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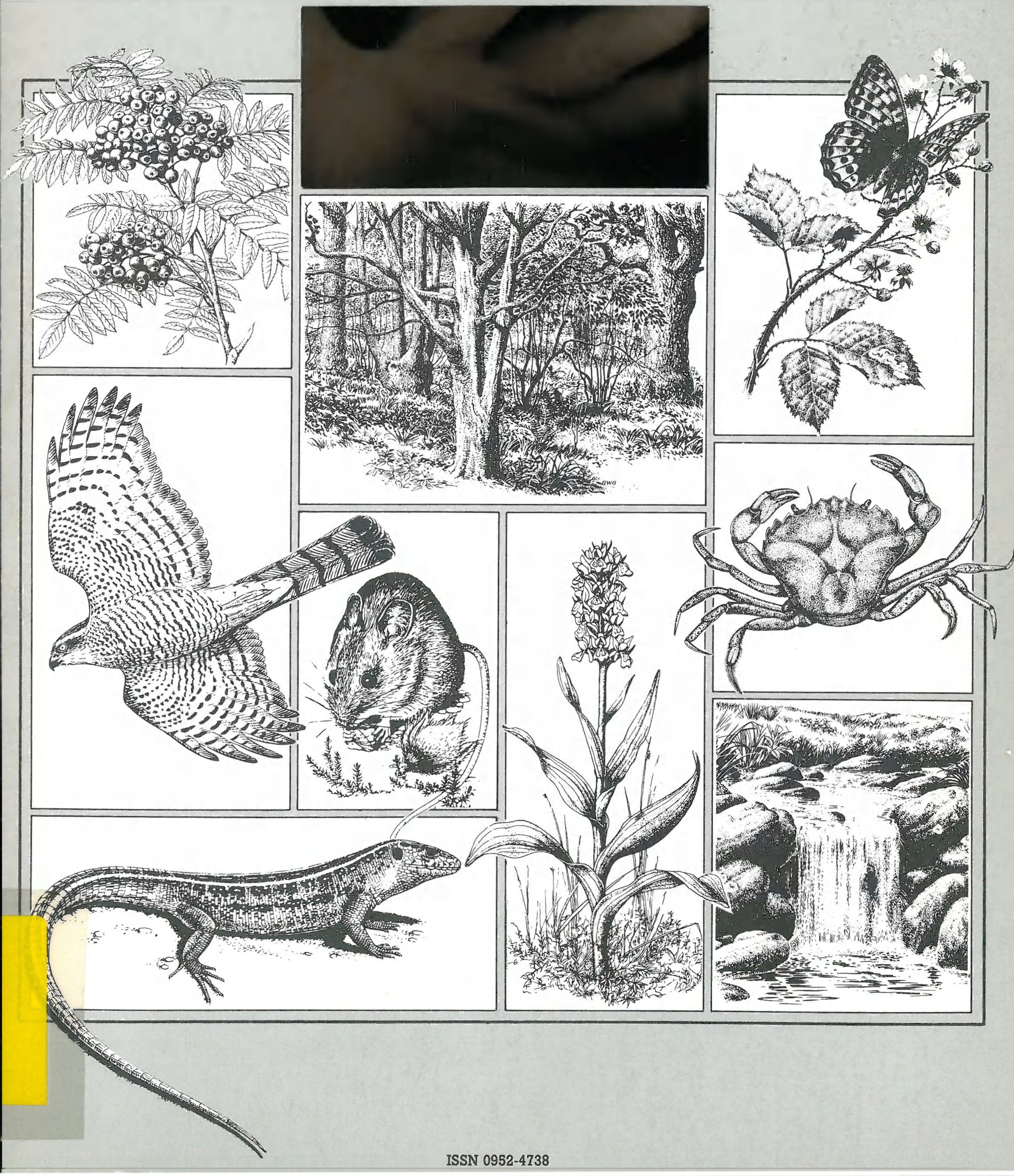

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No. 13

Saltmarsh vegetation of the Wash
An assessment of change from 1971 to 1985

Margaret I Hill

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NCC coastal ecology research programme

The Coastal Ecology Branch of the Chief Scientist Directorate was established in August 1979. One of the functions of the branch is to co-ordinate research and survey in the field of terrestrial coastal conservation. To this end a research programme has been developed with four main aims:

1. to describe the size, location and quality of the main coastal habitats in Great Britain (saltmarshes, sand-dunes, vegetated shingle, sea-cliffs, strandlines, 'reclaimed' land and maritime islands);

2. to assess the impact of major development projects on sites of national importance for nature conservation;

3. to provide guidance on the management of the main coastal habitats for nature conservation;

4. to investigate the role of physical and biological processes in the maintenance of natural and semi-natural coastal habitats.

The results are disseminated in various NCC publications:

a. CSD research reports: limited numbers of 'hard' copies are produced, usually by the contractor, and the contents are later made available as a CSD report on microfiche through NCC's Information and Library Services;

b. "Contract surveys";

c. "Research & survey in nature conservation";

d. "Focus on nature conservation".

This report represents one of the "Research & survey in nature conservation" series.

Dr Pat Doody
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Preface and acknowledgements

This report was produced as part of the NCC's research programme co-ordinated by the Chief Scientist Directorate at Peterborough. It forms part of a series of studies being undertaken to elucidate some of the effects of saltmarsh enclosure on the natural environment of the Wash.

The fieldwork was carried out during 1985. This, together with the subsequent analysis of vegetation community data, was supervised by Dr P F Randerson (University of Wales, Institute of Science and Technology), who carried out the original saltmarsh survey during the Wash Water Storage Scheme Feasibility Study.

Office and laboratory space was provided at Lincolnshire County Council's Freiston Hall Field Centre, and Mr Alan Bilham-Boult and his staff provided considerable assistance during the course of the work.

The report has been produced in two parts:

Part 1 Description of the work, results and analysis

Part 2 Two sets of vegetation maps drawn from aerial photographs taken in 1971 and 1982 (supplemented by 1984 photographs)

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1 Introduction

1.1 Background

The existing coastline of the Wash results from a long history of reclamation of its saltmarshes, which began in Roman times and has produced some 32,000 ha of agricultural land since the 16th century (Dalby, 1957). Further reclamations are clearly dependent on a continued renewal of saltmarsh habitats beyond the new embankments. Recent research has, however, questioned the assumption that saltmarsh development will occur at a rate capable of sustaining the current level of reclamation, approximately 6,000 ha per century.

Since 1979, NCC has adopted a policy of objection to all reclamation in the Wash SSSI. At the Gedney Drove End Public Inquiry in 1981 (Nature Conservancy Council, 1981), the appeal of the landowner was rejected on the grounds that the high conservation value of the site superseded the advantages of reclamation. In 1982, Lincolnshire County Council's Coastal Subject Plan proposed a moratorium on all reclamation until 1986. Norfolk County Council subsequently adopted a similar plan.

A Public Local Inquiry into the Lincolnshire Subject Plan upheld the Council's case and stressed the opportunity given by the moratorium to collect some objective evidence on the effect of reclamation which had been clearly lacking at the Inquiries. A joint Working Party on reclamation and conservation in the Wash, composed of representatives from NCC, MAFF and DoE, was set up to consider future policy. It recommended that more research should take place to "examine, in detail, the current vegetation, rates of accretion and likely future development of identified saltmarsh areas in relation to the dates of their last reclamation and past management". This survey aims, therefore, to fulfil these recommendations as they affect the vegetation of the saltmarshes and makes comparisons with the detailed work done for the Water Storage Scheme Feasibility Study in the 1970s (Randerson, 1975; Natural Environment Research Council, 1976). Other associated studies are being carried out on the availability of invertebrate food resources for waders and the value of the saltmarshes for insects, breeding birds and overwintering passerines.

1.2 The Wash and its significance

The Wash is the unfilled part of the Fenland basin which extended far inland at the end of the last glaciation (Steers, 1946). It incorporates the estuaries of four rivers - Witham, Welland, Nene and Ouse. The Wash SSSI includes the whole basin between the outer seawall and a line from Gibraltar Point to north of Hunstanton. This is a total area of more than 63,000 ha with approximately 31,000 ha above the low water mark. Within this are intertidal sand and mud flats, offshore sandbanks, shingle spits and saltmarshes. The saltmarshes make up a significant proportion of this habitat in Britain. The most recent estimate is of 3,600 ha, based on aerial photographs taken in 1982 (MAFF, 1983, in objections to the Lincolnshire Subject Plan), approximately 10% of the British saltmarsh area. This compares with an area of 4,240 ha calculated during the Water Storage Scheme Feasibility Study and based on 1971 aerial photographs.

The Wash is recognised to be of national and international importance for waders and wildfowl. In January 1985 the Wash supported more than 38,800 wildfowl, a highest total monthly count second only to the Inner Solway Firth in Britain. In 1984/5 it also held the second highest total number of waders - more than 135,000 individuals in winter and 173,000 over the whole year (Salmon & Moser, 1985). The numbers of 12 species are of international importance (Table 1.1). The site is also of significance for its migrant wader populations, wintering passerines (Prater, 1981), breeding birds (Cadbury et al., 1975) and common seals (Vaughan, 1975). These are described in more detail in submissions to the 1981 and 1983 Public Inquiries (Nature Conservancy Council, 1981; MAFF, 1983) and the report of the Wash Working Party.

1.3 The impact of reclamation

The immediate result of saltmarsh enclosure is the gradual replacement of the saltmarsh flora within the embankment owing to the leaching of salts. Some saltmarsh and paramaritime species may remain, at least temporarily, on the banks of old creeks and soak dykes within the enclosure (Gray, 1976). The process of reclamation begins with construction of a small (cradge) bank on the seaward side of the projected position of the new outer bank, giving a working area usually 40-70 m wide, protected from tidal inundation. Material for building the main bank is taken from a borrow pit excavated to landward of the cradge bank. Plant communities are therefore seriously disturbed or lost some 70 m to seaward of the seabank. The rate of silting-up of the borrow pits will depend on the frequency of flooding by the tide, which is related to the connections to the creek system and height of the cradge bank.

Saltmarsh is considered 'ripe' for reclamation when it reaches a height of approximately 3.4 m above Ordnance Datum and clearly it is the most mature vegetation types which will be lost. In practice, reclamation size is decided by such factors as the area: bank ratio, which determines the major cost of embankment. In some cases all the consolidated marsh will be enclosed at its narrowest point. Continued reclamations of the highest saltmarsh have, therefore, tended to maintain this habitat in an immature state and truncate the natural successional change. Over most of the Wash shoreline the saltmarshes form a relatively narrow fringe with a low species diversity. Despite this, their interest lies in a complex mosaic of communities which vary in subtle ways as a result of past grazing and reclamation. Some areas of older saltmarsh do exist and have developed more diverse upper marsh floras, and these are likely to be the sites of greatest conservation value.

After enclosure, the accretion rate beyond the new seabank increases, since the sedimentary environment is no longer at equilibrium. Saltmarsh spread will continue until equilibrium is re-established. The rate of spread will be determined by the supply of sediment, the shape of the intertidal profile and the proximity to the low water mark. MAFF (1983) estimated (based on the evidence of F J T Kestner) that equilibrium and stability of the marsh edge occur, on average, 30 years after reclamation, giving a marsh width of 500-900 m, 50% of this being achieved in the first six years and 92% in the first 18 years. MAFF also predicted that the total area of saltmarsh in the Wash would fluctuate between 2,500 and 4,500 ha, assuming a continuing programme of reclamation.

Table 1.1 Bird species of national and international importance wintering on the Wash

(based on data in Salmon, 1981, 1982, 1983; Salmon & Moser, 1984, 1985)

	Highest total monthly counts			
Species	Wash 1984/5	Wash average 1980/1-1984/5	Great Britain 1984/5	% of British population 1984/5
*Dark-bellied brent goose	14,212	18,188	89,000	16.0
*Shelduck	11,222	15,577	61,830	18.1
*Pintail	1,111	1,701	30,810	3.6
*Pink-footed goose	9,500	7,270	-/- 120,000	7.9
+Goldeneye	352	253	11,120	3.2
+Mallard	2,502	4,014	159,340	1.6
*Oystercatcher	(21,281)	22,222	209,800	10.6
*Grey plover	3,966	3,869	21,200	18.7
*Knot	77,050	75,165	194,000	39.7
*Dunlin	20,101	26,798	371,600	5.4
*Bar-tailed godwit	7,846	8,250	63,800	12.3
*Curlew	(1,405)	3,743	65,600	5.7
*Redshank	(1.643)	3,388	66,000	5.1
*Turnstone	(911)	863	12,700	6.8
+Sanderling	(85)	396	5,100	7.8

*International importance (>1% of world population)

+National importance (>1% of British population)
calculated from 5-year average if 1984/5 count incomplete

Brackets indicate an incomplete count.

-/- Estimated figure

It is now accepted that the low water mark in the Wash is relatively static and that there is some ultimate limit to saltmarsh colonisation. Thus, future reclamations will involve not only a short-term loss of saltmarsh habitat but a permanent loss of intertidal area and a steepening of its profile. The report of the Wash Working Party gives a value of 20% reduction in the intertidal area in the last 150 years. MAFF has predicted that this reduction in the intertidal zone will be in the order of 3,000 to 4,000 ha over the next 100 years, assuming a continuation of the current rate of piecemeal reclamation. This represents a loss of 17% of the current intertidal area. This study aims to assess the rate of spread and successional change in the saltmarsh, in particular that which has occurred since the reclamations of the 1970s, and to attempt to quantify the loss of intertidal area.

The impact of reclamation on the populations of birds, seals and invertebrates through the lost saltmarsh and intertidal sand and mud flats is less easy to predict. It is clearly dependent on the proximity of alternative similar habitats, the mobility of the animals and the degree to which these habitats are already exploited. Although new saltmarsh may eventually develop beyond the new seabank, this will be of no value to displaced animals if no suitable habitat is available in the intervening period. For example, the numbers of breeding redshank, which nest on the higher saltmarsh where there is some protection from flooding, have been shown to be particularly badly affected by reclamation (Nature Conservancy Council, 1981).

Any reduction in the intertidal area of the Wash is a loss of potential feeding grounds for waders and wildfowl. Changes in the distribution of invertebrate prey species may affect the feeding efficiency and behaviour of birds (Evans & Pienkowski, 1984). In the short term, removal of saltmarsh will have an immediate impact on the invertebrate populations of adjacent tidal flats owing to the disturbance of the sedimentary regime and a decrease in the input of organic detritus, an important food source. The significance of saltmarsh primary production in the total energy budget of the Wash is not known.

1.4 Comparison with 1971/4 saltmarsh vegetation survey

As part of the Water Storage Scheme Feasibility Study (Natural Environment Research Council, 1975), a comprehensive survey of the Wash saltmarshes was carried out (Randerson, 1975). Based on aerial photographs taken in 1971, this produced a vegetation map at a scale of 1:10,000 and a breakdown of the areas occupied by various plant communities. Twelve line transects were set up and used for detailed vegetation recording and measurement of accretion rates (see Fig. 1 on p. 23). The new study repeated the 1971/4 survey, using the same transects to give an objective record of vegetation trends. As shown in Fig. 1, several reclamations have taken place since the previous survey:

Wainfleet St Mary (1973)	80 ha
Wainfleet/Friskney Jubilee Bank (1976)	350 ha
Freiston shore (1976-79)	45 ha
Freiston shore (1979-80)	47 ha
Gedney Drove End (1978)	17 ha
Wingland (1974)	177 ha
Ongar (1974)	101 ha

Small areas totalling 41 ha were also enclosed on Fosdyke marsh and on the east shore of the Welland channel.

Thus the trends observed reflect the response to reclamation, as well as changes due to succession, climatic factors and grazing.

Note on nomenclature

Nomenclature for plant species in most cases follows that of Flora Europaea (Tutin et al., 1964-1980). On first mention, species are referred to by their generic and species names. Subsequently, the generic name only may be used, unless the species name is necessary for clarity. An exception to this is Elymus pycnanthus (Godron) Melderis, which is referred to as Agropyron pungens, the name used in the 1971/4 survey.

2 Vegetation mapping - extensive survey

2.1 Methods

2.1.1 1982/5 vegetation maps

The pattern of saltmarsh vegetation was drawn from black-and-white aerial photographs at a scale of 1:15,000, taken by MAFF in 1982. The vegetation was divided into communities as defined by the National Vegetation Classification (Table 2.1). These communities are described in section 2.2. The position of community boundaries was confirmed, as far as possible, by field observation in 1985. Communities were identified with the use of the NVC saltmarsh key and by comparing the vegetation of sample (usually 2 x 2 m) quadrats with the examples given in the NVC account (Rodwell, 1983). Problems in classifying communities according to the NVC are described in section 3.4.

Vegetation mapping in transitional and dynamic habitats, such as saltmarshes, poses a number of difficulties: communities merge gradually into each other and boundaries are not easily defined. Many areas are fine-scale mosaics of two or more vegetation types, reflecting differences in drainage and topography; these are hard to map over large areas. The clarity of boundaries on aerial photographs also differs according to the season in which they were taken. This is a particular problem in immature marshes where the proportion of annual species is high. The 1982 photographs used in this study were taken in March, when the seaward saltmarsh edge, where dominated by Salicornia, was poorly defined. This edge was, therefore, drawn from a set of aerial photographs taken in June 1984 (scale 1:20,000) and oblique photographs (both Cambridge University, 1984). The maps were drawn on transparent overlays and then corrected to the 1:10,000 Ordnance Survey grid with the use of photogrammetric plotting instruments. The area of each vegetation community was then calculated by means of a digital mapping system.

Table 2.1 Wash saltmarsh vegetation communities

National Vegetation Classification communities used (Rodwell, 1983)		Constant species (frequency in 2 x 2 m quadrats >80%)	Map code	Equivalent community used in 1971/4 survey
SM6	Spartina anglica	Spartina anglica	Sp	Spartina
SM8	Annual Salicornia spp.	Annual Salicornia spp.	Sa	Salicornia
SM9	Suaeda maritima	Suaeda maritima	Su	Not used
SM11	Aster tripolium var. discoideus	Rayless Aster tripolium Puccinellia maritima Salicornia spp.	As	Aster
SM10	Transitional low marsh	Puccinellia maritima Salicornia spp. Suaeda maritima	TLM	Puccinellia/Aster Puccinellia/Suaeda/ Halimione Puccinellia/Suaeda Puccinellia/Salicornia/ Aster
SM13	Puccinellia maritima Puccinellia-dominated subcommunity	Puccinellia maritima	P	Puccinellia
SM14	Halimione portulacoides Puccinellia-dominated subcommunity	Puccinellia maritima Halimione portulacoides	P/H	Puccinellia/ Halimione
SM14	Halimione portulacoides Halimione-dominated subcommunity	Halimione portulacoides	H	Halimione
SM24	Agropyron pungens (Elymus pycnanthus)	Agropyron pungens	A	Agropyron
SM13	Puccinellia maritima approaching Limonium--Armeria subcommunity, upper marsh subcommunity	Puccinellia maritima	UM	Upper mixed marsh
SM17	Artemisia maritima	Artemisia maritima Plantago maritima Festuca rubra Halimione portulacoides	UM	Upper mixed marsh
SM16	Festuca rubra Puccinellia maritima-dominated subcommunity	Festuca rubra Plantago maritima Glaux maritima Puccinellia maritima	UM	Upper mixed marsh
SM23	Spergularia marina--Puccinellia distans	Spergularia marina Puccinellia maritima Puccinellia distans	P/S	Not used

2.1.2 Comparison with 1971/4 vegetation maps

The vegetation maps produced as part of the previous survey (Randerson, 1975) were drawn from colour aerial photographs (scale 1:10,000, Fairey Surveys Ltd) taken in 1971. The vegetation communities were classified by their dominant and codominant species. There is a close relationship between these communities and those of the NVC, as shown in Table 2.1; this facilitates a comparison between the two surveys. Attempts were made to correct the maps to fit the Ordnance Survey baseline, as was done for the 1982/5 maps (section 2.1.1). However, this proved impossible owing to the degree of distortion of the photographs. The areas calculated by a dot-grid technique in the previous survey were therefore used for comparison. The outline of reclamations which have taken place since 1973 were transferred onto the vegetation maps, allowing the area of each community lost in reclamation to be measured by the dot-grid technique.

The two sets of vegetation maps form Part 2 of this report, which has been produced separately in limited numbers.

2.1.3 Saltmarsh width measurements

Changes in the width of saltmarsh were calculated at 46 points around the Wash shoreline by using the 1971/4 and 1982/5 vegetation maps. These points are marked on the maps (Part 2) and listed in Table 2.5. Measurements were also taken directly from aerial photographs taken in 1977 (scale 1:10,000) and 1984 (1:20,000) (both Cambridge University copyright). The most accurate assessment of the scale of change is the difference between the vegetation maps (the later set having been corrected to the Ordnance Survey baseline), as these have been checked by mapping in the field.

Details of aerial photography used in this study and the previous survey are given in Appendix 2.

2.2 Community descriptions

The communities used in this survey are described below. Further details are to be found in the NVC saltmarsh account (Rodwell, 1983) and in Adam (1978, 1981).

N.B. A species is defined as constant if its frequency in 2 x 2 m quadrats is greater than 80%.

2.2.1 Spartina anglica saltmarsh (SM6) Map code Sp

Vegetation ascribed to this community is dominated by Spartina anglica, which is the only constant species and often the only vascular plant present. It occurs mainly on the seaward saltmarsh edge, but patches may be found in poorly drained areas and pans throughout the marsh. The vegetation may be characterised by discrete tussocks or a continuous sward. Boundaries between Spartinetum and other communities are generally sharp and transitional vegetation types are rarely extensive. Spartina anglica saltmarsh occurs on both grazed and ungrazed sites.

Although palatable, large stands are avoided by grazing animals because of the soft substrate. Spartina does not respond well to trampling but may be maintained by grazing or cutting (Hubbard, 1965).

On the Wash, Spartina anglica has been planted at various sites, for example at Ongar around 1925 (Chapman, 1960). Hubbard & Stebbings (1967) estimated the area of Spartina in the Wash to be approximately 1,400 ha, using aerial photographs taken in 1958. This is generally accepted to have been an overestimate, although there are consistent reports of its rapid spread in the 1950s. Spartina dominates the pioneer community and forms a continuous sward only in the south-east corner of the Wash, around the River Ouse, where the sediment particle size is smallest (Randerson, 1975). At many sites the pioneer zone is a mosaic of Spartina- and Salicornia-dominated areas.

2.2.2 Annual Salicornia saltmarsh (SM8) Map code Sa

Included in this association are all stands in which annual species of Salicornia dominate and are the only constant species. On the Wash five species have been described S. dolichostachya and S. fragilis (tetraploids), S. europaea and S. ramosissima (diploids), and S. pusilla. The species were not separated in this survey and are referred to by the generic name only. Salicornia saltmarsh may be characterised by widely scattered individuals or dense stands. In the low marsh, the community may occur as a distinct zone or in a mosaic with patches of Spartina anglica and Puccinellia maritima saltmarsh which grade into the transitional low marsh (see below). Extensive areas of Salicornia saltmarsh are most prevalent on the sandier sites of the south and west shores. Dense stands are also found in old borrow pits and disturbed areas of the upper marsh.

2.2.3 Suaeda maritima saltmarsh (SM9) Map code Su

Suaeda maritima is the only constant species in this community, which occurs as small stands in old borrow pits and creek banks in the lower marsh. Annual Salicornia, Spartina anglica, Puccinellia maritima and Aster tripolium are also frequent. This community was not distinguished in the 1971/4 survey.

2.2.4 Aster tripolium saltmarsh (SM11 rayless and SM12 rayed) Map code As

Two Aster communities are distinguished in the NVC - SM11, dominated by rayless Aster tripolium var. discoideus with Puccinellia maritima and Salicornia as additional constants, and SM12, dominated by the rayed form but with rayless individuals also present. On the Wash, stands of Aster are usually dominated by the rayless form but include some rayed individuals. Salicornia, Puccinellia maritima, Suaeda maritima and Atriplex hastata are also frequent but not codominant with Aster. The community has a discontinuous distribution around the Wash, occurring on all three shores. In the lower marsh, the community is usually found above the Spartinetum and Salicornietum but at some sites may be the lowest colonist. Landwards the community grades into vegetation dominated by Puccinellia maritima and Halimione portulacoides. As described by Adam (1981), the community may grow on a hummock/hollow topography with Aster on top of the mounds and Puccinellia and Salicornia in the depressions. This morphology is found on the older west and south shore marshes, as at Wrangle, Leverton and Gedney Drove End. The distinction between Aster tripolium saltmarsh and the transitional low marsh community (with 3-5 codominant species) is often difficult, especially as the two communities occupy a similar tidal range.

2.2.5 Transitional low marsh vegetation (SM10) Map code TLM

In this community, Puccinellia martima is codominant with annual species of Salicornia and/or Suaeda maritima. In winter, it appears to be an open Puccinellia sward, forming a zone above the pioneer communities. The open structure of the sward may be maintained by goose-grazing in the Wash. At many sites, Puccinellia maritima, Salicornia spp., Suaeda maritima, Aster tripolium and Spartina anglica are codominant. Such transitional low marsh vegetation is found on both grazed and ungrazed sites and in low-lying areas within Puccinellia maritima and Aster tripolium saltmarsh. This community was defined in the 1971/4 survey as four Puccinellia communities with codominant Salicornia, Suaeda, Aster and Halimione (Table 2.1).

2.2.6 Puccinellia maritima saltmarsh (SM13)

This is probably the most widespread community of British saltmarshes. In the NVC, it includes a wide range of vegetation from low-diversity Puccinellia communities to swards dominated by herbaceous dicotyledons such as Limonium spp., Armeria maritima, Plantago maritima and Glaux maritima. The Wash Puccinellia maritima saltmarshes, however, show only a small sample of the variation in this community in Britain and have, therefore, been subdivided for this survey as follows.

2.2.6.1 Puccinellia-dominated subcommunity (low-diversity sward) Map code P

This is the major low to mid marsh community, where Puccinellia maritima is dominant and constant, forming a relatively closed sward in which other species are poorly represented. On grazed marshes the turf is short, with Salicornia, Spergularia marina and Spergularia media present in poached areas. At other sites, where grazing no longer occurs, Puccinellia forms a thick, springy mattress, extending to high levels on the marsh. These stands are often monospecific or contain frequent Atriplex hastata, as at North Wootton and Wolferton marshes.

2.2.6.2 Upper marsh subcommunity (high-diversity sward) Map code UM

This community is found only on older saltings (at least 3.2 m above Ordnance Datum) where species such as Limonium vulgare, Plantago maritima, Festuca rubra, Artemisia maritima and Triglochin maritima are present. On ungrazed sites, as on parts of Frampton marsh, this community forms islands within the Agropyron pungens sward, occupying the lower areas between creek banks. The non-grass species rarely comprise more than 10% cover. On grazed marshes, a diverse Puccinellia maritima community is found on the highest ground - on creek banks as at Kirton/Frampton, above a small cliff at Leverton, and on hummocks of discarded dredge spoil at Wrangle outmarsh. In some places, the community may approach the Limonium--Armeria subcommunity of the NVC, with Puccinellia forming less than 10% of the sward, but this is rare.

2.2.7 Halimione portulacoides saltmarsh (SM14)

This is a species-poor community, with Puccinellia maritima and Halimione portulacoides as the only constants. The distinction between the two subcommunities described below lies in the dominance of Halimione. On the Wash, Halimione or Puccinellia/Halimione is a major mid to upper marsh community and occupies a zone above or between the Puccinellia saltmarsh areas. At some sites it is found throughout the marsh, grading into a pioneer, Aster or transitional low marsh at its lower limit. Halimione typically invades the lower marsh levels along the well-drained creek margins.

2.2.7.1 Halimione subcommunity Map code H

Halimione is the dominant species, with more than 75% cover. Puccinellia forms an understorey with occasional individuals of Cochlearia spp. and Suaeda maritima. This community is largely absent from grazed marshes and on some sites is confined to creek banks.

2.2.7.2 Puccinellia subcommunity Map code P/H

Halimione and Puccinellia are codominant, either closely intermixed or as a fine-scale mosaic. This is in contrast to the NVC and Adam (1981), where the latter is treated as a mosaic of Puccinellia and Halimione communities. This level of scale was considered too small for this survey.

2.2.8 Agropyron pungens (Elymus pycnanthus) saltmarsh (SM24) Map code A

Agropyron pungens is the dominant and only constant species in this community. On the Wash, large areas occur only on the older marshes, where the species is found initially on creek levees and then spreads to the between-creek areas. Many stands are virtually pure Agropyron pungens; the seaward edge tends to be the most open and diverse owing to the accumulation of drift material. Some upper marsh sites show a mosaic vegetation with patches of Agropyron, Puccinellia and Artemisia. On younger marshes, Agropyron occurs only on the driftline, seabank base or cradge bank. Extensive Agropyron swards are absent from grazed sites. Sheep-grazing, in particular, is thought to prevent establishment of Agropyron, although sheep will avoid large stands (Cadwalladr & Morley, 1973).

2.2.9 Festuca rubra saltmarsh (SM16) Puccinellia subcommunity

This community contains Festuca rubra, Puccinellia maritima, Plantago maritima and Glaux maritima as constant species in varying proportions. The cover of Festuca rarely exceeds 40%. In the NVC, Juncus gerardii is also listed as a constant species, but this is not applicable to the Wash saltmarshes, where it is rare. Fragments of Festuca rubra vegetation are found on the highest levels of grazed and ungrazed sites in stands of Puccinellia maritima saltmarsh (upper marsh subcommunity), within which it was included for mapping purposes.

2.2.10 Artemisia maritima saltmarsh (SM17)

This community has Artemisia maritima, Plantago maritima, Festuca rubra and Halimione portulacoides as constant species. Stands are fragmentary within Puccinellia (upper marsh subcommunity) or Halimione vegetation, or associated with driftlines, cradge banks and mounds of dredge spoil. As with Festuca rubra saltmarsh, this community was included in stands of Puccinellia maritima saltmarsh (upper marsh subcommunity) for mapping.

2.2.11 Spergularia marina--Puccinellia distans saltmarsh (SM23) Map code P/S

This community contains Puccinellia maritima, Puccinellia distans and Spergularia marina as the constant species and has the appearance of an open Puccinellia sward with abundant Spergularia. The proportion of the two Puccinellia species is difficult to determine, especially in the absence of flowers. Small stands are found on the older marshes of the west shore, along paths and cattle-poached areas. This community was not distinguished in the 1971/4 survey.

2.3 Results

2.3.1 Areas of vegetation communities

The areas of various plant communities taken from the 1982/5 and 1971/4 vegetation maps are given in Tables 2.2-2.4. The differences found comprise, first, loss of habitat owing to reclamation and erosion of saltmarsh and, secondly, changes in the constituent species owing to the effects of grazing, climate and natural successional development. Examples of vegetation maps of 1971/4 and 1982/5 are given in Fig. 2.1a-h.

Table 2.2 Areas of vegetation communities (hectares)

NVC code	Community	Area in 1971/4	Area in 1982/5	Area lost in reclamation since 1973	Area gained/lost outside reclamations	Net change in area between 1971/4 & 1982/5
SM6	Spartina anglica	207.3	96.7	4.6	-106	-110.6
SM8	Annual Salicornia	378.0	208.6	42.6	-126.8	-169.4
SM6/8	Spartina/Salicornia	Not used	80.9	-	-	-
SM9	Suaeda maritima	Not used	4.8	-	-	-
SM11	Aster tripolium var. discoideus	530.6	134.1	12.3	-384.2	-396.5
SM10	Transitional low marsh	70.6	286.7	-	+216.1	+216.1
SM13	Puccinellia maritima Puccinellia-dominated subcommunity	487.8	1243.7	123.4	+879.3	+755.9
SM14	Halimione portulacoides Puccinellia-dominated subcommunity	525.7	1051.1	28.0	+553.4	+525.4
SM14	Halimione portulacoides Halimione-dominated subcommunity	1294.5	117.6	502.2	-674.7	-1176.9
SM24	Agropyron pungens	360.6	471.0	52.1	+162.5	+110.4
SM13	Puccinellia maritima upper marsh subcommunity	385.5	257.1	88.6	-39.8	-128.4
SM23	Spergularia marina--Puccinellia distans	-	4.0	-	-	-
-	Borrow pits--bare ground	-	201.4	9.7	-	-
	Total	4240.6	4157.7	863.5	+780.6	-82.9

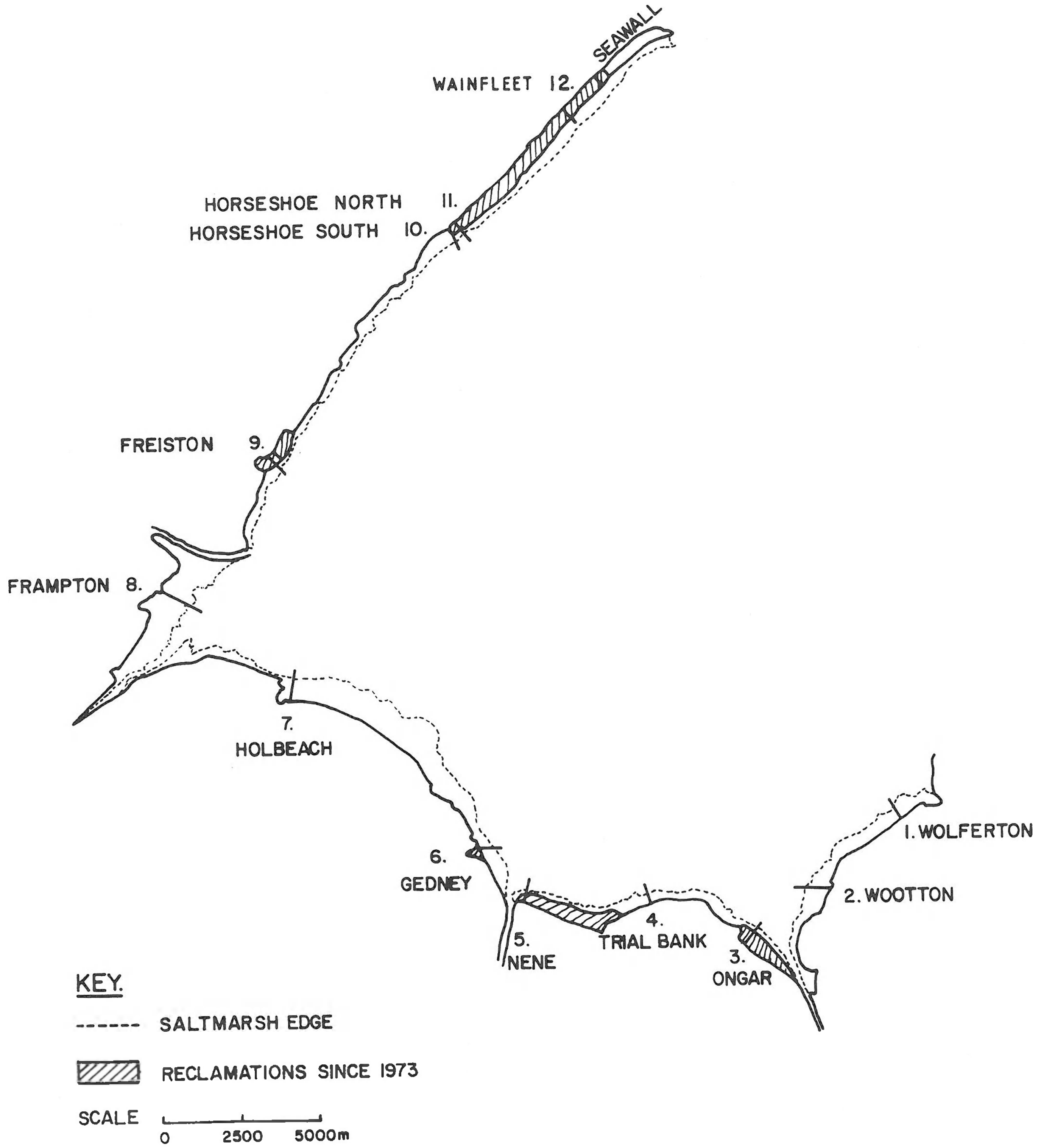
Table 2.3a Areas of vegetation communities (hectares) in 1971/4, subdivided by shoreline section

NVC code	Community	West shore	Witham to Welland	Welland to Nene	Nene to Ouse	East shore
SM6	Spartina anglica	9.1	0	7.3	112.0	78.9
SM8	Annual Salicornia	215.4	22.8	135.7	1.8	2.3
SM9	Suaeda maritima	-	-	-	-	-
SM11	Aster tripolium var. discoideus	123.2	56.3	198.4	88.7	64.0
SM10	Transitional low marsh	44.6	0	3.5	5.7	16.8
SM13	Puccinellia maritima Puccinellia-dominated subcommunity	113.3	46.1	139.2	151.1	38.1
SM14	Halimione portulacoides Puccinellia-dominated subcommunity	153.8	119.2	127.0	1.4	124.3
SM14	Halimione portulacoides Halimione-dominated subcommunity	334.8	308.6	257.0	315.7	78.4
SM24	Agropyron pungens	31.1	131.9	188.5	0	9.1
SM13	Puccinellia maritima upper marsh subcommunity	87.0	141.4	147.3	0	9.8
SM23	Spergularia marina--Puccinellia distans	-	-	-	-	-
	Total	1112.3	826.3	1203.9	676.4	421.7

Table 2.4 Total saltmarsh area (hectares) in 1971/4 and 1982/5, subdivided by shoreline section

	Area in 1971/4	Area reclaimed since 1973	Area in 1982/5	Net change 1971/4 - 1982/5	Gain outside reclamation
Gibraltar Point to Witham	1112	527	928	-184	343
Witham to Welland	826	0	844	+18	18
Welland to Nene	1204	59	1473	+269	328
Nene to Ouse	676	278	448	-228	50
East shore	422	0	466	+44	44
Total	4241	864	4158	-83	781

Figure 1. The coastline of the Wash showing transect locations and reclamations since 1973



KEY

MAP CODE	NVC COMMUNITY
Sp	*Spartina anglica* saltmarsh (SM6)
Sa	Annual *Salicornia* saltmarsh (SM8)
Sa/Sp	*Spartina/Salicornia* mosaic (SM6/8)
Su	*Suaeda maritima* saltmarsh (SM9)
TLM	Transitional low marsh vegetation (SM10)
As	*Aster tripolium* var. *discoideus* saltmarsh (SM11)
P	*Puccinellia maritima* saltmarsh *Puccinellia maritima* dominated subcommunity (SM13)
H	*Halimione portulacoides* saltmarsh *Halimione portulacoides* dominated subcommunity (SM14)
P/H	*Halimione portulacoides* saltmarsh *Puccinellia maritima* dominated subcommunity (SM14)
A	*Elymus pycnanthus* saltmarsh (*Agropyron pungens*) (SM24)
UM	*Puccinellia maritima* saltmarsh "Upper marsh subcommunity" (SM13)
P/S	*Puccinellia distans* - *Spergularia marina* (SM23)
BP	Borrow pits (may be open water, bare mud, or very sparse vegetation)
REC	Reclaimed
BG	Bare ground
.....	Width measurement point
*	Transect sites

FIG 2·1 a WOLFERTON

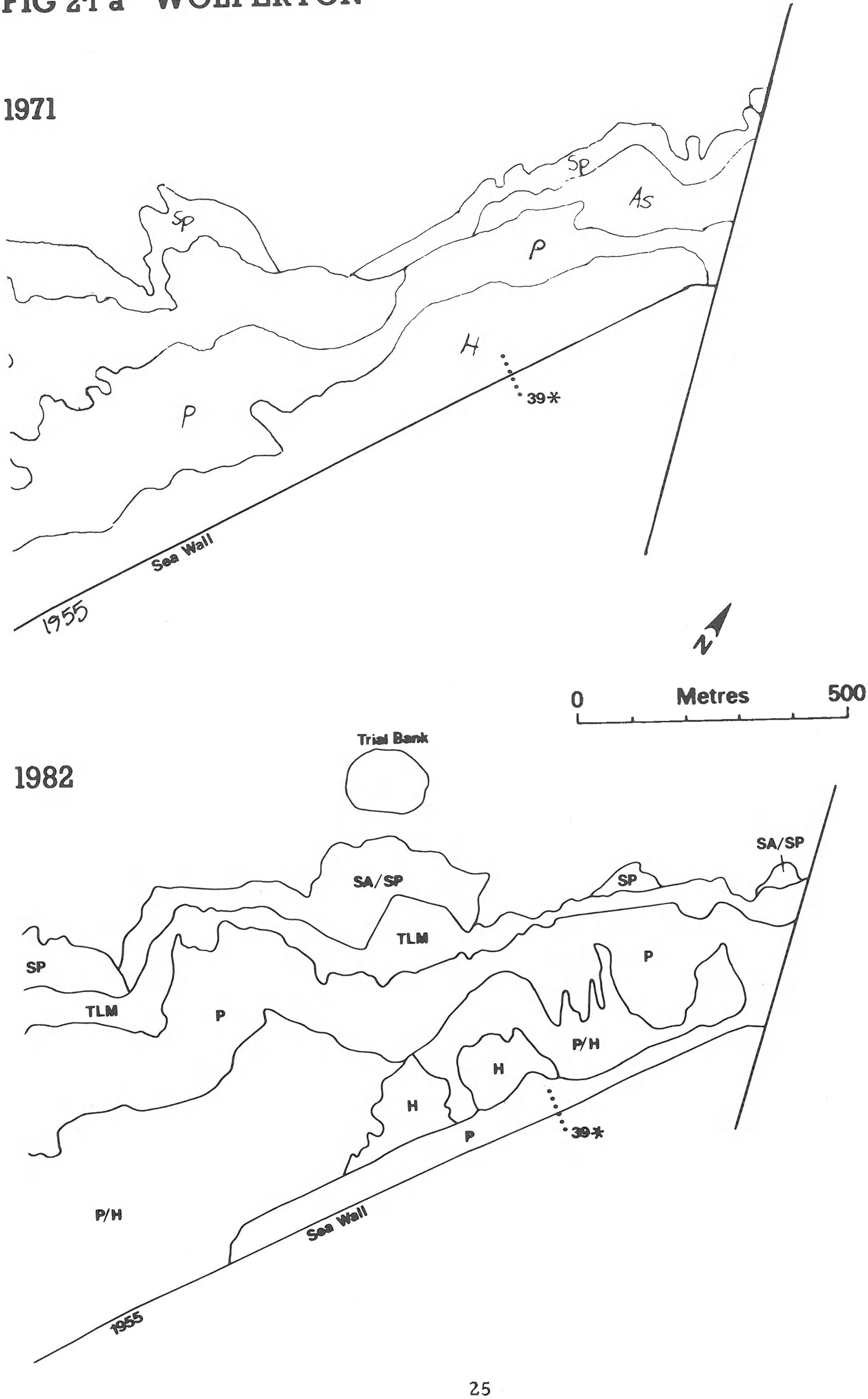


FIG 2·1 b WOOTTON

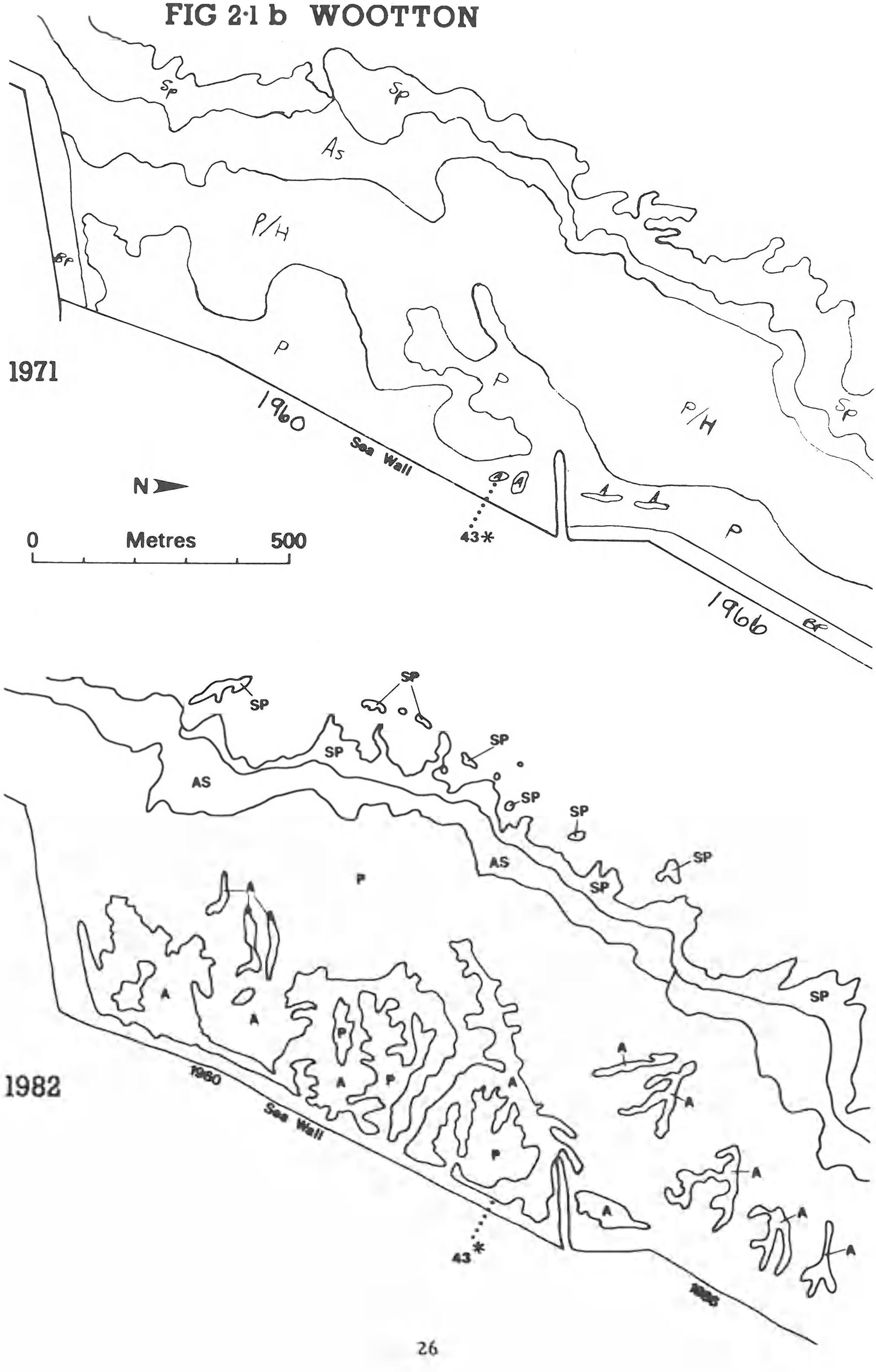


FIG 2·1 c TERRINGTON (Trial Bank)

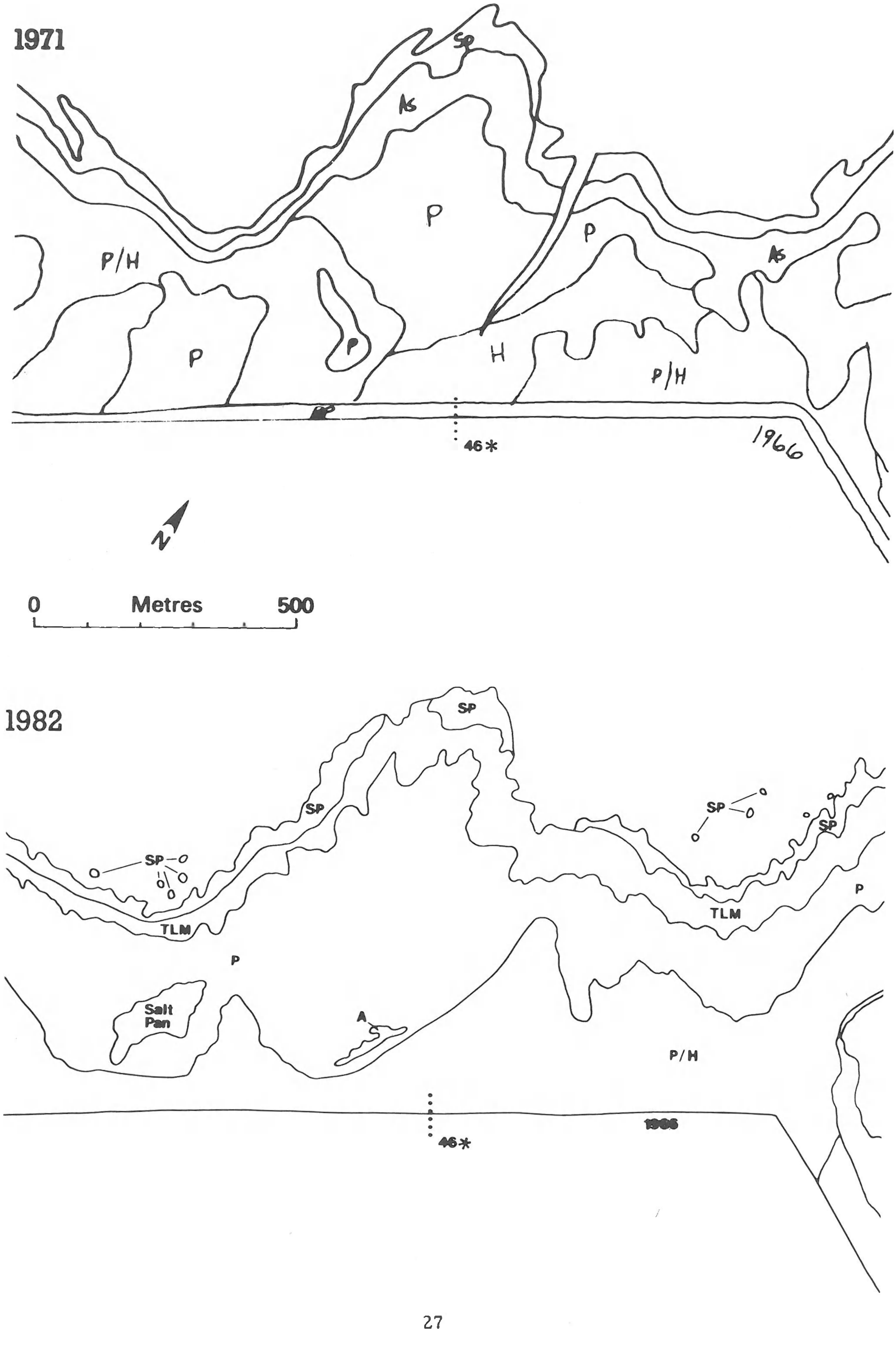


FIG 2·1 d GEDNEY DROVE END

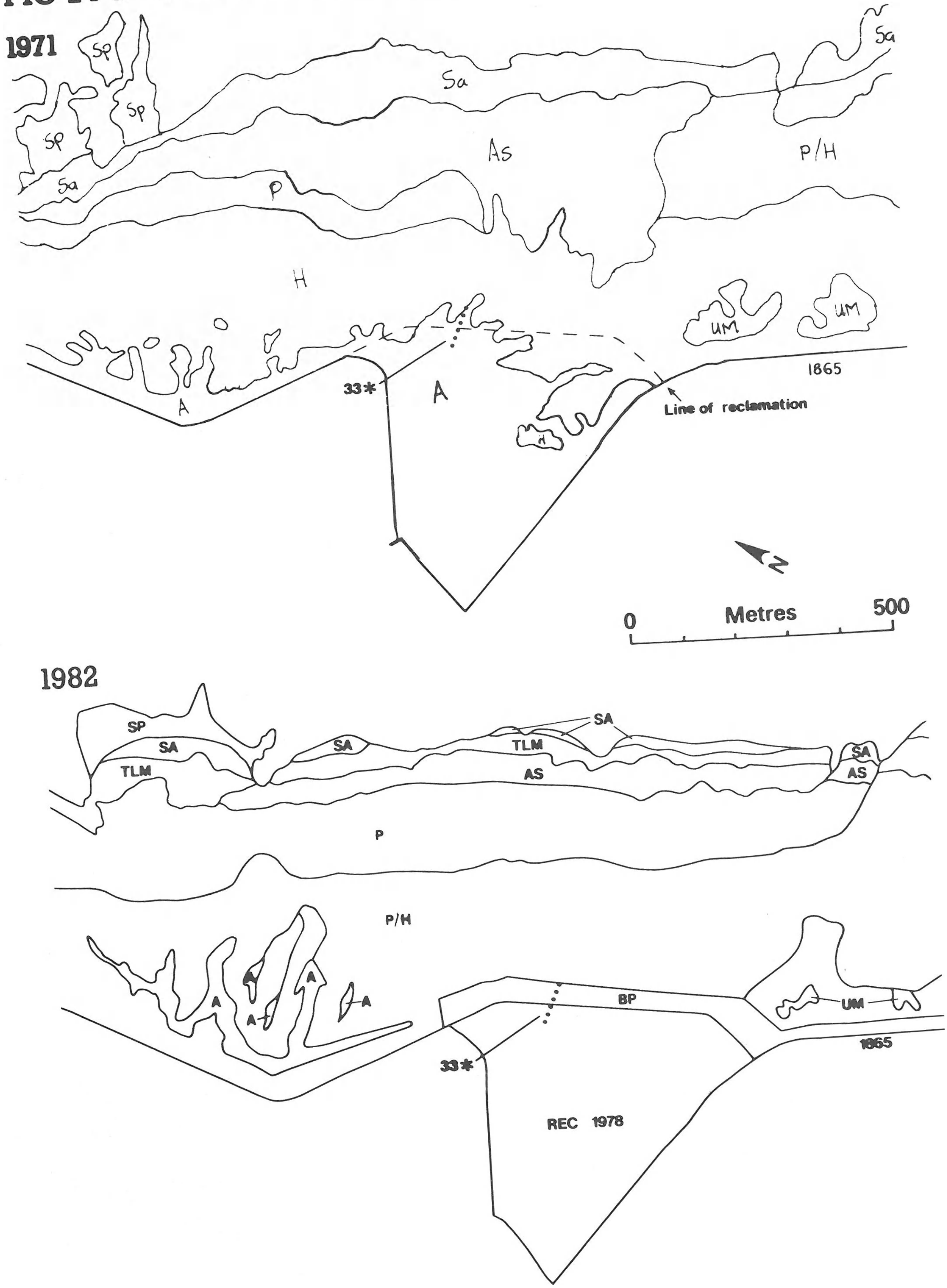


FIG 2·1 e HOLBEACH

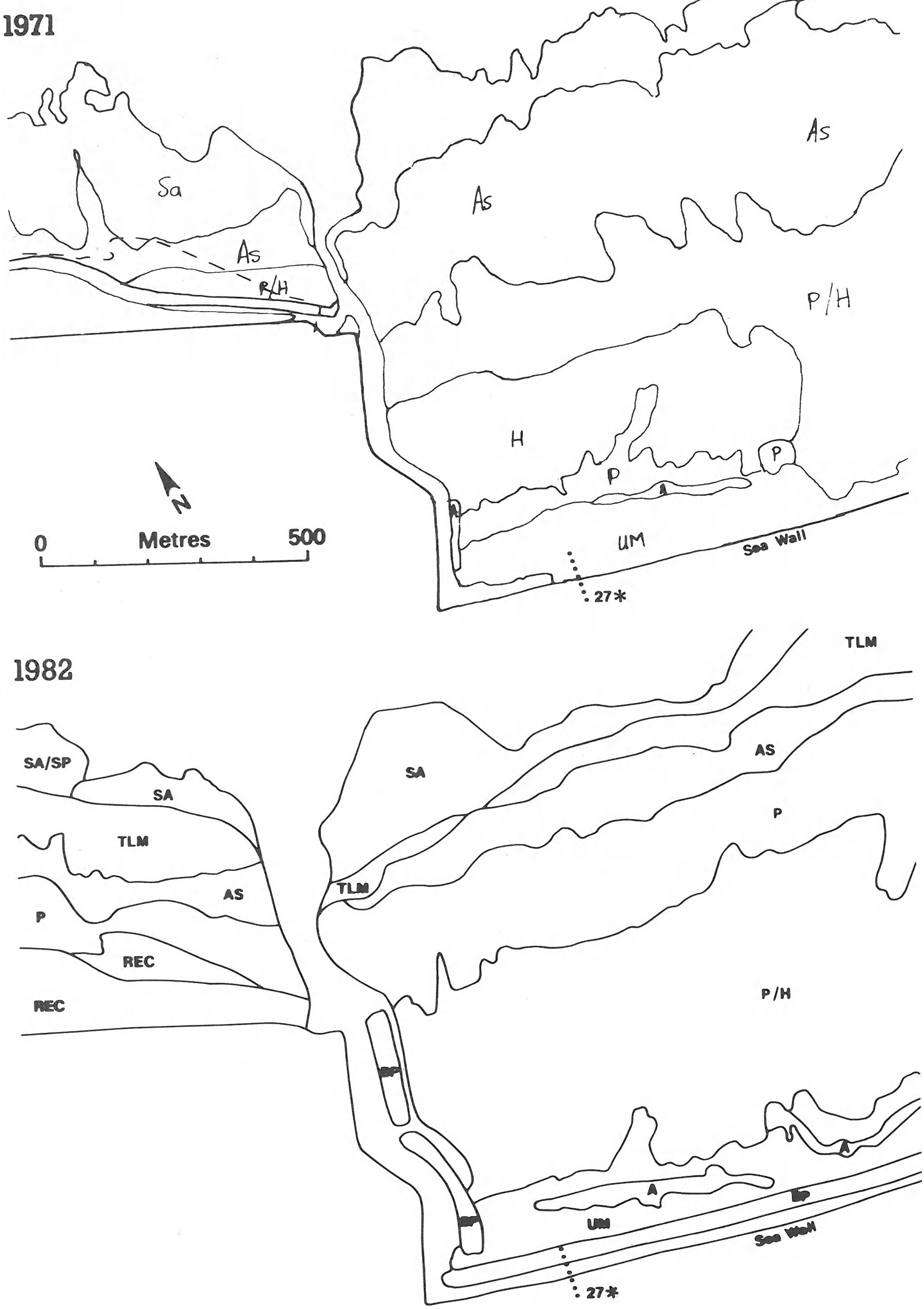
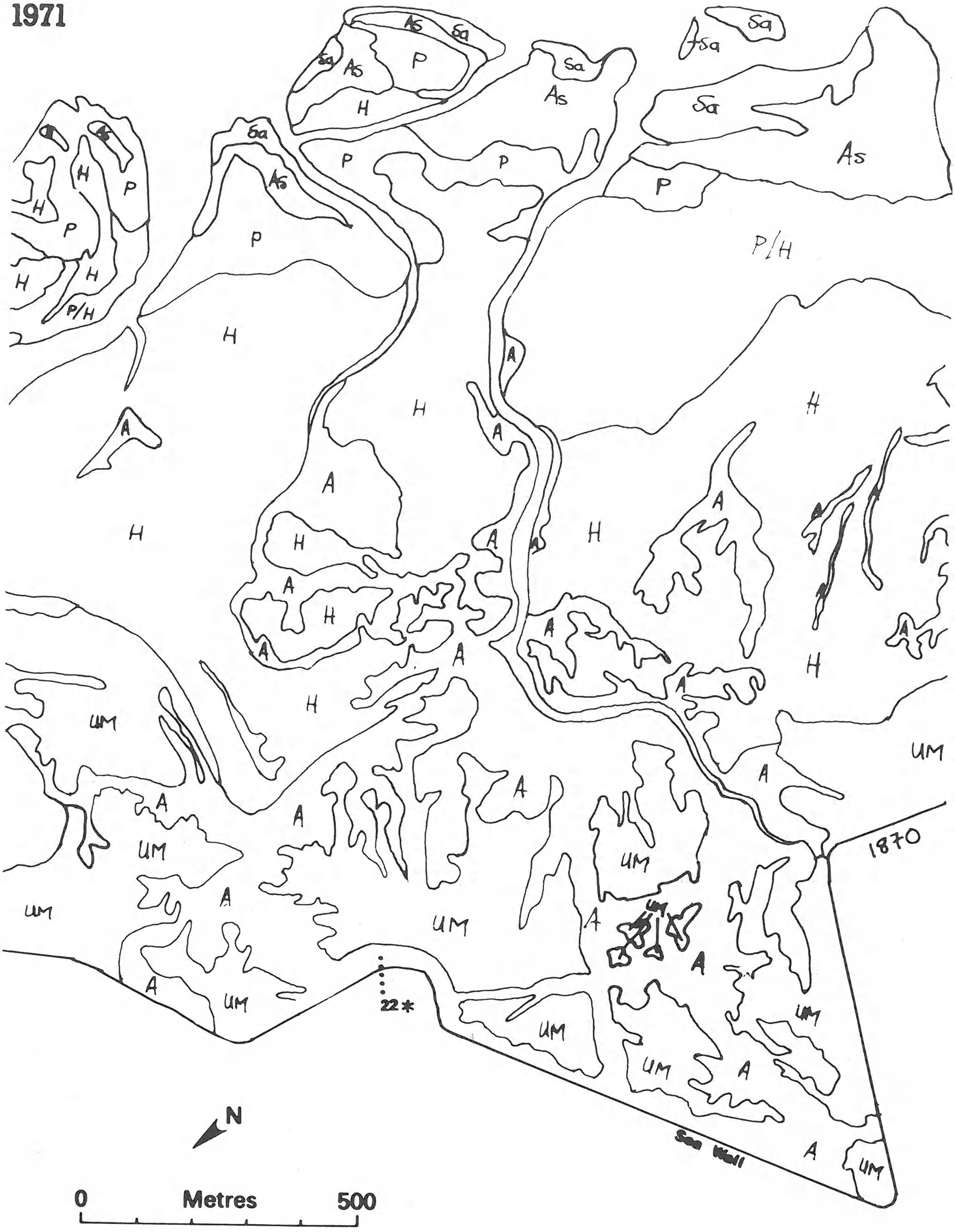


FIG 2·1 f FRAMPTON

1971



1982


SA/SP
SA/SP
SP
SA
SA
TLM
TLM
TLM
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TLM
H
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A
A
A
A
UM
P/S
22*
1870
Sea Wall

FIG 2·1 g HORSESHOE

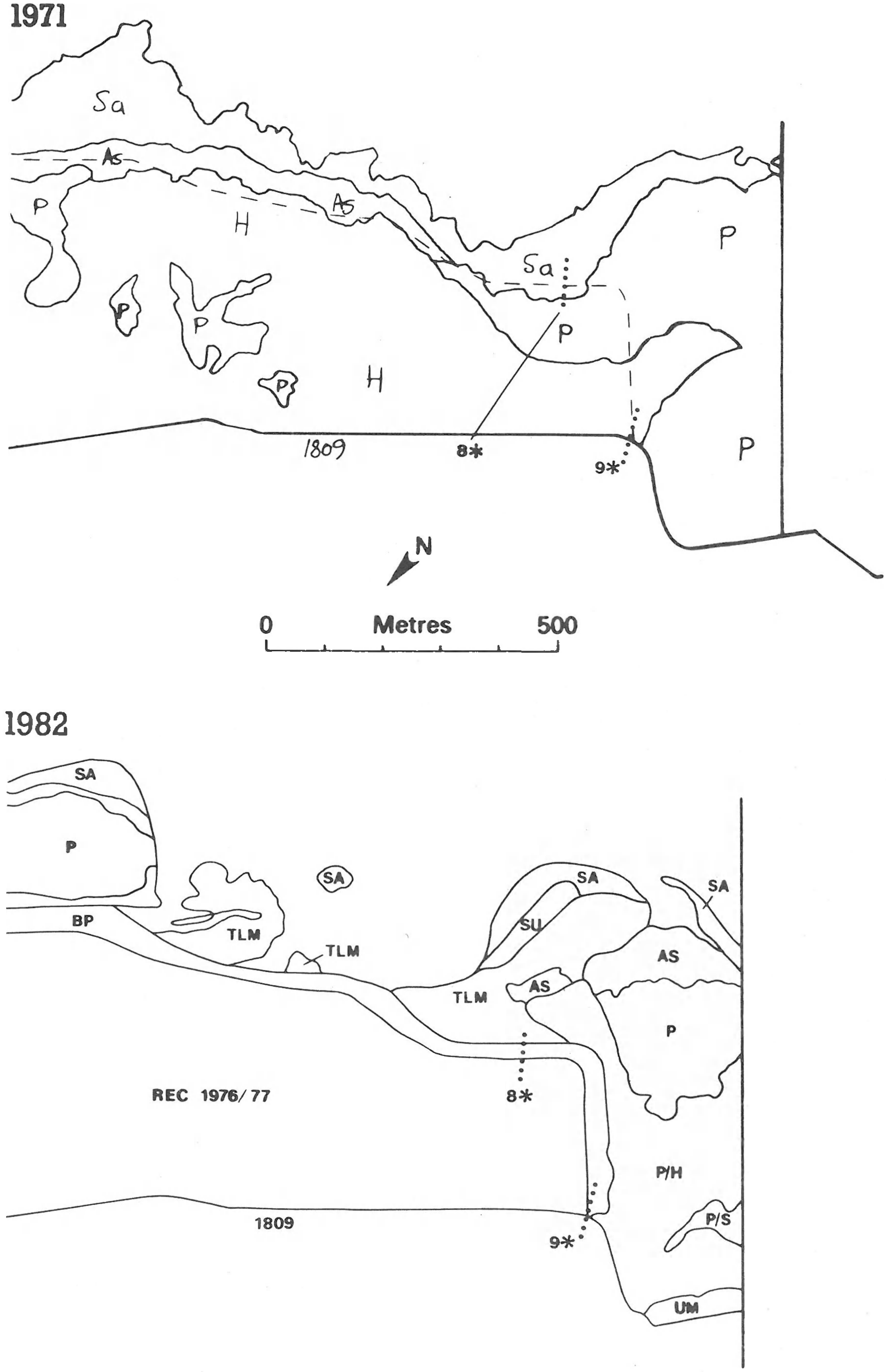
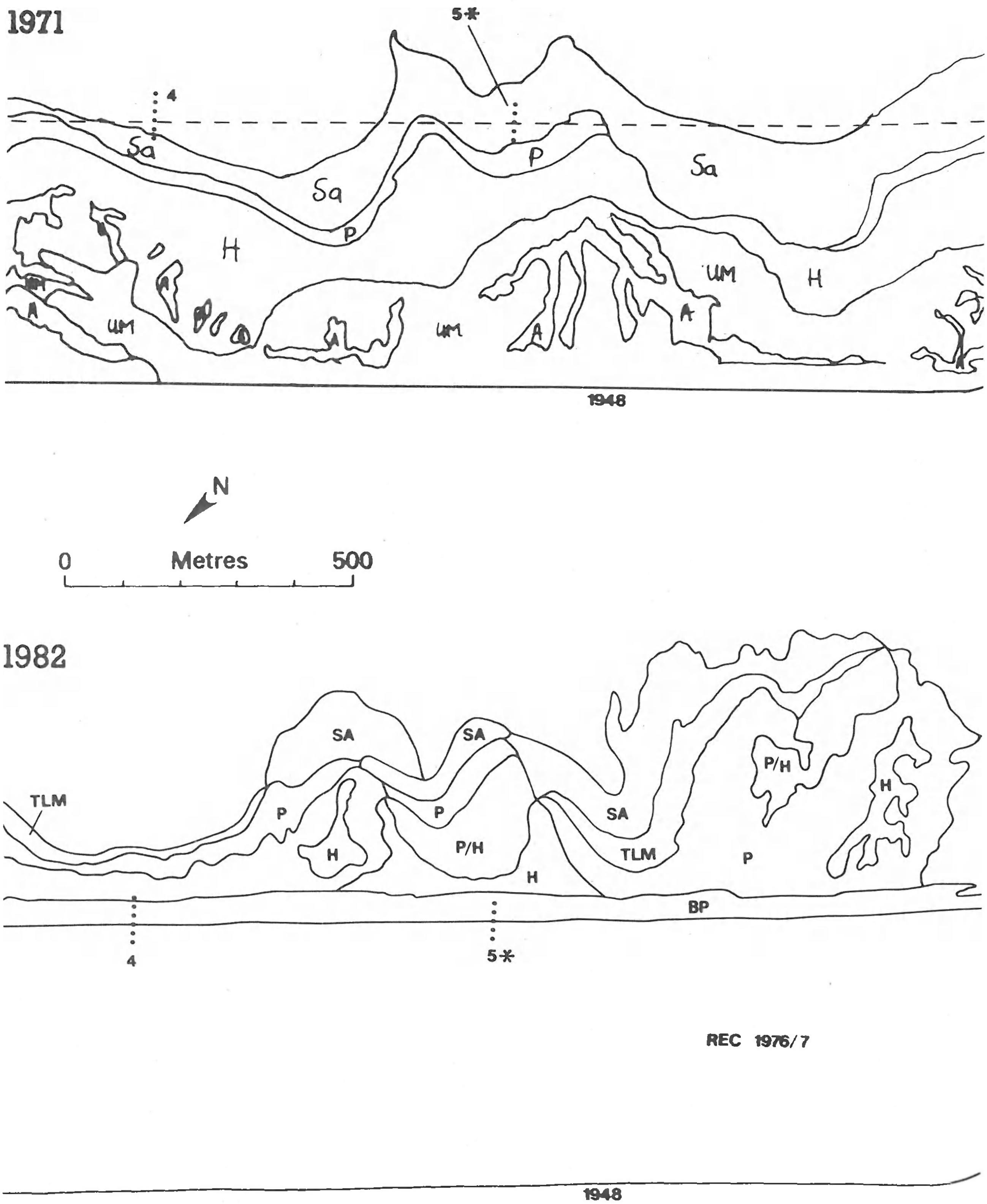


FIG 2·1 h WAINFLEET



The major trends observed were as follows.

2.3.1.1 Decline in Halimione portulacoides saltmarsh (spread of Puccinellia maritima saltmarsh)

In a survey of the west shore of the Wash by Newman & Walworth (1919), Halimione was the most extensive community and was codominant with Festuca rubra over large areas. In 1971/4, Halimione dominated 1,295 ha (31%) of the saltmarsh area, with a further 526 ha (12%) codominated by Puccinellia maritima and Halimione (Table 2.2). In contrast, in the present survey, only 118 ha (3%) was dominated by Halimione. This dramatic decline is partly a result of reclamation: 502 ha of Halimione saltmarsh have been enclosed since 1973 (Table 2.3b). However, the dominance and extent of Halimione have also declined in the remaining areas. Replacement has been largely by Puccinellia maritima, with the result that the area of both Puccinellia/Halimione and Puccinellia saltmarsh has increased since the previous survey. The former has shown a net increase of 525 ha to 1,051 ha (25% of total saltmarsh area) and the latter an increase of 756 ha to 1,244 ha (30%) (Table 2.2).

Vegetation maps of Wolferton, Gedney, Holbeach and Frampton marshes (Fig. 2.1a, d-f) show clearly the loss of Halimione.

This increase of Puccinellia maritima at the expense of Halimione is perhaps contrary to the generally expected pattern of successional change. There are a number of possible reasons. It may be due, for example, to the frost sensitivity of Halimione, as described by Beeftink (1977), and the severe winters of 1978/9, 1981/2 and 1984/5. Alternatively, the Halimione populations may undergo a natural cycle of ageing and regeneration. The influence of grazing is complex: in general Halimione would be expected to suffer under heavy grazing and to have increased in response to the decline in the use of outmarshes for grazing (see section 4.1). Since the opposite has occurred, alternative hypotheses are necessary: for example, with the withdrawal of grazing, Puccinellia may respond rapidly to produce a tall, dense sward which could overwhelm the Halimione bushes.

2.3.1.2 Decline in Puccinellia maritima upper marsh subcommunity

This is the most diverse vegetation community on the Wash saltmarshes. It includes fragments of Festuca rubra and Artemisia maritima communities (sections 2.2.9 and 2.2.10). It has decreased from 386 ha (9%) in 1971/4 to 257 ha (6%) in this survey (Table 2.2). The change is largely due to a loss of 89 ha in recent reclamations, as at Wainfleet marsh (Fig. 2.1h). Raising and rebuilding of the seabanks and digging the associated borrow pits are also a significant factor in the loss of this community.

Usually, the top 50 to 100 m of saltmarsh are affected, and this may comprise a large proportion of the remaining upper marsh vegetation. Diverse driftline communities, which may act as a seed source for invasion by upper marsh species, are also lost. This may be compensated for by the piles of dredge spoil, new cradge banks and causeways across the borrow pits, which are colonised by such species as Armeria maritima, Artemisia maritima and Suaeda fruticosa.

A diverse Puccinellia/Festuca upper marsh community would clearly become more widespread with a decrease in the rate of reclamation. Newman & Walworth (1919) recorded large areas of such communities at grazed and well-drained sites on the northern end of the west shore at a time when no reclamation had occurred for 70 years. A loss of Puccinellia maritima upper marsh subcommunity has also resulted from the spread of Agropyron pungens, particularly in the ungrazed section of Frampton marsh (Fig. 2.1f; section 2.3.1.4 below).

2.3.1.3 Decline in Aster tripolium saltmarsh

The area of Aster tripolium saltmarsh has declined since 1971/4 from 531 ha (13%) to 134 ha (3%) (Table 2.2). Aster is still abundant, occurring throughout the succession, but the cover in the zone to landward of the pioneer has declined, leaving a community with several codominants, i.e. transitional low marsh vegetation, SM10. This transitional community now occupies 287 ha (7%), as compared with 71 ha (2%) in 1971/4.

The reason for this increase in the area of transitional low marsh vegetation at the expense of Aster communities is not clear, especially since the distribution of the species is relatively unaffected. It is possible that either of the survey years was anomalous or that the definition of Aster communities was clearer on the 1971 photographs (see also section 4.2). The lower marsh Aster populations have a high proportion of perennial individuals (Gray, Parsell & Scott, 1979), but may show year-to-year variation in growth and flowering, as may the other species in the sward. In the present survey, the percentage cover of Aster in the zone above the pioneer zone was greatest on the south and east shores of the Wash, particularly at Gedney, Wingland, Ongar and North Wootton outmarshes (Table 2.3c). At North Wootton (Fig. 2.1b), a well-defined Aster zone, with plants up to 1.5 m tall when flowering, is found to landward of the Spartinetum, into which some invasion has occurred.

2.3.1.4 Increase in Agropyron pungens

The area of Agropyron pungens shows an overall increase from 361 ha (9%) in 1971/4 to 471 ha (11%) in this survey (Table 2.2). The loss of Agropyron in reclamations, as at Gedney Drove End

(Fig. 2.1d) and Wainfleet (Fig. 2.1h), is offset by its increase at some sites - notably the ungrazed parts of Frampton marsh (Fig. 2.1f). At Frampton, Agropyron has spread outwards from the creek banks, infilling islands of diverse Puccinellia sward. The lower limit of colonisation has also moved seawards. The Kirton/Frampton marsh is recognised as being of high conservation value (Lincolnshire County Council, 1982), but this status will be threatened in the ungrazed parts if Agropyron spread continues. The band of Agropyron at Wootton marsh (Fig. 2.1b) has also increased in area since 1971/4, but growth will be limited in future as the site is, in general, poorly-drained.

2.3.1.5 Decline in Spartina anglica and annual Salicornia saltmarsh

The area of pioneer communities (annual Salicornia, Spartina and Spartina/Salicornia) in 1982/5 was 386 ha (9% of the total saltmarsh area) - significantly less than the 585 ha (14%) found in 1971/4. This reflects an increasing maturity of the vegetation communities and successional change in the low to mid marsh zones. Clearly, some new pioneer communities have developed to seaward of recent reclamations (Fig. 2.1g, h), but this has not offset the overall trend towards the replacement of sparse pioneer communities.

As in 1971/4, most pioneer communities on the west shore were dominated by Salicornia, with Spartina communities found mainly on the finer sediments of the south-east corner, around the Ouse outfall (Table 2.3a, c). However, between the Welland and the Nene outfalls, the proportion of Spartina in the pioneer zone has increased significantly, although the total area of pioneer vegetation has decreased. This increase in Spartina has occurred mainly at Fosdyke Wash, where saltmarsh now extends out to the training wall on the east side of the Welland channel. This suggests that there may have been a change in the sediment composition of this area towards a smaller particle size.

2.3.1.6 Total saltmarsh area

A comparison of total saltmarsh areas (Tables 2.3a, c and 2.4) shows a net loss of saltmarsh on the sections of shoreline where the largest reclamations have occurred. A net loss of 184 ha was recorded on the west shore between Gibraltar Point and the Witham outfall and of 228 ha between the Nene and the Ouse. The development of new saltmarsh after reclamation has, however, been more extensive on the west shore - 343 ha compared with only 50 ha between the Nene and the Ouse. On the sections of shoreline where no reclamation has occurred since the previous survey, the area of saltmarsh has remained relatively stable, increasing by 44 ha on the east shore and by 18 ha at Kirton and Frampton marshes. Between the Welland and the Nene outfalls, the saltmarsh has increased by 269 ha, mainly in the Fosdyke area and on the eastern side of the Holbeach range.

Overall, the area of saltmarsh has declined by 83 ha, and 781 ha of mudflats have been colonised by saltmarsh vegetation since the previous survey.

2.3.2 Saltmarsh width measurements

The width of saltmarsh at any particular point is determined by the balance between accretion and erosion, a stable width being achieved when these opposing forces are in equilibrium at the marsh edge. This balance can be upset by man-made effects such as reclamation, construction of training walls, dredging and the disposal of dredge spoil. Other influencing factors, such as the supply of sediment and movement of channels, may change naturally or as a result of engineering works. The rate of movement of the saltmarsh edge in response to a change in the sedimentary regime will itself depend on other factors such as the slope of the intertidal zone.

The measurements of marsh width (Table 2.5) show considerable variation in stability of the edge. The highest rate of spread (460 m since 1971/4), giving an extensive Spartina pioneer community, was found near the Steeping River (point 1), where the last reclamation occurred in 1966. Rapid seaward spread was also found on the northern part of the west shore (points 2-8), where 110-295 m of mudflat have been colonised since 1971/4 in front of the Wainfleet and Friskney reclamations of 1973 and 1977. This gives a mean value of approximately 20 m per annum. These values are comparable to those of Inglis & Kestner (1958), i.e. peak values of 35-45 m per annum, falling to 8 m per annum in response to reclamation and outfall construction on the west shore.

On the south shore, response to the 1974 Wingland reclamation has been less than at Wainfleet/Friskney, the saltmarsh edge having moved 50-120 m seawards since 1971/4 (points 35, 36, 37). The pioneer zone is steeper and the particle size smaller here (Randerson, 1975) than on the West shore. Inglis & Kestner (1958), for the period 1917-1952, give values of 51 m per annum seaward spread immediately after reclamation at Wingland, 17 m per annum near the River Ouse, and 21 m per annum near the Nene. This indicates that a decrease in the rate of response to embankment has occurred in recent years. Colonisation in front of the 1974 reclamation at Terrington marsh (point 41) has been 85 m since the previous survey. Further spread will, however, be limited by the Lynn Channel nearby.

At Freiston shore, the edge of consolidated marsh has retreated by 165 m (point 16) and moved seawards by only 60 m at point 17, despite the Home Office reclamations of 1976-79 and 1979-80. This may result from problems in stabilising the bank, which was breached and then rebuilt to landward of its original position. Borrow pits have been dug to a greater distance (250 m) than usual from the seabank and vegetation cover is fragmentary. Problems with erosion of the new seabank were also met at point 7, at the southern end of the Wainfleet/Friskney reclamation.

Table 2.5 Width of saltmarsh at selected points, taken from 1971/4 & 1982/5 vegetation maps and 1977 & 1984 aerial photographs

Extension is calculated from the difference in marsh width between 1971/4 and 1982/5 vegetation maps, taking account of the width of any reclamations which took place between these dates. When two values are given for marsh width, the first gives the edge of consolidated marsh and the second (bracketed) gives the seaward edge of a sparse pioneer zone.

Point	Grid reference (*Transect sites)	Marsh widths (m) from Outer Bank 1971/4	1977	1984	1982/5	Last reclamation Date	Width (m) since 1973	Extension (m) 1971/4 to 1982/5
1	550578	350	420+	820	810	1966	-	+460
2	541573	440	80	260	240	1973	470	+270
3	534566	660	270	300	290	1973	480	+110
4	523555	380	30	160	135	1976/7	460	+215
5	518551*	500(800)	230	340	345(455)	1976/7	450	+295
6	509542	490	200	300	290	1976/7	430	+230
7	497528	210	0	160	155	1976/7	210	+155
8	473507*	350	100	320	335	1976/7	260	+245
9	470508*	500	580	560	600	1809	-	+100
10	458497	490	510	560	550	1962	-	+60
11	447486	420	450(800)	520(780)	530(775)	1809	-	+110
12	439476	680	740(940)	650(900)	655(935)	1809	-	-25
13	430459	260	250	280	265	1972	-	+5
14	425452	290	240(350)	320(430)	285	1972	-	-5
15	418445	250	270	360	310	1972	-	+60
16	406433	960	830	250	235	1979/80	560	-165
17	406423*	920	370	410	400(440)	1976	580	+60
18	399414	460	450	460	430	1952/65	-	-30
19	393399	500	480	470	480	1952	-	-20
20	369388(E)	2155	2040	2140	2170	1865	-	+15
21	369388(SE)	1690	1620	1690	1665	1865	-	-25
22	362379*	1770	1720	1820	1750	1870	-	-20
23	355365	1260	1240	1340	1325	1870	-	+65
24	351357	1010	980	1020	1000	1870	-	-10
25	372352	1350	1560	1580	1425	1949	-	+75
26	388354	450	550	620	620	1950	-	+170
27	412339*	1125	1100	1080	1120	1838	-	-5
28	423337	1080	1015	1010	1040	1838	-	-40
29	438329	1060	1000	1040	1040	1838	-	-20
30	453320	1450	1480	1600	1560	1840	-	+110
31	464303	1280	1330	1400	1370	1875	-	+90
32	477293	450	440	450	475	1875	-	+25
33	482283*	985	590	560	550	1978	330	-105
34	486275	625	640	680	710	1865	-	+85
35	501267*	660	250	400	440	1974	270	+50
36	504266	675	260(350)	320	370	1974	425	+120
37	513263	770	380	380	390	1974	490	+110
38	528260	650	290(340)	360	395	1974	380	+125
39	546264*	380	310(440)	480	500	1955	-	+120
40	567262	400	-	420	450	1955	-	+50
41	584253*	780	-	340	335	1974	530	+85
42	601256	270	-	290	290	1967	-	+20
43	611268*	665	-	720(800)	700(780)	1960/6	-	+35
44	617279	410	-	540	510	1966	-	+100
45	632289	510	-	680	640	1966	-	+130
46	643297*	775	-	800	800	1966	-	+25

Here, a short section of bank was originally sited beyond the limit of consolidated marsh, but was later rebuilt, following the marsh edge.

Inglis & Kestner (1958) showed that, in the absence of reclamation or large-scale engineering works, the saltmarsh edge is relatively stationary. This is confirmed by the current survey for marshes where no embankment has taken place since the 19th century, such as Leverton (point 12), Holbeach Range (points 27, 28, 29), Kirton/Frampton (points 20, 21, 22, 24) and Gedney/Lutton (point 32). However, some sites in older marshes showed less stability: extension of about 100 m has occurred at points 30 and 31 on the east side of the Holbeach range and at the Horseshoe south transect (point 9). This may result from local movements of creeks beyond the marsh edge.

The current rate of colonisation in front of reclamations of intermediate age is also variable. Saltmarsh width to the north end of the 1972 Leverton reclamation (points 13, 14) has stayed relatively constant since 1971/4. Clearly some extension would have been expected. The pioneer zone in this area is narrow and shows a hummock/hollow topography characteristic of a balance between erosion and deposition (Coles & Curry, 1976). However, at the south end of this reclamation (point 15) an extension of 60 m was found. Rapid saltmarsh formation is also evident near the Trial Bank transect (point 39) - owing to the protection afforded by the trial bank and the causeway leading out to it. On Wootton and Wolferton marshes (points 42-46), a seaward spread of 20-130 m has occurred since 1971/4. This may be a continued response to the 1960s reclamations or the result of an increased supply of sediment from the dredging of the Lynn channel. 100,000 to 200,000 tonnes of dredged spoil are deposited per annum three miles seaward of the Ouse mouth.

In summary, generalisations on the rate of saltmarsh formation are not possible for the whole of the Wash owing to the overriding influence of local factors. The MAFF (1983) estimates (section 1.3; based on the evidence of Kestner) of 250-450 m spread in the first six years after reclamation (42-75 m per annum) and 460-830 m in the first 18 years after reclamation (26-46 m per annum) are only achieved in the most favourable circumstances. At some sites, for example in front of the 1972 Leverton and 1974 Wingland reclamations, significantly lower rates were observed. Proximity to the main river channels must also prevent further spread in some areas.

3 Vegetation monitoring - intensive survey

3.1 Methods

The 12 transect sites (Fig. 1) were chosen in 1973 as representing the range of saltmarsh vegetation in the Wash, including variation due to marsh age, location, sediment size and grazing. Transects were marked by a line of posts at 100 m intervals, running perpendicular to the seabank. In the present survey, the vegetation monitoring involved two distinct approaches:

i) systematic sampling at regular intervals along the transect - "transect points" (which were not recorded in 1973);

ii) re-recording the study sites located in 1973 - "study sites".

Methods followed the NVC field manual (Rodwell, 1980) where appropriate.

3.1.1 Transect points

Samples were located close to each 100 m post in areas of homogeneous vegetation. Homogeneity in this sense is taken to mean that the quadrat is not placed across visually obvious vegetation boundaries. Frequency and cover (Domin scale 1-10: Table 3.1) were recorded for all plant species in 10 (usually 2 x 2 m) quadrats during August and September 1985. Where transect posts lay close to a boundary between vegetation types or within an obvious mosaic, records were taken in both stands. Detailed vegetation records were not taken at the Freiston transect as the continued digging of borrow pits made access impossible.

3.1.2 Study sites (A, B, C...)

These 10 x 10 m sites were chosen in 1973 to sample the vegetation zonation along transects, there being between three and six sites per transect. At five transects, Ongar, Nene, Freiston, Horseshoe North and Wainfleet, almost all the marsh present in 1973 has been reclaimed and the sites could not be located. Sites Gedney A and Horseshoe South A have also been lost in reclamations. All the remaining sites, except Frampton F, were found, i.e. 29 out of the 51 set up in 1973.

Each 10 x 10 m site was divided into 25 2 x 2 m quadrats. Domin cover estimates were made in 10 quadrats chosen according to a predetermined scheme. Frequency was calculated over all 25 quadrats. To provide a direct comparision with the 1973 survey, cover for each species for the whole site was recorded using the Braun-Blanquet scale (Table 3.1). It should be noted that the study sites - because of the succession within them - do not necessarily still provide a representative sample of vegetation types along a transect, nor do they necessarily lie in homogeneous stands.

Table 3.1 Key to vegetation classification

a) Braun-Blanquet range

Cover (%)	Value	TWINSPAN pseudospecies
<5	0.3	1
5-20	1	2
21-40	2	3
41-60	3	4
61-80	4	5
>80	5	6

c) Frequency (constancy) value

Frequency (%)	Value	Pseudospecies
1-20	I	1
21-40	II	2
41-60	III	3
61-80	IV	4
81-100	V	5

b) Domin range

Cover (%)	Value	TWINSPAN pseudospecies
(Rare	1	)
<4 (Occasional	2	) 1
(Frequent	3	)
4-10	4	)
11-25	5	) 2
26-33	6	3
34-50	7	4
51-75	8	5
76-90	9	)
91-100	10	) 6

d) Site codes

1)	Wolferton	Wolf
2)	Wootton	Woot
3)	Ongar	Onga
4)	Trial Bank	Tri
5)	Nene	Nene
6)	Gedney	Ged
7)	Holbeach	Holb
8)	Frampton	Fram
10)	Horseshoe South	HSS
11)	Horseshore North	HSN
12)	Wainfleet	Wain

3.2 Analysis

The vegetation at each transect point and study site was assigned to an NVC community with the use of the saltmarsh key and examples of records in the NVC manual. Community descriptions are given in section 2.2. The complete set of floristic data, presented as frequency (constancy) values and Domin ranges, is given in the Appendices 1-7. These data were analysed with the use of the computer programs TWINSPAN and DECORANA (Hill, 1979a, b). Notes on their use in relation to the NVC scheme are given by Malloch (1985).

TWINSPAN (Two Way INdicator SPecies ANalysis) constructs a classification of the sample quadrats and derives a classification of species from this according to their ecological preferences. The classification is obtained by successive divisions of quadrats arranged along ordination axes. To make use of cover and frequency data (instead of just presence/absence), each species is divided into a number of "pseudospecies" which represent part of the range of quantitative variation. The divisions, or cut levels, used to delimit the pseudospecies are given in Table 3.1. Alternative cut levels were used in the analysis, then changed to improve differentiation at higher cover levels. The classification of sample quadrats and study sites using cover or frequency data can be compared with NVC communities and used to describe the range of vegetation types.

Classification tables are presented on pp. 50-52 for:

Study sites 1973 and 1985	Braun-Blanquet cover data	Fig. 3.1.
Study site quadrats 1985	Domin cover data	Fig. 3.2.
Transect point quadrats 1985	Domin cover data	Fig. 3.3.

DECORANA (DEtrended CORrespondence ANAlysis) is an ordination program derived from reciprocal averaging, but where correlations between the first and higher axes have been removed. Thus, ordination diagrams can be produced to show the relative similarities of species and sites with respect to constructed axes which represent floristic variation.

Ordination diagrams are presented on pp. 53-55 for:

Transect point quadrats 1985	Domin cover data	Fig. 3.4.
Study sites 1973	Braun-Blanquet cover data	Fig. 3.5.
Study sites 1985	Braun-Blanquet cover data	Fig. 3.6.

3.3 Results

3.3.1 General discussion

Of the 29 study sites recorded in both 1973 and 1985, only nine came out in the same group of the TWINSPAN analysis for both dates (Fig. 3.1); i.e. at these sites the vegetation had not changed significantly. The changes in vegetation communities at study sites (Table 3.2) confirmed those found through mapping (section 2.3.1). By 1985, of the 10 study sites which had more than 80% Halimione cover in 1973, five had been lost in reclamations, two had remained as dense Halimione, and three had Puccinellia as the most abundant species. Halimione had become Puccinellia/Halimione at Holbeach B and Frampton D and a low-diversity Puccinellia sward at

Wolferton A. Atriplex hastata had increased significantly in abundance since 1971/4. The TWINSPAN classification separates the 1985 Puccinellia/Atriplex communities of Wolferton and North Wootton marshes (see section 2.2.6.1) from other Puccinellia communities. Atriplex hastata is known to show considerable year-to-year variation and hence no conclusions can be drawn on long-term trends without records for intervening dates. Aster-dominated study sites of 1973 showed a decrease in the cover of Aster, as was found by mapping. For example, Aster/Suaeda was replaced by Puccinellia/Salicornia at Trial Bank D and Aster/Puccinellia/Salicornia by Salicornia/Suaeda/Puccinellia at Holbeach D. However, Aster became more abundant at Wootton E, invading the Spartina pioneer zone, and at Horseshoe South C. These last sites, therefore, follow the expected pattern of successional change. An increase in the area and dominance of Agropyron pungens was confirmed to have occurred along the Frampton transect. The species maintained a greater than 80% cover at site B and increased in abundance at sites A, C and D. This spread was at the expense of a diverse Puccinellia sward in the upper marsh and of a Puccinellia/Halimione community at lower levels. Some other changes in vegetation communities between the two surveys were part of overall successional development and a decrease in the abundance of low marsh species. This is seen, for example, at Holbeach C and E, Wolferton B, Trial Bank C and Gedney C.

The classification of sites compares well with the NVC communities (Figs 3.1-3.3). The most frequent vegetation types are Puccinellia (SM13) (340 out of 674 transect points and 161 out of 290 study site quadrats) and Puccinellia/Halimione (SM14 Puccinellia-dominated subcommunity) (84 transect points and 30 study site quadrats). The first level of division is between Agropyron (SM24) and non-Agropyron communities, the species diversity of the former being very low and the majority of quadrats being pure stands. The secondary division is generally between communities of lower and upper marsh levels, Halimione being characteristic of the latter. In subsequent divisions, the classification separates the Spartina-dominated pioneer communities (SM6) of the south-east corner of the Wash from the Salicornia-dominated pioneer vegetation (SM8) of the remaining sites. The classification of data from whole 10 x 10 m study sites in 1973 and 1985 (Fig. 3.1) and their component quadrats in 1985 (Fig. 3.2) separates the high-diversity Puccinellia swards (SM 13 upper marsh subcommunity) at Frampton and Holbeach from other Puccinellia communities. However, in the classifications of 1985 data from transect point quadrats this division does not occur (Fig. 3.3).

The distribution of sites on the first two axes of ordination (Figs 3.4-3.6) show similar groupings to the above - two separate pioneer communities, a homogeneous low to middle marsh and greater diversity in the upper marsh. The first axis is strongly related to the maturity (height above Ordnance Datum) of the site.

3.3.2 Details of changes in the vegetation along transects

The changes in study sites are summarised in Table 3.2, in which all species with a cover of more than 20% are included. For detailed vegetation records see Appendix.

Table 3.2 Changes in study site vegetation between 1973 and 1985

Within each community the species with cover values of >20% are listed in order of decreasing abundance. Emboldened species are dominant or codominant.

Transect/ Study site	Distance from seabank (m)	Vegetation in 1973	Vegetation in 1985
Wolferton			
A	90	**Halimione**/Puccinellia	**Puccinellia**
B	450	**Puccinellia**/**Suaeda**	**Puccinellia**
C	690	**Puccinellia**/**Aster**/Salicornia	**Puccinellia**/Aster
D	750	**Spartina**/**Salicornia**/Puccinellia	**Spartina**/Suaeda/Puccinellia
Wootton			
A	80	**Puccinellia**	**Puccinellia**
B	260	**Puccinellia**	**Puccinellia**
C	560	**Puccinellia**/**Suaeda**	**Puccinellia**/Atriplex hastata
D	610	**Puccinellia**/Aster	**Puccinellia**/Atriplex hastata
E	630	**Spartina**/**Aster**/Salicornia	**Aster**/Spartina/Puccinellia
Trial Bank			
A	90	**Puccinellia**/Halimione	**Puccinellia**
B	215	**Halimione**/Puccinellia/Suaeda	**Halimione**/Puccinellia
C	285	**Puccinellia**/Suaeda/Halimione	**Halimione**/Puccinellia
D	350	**Aster**/Salicornia	**Puccinellia**/Salicornia
Gedney			
B	215	**Halimione**/Puccinellia/Suaeda	**Halimione**/**Puccinellia**
C	360	**Puccinellia**/**Suaeda**	**Puccinellia**/Halimione
D	570	**Aster**/Suaeda	**Aster**/Salicornia

Table 3.2 (continued)

Transect/ Study site	Distance from seabank (m)	Vegetation in 1973	Vegetation in 1985
Holbeach			
A	100	**Halimione/Puccinellia**/Artemisia (mosaic)	**Puccinellia/Halimione**/Artemisia (mosaic)
B	350	**Halimione**	**Puccinellia**/Halimione
C	650	**Suaeda**/Puccinellia	**Puccinellia**/Suaeda
D	920	**Aster**/Puccinellia/Salicornia	**Salicornia/Suaeda**/Puccinellia
E	1020	**Salicornia**	**Salicornia**/Suaeda
Frampton			
A	120	**Puccinellia**/Halimione/Festuca (mosaic)	**Puccinellia**/Agropyron/Festuca (mosaic)
B	380	**Agropyron**	**Agropyron**
C	480	**Puccinellia/Halimione**	**Puccinellia/Agropyron**/Halimione
D	1180	**Halimione**	**Puccinellia**/Halimione
E	1600	**Puccinellia/Salicornia/Aster**	**Puccinellia/Salicornia/Aster**
Horseshoe South			
B	360	**Suaeda**/Aster/Puccinellia	**Puccinellia**/Salicornia
C	480	**Salicornia**/Suaeda	**Puccinellia/Aster**
D	100	**Puccinellia**/Salicornia	***Puccinellia**/Spergularia/ Salicornia

* includes Puccinellia distans.

3.3.2.1 Wolferton

Most of the saltmarsh is covered by a lush carpet of Puccinellia, except for a band of Halimione and Agropyron at approximately 70 m, presumably the site of the old cradge bank. Site A (90 m) has changed from a community of Puccinellia and Halimione codominants to a Puccinellia sward with less than 20% Halimione cover. Atriplex hastata, not present in 1973, is now a constant species. Site B (450 m) was a Puccinellia/Suaeda community in 1973, since when the cover of Suaeda has declined to leave a low-diversity sward with occasional Halimione and Aster. Site C (690 m) has remained a Puccinellia-dominated community but with decreased cover of Aster, loss of Salicornia and invasion by Atriplex and Halimione. Seaward of this is a mixed community approaching Asteretum in parts. At site D (750 m) there has been successional development from a pioneer community of Spartina and Salicornia to a transitional low marsh with Spartina as the most abundant species. The pioneer zone is narrow, mainly Spartina, invaded by Aster in some places. The marsh edge is bounded by a creek, beyond which there are a few outlying Spartina clumps, and has remained stable in recent years.

3.3.2.2 Wootton

The vegetation along the transect is unusually homogeneous - a dense Puccinellia sward throughout to 625 m from the seawall, except for a band of Agropyron at 100-250 m. Sites A (80 m), B (260 m) and C (560 m) have all remained as Puccinellia-dominated communities since 1973, but have shown changes in associated species. There has been a marked increase in the frequency and cover of Atriplex hastata and complete loss of Spartina, Suaeda (A, B, C) and Halimione (B, C). The decline in Halimione is particularly striking. At site D (610 m), a similar trend has occurred - the vegetation remaining a Puccinellia/Aster community, but with an increased abundance of Atriplex hastata and decrease in Spartina, Suaeda and Salicornia. The band of Asteretum now at 625-680 m has moved seawards since 1973, invading the Spartinetum. At site E (630 m), Aster was the most abundant species at both surveys, but the cover of Salicornia has decreased and that of Puccinellia increased. The pioneer zone from 700 m is extensive and colonised by Spartina. The transition from Puccinellia sward to pioneer zone occurs over a short distance with a steep profile, but the pioneer zone itself is wide and gently sloping.

3.3.2.3 Ongar

The 1974 reclamation enclosed 550 m of the original transect. The upper 240 m are now a Puccinellia sward with abundant Aster. A Halimione/Puccinellia community (as had been at Site B in 1973) is now absent - Halimione occurring only on the few small creek banks. Vegetation from 240-280 m is of a transitional nature, with Aster, Puccinellia, Salicornia and

Spartina as codominants. The narrow pioneer zone is mainly Spartinetum in a substrate of very soft mud. The upper 100 m of saltmarsh were lost in 1986 in the digging of new borrow pits.

3.3.2.4 Trial Bank

The sedimentary regime in this area has been affected by the construction of the inshore trial bank in the 1970s. This has encouraged rapid saltmarsh spread and successional change in the lower marsh. The top 80 m of saltmarsh were lost in 1984/5 in bank rebuilding work. Site A (90 m) has remained as a Puccinellia sward, but the abundance of Halimione has decreased; Spartina and Salicornia are now absent. Site B (215 m) has also remained relatively unchanged as dense Halimionetum with an understorey of Puccinellia (SM14 Halimione-dominated subcommunity). Site C (285 m) was a Puccinellia/Suaeda community in 1973; both these species have declined and have been replaced by Halimione to give more than 60% cover of this species. Vegetation at site D (340 m) has changed from an Aster/Salicornia community in 1973 to Puccinellia/Salicornia in 1985. The frequency of Halimione has also significantly increased at this site. The pioneer zone is extensive, dominated by Salicornia with patches of Spartina.

3.3.2.5 Nene

The 1974 reclamation enclosed 300 m of the original transect. The top 200 m are now an open Puccinellia community with a large Aster component. Below this is a band of Asteretum to about 380 m from the seabank. The pioneer zone (380-460 m) is a mosaic of Salicornia, Spartina and Aster with hummock/hollow topography. The Halimione/Aster community (site A in 1973) is now absent.

3.3.2.6 Gedney

The top 300 m of the original transect were lost in the small 1978 reclamation, leaving no extensive upper marsh or Agropyron community. Below this, the marsh is dominated by a Puccinellia/Halimione mosaic. At site B, Halimione has declined from more than 80% to less than 60% cover. At site C, the vegetation was dominated by Puccinellia at both surveys, but the cover of Suaeda has declined and that of Halimione increased. Site D has continued to be a transitional low marsh community since 1973, but the cover of Aster has decreased from more than 80% to less than 60%. The pioneer zone is narrow with hummock/hollow topography. In some places, Aster is the lowest colonist and 'relict' Aster clumps are found beyond the marsh edge, which has retreated in recent years (Table 2.5).

3.3.2.7 Holbeach

Site A (90 m) has not changed significantly since 1973, remaining a mixed community of Puccinellia, Artemisia and Halimione with other upper marsh species such as Limonium, Festuca, Plantago and Triglochin. The cover of Agropyron and Festuca has, however, increased and that of Halimione decreased. This and the invasion of species such as Atriplex littoralis and Cochlearia may result from the proximity of a new cradge bank and the collection of drift material at the site. From 150 to 450 m, the vegetation is composed of patches of Puccinellia and Halimione, suggesting a recent decline in Halimione. Site B (350 m) has changed from almost 100% Halimione cover in 1973 to less than 40% in 1985. From 500 to 700 m the vegetation is mainly Puccinellia with varying amounts of Halimione, Suaeda and Aster. Site C (650 m) was a Puccinellia/Suaeda community at both surveys. The area from 900 to 1,100 m is heavily goose-grazed in the winter; this will tend to prevent Puccinellia from forming a closed sward and leave space for invasion by annuals. Site D (920 m) has remained as a transitional low marsh community, but since 1973 the cover of Aster has declined and that of Salicornia and Suaeda has increased. At site E (1,020 m), successional change has occurred, the Salicornietum having an increased component of Suaeda and Puccinellia by 1985.

3.3.2.8 Frampton

The transect crosses the ungrazed section of the marsh. In both 1973 and 1985, site A (120 m) comprised a diverse Puccinellia sward with Limonium, Festuca, Triglochin and Plantago. Since 1973, some invasion by Agropyron has taken place to give 20-40% cover by 1985. Site B (380 m) consisted of complete Agropyron cover in both surveys. Site C (480 m) was Puccinellia/Halimione in 1973, since when it has been invaded by Agropyron (now more than 40% cover). Annual species such as Salicornia and Suaeda have also been lost from this site. At site D (1,180 m), Halimione has declined from more than 80% to less than 40% cover, being replaced mainly by Puccinellia. At 1,200-1,400 m the vegetation is mostly a Puccinellia lawn of low species diversity. At 1,500 m Halimione becomes codominant with Puccinellia and, below this, grades into a pioneer zone of Salicornia and Spartina. Site E was a Puccinellia/Salicornia/Aster community in both surveys, with an increased frequency of Halimione in 1985.

3.3.2.9 Freiston

The transect site is still subject to considerable disturbance and the excavation of borrow pits to a distance of 250 m from the seabank. Vegetation cover on the remaining area is fragmentary, with more than 50% bare ground throughout. Beyond a large creek at 300 m there is wide but sparse Salicornia pioneer zone.

3.3.2.10 Horseshoe South

Saltmarsh fronting the 1809 bank to the south of the transect line is heavily grazed and poached. Hummocks bear a mixed community of Festuca rubra, Glaux, Artemisia, Plantago, Spergularia, Agropyron and Puccinellia. Site D (which exemplifies the remaining grazed upper marsh area) is a short turf of Puccinellia maritima, Puccinellia distans, Spergularia marina and Salicornia. It has changed little since 1973, with a small increase in the cover of Spergularia and Suaeda. Site B (grazed) at 360 m has changed from a Suaeda/Aster/Puccinellia to a Puccinellia/Salicornia community. Site C (480 m) has shown successional development from Salicornia/Suaeda to Puccinellia/Aster.

3.3.2.11 Horseshoe North

The 1976 reclamation enclosed all the existing consolidated marsh at this point. The vegetation is now an open sward containing a high proportion of annuals. It grades from a Puccinellia community at 100 m to Salicornia at 300 m, with dense Suaeda populations on the creek banks. The driftline community is particularly diverse at this site.

3.3.2.12 Wainfleet

After the 450 m-wide 1976 reclamation, 50 m of saltmarsh remained beyond the new seabank. The top 150 m of marsh are now dominated by Halimione, as in 1973. Below this, the vegetation is Puccinellia-dominated and then grades into an extensive Salicornia pioneer community. The zonation follows a zigzag pattern, Halimione reaching its maximum extent in the creek embayments and Puccinellia filling the between-creek areas.

3.4 Problems in using the National Vegetation Classification for saltmarsh

Saltmarshes, in general, do not show clear boundaries between vegetation types. This is particularly so on the Wash, where species such as Puccinellia maritima and Aster tripolium occur throughout the succession and species diversity is low. Hence, arbitrary decisions have to be made and communities defined by slight changes in relative abundance. The NVC (Rodwell, 1983) is useful in defining these boundaries but can group together a variety of communities (as in Puccinellia maritima saltmarsh, Puccinellia-dominated subcommunity). It was found more convenient to use a division into low-diversity (Puccinellia subcommunity) and higher-diversity swards (upper marsh subcommunity) as in Adam (1981).

Similar problems arise, therefore, in the classification of sites with the use of the TWINSPAN program: a large number of samples and a small number of species do not make an ideal data-set. In some cases groups were split in ways which do not relate simply to field communities. However, in general, a good match is found between NVC and TWINSPAN-generated communities, especially for the cover data at transect points (Fig. 3.3). Frequency data are less helpful, as most records are for frequencies below 20% or above 80%. The cover data for study site quadrats produce a less clear-cut classification (Fig. 3.2) than the transect points because the records are not necessarily for homogeneous stands. This is an inherent problem in using the NVC for the re-recording of permanent quadrats even when these were chosen originally as samples of homogeneous stands.

Fig. 3·1 Hierarchical classification of study sites. Produced by TWINSPAN, using floristic cover (Braun-Blanquet Scale) data from 29 10x10m sites recorded in both 1973 & 1985

FOR SITE CODES, PSEUDOSPECIES CUT LEVELS AND COVER VALUES SEE TABLE 3·1
FOR NVC COMMUNITIES SEE TABLE 2·1

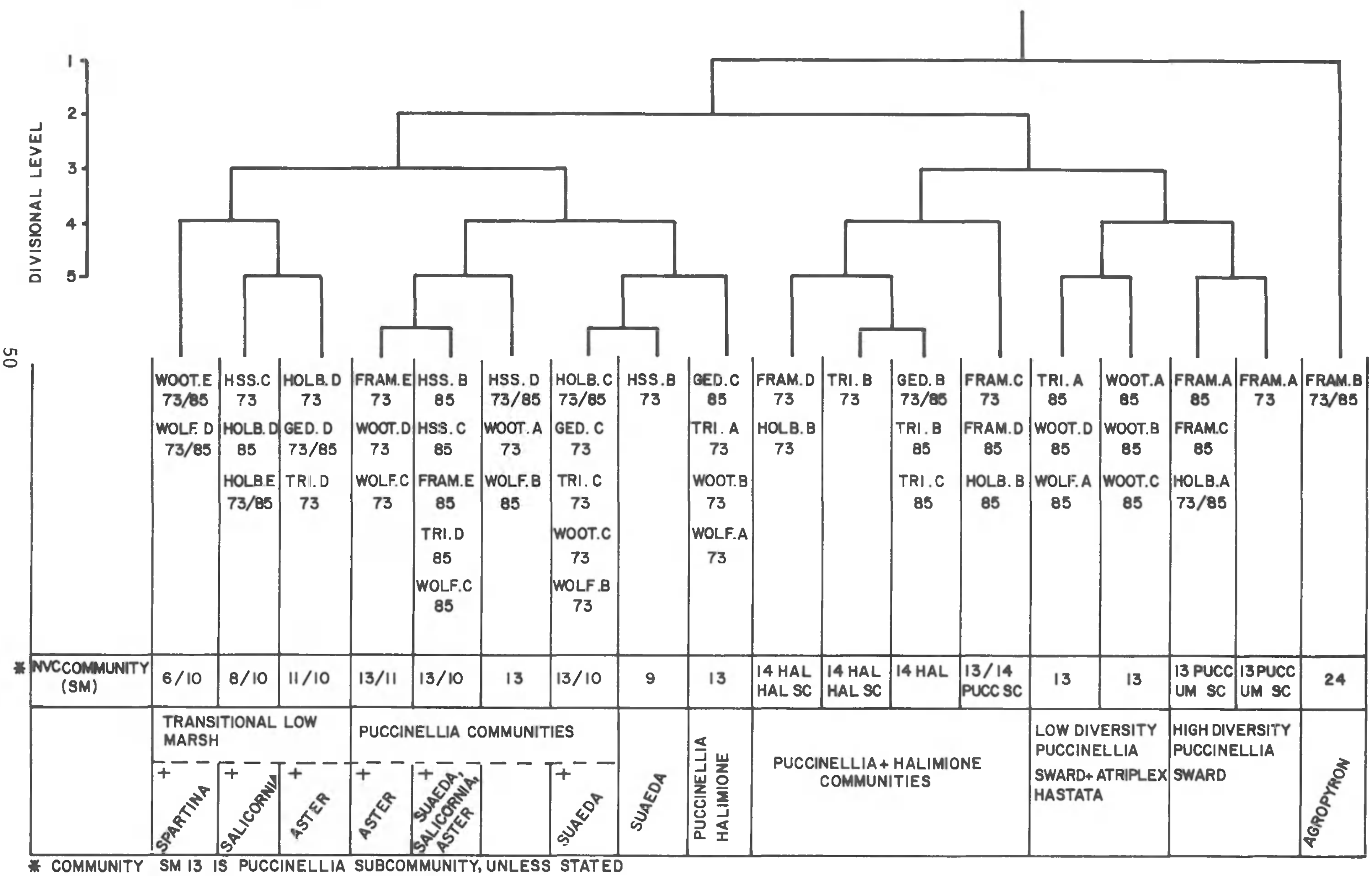
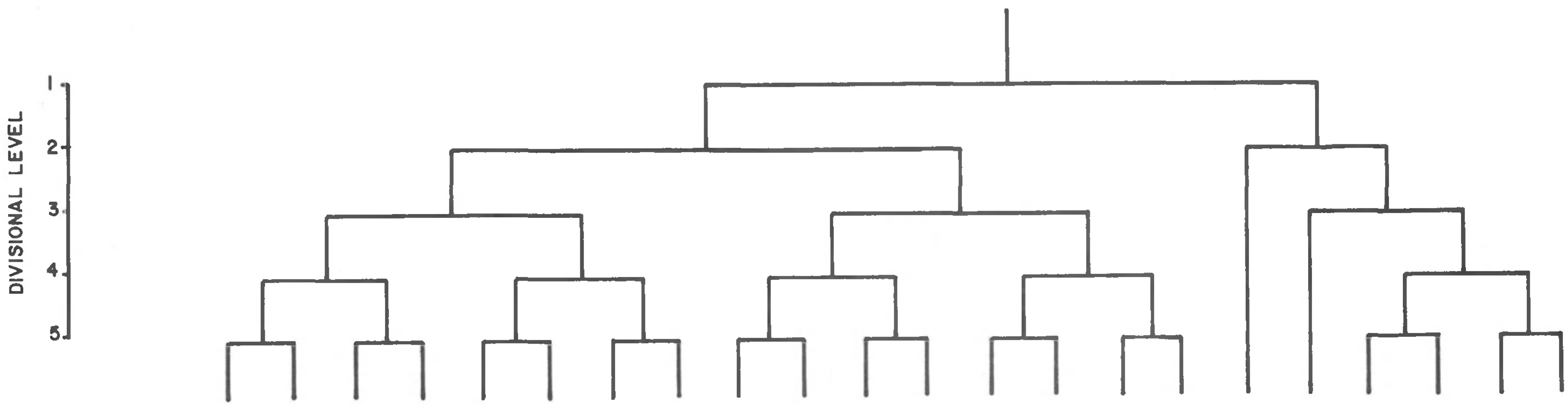


Fig 3·2 Hierarchical classification of study site quadrats. Produced by TWINSPAN, using floristic cover (Domin Scale) data from 290 quadrats (29 sites) recorded in August / September 1985

FOR PSEUDOSPECIES CUT LEVELS AND COVER VALUES SEE TABLE 3·1
FOR NVC COMMUNITIES SEE TABLE 2·1



* NVC COMMUNITY (SM)	6/10	6/10	6/11	6/11	8	8/10	13/11	13	14 HAL HAL SC	14 HAL PUCCSC	14 HAL PUCCSC	14 HAL PUCCSC	13 PUCC UM SC	13	13	13	24/13	24/17	24	24	24	24
DESCRIPTION	SPARTINA COMMUNITIES				SALICORNIA COMMUNITIES		PUCCINELLIA COMMUNITIES			PUCCINELLIA HALIMIONE COMMUNITIES			PUCCINELLIA COMMUNITIES				AGROPYRON COMMUNITIES					
	SPARTINA >35 % COVER +SUAEDA, SALICORNIA		+ ASTER		+PUCCINELLIA	+ ASTER	+ ASTER	+SALICORNIA, SUAEDA	HALIMIONE > 75 % COVER	HALIMIONE >50 % COVER	+ARTEMISIA	PUCCINELLIA > 34 % COVER	HIGH DIVERSITY SWARD	PUCCINELLIA >50 % COVER	PUCCINELLIA >75 % COVER LOW DIVERSITY	+ ATRIPLEX HASTATA	+FESTUCA, PUCCINELLIA, HALIMIONE	+ ARTEMISIA	PURE STAND	+HALIMIONE	+ ASTER, PUCCINELLIA	+PUCCINELLIA
NUMBER OF QUADRATS	7	5	4	5	12	24	19	19	21	7	1	22	6	60	47	10	2	2	10	2	1	4

* COMMUNITY SM13 IS PUCCINELLIA SUBCOMMUNITY, UNLESS STATED

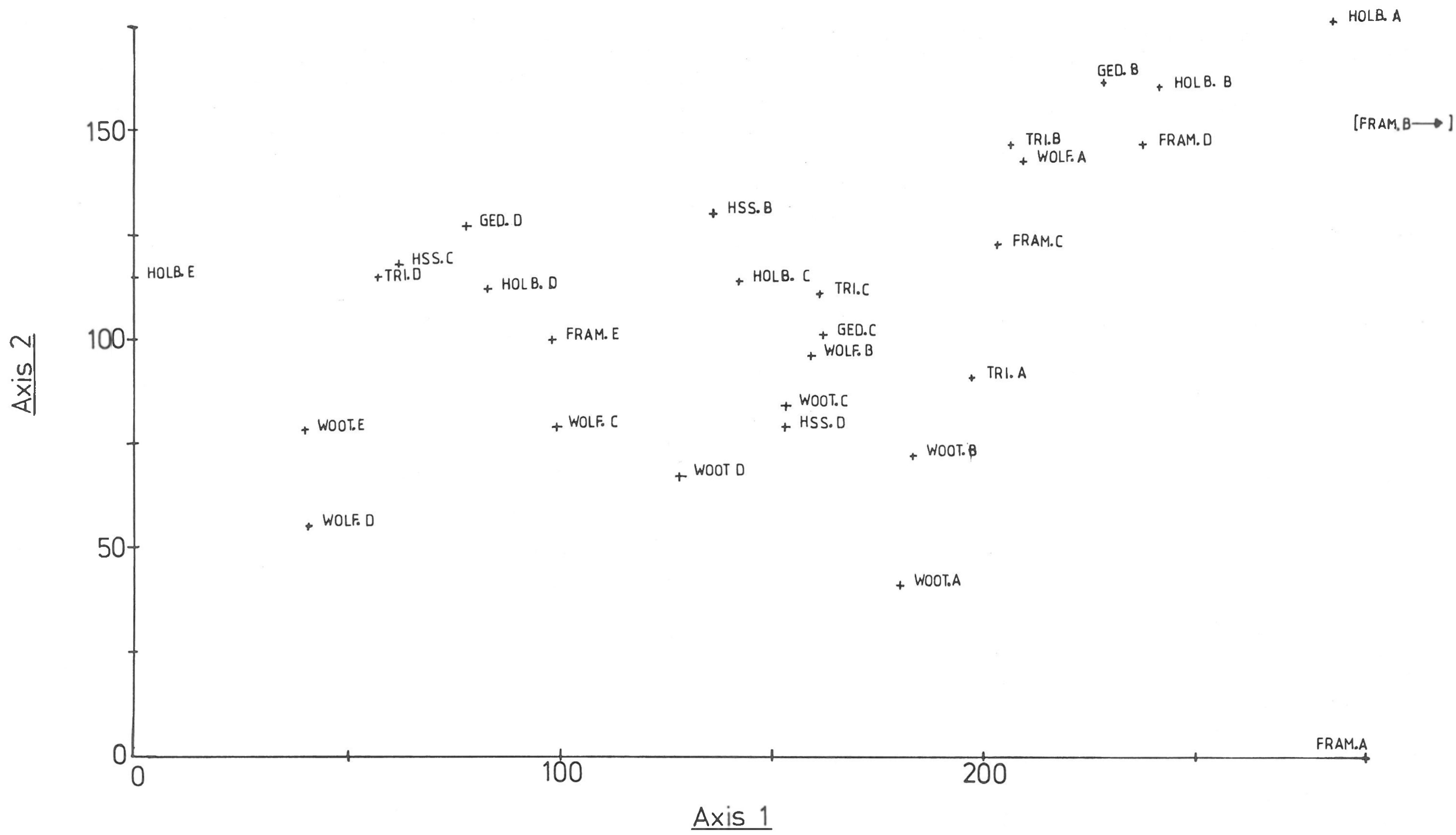


FIG. 3·5:
DISTRIBUTION OF STUDY SITES ON THE FIRST 2 ORDINATION AXES. PRODUCED BY 'DECORANA' USING FLORISTIC COVER DATA FROM SITES RECORDED IN 1973.
FOR SITE CODES SEE TABLE 3·1

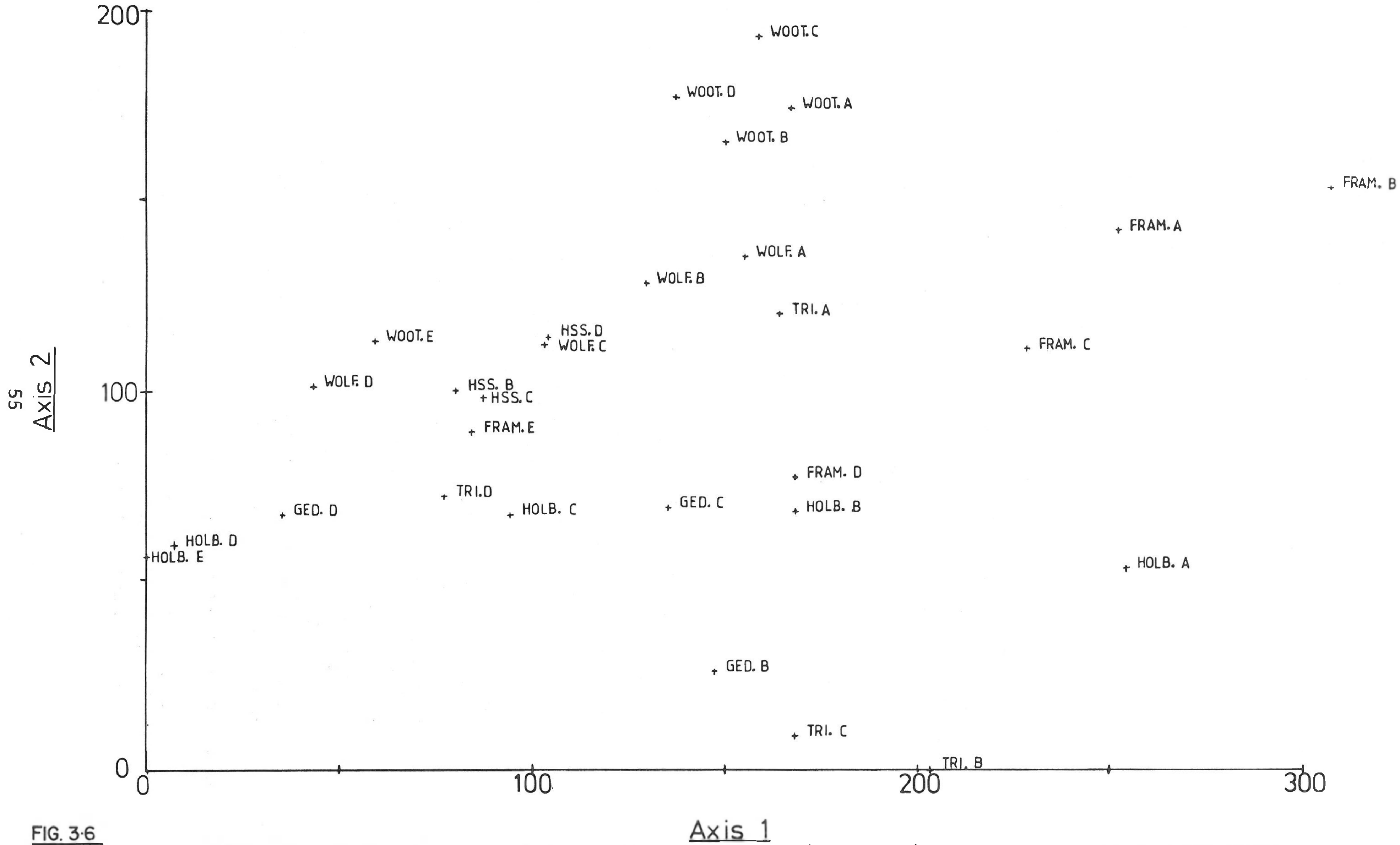


FIG. 3·6
DISTRIBUTION OF STUDY SITES ON THE FIRST 2 ORDINATION AXES. PRODUCED BY 'DECORANA' USING FLORISTIC COVER DATA FROM SITES RECORDED IN 1985.
FOR SITE CODES SEE TABLE 3·1

4 Grazing

4.1 Livestock

4.1.1 Grazing levels

The previous survey (Randerson, 1975) noted that the summer grazing of sheep and cattle on the saltmarshes had decreased with the increase in arable farming around the Wash. This trend has continued in recent years. Wilkinson (1980) estimated the area of grazing marshes to be 972 ha (Wrangle 178 ha; Freiston 62 ha; Frampton 220 ha; Kirton 256 ha; Gedney 136 ha; Terrington 120 ha). The current grazing levels are shown in Table 4.1. It should be emphasised that these levels vary considerably with the tides, the weather, the growth of vegetation and the time of year. It is also difficult to define the area grazed, as the animals preferentially graze the seabank and parts of the marsh which are accessible to them. Varying amounts of pasture are also provided behind the seabank for refuge at high tide and for fresh drinking water. The cattle are usually put out on the marsh from April/May until October/November. The average level of grazing by cattle is approximately one animal per hectare. Higher levels may be found, for example on Wrangle marsh, where farmers own grazing rights to relatively small sections. The levels of grazing have been particularly low in 1984-86 owing to the raising of seabanks by the Anglian Water Authority: access for stock is not possible during construction and until grass is re-established on the bank.

Cattle-grazing is most common on the west shore, with the majority of the frontage from the southern end of the Wainfleet/Friskney reclamation to Butterwick Pullover being grazed at varying levels (Fig. 4.1). Sheep-grazing is now restricted to the area from Freiston shore to the Witham. Marshes fronting the 1976-79 and 1979-80 Home Office reclamations are ungrazed at present, as work is still continuing on stabilising the wall. The Kirton/Frampton marshes were grazed by sheep until 1945 and subsequently by cattle. Since the early 1970s horses and cattle together have grazed the northern end of Frampton marsh on the Scalp and around the Witham channel. The central area remains ungrazed. Kirton marsh is usually fairly heavily grazed by cattle, but rebuilding the seabanks in 1985/6 has restricted access and the number of stock has been reduced. On the south shore, marshes between the Welland and the Nene outfalls have been ungrazed since 1980. Prior to this, some grazing did occur on Gedney and Lutton outmarshes. Bank rebuilding has also prevented grazing on the marshes at Terrington and Ongar Hill, which are usually cattle-grazed. On the east shore, the northern section of Wolferton marsh (Sandringham Estate) was last grazed in 1978. In most years cattle-grazing occurs only at the southern end of Wootton marsh. In 1985, however, some cattle were put out north of the Wootton transect - presumably because access to the southern part of the marsh was restricted.

4.1.2 The effect of grazing on saltmarsh vegetation

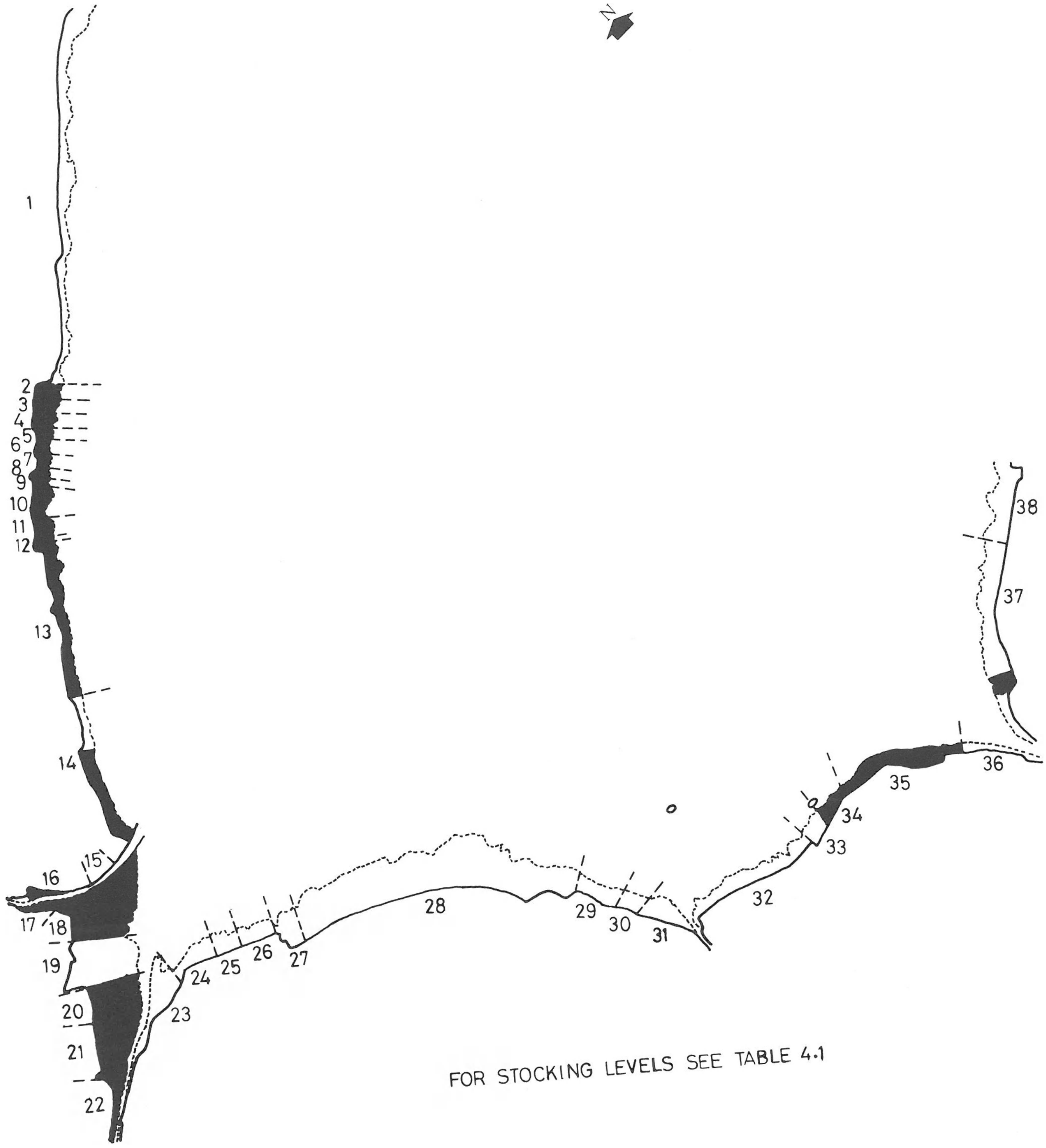
Grazing influences saltmarsh vegetation by trampling, manuring (which adds nutrients) and selective feeding (Long & Mason, 1983). In general, the sward becomes shorter and more open, favouring prostrate herbs and

Table 4.1 Stocking levels

Section	Occupier	Current grazing (1985, unless stated)
1	MOD/G H Bowser Ltd	Ungrazed
2	P R Cooper	10-17 cows + calves (1986, 32 cows + calves)
3	G H Caudwell	20-25 cattle (1986, less than 20 cattle)
4	T Bowles & Son	Cattle-grazed: varying levels (1986, 16 cattle in sections 4 and 5)
5	H M Clarke (Farms) Ltd	40-50 cattle
6	Staples Bros Ltd	Cattle-grazed: numbers unknown (1986, 58 cattle in sections 6 and 7)
7	P R Cooper	Cattle-grazed: similar level to section 2
8	S G Danby & Sons	15 cows and calves (April to July 1986, 18 cattle)
9, 11	J Saul	30 cows and calves
10	E W Bowser Ltd	Cattle-grazed: varying levels (1986, 45 cattle in sections 10 and 12)
12	E Cook	Cattle-grazed: varying levels (ungrazed 1982/3)
13	J Saul	50 in-calf heifers (1986, 55 cattle)
14	Home Office (North Sea Camp)	Sheep-grazed throughout year; ungrazed in front of 1976-7 and 1979-80 reclamations
15	A Lealand & Son)	Alternate sections grazed by 38 bullocks
16	A Lealand & Son)	
17	A E Lenton/R Tunnard	35 horses (mares and foals)
18	R Tunnard/LSHTNC/RSPB	40 horses and 40-50 cattle, or 80 horses and few cattle (1986, ungrazed)
19	D W & T E D Dennis	Ungrazed
20	Cargill (Frampton Farms Ltd)	10 cattle (1980-84, up to 50 cattle)
21	F Holmes	113 cows and calves (usually 150-175) (1986, 119 cattle)
22	W Dennis & Son	1985 and 1986 ungrazed (1981-83, 35-40 cattle)
23	J Ward & Son	Ungrazed (since 1980)
24	Hay & Son	Ungrazed (since 1980)
25	Hay Farming Ltd	Ungrazed (since 1980)
26	G Thompson (Farms) Ltd	Ungrazed
27	Caudwell Farms Ltd	Ungrazed
28	MOD	Ungrazed
29	P E Ashford	Ungrazed (since 1980)
30	J E Fines	Ungrazed (since 1980)
31	NCC (NNR)	Ungrazed; last grazed 1979/80
32	J H Proctor	Ungrazed since 1974 Wingland reclamation
33	W H Kerkham	Ungrazed (since 1980)
34	L Symington (Farms) Ltd	Ungrazed 1984-6 (usually cattle-grazed)
35	E A Lane Ltd	Ungrazed 1985-6 (usually 50-60 cattle)
36	W D Kerkham	Ungrazed (since 1980)
37	W Burt	50 cattle to south end of section only (1985, cattle-grazed to north end of section)
38	Crown Estate/ Sandringham	Ungrazed since 1978

FIG. 4.1 LOCATION OF GRAZING MARSHES

GRAZING MARSH ■   SALTMARSH EDGE -------



FOR STOCKING LEVELS SEE TABLE 4.1

grasses. Species such as annual Salicornia, Puccinellia maritima and Armeria maritima tend to be encouraged by grazing, whereas others such as Limonium spp., Spartina anglica and Aster tripolium are not. Removal of grazing leads to a high aerial biomass and the accumulation of litter. There is, in general, an inverse relationship between a high standing crop and species diversity (Grime, 1979). Little experimental work has, however, been carried out in Britain on the effects of particular grazing regimes on the species composition of saltmarsh communities.

Ranwell (1961) showed that different grazing regimes could alter the course of succession on a Spartina marsh at Bridgwater Bay. In particular, sheep-grazing favoured the spread of Puccinellia and the tillering of Spartina, which in turn reduced the available ground space for the invasion of Atriplex hastata. In the absence of grazing Spartina was replaced by Phragmites australis and Scirpus maritimus. This is, however, of little relevance to the Wash saltmarshes, where Spartina does not form extensive swards and there are no transitions to freshwater marsh. Cadwalladr & Morley (1974), working at Bridgwater Bay, found that experimental mowing in September prevented Festuca rubra from developing a tussocky growth form and maintained a Puccinellia sward.

Bakker (1978, 1985), recording the impact of various grazing and mowing regimes on saltmarsh vegetation in the Dutch Frisian Islands, found a complex pattern of responses. A decreased species diversity was found after the removal of grazing, leading to dominance by a single species and a coarse-grained vegetation mosaic. A pure Agropyron community developed, for example, from more species-rich Artemisia maritima and Juncus maritimus. Conversely, a resumption of cattle-grazing was followed by an increase in diversity, the vegetation mosaic becoming fine-grained once the dominance of one species had been lost. A decrease in the cover of Agropyron pungens occurred in all combinations of grazing and mowing, usually in the first or second years of the experiment. Treatments causing the greatest changes involved mowing early in the growing season followed by grazing or mowing again, i.e. cultural practices which maintain a short sward. When grazed, the vegetation types Festuca rubra/Limonium vulgare, Juncus maritimus and Artemisia maritima showed a tendency to regression and an increase in the cover of Puccinellia, Spergularia and other low marsh species. Grazing and/or mowing also caused an increase in Agrostis stolonifera, Plantago maritima and Juncus gerardii in comparison with control plots. A stocking rate of 1.6 animals/ha was considered to be too high, giving severe trampling effects.

On the Wash, the effect of grazing is also to maintain an open, short Puccinellia sward (including Puccinellia distans and Spergularia in the most heavily poached areas of older marshes). A more diverse community with fragments of Artemisia maritima, Festuca rubra and Plantago maritima develops on the creek banks of relatively heavily grazed, older marshes - as is seen at Kirton/Frampton. In less heavily grazed areas, Agropyron forms a narrow fringe on the creek banks. The absence of grazing on high, well-drained sites (as in the central section of Frampton marsh) allows extensive swards, often almost pure stands, of Agropyron to develop. Grazing also prevents the dominance of Halimione, although it may form a significant part of the vegetation in lightly grazed areas. Similarly, a sward of tussocky Festuca rubra and Limonium vulgare (fragments of which are found at Frampton and on the Holbeach range) will not develop on a heavily grazed site. As described in section 2.3.1.1, removal of grazing may also favour the development of dense, low-diversity Puccinellia swards. This may partially explain the recent spread of Puccinellia-dominated communities at the expense of Halimione. Grazing clearly diverts the course of succession, and marshes which have been previously heavily grazed will require continuing management to maintain their diversity. Ultimately, however, ungrazed marshes (as on the North Norfolk coast) can develop a high species diversity, with a sward with a lower proportion of grass species. The ideal situation for conservation purposes (maximising structural and species diversity) is a mixture of ungrazed and grazed marshes with a variation of stocking levels within the latter.

4.2 Wildfowl

Grazing by geese, especially brent geese, may have an important influence on the species composition of some low marsh communities. The highest monthly counts of brents in the Wash have increased markedly since the mid 1970s from 4,300 in 1973/4 to 11,400 in 1979/80 and a peak of 24,300 in 1982/3. A subsequent decline has taken place to 14,200 in 1984/5. These changes in the Wash population have been part of a general increase in the population of brents worldwide owing to a succession of good breeding years. An increase in goose-grazing can be expected to maintain an open community in the low marsh with a high proportion of annuals. The replacement of Aster tripolium saltmarsh by transitional low marsh vegetation (section 2.3.1.3) may be at least partly due to more intensive grazing of the lower marsh by brent geese. Joenje (1985) found that grazing by wildfowl on recently embanked sandflats favours the survival of annual plant colonisers and retards succession towards perennial grassland. Ranwell & Downing (1959) found that, on reaching their wintering grounds at Scolt Head Island, brent geese fed first on Zostera beds, then on Enteromorpha and finally on Puccinellia and Aster of the lower saltmarsh by the end of the winter. Further increases in the population of brent geese or reduction in the saltmarsh/intertidal feeding grounds could force the geese to move to alternative feeding grounds in other estuaries or in nearby cereal fields. A relatively immature saltmarsh is most suitable to encourage wildfowl grazing: Cadwalladr et al. (1972) have shown that wigeon prefer to feed on swards of Puccinellia and Agrostis tenuis rather than tussocky Festuca.

5 Accretion rates

5.1 Methods

5.1.1 Kestner cores

Accretion was measured by the technique of Kestner (1959). In principle, the technique involves marking the present substrate level by a T-shaped plug of white silica flour of known depth. Thus erosion of or accretion over the core can be measured directly. Cores were inserted into the marsh surface at three stations (lower, middle and upper marsh) per transect. At each station, a line of five cores, 1 m apart, were located precisely by markings on a wire stretched between wooden posts. Cores were inserted by removing a plug of soil (2.5 cm in diameter; 10 cm in depth) with the inner tube of the corer. The outer tube was then filled with a silica flour paste, a thick slurry of finely milled silica (200 mesh) mixed with water. After removing the outer tube, more silica paste was spread over the surface, so marking the current substrate level. Cores were put in during June/July 1985 and dug up in April 1986 with a 10 cm diameter corer. The retrieved cores were split with a sharp knife and the sediment accumulation measured. It proved impossible to retrieve the cores at the Ongar transect owing to bank rebuilding work.

5.1.2 Transect profiles

Elevations along the transects at Nene, Gedney, Horseshoe North and Wainfleet (where rapid accretion was expected because of recent reclamations) were determined by optical levelling, to give detailed profiles. These provide a direct comparison with the elevations measured in 1973, and thus a longer-term estimate of the rate of accretion.

5.2 Results

5.2.1 Kestner cores

The mean annual accretion rates obtained show (Table 5.1) that, in general, accretion is continuing at rates comparable to those found in the previous survey. As expected, the rates increase towards the seaward edge of most transects. The highest rates (more than 25 mm per annum) were found at Wolferton (700 m), Trial Bank (400 m), Nene (200 m), Horseshoe North (300 m) and Wainfleet (300 m). Accretion is clearly lower on the older marshes, although relatively high rates are still found in their pioneer zones (for example at Holbeach 1,000 m and Frampton 1,700 m). Elevated accretion rates were found in front of some recent reclamations, notably at Wainfleet. However, at Freiston accretion was barely detectable and complete erosion of the lowest core site had occurred. This presumably results from the continuing work being carried out to stabilise the new seabank of the 1979-80 reclamation and the excavation of further borrow pits. The majority of suspended sediment will be deposited in the borrow pits rather than on the remaining marsh surface. An unexpected trend was also found at the Nene transect, where the accretion rate declined with distance from the seabank. The topography of the pioneer zone in this area is hummock/hollow with many parallel drainage channels. This pattern of accretion will lead to a steepening of the marsh slope and may be related to the lower than expected rate of seaward spread found in front of the Wingland reclamation (section 2.3.2; Table 2.5).

Table 5.1 Accretion rates: summary of results and comparison with 1971/4 survey

Note: Values in brackets give approximate distance from 1973 outer seabank, for comparison with 1971/4 locations.
NM = not measured.

Transect	1985/6 survey			1971/4 survey		
	Distance (m) from outer seabank	Height (m) AOD	Accretion rate (mm per annum)	Distance (m) from seabank	Height (m) AOD	Accretion rate (mm per annum)
Wolferton	100	NM	2.6	A 90	3.44	2.8
	400	NM	17.8	B 450	2.97	13.9
				C 690	2.88	31.0
	700	NM	26.4			
				D 750	2.56	19.9
Wootton				A 80	3.51	2.1
	200	NM	3.1			
				B 260	3.51	7.3
	500	NM	22.7			
				C 560	3.25	26.9
				D 610	2.99	20.2
				E 630	2.78	22.0
	700	NM	28.8			
Trial Bank	100	NM	6.9	A 90	3.42	3.9
				B 215	3.36	8.4
	300	NM	22.6	C 285	3.12	6.9
	400	NM	28.7	D 350	2.89	11.8
Nene	300 m reclamation			A 100	3.30	6.7
				B 200	3.32	12.6
				C 370	3.29	NM
	200(500)	3.12	27.5			
	300(600)	2.78	23.1	D 620	2.66	22.9
	400(700)	2.58	15.0			
Gedney	300 m reclamation			A 260	3.52	1.5
	100(400)	3.30	7.4			
				B 515	3.10	7.1
	300(600)	2.89	19.4	C 660	2.89	11.1
				D 870	2.65	8.2
	600(900)	2.12	18.9			
Holbeach				A 100	3.59	1.5
	200	NM	4.6			
				B 350	3.36	3.2
	600	NM	18.9			
				C 650	2.93	9.8
				D 920	2.69	11.8
	1000	NM	21.1	E 1020	2.45	25.8

Table 5.1 (continued)

Transect	1985/6 survey Distance (m) from outer seabank	Height (m) AOD	Accretion rate (mm per annum)	1971/4 survey Distance (m) from seabank	Height (m) AOD	Accretion rate (mm per annum)
Frampton	300	NM	2.6	A 120	3.51	1.3
				B 380	3.74	1.7
				C 480	3.43	1.8
	1100	NM	6.2	D 1180	3.39	4.4
				E 1600	2.85	15.1
	1700	NM	15.8	F 1700	2.67	16.3
Freiston	560 m reclamation			A 80	3.37	1.9
				B 475	3.14	5.3
	100(660)	NM	2.1	C 700	2.72	9.1
	200(760)	NM	1.8	D 780	2.59	11.6
	250(810)	NM	All cores eroded			
Horseshoe South				A 105	3.25	2.6
	300	NM	13.1	B 360	2.78	16.9
	400	NM	23.2	C 480	2.56	26.6
	500	NM	20.2	D 100	3.29	4.4
Horseshoe North	280 m reclamation			A 70	3.37	2.3
				B 180	2.99	11.2
	100(380)	3.06	8.6	C 320	2.81	25.5
	200(480)	2.54	21.2			
	300(580)	2.48	33.0			
Wainfleet	450 m reclamation			A 110	3.22	0.7
				B 240	3.35	1.5
				C 370	3.12	6.1
				D 480	3.04	10.6
	100(550)	3.05	6.1			
	200(650)	2.90	13.9			
	300(750)	2.83	26.5			

FIGURE 5·1a

WAINFLEET

450m RECLAMATION IN 1976

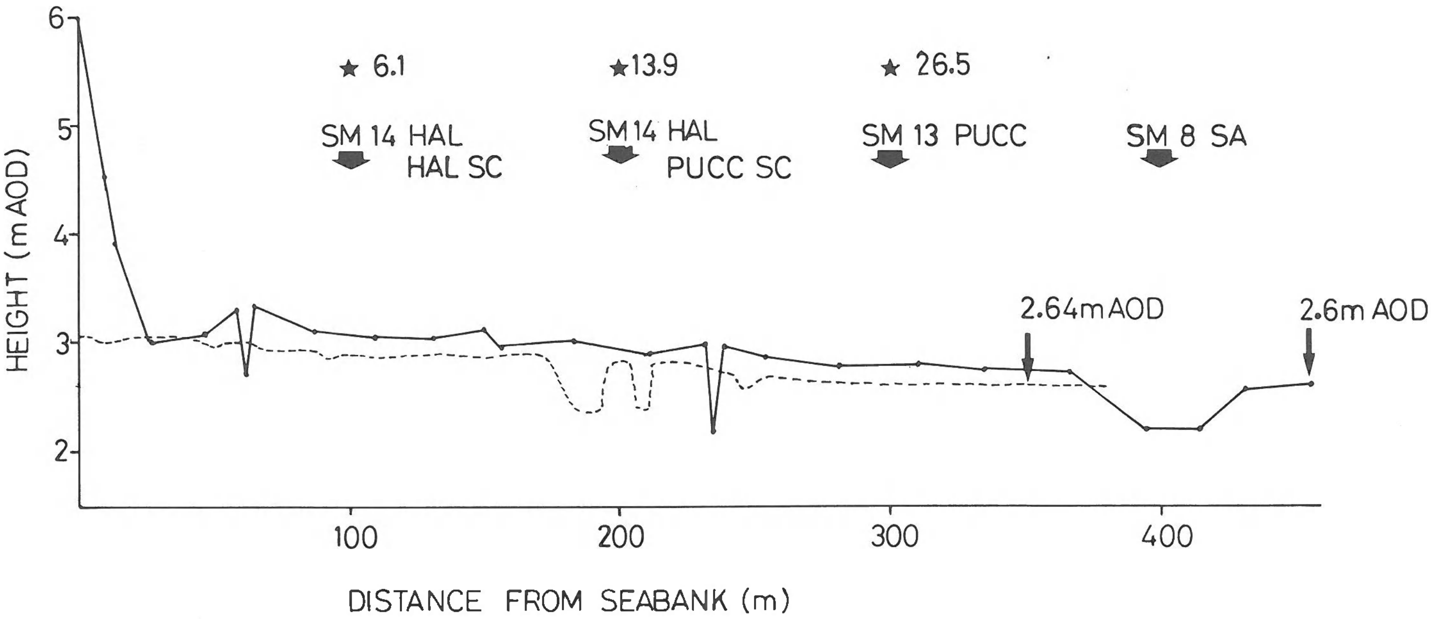


FIGURE 5·1b

HORSESHOE NORTH

280m RECLAMATION IN 1976

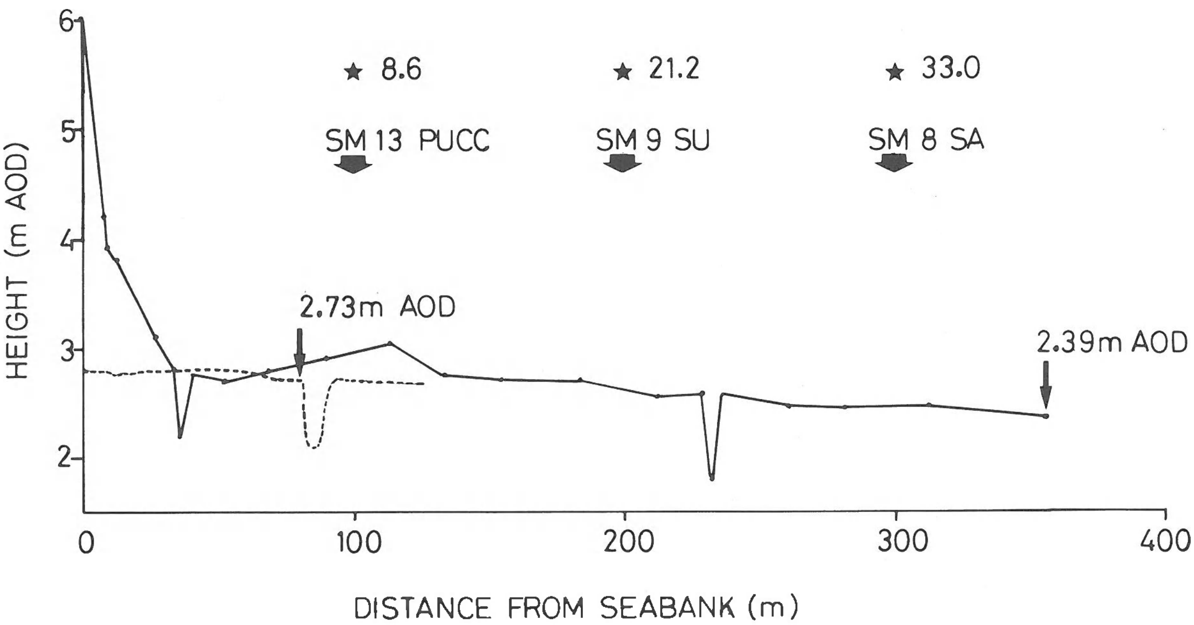


FIGURE 5·1c

c) GEDNEY

300m RECLAMATION IN 1978

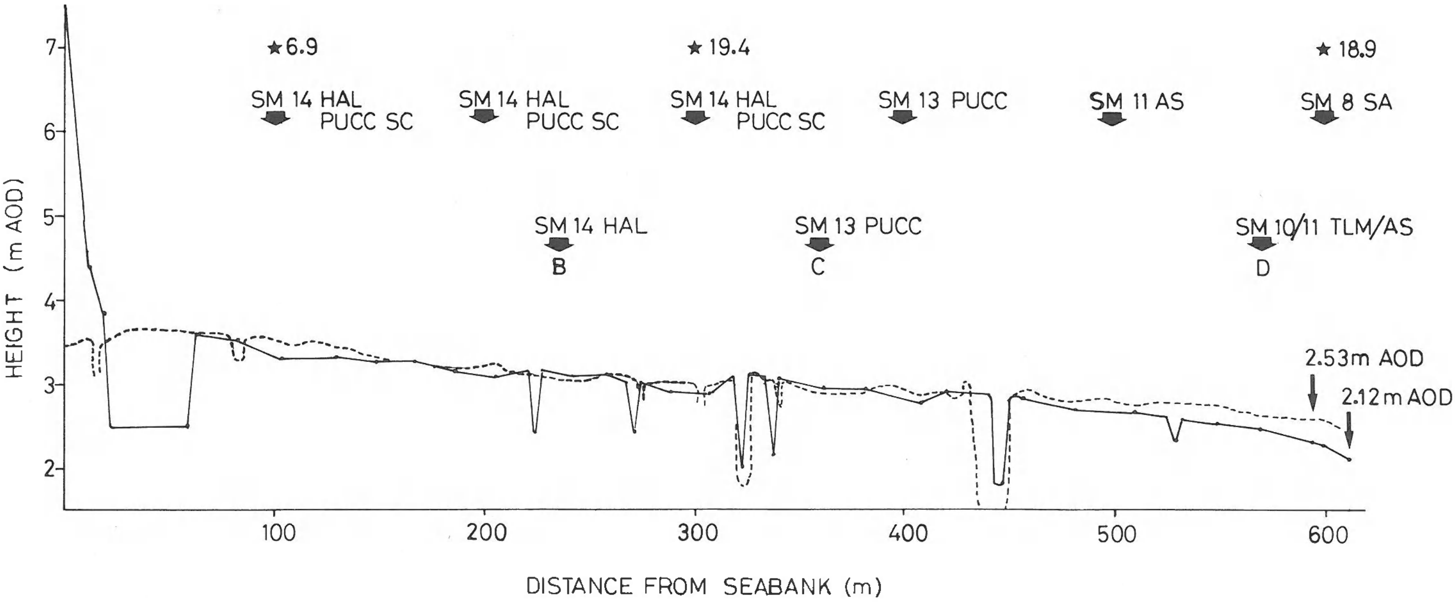
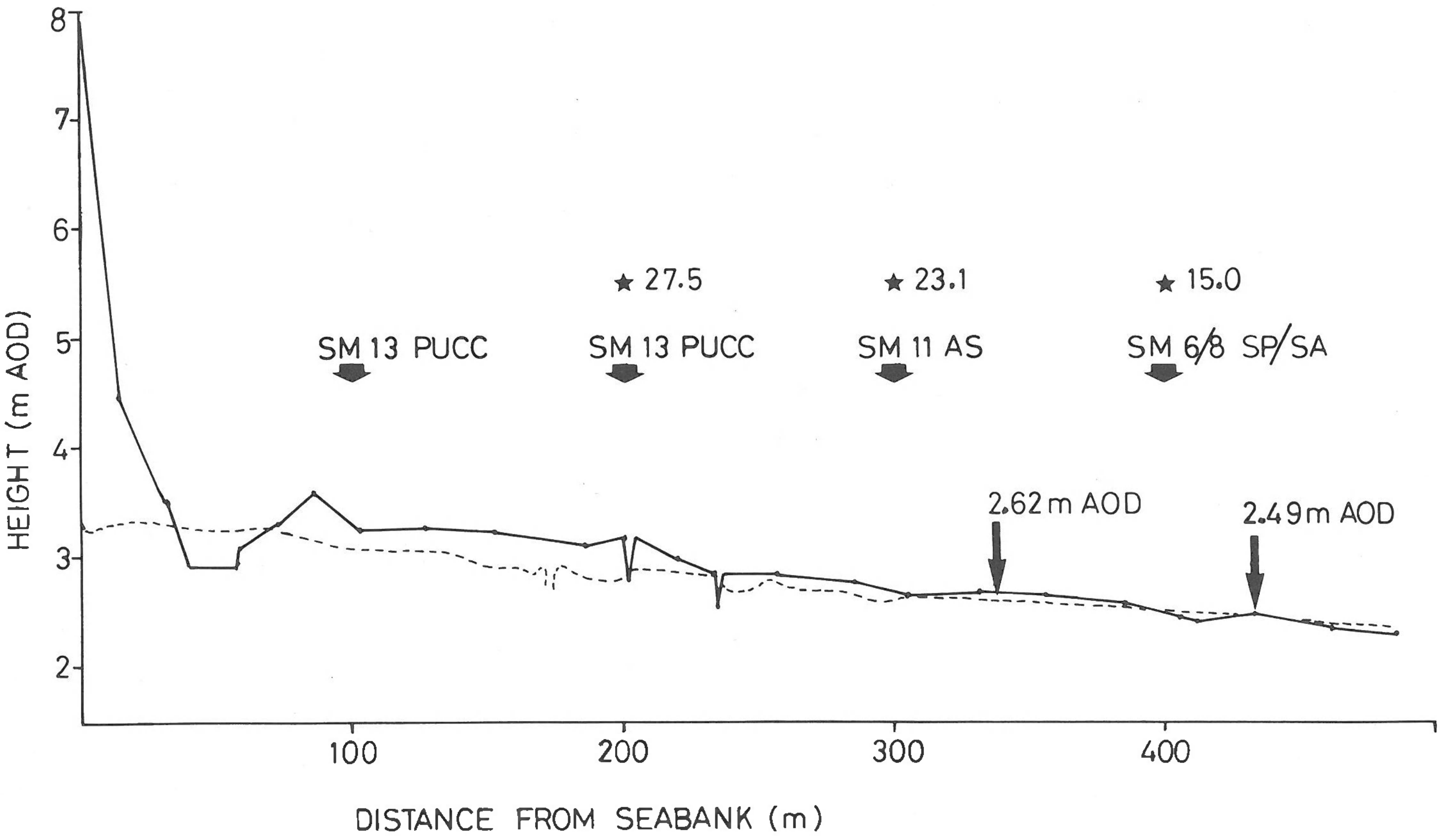


FIGURE 5·1d

NENE BANK

300m RECLAMATION IN 1974



6 Summary and appraisal

6.1 Total saltmarsh area

The total area of saltmarsh in the Wash, measured from the vegetation maps produced in this survey, was found to be 4,158 ha. This amounts to some 9% of the area of this habitat in Britain (approximately 44,000 ha). Thus, a net reduction of 83 ha has occurred since the previous survey (Randerson, 1975). Since 1973, 864 ha of saltmarsh have been reclaimed, mainly on the west shore between the Nene and Ouse outfalls. Clearly, considerable areas of new saltmarsh have developed in response to reclamation, although a net loss of saltmarsh has occurred in the sections of shoreline in which the largest reclamations took place. New saltmarsh formation has been most rapid on the west shore (343 ha), as compared with only 50 ha between the Nene and the Ouse. A significant spread of saltmarsh was found to have occurred between the Welland and the Nene; in the remaining areas the saltmarsh extent remained relatively constant.

Assuming that the low water mark has remained static, any reclamation results in a permanent loss of intertidal area. Of the remaining intertidal zone, 781 ha of mud or sand flats have become colonised by saltmarsh since the previous survey -a loss of approximately 3% of their area. The impact and significance of this loss on the populations of waders and wildfowl and on the invertebrates on which they feed is being investigated by Goss-Custard and others from the Institute of Terrestrial Ecology (Goss-Custard et al., 1987).

This survey has shown that there is considerable variation in the rate of saltmarsh spread after reclamation owing to the overriding influence of local factors. The values given by MAFF (1983) for the expected rates of spread and the time taken for equilibrium to be re-established clearly overestimate this rate in the Wash as a whole. Since the previous survey, these high rates have only been achieved in the most favourable circumstances, mainly on the northern section of the west shore. The relatively low rate of spread on the south shore between the Nene and the Ouse is a particular cause for concern. It suggests that this section of the shoreline may be unable to sustain a high rate of reclamation in the future. Measurements of the rate of accretion and a comparison of transect profiles have also highlighted this situation. Similarly, the extent of new saltmarsh formation in front of the 1972 Leverton reclamation was also significantly less than expected. In general, however, the rates of sediment accretion are comparable to those found during the Water Storage Scheme Feasibility Study, i.e. between 15 mm and 30 mm per annum near the seaward edge of the saltmarsh. It should also be noted that further seaward spread will not be possible at some sites owing to the proximity of a major channel or outfall; this applies, for example, to Kirton/Frampton, Ongar Hill and Lutton outmarshes.

6.2 Changes in vegetation communities

This survey has shown considerable changes in the extent of the saltmarsh vegetation communities since the early 1970s. The differences found result from loss of habitat due to reclamation and erosion and also from changes in the constituent species owing to the effects of grazing, climate and succession.

6.2.1 Losses due to reclamation

The communities lost after reclamation are mostly those of the mid to upper marsh zones. However, at some sites all the existing marsh (including lower marsh) communities were enclosed. Halimione portulacoides saltmarsh (Halimione-dominated subcommunity) has been particularly severely affected by reclamation; 39% (over 500 ha) of the area of this community recorded in the previous survey has since been enclosed. In addition, 25% of the original area of Puccinellia maritima (Puccinellia-dominated subcommunity), 23% of Puccinellia maritima upper marsh subcommunity, 14% of Agropyron pungens (Elymus pycnanthus) and 11% of annual Salicornia saltmarsh have been lost in reclamation. The digging of borrow pits during the recent programme of raising seabanks is also a significant factor in the loss of Puccinellia maritima upper marsh subcommunity.

6.2.2 Other changes and the influence of grazing

The most widespread and dramatic change since the previous survey has been the decline in dominance and distribution of Halimione and its replacement largely by Puccinellia maritima. This has resulted in an increase in the area of Puccinellia maritima saltmarsh (Puccinellia-dominated subcommunity) and Halimione portulacoides saltmarsh (Puccinellia-dominated subcommunity). Together, these communities now occupy 55% of the total saltmarsh area. This change is thought to be largely a result of recent cold winters, although the continuing reduction in the use of the marshes for grazing may also be important.

The other significant change in the older marshes has been the invasion of Puccinellia maritima upper marsh subcommunity by Agropyron pungens. The former community also contains fragments of Artemisia maritima and Festuca rubra saltmarsh and is the most diverse saltmarsh vegetation community on the Wash in terms of both its component species and the structure of the vegetation. Stands of Agropyron pungens are, in contrast, homogeneous in structure and of a very low species diversity.

This trend is the expected pattern of succession on well-drained sites in the absence of grazing. The introduction of a low level of grazing, ideally by sheep, would help to limit the spread of Agropyron. Grazing is, however, likely to be concentrated at the margin of the Agropyron sward, and the effect should be closely monitored to prevent overgrazing of the remaining areas of diverse vegetation. An alternative method of controlling the spread of Agropyron would be a modification of the drainage regime, to increase the frequency and duration of flooding between creeks in the upper marsh.

In general, the effect of reduced grazing pressure has been to encourage the development of tall, dense and relatively homogeneous swards of Puccinellia maritima, often with Atriplex hastata as an associated species. This decline in structural diversity is of considerable significance for wintering wildfowl, which preferentially graze a shorter turf, and also for breeding bird populations such as redshank, which nest mainly in a 'tussocky' sward.

Other communities require continued grazing if they are to persist - for example the Spergularia marina--Puccinellia distans community which occupies small areas of heavily cattle-grazed marsh on the west shore. The maintenance or reintroduction of grazing at a range of densities would clearly be of value in offsetting the increasing homogeneity and lack of diversity of the Wash saltmarshes.

The other major vegetation changes observed were a decrease in the cover of Aster tripolium and in the area of Spartina anglica and annual Salicornia communities. This decline in the extent of pioneer communities compared with that recorded in the previous survey reflects successional development in the lower marsh zones. A reduction in the area occupied by Salicornia and Aster may significantly reduce the availability of food for the populations of wintering passerines, particularly twite, which feed on the seed of these species (Davies, 1987). In the past, extensive Spartina communities were recorded in the Wash, as in other estuaries on the east coast. However, Spartina now forms only relatively small stands and pioneer communities totalling 97 ha, largely in the south-east corner around the Great Ouse outfall. Similar reductions in the area of Spartina marsh have also been recorded at many other sites such as Hamford Water, Dengie Flats and the estuaries of the Blackwater, Crouch and Colne (NCC, unpublished data).

6.3 Recommendations for future work

6.3.1 Transect profiles

The transects at Wolferton, Wootton, Ongar, Trial Bank, Holbeach, Frampton and Horseshoe South should be levelled to provide a comparison with the 1973 profiles.

6.3.2 Vegetation monitoring

Recording of vegetation at transect point and particularly study site quadrats should be repeated at five-yearly intervals with the use of NVC techniques. Preferably, all sites should be recorded in a single season, rather than a few transects per year. The present survey has shown that changes along the transects are representative of changes in the saltmarsh vegetation on a larger scale throughout the Wash. The complete survey, including production of a full set of vegetation maps, should be repeated after 10-15 years.

6.3.3 Grazing

In the light of the vegetation changes described in this report, it is clear that the introduction of positive grazing management should be considered in the marshes owned or leased by conservation bodies. The effect of different stocking rates and periods of grazing on the course of succession are not well understood. Experimental trials with different grazing levels and durations would be very useful in planning future management. Such trials should include monitoring of the vegetation and assessment of the value of different grazing regimes in providing habitats for invertebrates and birds.

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Appendix 1 Vegetation records: details of frequency values and Domin ranges

	WOLFERTON STUDY SITES				WOLFERTON TRANSECT POINTS						WOOTTON STUDY SITES				
Distance from seabank (m)	A 90	B 450	C 690	D 750	200	300	400	500	600	800	A 80	B 260	C 560	D 610	E 630
Species															
Salicornia spp.		I,0-1		V,3-5		I,0-1								I,0-1	IV,0-3
Suaeda maritima	II,0-2	III,0-2,	V,1-4	V,4-8	I,0-1	IV,0-4		I,0-1	I,0-1					III,0-3	II,0-2
Spartina anglica	I,0-7	II,0-6	III,0-4	V,5-8		I,0-1		I,0-2		II,0-8				II,0-4	V,3-8
Aster tripolium	V,1-4	V,0-5	V,2-7	V,3-8	IV,0-3	V,1-5	V,2-4	V,0-4	V,0-5		I,0-1	V,0-4	II,0-1	V,0-4	V,3-8
Puccinellia maritima	V,7-10	V,0-10	V,7-10	V,3-7	V,7-10	V,8-9	V,7-10	V,9-10	V,8-10		V,10	V,9-10	V,8-10	V,7-9	V,3-7
Halimione portulacoides	IV,0-8	I,0-1	II,0-5		V,1-8	V,1-7	III,0-8	II,0-5	II,0-6						
Cochlearia spp.	IV,0-3	I,0-1			I,0-1						I,0-1	I,0-1	III,0-1	II,0-1	
Atriplex hastata	V,0-4	II,0-1	III,0-3	I,0-1	V,1-5	IV,0-3	IV,0-4	II,0-2	I,0-2		V,1-3	V,3-5	V,2-6	V,4-7	III,0-2
Agropyron pungens											II,0-1				
Festuca rubra															
Plantago maritima															
Triglochin maritima	I,0-1													I,0-1	
Artemisia maritima															
Limonium spp.															
Spergularia marina															
Atriplex littoralis															
*NVC community (SM)	13 Pucc	13 Pucc	13 Pucc	6/10 Sp/TLM	14 Hal Pucc Sc	13 Pucc	13 Pucc	13 Pucc	13 Pucc	6 Sp	13 Pucc	13 Pucc	13 Pucc	13 Pucc	11 As

* Note: Community SM13 Puccinellia is Puccinellia subcommunity (Sc) unless stated.

Appendix 1 Vegetation records: details of frequency values and Domin ranges (continued)

	WOOTTON TRANSECT POINTS							ONGAR TRANSECT POINTS					TRIAL BANK STUDY SITES			
Distance from seabank (m)	200	300	400	500	600	700	800	100	200	250	300	330	A 90	B 215	C 285	D 350
Species																
Salicornia spp.					I,0-1	V,2-4	IV,0-2	I,0-1	V,4-6	V,4-6	V,3-8	II,0-2			III,0-2	V,5-7
Suaeda maritima						V,0-3		V,2-3	V,0-5	III,0-3	I,0-1		I,0-1	I,0-1	V,2-5	V,3-5
Spartina anglica		II,0-4	I,0-2	II,0-1	III,0-4	V,6-9	III,0-9	III,0-6	V,1-8	V,0-9	V,8-10	V,1-6				IV,0-4
Aster tripolium		V,0-4	III,0-3	IV,0-3	V,1-4	V,6-8		V,3-6	V,3-6	V,4-8	V,0-5	I,0-1	I,0-1	IV,0-3	IV,0-4	V,3-6
Puccinellia maritima		V,9-10	V,8-10	V,8-10	V,7-8	IV,0-5		V,8-10	V,6-9	V,4-8	IV,0-3		V,8-10	V,2-6	V,2-7	V,6-8
Halimione portulacoides								I,0-2					II,0-6	V,8-10	V,7-10	V,0-6
Cochlearia spp.		I,0-1	II,0-1	III,0-2	II,0-1								I,0-1			
Atriplex hastata	III,0-2	V,2-4	V,3-6	V,3-6	V,6-8	V,1-3		I,0-1					I,0-1			
Agropron pungens	V,10															
Festuca rubra																
Plantago maritima																
Triglochin maritima																
Artemisia maritima																
Limonium spp.																
Spergularia marina																
Atriplex littoralis																
NVC community (SM)	24 Ag	13 Pucc	13 Pucc	13 Pucc	13 Pucc	6/11 Sp/As	6 Sp	13 Pucc	13 Pucc	10 TLM	6 Sp	6 Sp	13 Pucc	14 Hal Hal Sc	14 Hal Hal Sc	10 TLM

Appendix 1 Vegetation records: details of frequency values and Domin ranges (continued)

	TRIAL BANK TRANSECT POINTS					NENE TRANSECT POINTS				GEDNEY STUDY SITES			GEDNEY TRANSECT POINTS		
Distance from seabank (m)	100	200	300	400	500	100	200	300	400	B215	C360	D570	100	200	300
Species															
Salicornia spp.			V,4-6	V,7-9	V,2-5		V,2-4	V,3-5	V,5-7	I,0-1	II,0-2	V,5-7			I,0-1
Suaeda maritima		I,0-1	V,4-6	V,1-5	III,0-2	V,0-6	V,3-6	V,2-4	I,0-1	V,1-4	V,3-6	V,3-5		IV,0-2	V,2-6
Spartina anglica	I,0-1		IV,0-7	V,2-5	III,0-3		IV,0-5	IV,0-7	V,0-8		I,0-5	II,0-5			I,0-2
Aster tripolium	II,0-2	V,1-5	V,1-4	IV,0-6		V,2-7	V,3-5	V,7-9	III,0-3	V,1-5	V,3-5	V,6-8	V,1-4	V,1-5	V,1-4
Puccinellia maritima	V,7-10	V,4-8	V,6-8	V,0-4	II,0-1	V,7-10	V,7-9	V,4-6	IV,0-2	V,4-9	V,5-9	V,2-5	V,4-8	V,4-9	V,5-9
Halimione portulacoides	IV,0-8	V,6-10	II,0-5			III,0-6	II,0-4			V,4-9	V,0-8	I,0-1	V,6-9	V,5-9	V,3-9
Cochlearia spp.													II,0-1		
Atriplex hastata						II,0-2									
Agropyron pungens															
Festuca rubra															
Plantago maritima															
Triglochin maritima															
Artemisia maritima															
Limonium spp.													I,0-3		
Spergularia marina															
Atriplex littoralis															
NVC community (SM)	13 Pucc	14 Hal Pucc Sc	13 Pucc	8 Sa	8 Sa	13 Pucc	13 Pucc	11 As	8/6 Sa/Sp	14 Hal Pucc Sc	13 Pucc	10/11 TLM/As	14 Hal Pucc Sc	14 Hal Pucc Sc	14 Hal Pucc Sc

Appendix 1 Vegetation records: details of frequency values and Domin ranges (continued)

	GEDNEY TRANSECT POINTS cont.			HOLBEACH STUDY SITES					HOLBEACH TRANSECT POINTS						
Distance from seabank (m)	400	500	600	A95	B350	C650	D920	E1020	100	200	300	400	500	600	700
Species															
Salicornia spp.	V,1-4	V,4-6	V,0-3			V,0-3	V,6-8	V,4-9						II,0-1	V,1-4
Suaeda maritima	V,1-4	V,1-4			I,0-1	V,4-8	V,4-7	V,4-7	I,0-1		I,0-1	III,0-4	V,2-5	V,4-7	V,3-8
Spartina anglica	II,0-7	III,0-3				I,0-1	II,0-7	IV,0-4				I,0-5	I,0-1	I,0-1	
Aster tripolium	V,1-5	V,6-8		III,0-2	V,1-4	V,3-6	V,3-6	V,3-5	II,0-1	IV,0-2	V,1-3	V,2-5	V,2-6	V,3-5	V,2-5
Puccinellia maritima	V,4-8	V,5-7	I,0-1	V,0-9	V,6-10	V,5-9	V,4-5	V,1-4	V,4-9	V,5-10	V,5-10	V,5-9	V,8-9	V,6-9	V,5-8
Halimione portulacoides	IV,0-10	I,0-2		V,1-6	V,2-8	IV,0-8			V,3-6	V,2-8	V,0-9	V,1-9	V,1-5	V,0-6	V,4-8
Cochlearia spp.				V,0-2					III,0-4	I,0-2					
Atriplex hastata															
Agropyron pungens				II,0-10					III,0-8	I,0-5					
Festuca rubra				II,0-7					II,0-5						
Plantago maritima				I,0-1					II,0-5						
Triglochin maritima				I,0-1					I,0-1						
Artemisia maritima				IV,0-9					IV,0-8						
Limonium spp.				I,0-1	I,0-5				I,0-3						
Spergularia marina									I,0-1						
Atriplex littoralis				II,0-1					I,0-3						
NVC community (SM)	13 Pucc	11 As	8 Sa	13 Pucc UM Sc +24 Ag +17 Art	14 Hal Pucc Sc	13 Pucc	10 TLM	8 Sa	13 Pucc UM Sc +24 Ag +17 Art	14 Hal Pucc Sc	14 Hal Pucc Sc	14 Hal Pucc Sc	13 Pucc	13 Pucc	14 Hal Pucc Sc

Appendix 1 Vegetation records: details of frequency values and Domin ranges (continued)

	HOLBEACH cont. TRANSECT POINTS		FRAMPTON STUDY SITES					FRAMPTON TRANSECT POINTS							
Distance from seabank (m)	800	1100	A120	B380	C480	D1180	E1600	200(a)	200(b)	300(a)	300(b)	600(a)	600(b)	700(a)	700(b)
Species															
Salicornia spp.	V,4-5	V,5-8					V,5-8								
Suaeda maritima	V,3-5	III,0-2				III,0-2	II,0-3		I,0-2				I,0-2		
Spartina maritima	I,0-1	IV,0-5		I,0-1			III,0-5								
Aster tripolium	V,4-6	I,0-1	II,0-2		IV,0-3	V,0-5	V,5-6		V,1-3		I,0-1	III,0-2		IV,0-3	
Puccinellia maritima	V,7-8	IV,0-1	V,0-10	I,0-1	V,3-9	V,7-10	V,5-8		V,10		V,9-10	V,10		V,10	II,0-2
Halimione portulacoides	II,0-5		V,0-6	I,0-1	IV,0-8	IV,0-8	III,0-4	II,0-3	III,0-4	I,0-1	III,0-5	I,0-2		II,0-1	II,0-3
Cochlearia spp.			II,0-1		II,0-1				II,0-2	II,0-1		V,0-2	III,0-4		I,0-1
Atriplex hastata			I,0-1		III,0-4				II,0-1	I,0-1		III,0-1	IV,0-2	II,0-1	I,0-1
Agropyron pungens			IV,0-10	V,10	V,0-9	I,0-5		V,10		V,10			V,10		V,10
Festuca rubra			III,0-8		I,0-3				IV,0-3		I,0-4				
Plantago maritima			I,0-1												
Triglochin maritima			III,0-5						I,0-1		II,0-4				
Artemisia maritima															
Limonium spp.			II,0-6						II,0-3		I,0-1				
Spergularia marina															
Atriplex littoralis															
NVC community (SM)	13/11 Pucc/As	8 Sa	13 Pucc UM Sc +24 Ag	24 Ag	24 Ag +14 Hal Pucc Sc	13 Pucc +14 Hal Pucc Sc	10 TLM	24 Ag	13 Pucc UM Sc	24 Ag	13 Pucc UM Sc	13 Pucc	24 Ag	13 Pucc	24 Ag

Appendix 1 Vegetation records: details of frequency values and Domin ranges (continued)

	FRAMPTON cont. TRANSECT POINTS										HORSESHOE SOUTH STUDY SITES			HORSESHOE SOUTH TRANSECT POINTS	
Distance from seabank (m)	800	900	1000(a)	1000(b)	1100	1300	1400	1500	1700	1750	B360	C480	D100	100	200
Species															
Salicornia spp.						V,1-2	V,2-4	V,3-5	V,5-8	V,5-9	V,4-8	V,3-5	V,3-6	III,0-2	II,0-3
Suaeda maritima				III,0-1	I,0-4	V,4-7	V,3-7	V,3-6	V,4-6	IV,0-4	V,0-3	V,3-4	V,2-5	V,2-6	V,1-4
Spartina anglica								I,0-2	IV,0-4	V,4-8	I,0-1	I,0-1	IV,0-4	I,0-1	
Aster tripolium			V,2-3	III,0-1	V,2-6	V,4-6	V,4-7	V,4-5	V,4-5	V,4-5	V,2-5	V,3-7	V,1-3	IV,0-3	V,1-2
Puccinellia maritima		IV,0-3	V,9-10	IV,0-4	V,8-10	V,5-9	V,6-9	V,5-8	V,4-5	V,3-4	V,8-9	V,4-9	V,8-9	V,6-8	V,2-5
Halimione portulacoides			II,0-5	III,0-2	III,0-5	IV,0-6	IV,0-4	V,4-8	III,0-6		III,0-3	II,0-4	III,0-2	II,0-2	V,9-10
Cochlearia spp.		II,0-1		IV,0-2									III,0-2		
Atriplex hastata				III,0-1											
Agropyron pungens	V,10	V,10		V,10	I,0-3										
Festuca rubra															
Plantago maritima															
Triglochin maritima															
Artemisia maritima															
Limonium spp.					I,0-1								II,0-1		
Spergularia marina													V,2-5		
Atriplex littoralis															
NVC community (SM)	24 Ag	24 Ag	13 Pucc	24 Ag	13 Pucc	13 Pucc	13 Pucc	14 Hal Pucc Sc	8 Sa	8/6 Sa/Sp	13 Pucc	13/11 Pucc/As	23 Pucc/ Sperg	13 Pucc	14 Hal Hal Sc

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