 %-level.

Organic matter

The values varied greatly from locality to locality; in general they were higher in the upper soil layer (0–5 cm) than below 5 cm (fig. 16); exceptions were the soils at loc. II and III, which can possibly be related to a greater age of these marshes. There were, however, no differences between these localities and the others with regard to the composition and vitality of the vegetation.

The general features of the distribution of organic matter within the marshes are shown in fig. 22. The values were rather low in the lowermost part of the marshes as well as in the highest part of the upper marsh, corresponding to more sparse vegetation-cover in these parts. The highest values were found in the middle part of the marsh, with maximum at level R.E. 60–80, corresponding to the levels where *Carex glareosa* grows most vigorously and forms dense tufts. In the epilittoral, the organic matter varied with type of vegetation, but the values were in general higher than in the upper marsh. Organic matter appeared to be a function of type and development of the vegetation and was not correlated with relative elevation ($r = 0.01$).

Cation exchange capacity (CEC) (fig. 22)

CEC is related to the content of organic and inorganic colloidal anions in the soil, that is humus-colloids and clay-particles. The correlation between CEC and organic matter in the present material was highly significant ($r = 0.67$). Due to the low number of determinations of soil texture (table I) the importance of the clay-colloids cannot be estimated; the negative correlation between CEC and relative elevation ($r = -0.21$) compared with the lack of correlation between organic matter and relative elevation indicates, however, that clay may contribute to the CEC, especially in the lower marsh.

The base saturation, calculated as adsorbed Na + Mg + Ca + K in % of the CEC, declined gently from about 85 % at the lower marsh limit to about 50 % in the uppermost marsh and epilittoral.

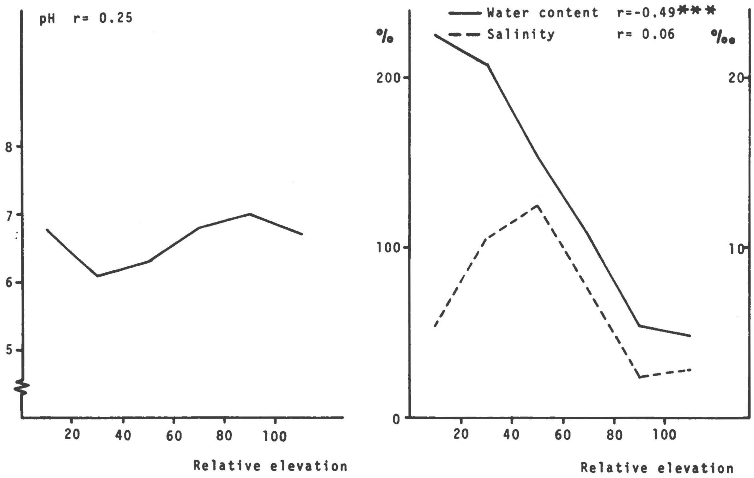

Fig. 24. pH, soil water content (% of dry weight), soil salinity (‰) in relation to relative elevation, with correlation coefficients (r).

Water content

The values varied very much from locality to locality (fig. 17). A general decline in water content, however, from the lower marsh limit to the epilittoral was found; the correlation with relative elevation was highly significant (r = −0.49) (fig. 24).

The water content was significantly positively correlated with the factors, which like water content declined significantly from lower to upper marsh. In contrast to this the correlation with organic matter and CEC, factors in common related to the water-holding capacity of the soil, were far more weak (r = 0.17 and 0.32) respectively. Nevertheless, the organic matter as well as the clay content of the soil must be of great importance to the water conditions in the salt marsh, especially in its higher parts, where the water-table is well below the surface and inundation rare. The high water contents in the lower marsh where the content of organic matter is generally low, may be conditioned by a highlying water-table and frequent inundation as well as a certain content of clay, especially clearly demonstrated in loc. V.

Soil salinity

The soil salinity is defined as the concentration of soluble salts in the soil solution. Soil salinity was not correlated with relative elevation (r = 0.06); the values were low in the lowermost marsh and in the upper marsh and epilittoral, and high at levels from R.E. 20 to about 60 (fig. 24). The high salinity in the middle of the marsh corresponded to similar maxima in water-extractable metals and Cl and specific conductivity, and might be explained by concentration of the soil solution caused by 1) evaporation from the soil surface in periods between the few inundations at this level, together with 2) only slight leaching from the upper soil layers due to the generally low precipitation within the investigation area (p. 15).

pH

In the lowermost marsh as well as in the upper marsh and near epilittoral the values were generally about 7. At levels about R.E. 20–60 the values were somewhat lower, about 6.2 (fig. 24). The significance and importance of this variation is, however, uncertain and the few significant correlations with other factors (table II) give no clear indications of the possible effect of pH within the salt marshes. pH in salt marsh soils and the effect on the distribution of the plants in salt marshes are thoroughly discussed by SIIRA (1970).

Phosphorus

The values of P, extractable with 0.2 N H_2SO_4, were remarkably high and the distribution in relation to relative elevation was rather marked (fig. 25). The mean value in the lowermost marsh was about 525 ppm; from R.E. 20–80 the values declined rather distinctly, with minimum of about 225 ppm at R.E. 60–80. Similar magnitude and distribution of P have been found in the subarctic salt marshes in Northern Norway (VESTERGAARD, 1972). Decline in P from the water boundary landwards has also been found by SIIRA (op.c.) in salt marshes at the Bothnian Bay. SIIRA suggests increased consumption by the vegetation at higher levels as a possible explanation.

EDTA-extractable Cu, Pb, Zn and Ni (fig. 25)

The values of Cu, Pb, Zn and Ni generally declined from the lowermost to the uppermost marsh level. This trend was most marked in Cu with mean values of about 40 and 8 ppm in the lower and upper marsh respectively and with a correlation coefficient with relative elevation of $r = -0.60$, and least marked in Pb. The values in the epilittoral were generally higher than in the uppermost salt marsh.

Pb was significantly correlated with organic matter ($r = 0.46$), but with no other factors, nor with relative elevation. Pb seems therefore mainly bound to and conditioned by soil organic matter.

On the contrary, Cu, Zn and Ni were negatively correlated with relative elevation and positively correlated with water content at varying levels of significance. However, these metals were not correlated with organic matter and seem therefore not especially bound to the organic matter in the soil. A possible explanation of the high values in the lower marsh may be formation of metal sulphides caused by temporary reducing conditions in the more clayed, often waterlogged soils at these

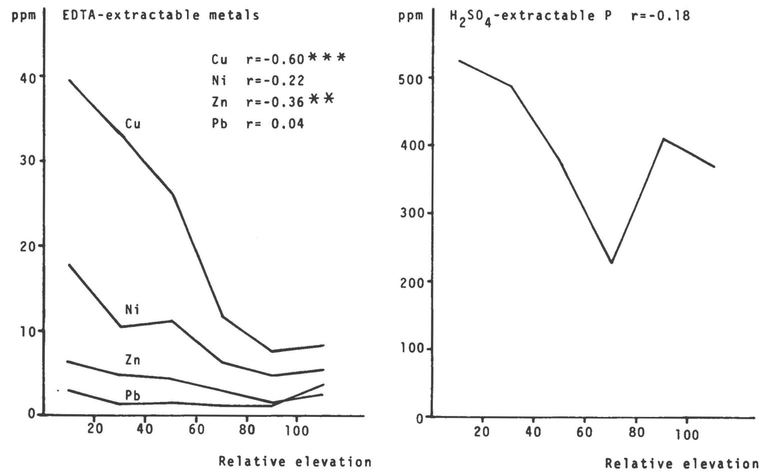

Fig. 25. EDTA-extracted metals (ppm/soil) and P (ppm/soil) in relation to relative elevation, with correlation coefficients (r).

levels. The redox-conditions in salt marshes are treated by Siira (1970), who demonstrates a negative correlation between the redox potential and pH in salt marsh soils. The increase in pH found in the present material at levels from about R.E. 50 to the lower marsh limit, may be an indication of reducing conditions in the soils of the lower salt marsh.

Edaphic factors and the distributions of the plants

In accordance with the relationship to relative elevation three groups of soil factors seem apparent:

1) A complex of significantly inter-correlated factors, which express quantity or concentration of soluble salts in the soil:

Water-extractable Na, Mg, Ca, K and Cl
Water-extractable Na + Mg + Ca + K
Specific conductivity
Soil salinity

The values of these factors were high but very variable within the salt marsh and low in the epilittoral. The presence of great quantities of soluble salts in the salt marsh is clearly of great ecological importance. It excludes plant species not tolerant of high osmotic pressure of the soil solution and favours tolerant species and is thus a decisive determinant of the floristic composition of the salt marsh, compared with the epilittoral. The role of soil salinity as a plant distributing factor within salt marshes has been discussed by many authors; the great variability and lack of correlation of salinity with height in the present material indicates, however, that salinity is no important determinant of the vegetational gradients within the salt marshes studied (cf. TYLER, 1969 b and 1971).

2) Factors, which were significantly correlated with relative elevation and form more or less continuous gradients from the lower salt marsh limit to the epilittoral:

a. Negatively correlated with relative elevation (levels of significance marked, by an x, xx or xxx):

Soil water content	xxx
Adsorbed Na	xxx
– Mg	x
– K	xx
– Na + Mg + Ca + K	xxx
– Na in $^0/_0$ of sum of adsorbed metals	xxx
Water extr. Na in $^0/_0$ of sum of water-extr. metals	xxx
EDTA-extr. Cu	xxx
– Zn	xx

b. Positively correlated with relative elevation:

Water-extr. Ca in $^0/_0$ of sum of water-extr. metals	xxx
Adsorbed Ca in $^0/_0$ of sum of adsorbed metals	xxx

Among these factors the soil water gradient and the gradient of water-extractable Na as a percentage of the sum of water-extractable metals seem particularly possible as potential co-determinants in the vegetational differentiation within the salt marsh.

The importance of the soil water gradient has been discussed by TYLER (1971), who points to the lack of oxygen, caused by frequent inundation and high soil water content, as possibly the main decisive factor in the differentiation of the vegetation. Specific adaptations to a low-oxygen substrate, such as aerenchymatic tissues, seem, however, not to be found in the species of the present salt marshes.

Excess Na is a crucial problem in the function of plants in saline environments, and much work is presently being done in this field (cf. JEFFERIES, 1972; WAISEL, 1972; ALBERT, 1975). The possible effect of the Na-gradient in the salt marshes might be due to differing abilities of the plant species to maintain a favourable ion uptake and regulation at high percentages of Na in the soil solution.

The gradients of Cu and Zn seem conditioned by the soil water content and the redox-conditions; it is not known whether they have any effect of the differentiation of the vegetation of the salt marshes.

The gradients of adsorbed Na, Mg and K are possibly of minor importance to the differentiation of the vegetation of the salt marshes, as the adsorbed metals do not influence the osmotic potential of the soil directly.

3) Factors with other patterns of distribution in relation to relative elevation, which have been discussed individually earlier in this chapter:

pH
H_2SO_4-extractable phosphorus
Soil organic matter
Cation exchange capacity.

Conclusion

From the present investigation the following general characteristics of the coastal salt marshes in the Disko area seem apparent:

1. The salt marshes are developed at protected places along the coast on marine or fluviale sediments of varying texture.

2. The vertical deliminations of the salt marshes seem to be mean high water level (MHW), marked by the lowermost level of *Puccinellia phryganodes*, and mean high water level at springtide (MHWS), marked by the uppermost level of *Carex glareosa*. Landwards the salt marsh vegetation changes into *Salix glauca* scrub, heath vegetation, sand dune or, locally, fresh-water marsh.

3. The salt marshes form ecoclines between the lower and upper marsh limits. The ecoclines are composed of vegetational and environmental gradients.

4. The vegetational gradients are formed by sequences of overlapping species with increasing height above MHW. The number of species per m^2 increases from the lower to upper marsh limit.

5. The environmental gradients are formed by decreasing frequency of tidal inundation with increasing height above MHW and by several edaphic factors, which reflect the inundation gradient: decreasing soil water content, decreasing content of adsorbed metals, decreasing percentage of Na, decreasing content of Cu and Zn, and increasing percentage of Ca, with increasing height above MHW. Of these environmental gradients, especially the gradients of soil water content and percentage of Na together with the inundation gradient, seem possible determinants in the formation of the vegetational gradient.

6. Based upon the dominance of the two most important species of the species-sequences, the salt marsh ecocline can be divided into two parts:

a. A lower salt marsh, from relative elevation zero to 30–70, dominated by *Puccinellia phryganodes*, with 1–5 species per m^2 and edaphically characterised by generally high water content, high values of soluble Cl and soluble and adsorbed metals, especially Na and Mg, and high values of Cu, Zn and Ni.

b. An upper salt marsh, from relative elevation 30–70 to 100, dominated by *Carex glareosa*, with higher species number, especially in the uppermost part, and edaphically characterised by generally low water content and values of soluble Cl and soluble and adsorbed metals, which are intermediary between the high values found in the lower salt marsh and the rather low values found in the epilittoral.

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