Fld Stud. (1970), 3, 331–356

THE CEFNI SALT MARSH, ANGLESEY, AND ITS RECENT DEVELOPMENT

By J. R. Packham and M. J. Liddle*
The Polytechnic, Wolverhampton

The Cefni salt marsh on the eastern side of the Malltraeth Estuary forms part of the Newborough Warren National Nature Reserve. Drainage and forestry operations during and since the Second World War have caused changes in the pattern of substrate deposition. The increased shelter and the rise in level were sufficient to enable *Puccinellia maritima* and other pioneer plants to invade a previously bare area of the Malltraeth Sands and by 1956 nearly five hectares of new marsh had developed; the plant succession is described. The new marsh and other areas have since been invaded by *Juncus maritimus* and *Spartina anglica*. The rapid spread of *Spartina* seems certain to change the present character of the marsh very considerably. In 1969 further extensive areas of the Malltraeth Sands were colonized by *Salicornia* and other pioneer plants.

Aerial photographs have been used in mapping the vegetation of the marsh whose soils, geology and drainage are briefly described. A list of birds observed on the marsh is given. Control of *Juncus maritimus* by cutting is discussed together with aspects of the biology of some of the more important pioneer plants.

CONTENTS

Introduction

The Newborough Warren National Nature Reserve in the South of Anglesey consists very largely of open sand dunes adjoining coniferous woodland managed by the Forestry Commission, but there is also a certain amount of salt marsh. The strip associated with the western side of the Braint Estuary has some interest, but is relatively narrow and the Cefni Marsh on the west of the reserve has a far greater area (Fig. 4). The salt marsh now forming behind Abermenai Point is eventually likely to rival the Cefni Marsh in size, but is at present still in the *Salicornia* stage.

South of Malltraeth Yard the River Cefni widens into a broad estuary which opens into Malltraeth Bay and is exposed to sea winds from the south and west. The estuary is shallow and at low tide the shining surface of the Malltraeth Sands is broken only by the deep river channel on the western side, where there are extensive low cliffs cut in the Coal Measures and Pre-Cambrian. On the eastern side of the

* Present address: University College of North Wales, Bangor, North Wales

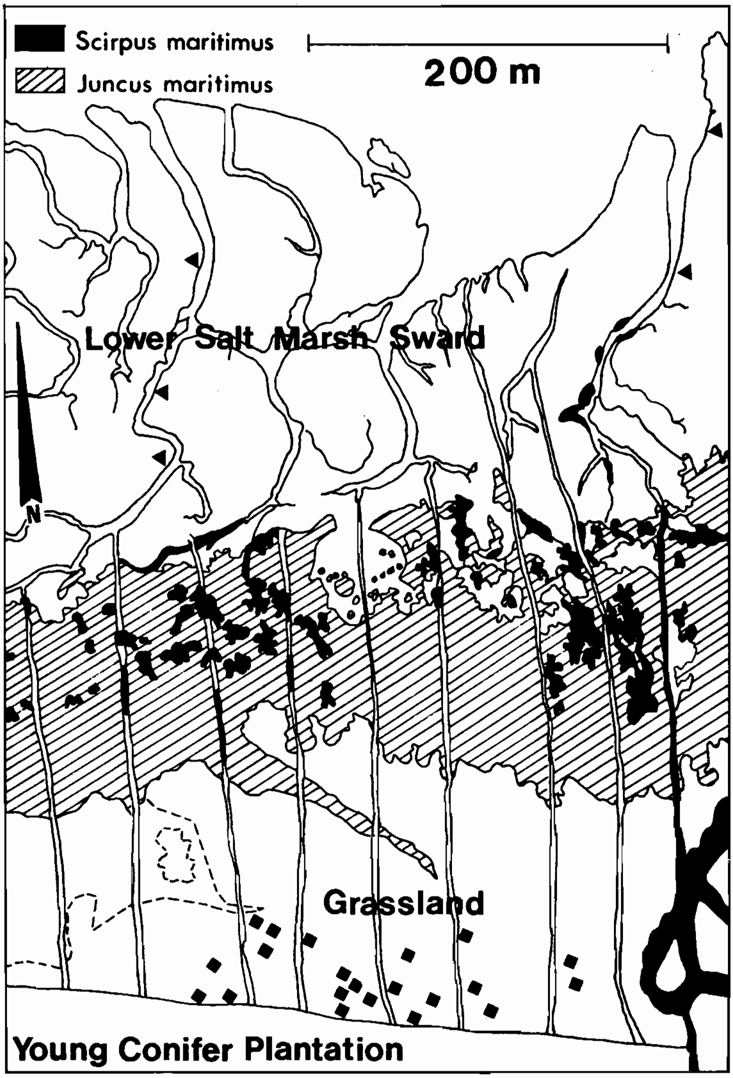

FIG. 2.
Interpretation of Plate 1: symbols as Fig. 1

estuary the shore runs slightly west of north from Llanddwyn Island, before curving east in an arc which finally swings north to Malltraeth Yard. Sand and silt deposited within this sheltered arc have gradually built up the region on which the Cefni Marsh has developed. Sand, including some eroded from the dunes to the south, has been carried by the wind to the developing marsh whose substrate is predominantly sandy at the southern end. It is probable that much of the finer material has been brought into the estuary by the Cefni, whose flow, together with drainage water running off the marsh, considerably dilutes the salt seawater.

The marsh, whose vegetation is shown in Fig. 1, measures almost 2·9 km. in a NNE–SSW direction and its maximum width, perpendicular to the general run of the shore, is about 500 m. A more detailed map of the plant zones is given

PLATE I.
Aerial photograph of a small portion of the Cefni Marsh (approximately 1:7000)

in Fig. 2. The landward edge of the marsh is formed by the seawall known as the Cob to the north, while the forest fence or margin of the main planted area bound it to the south.

Parts of the marsh have risen relatively rapidly in recent years and its main points of interest lie in the pattern of development, the types of colonization and the influences of drainage operations, forestry and the construction of wind breaks upon these two features. A number of records concerning these operations and their effects are available, as are aerial photographs taken since the Second World War. The map showing the zonation of the marsh is based upon direct observation and aerial photographs. A number of soil analyses have been made to help elucidate the development of the marsh which is in a very dynamic state and in which *Spartina* and *Juncus maritimus* are, as in the Braint Estuary, spreading rapidly.

Methods

Mapping

Aerial photographs taken on 1 June 1966 were used in making the vegetation maps. Differences in density on a single photograph were largely due to variations in water régime, the wetter areas appearing darker. The margin of such a damp area is indicated by a dotted line on Fig. 2. Stereo pairs of photographs are frequently used in distinguishing types of vegetation by characteristic textures (Olson, 1964) and this method helped in the initial stages. Conventional ground mapping along part of transect XY (Fig. 1) quickly provided a map of a small area for use in interpreting the aerial photographs. A number of random checks of the preliminary map were made by walking over the marsh with whole plate prints of the photographs and fixing positions at creek junctions. Observations along a small number of transects were especially useful when communities graded into each other.

The final large map was produced by mounting very large photographic prints on hardboard and drawing the boundaries between different types of vegetation with Indian ink. A tracing a metre long was then reduced photographically. The aerial photographs were of good quality, but had infra-red or ektachrome versions been available greater detail would have been visible and interpretation would have been easier. The orange tints produced in autumn by *Scirpus maritimus* came out very clearly in colour photographs taken from the Malltraeth Sands and such seasonal effects could well be exploited by aerial photographs in colour. The expense of such aerial colour photographs as we have seen appears to be thoroughly justified when working on vegetation of any complexity.

Transect XY was levelled with a survey staff and levelling telescope. When ranging poles were left at the transect posts so that the positions reached by high water spring tide could be marked on the very calm night of 24/25 September 1968, the maximum difference from the instrumental levelling at any point was only 0·1 ft. (0·03 m.).

Vegetation records

A number of general observations concerning the vegetation were found in reports held by the Nature Conservancy, Bangor, but the only consistent record over a period of time is that for the observation plot (Table 3). Table 2 is a provisional species list for the marsh showing environment and growth form. Table 4 gives cover values for the squares A, B, C and D whose positions are shown by Fig. 1.

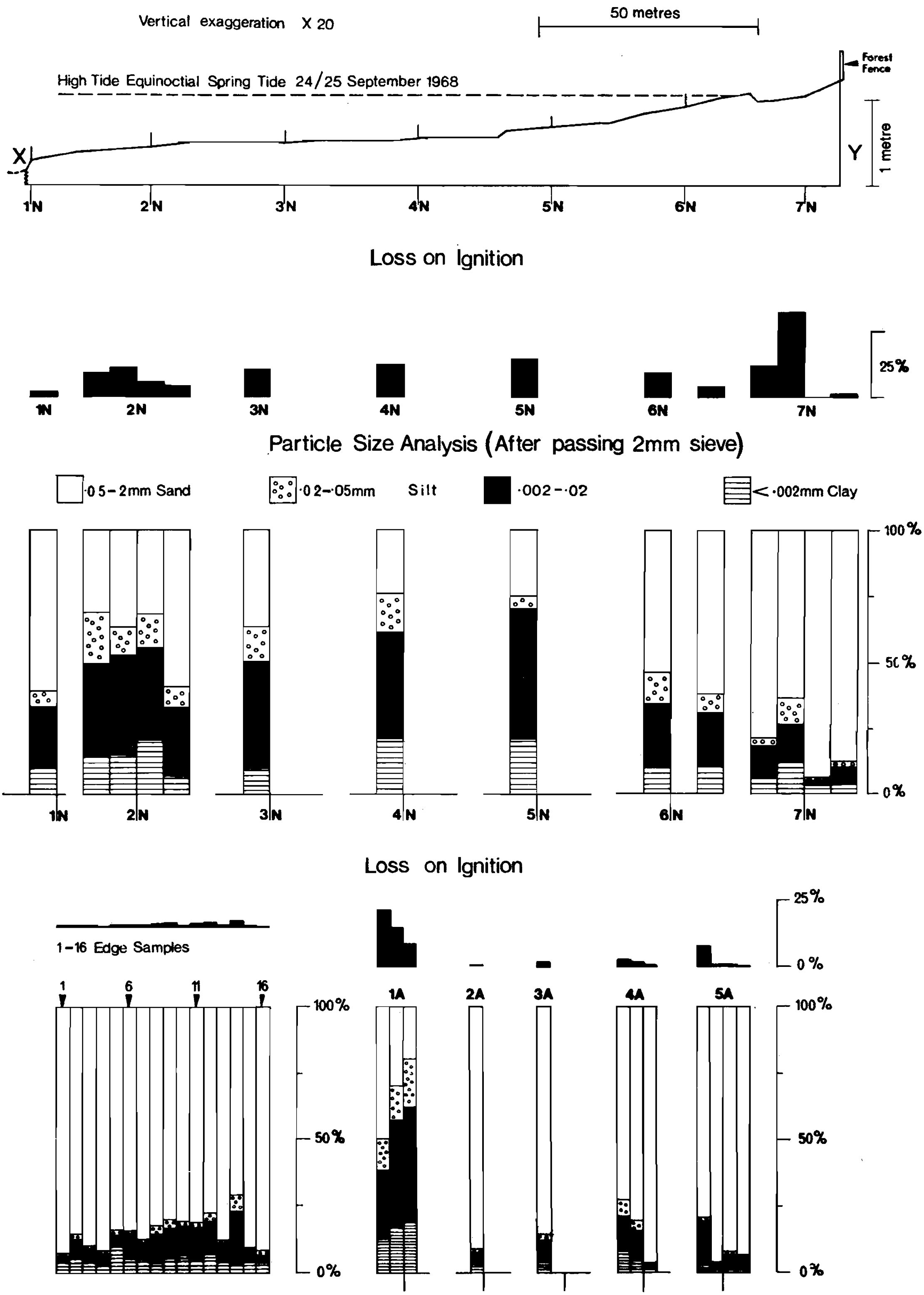

Fig. 3.

Relief of transect XY together with mechanical analyses and loss-on-ignition data for transect points 1N-7N, edge samples 1–16 and sites 1A–5A.

The edge samples were at 0–5 cm. depth and within 10 cm. of the colonized area. Samples from sites 1N–7N and 1A–5A were at 4–6 cm. (column on the left of each block), 9–11 cm., 19–21 cm., or 39–41 cm. (column on right of each block).

Table 1. *Vegetation and chemical analyses for sample sites N1–N7, 1A–5A*

The species shown were within 0.5 m. of the sampling points. Position 4A was adjacent to plot D. Position 5A was by the observation plot while 1A was in vegetation similar to that of Plot A

(1) 4–6 cm.
(2) 9–11 cm.
(3) 19–21 cm.
(4) 39–41 cm.

\+ present
. absent
va very abundant
ND not determined

Station	N1	N2				N3	N4	N5	N6		N7				1A			2A	3A	4A			5 A			
Depth	2	1	2	3	4	2	2	2	2	4	1	2	3	4	1	2	3	2	1	1	2	3	1	2	3	4
pH	7.9	7.8	7.5	7.9	7.9	7.7	7.5	7.3	6.5	6.6	5.8	5.7	6.3	5.6	6.1	5.8	6.2	8.2	7.7	7.7	7.6	8.4	6.9	8.0	7.7	8.1
Extractable Cations (meq/100g.) Ca		2.3	8.5	18.0	13.5	15.0	9.5	7.0	6.9	1.3	3.4	6.2	0.3	13.5						8.3	11.0	32.5	9.5	7.0	7.0	8.8
Mg		0.41	4.3	10.2	7.8	23.3	11.8	7.8	25.5	6.7	9.4	1.0	6.8	7.8						1.0	18.4	0.4	6.9	1.0	6.8	1.5
K		3.0	3.4	3.3	1.8	2.2	2.6	1.3	2.8	0.9	2.6	2.2	0.3	0.8						1.1	0.4	0.4	1.8	0.31	0.26	0.46
Na	ND	73.1	92.2	34.0	26.8	104.4	30.3	20.5	80.0	10.0	59.2	34.1	5.2	3.5						29.2	21.2	8.7	29.2	4.4	3.1	8.7
Mn		0.26	0.32	0.30	0.41	0.43	0.41	0.26	0.30	0.12	0.26	0.04	0.02	0.02		ND		ND	ND	0.09	0.04	0.04	0.12	0.04	0.04	0.04
Extractable P_2O_5 mg./100g.		6.9	9.2	6.2	4.6	6.8	6.4	5.5	5.5	12.5	5.9	5.8	7.3	8.2						5.2	6.9	1.7	8.2	1.7	3.4	2.5
Species																										
Agrostis stolonifera	.		.			.	+	+	va			+				.		.	.		.			.		
Armeria maritima	.		+			+	.	.	.			.				+		.	.		+			+		
Aster tripolium	+		+			+	+	.	.			.				+		.	.		+			+		
Atriplex sp.	.		.			.	+	+	.			.				.		.	.		.			.		
Carex extensa	.		.			.	.	.	.			+				.		.	.		.			+		
Festuca rubra	.		.			.	.	+	va			va				+		.	.		.			.		
Glaux maritima	.		.			+	+	+	+			+				+		.	.		.			+		
Holcus lanatus	.		.			.	.	.	.			+				.		.	.		.			.		
Juncus gerardii	.		.			.	.	.	.			+				.		.	.		.			+		
Juncus maritimus	.		.			.	.	.	va			+				.		.	.		.			+		
Leontodon autumnalis	.		.			.	.	.	.			+				.		.	.		.			.		
Oenanthe lachenalii	.		.			.	.	.	+			+				.		.	.		.			.		
Plantago maritima	+		+			+	.	.	.			.				+		.	.		.			+		
Puccinellia maritima	+		+			+	.	.	.			.				.		.	+		+			+		
Rumex crispus	.		.			.	.	.	+			.				.		.	.		.			.		
Salicornia sp.	+		+			+	.	.	.			.				.		.	+		+			.		
Scirpus maritimus	.		.			+	va	va	.			.				.		.	+		+			+		
Spartina anglica	va		.			.	.	.	.			.				.		+	+		.			.		
Spergularia media	+		+			+	.	.	.			.				.		.	.		+			.		
Suaeda maritima	.		.			.	.	.	.			.				.		.	.		+			.		
Triglochin maritima	+		+			+	+	+	+			.				+		.	.		+			+		

Each had sides 10 m. long. Twenty positions were defined in each square using pairs of random numbers and these were used as central locations for a ten point frame (sharpened pins of 3 mm. diameter at 6 cm. intervals). Records were obtained for top cover (200 points per square), cover repetition and the number of species touching each pin. Cover repetition, in which all intersects between the pin and parts of plants are noted, is of some value as a measure of yield (Kershaw 1964). Pins of large diameter give a larger number of such intersects than slender pins, but in this instance the measurements were purely comparative and intended to illustrate the variation which occurs in the lower salt marsh sward.

Fig. 5 gives records of the distribution of species in relation to micro-relief. These were obtained using a topograph of the kind described by Boorman and Woodell (1966). Steel welding rods 3 mm. in diameter and ground to a uniform length of about 64 cm. are pointed and used as pins in a frame on which a sheet of millimetre graph paper is glued to a board. The topograph can be levelled by means of the adjustable legs set in aluminium tubes. When the pins, which are at 2 cm. intervals, touch the surface of the ground, their tops accurately reflect the microtopography. A transparent setsquare is used to avoid parallax when determining the heights of the pin tops. The existence of small variations in topography in the 2 cm. gaps between the pins is acknowledged, but by ascribing to 1 $cm.^2$ areas the heights of the adjacent pins the general trend of plant distribution in relation to microtopography can be shown. A 500 cm. $\times$ 1 cm. transect was investigated and a point was allocated to the species occupying the major portion of each 1 cm. square. A second transect (300 cm. $\times$ 1 cm.) had the same topograph zero.

Soil analysis

Mechanical analysis was carried out after dispersal of soil aggregates in 25 ml. 5 per cent Calgon solution with 400 ml. water, shaken for approximately 2 hours. Particle size gradings for material not exceeding 2 mm. in diameter were determined by Bouyoucos hydrometer. Loss-on-ignition figures are for soils first dried at 105 °C, and then ignited at 375 °C for 16 hours, a procedure which avoids loss of structural water from clay minerals and which is believed to avoid any loss of carbon dioxide from carbonates (Ball 1964). No corrections are made to the figures which are good estimates of total organic matter.

Soil nutrients and pH were determined on air-dried samples. Exchangeable cations were analysed in neutral N ammonium acetate extracts at a 5 g. soil: 200 ml. extractant ratio: potassium and sodium by flame photometer; manganese, calcium and magnesium by atomic absorption spectrophotometer employing methods in use during 1969 in the Pedology Section, Nature Conservancy, Bangor. Extractable P_2O_5 was determined in N/2 acetic acid extractant at the same soil: solvent ratio, using a molybdate blue colorimetric method.

Topography, geology, drainage and soils

The landward side of the marsh is theoretically fixed by the upper limit of equinoctial spring tides, though man-made boundaries have been used in practice. The slope towards the estuary is very gentle apart from the northern region where erosion cliffs are present. Transect XY, shown in Fig. 3, is typical and here there is a rise of only 1·03 m. in the 186 m. from the edge of the shore to the forest fence. Even the Cob, which prevents the sea from flooding Malltraeth Marsh, is only a metre or two above the Cefni Marsh. Ridges on either side of the Malltraeth Estuary have a SW–NE trend and form part of the longitudinal drainage system of Anglesey. Before the Cob was built the distance, at high spring tides, between water flowing from the Malltraeth Estuary in the south and Red Wharf Bay in the north was only three miles. This valley is along the Berw line of faulting and it contains the largest tracts of marine alluvium found on Anglesey (Greenly 1919), but the situation on the Malltraeth Marsh is not known in detail and huge areas are covered by Pleistocene glacial drift, especially boulder clay, which is so extensive on Anglesey. The main rock ridge on the reserve (Fig. 4) consists of Pre-Cambrian volcanic rocks of the Mona complex, but blown sand extends from the Malltraeth (Cefni) Estuary to the Braint Estuary and the surface of the Cefni Marsh is largely formed from it. It seems likely, however, that borings would produce evidence of further marine alluvia and boulder clay beneath the marsh. Glacial drift occurs beneath most other parts of the reserve.

As the superficial deposits are largely sandy, drainage is good, but there is considerable variation in particle size gradings of the substratum in various parts of the marsh (Table 1 and Fig. 3), with silt being more common in the north. The depth at which the dark sulphide zone is encountered is critical as the roots of many plants do not thrive under such reducing conditions.

The drainage pattern is shown by Fig. 1. There is a large number of artificial ditches, which now drain the marsh and the conifer plantations behind it, as well as the more natural system present in parts of the lower salt marsh sward. After heavy storms ditches are often filled with sand swept down from the conifer plantations. Relatively fresh water is then discharged on to the surface of the marsh until the ditches are recut. A new ditch crossing the transect XY was cut in 1969 and it is likely that further ditches will be cut in the future. The rate of flow in streams from the "Rock Ridge" is considerable after heavy rain and they are often almost fresh as they cross the marsh.

Many parts of the lower salt marsh sward are heavily dissected by salt pans, from which trapped water evaporates in summer often producing conditions so saline that few plants can grow. Salt pans must have been present since the marsh began to develop and it is still easy to stumble into the deeper portion of an old pan largely overgrown by *Scirpus maritimus* or some other tall species. Primary salt pans develop as marshes are forming, a process now occurring in the young marsh where hummocks of wind and water-borne particles form around pioneer plants, such as *Puccinellia*, which slow the rate of flow and trap material between the leaves. Once a bare hollow has developed it tends to become gradually lower in relation to ground covered by vegetation. There is little to consolidate substratum which enters such a hollow and increased summer salinity discourages colonization.

Secondary pans form in the secondary marsh which commonly develops below and in front of erosion cliffs. Such a situation is developing in the northern eroded region of the Cefni Marsh. Yapp *et al.* (1917) described two further types of pan found in European marshes. Creek pans formed when vegetation dams off a minor creek or tributary and residual pans, developed when vegetation slowly grows across and breaks up the bare area of any other form of pan, are both present in this marsh. "Rotten spots", which are found in New Hampshire, U.S.A., where the

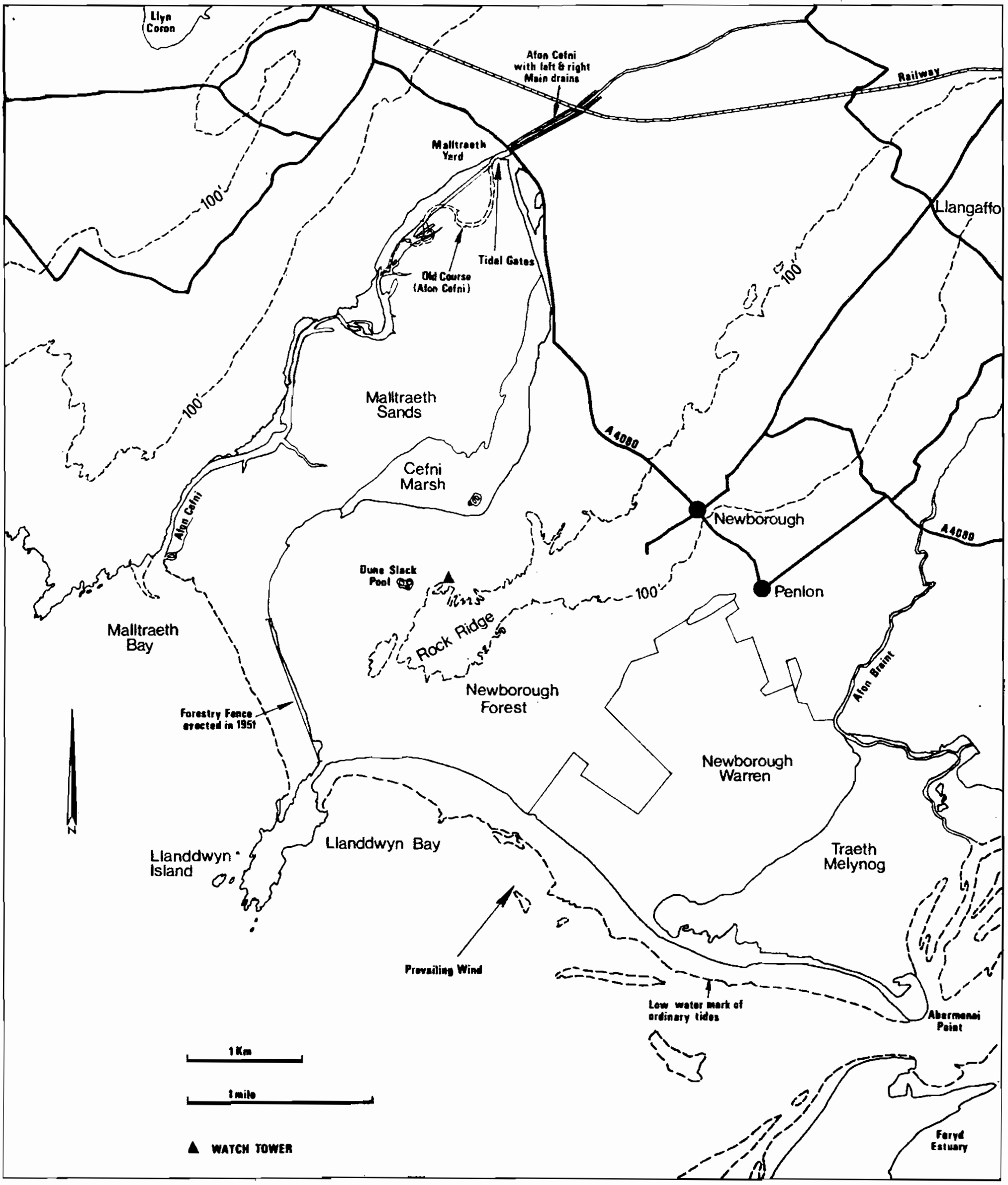

Fig. 4.
Map of the Newborough Warren NNR showing course of the River Cefni before and after straightening.

snow lies on the salt marshes for a long period every year (Chapman, 1960), are not found in Europe, but tidal litter may cause bared patches.

Loss-on-ignition figures (Fig. 3) show that there is a very low proportion of organic matter in the samples of uncolonized substratum taken along the shore margin, within 10 cm. of the colonized area. These samples also illustrate the general increase in silt content towards the north of the marsh. Sample 14 was taken from the base of a salt pan which now drains directly into the sea, while Sample 15 is from a position liable to scouring.

Table 1 provides information concerning soil reaction and nutrient content for soils which were dried very soon after collection, ground, and passed through a 2 mm. sieve. The pH of soils frequently inundated by the sea is seen to be high. There is a gradual fall in pH going up the shore from 1N to 7N along Transect XY, but soil reaction does not fall below neutrality until 6N is reached. One might expect a steady rise in pH down the profile due to leaching at 7N, but this did not occur. The forestry ditch cut near this position in 1969 showed that deposition here had been very intermittent, there being at least one fossil grassland soil level and two levels where old *Scirpus maritimus* rhizomes were very abundant, as well as relatively pure sand, within a depth of less than a metre. Material deposited during successive inundations varies and it is probably this which accounts for the rather random variation in extractable P_2O_5 levels with depth. Sodium concentrations are markedly greater in the shallower layers of all the profiles. The soils were collected in September 1968, during a period of very high tides (Fig. 3). It is known that sea water saturates the surface layers only during brief periods of flooding and it is the soil atmosphere trapped just below the substrate surface that enables many plants to survive.

There are variations in organic matter and hydrogen ion concentration, both tending to be greater in the older soils found on the higher ground, but it is difficult to find any consistent pattern of variation in soil nutrient distribution going inland from the margin of the estuary.

Although Sample 1A came from very near the eroded shore margin it was in a long established part of the marsh and not flooded so frequently as marginal areas to the south. The soil was rich in humus, had a relatively low pH and was more subject to leaching than other soils in the A series. 1A, which is near Plot A, is markedly rich in silt and also has a relatively high relief which favours *Festuca rubra* relative to *Puccinellia maritima*. In many estuaries *Spartina* is remarkable for its ability to establish in deep viscous mud, but it also thrives on sand as at 2A.

Profile pits and mechanical analyses along the Transect XY revealed considerable differences which are presumably related to changing sources of substrate. At 5N there was sloppy mud at 90 cm. Sand commenced at 28–36 cm. in Pit 6N, below material containing a good deal of drift, while the amount of silt and clay in the bottom of 7N was low. Sequences of four samples down to 40 cm. were taken for 2N and 7N whose loss on ignition figures contrast sharply. The low values for the bottom levels at 7N were the first indication of a sudden inundation of sand only the top of which had since been greatly enriched by organic material. The black sulphide layer was within 2·5 cm. of the surface at 1N, 5–15 cm. deep (uneven surface) at 2N and deeper further up the shore. The black zone is within a centimetre of the surface in some parts of the estuary.

THE VEGETATION AND ITS ZONATION

The Cefni Marsh and its drainage channels provide a wide range of microhabitats. Table 2 gives the life forms of the flowering plants observed and where they were found, the predominance of hemicryptophytes being especially noteworthy. Salt marshes in widely different parts of the world have hemicryptophytes as the dominant element and therophytes as the next most important group. This is probably true here also as some therophytes were undoubtedly missed. The main divisions of the vegetation, as it existed in 1966–1968, are shown in Fig. 1. This map is on a small scale and a number of vegetation types which can be distinguished on the ground are here placed together as "*Scirpus maritimus/Juncus maritimus* and components of the lower salt marsh sward". In many areas, including that shown in Fig. 2, the

Table 2. *Life forms of plants in relation to habitat*

s = Lower salt marsh sward
JS = *Juncus maritimus/Scirpus maritimus* area
FJ = *Festuca rubra* with varying amounts of *Juncus maritimus*
F = Grassland (mainly *Festuca rubra*)
l = Drift line or near it
B = Banks, hummocks and spoil heaps
M = Moist ditch margins, damp bases of large banks and pool edges
P = Pools, ditches, and streams

Where a species has more than one life form listed in Clapham, Tutin and Warburg (1962) both are included. The grassland habitat is under-recorded.

	Whole marsh	s	JS	FJ	F	l	B	M	P
Phanerophytes	6	1	—	2	1	1	3	—	—
Chamaephytes	10	3	1	2	—	—	8	3	—
Hermicryptophytes	68	12	13	29	7	19	40	17	—
Geophytes	6	2	2	3	1	1	5	3	1
Helophytes	16	7	4	6	1	3	3	8	2
Hydrophytes	4	1	1	1	—	1	—	1	3
Therophytes	14	2	3	3	2	3	9	4	—
Total species/life forms	124	28	24	46	12	28	68	36	6
Total species	105	22	21	41	12	26	58	29	5

Scirpetum maritimi is quite distinct from the Juncetum maritimi, although surrounded by it. Sea club-rush very often grows on ground a few cm. lower than that supporting *Juncus maritimus* and is consequently frequently flooded with brackish water, even when the ground has not been covered by the tide for several days. This agrees with the observations of Ranwell *et al.* (1964), who placed *Scirpus maritimus* in a group of plants characteristic of permanently wet or frequently submerged marshland sites. *Spartina anglica*, *Schoenoplectus tabernaemontani* and *Phragmites communis* also belong to this group. *Juncus maritimus*, on the other hand, was placed with *Agropyron pungens*, *Agrostis stolonifera* and *Juncus gerardii* in a category where soil moisture could fall as low as 20 per cent although the plant also grows in permanently damp sites on the Cefni marsh.

The concentrations of soluble nitrogen and phosphorus in soils in all parts of salt marshes normally lie in the same range, but the rare occurrence, small size and reddish tints of *Salicornia* plants found in the areas mapped as *Juncus maritimus/Scirpus maritimus* with small areas of grassland, suggest that shortage of available nitrogen and phosphorus may be an important factor in limiting the distribution of the genus in this region. Pigott (1969) points out that the main difference between the upper and the lower marsh from the nutrient point of view is that the soils of the upper marsh are already being exploited by perennial plants, so the amounts of nitrogen and phosphorus available to therophytes are greatly reduced. He also describes experiments on the upper marsh at Holme-next-the-sea, Norfolk, where a single addition of ammonium nitrate and sodium phosphate was made to plots containing *Salicornia europaea*. By late summer the *S. europaea* growing on these plots had grown larger and greener than the plants on the control plots. The phosphorus figures for the shallowest depth (4–6 cm.) sampled on the Cefni Marsh are not very high irrespective of whether *Salicornia* is present or not, but nutrient additions might enable the plant to compete more efficiently with the taller perennials.

Ranwell *et al.* (1964), working around Poole Harbour, recorded chlorinity tolerances for a number of species including *Spartina anglica* (2·44 per cent), *Juncus maritimus* (2·39 per cent.), *Schoenoplectus tebernaemontani* (1·71 per cent) and *Scirpus maritimus* (1·71 per cent). *Phragmites communis*, which has not been found on the Cefni marsh, had a much lower tolerance of 1·2 per cent chlorinity, compared with 2·12 per cent for normal seawater, and its minimum distance from the mouth of Poole Harbour was 5·3 km. These chlorinity tolerance determinations, made as a result of a large number of spot tests at 10–12 cm. depth, appear to have significance as far as the distribution of plants on the Cefni Marsh is concerned. Stands of *Schoenoplectus tabernaemontani* and *Scirpus maritimus* are found in areas where the water is brackish and although both occur at the edge of the shore they do not do so at the seaward, and thus more saline, end of the marsh where *Spartina* is becoming particularly well established.

The most interesting zone is that which is here given the name of lower salt marsh sward. This community includes a considerable number of species which are associated in various parts of the large area on the outer side of the marsh, producing a low growing vegetation whose appearance is very different from the tall *Juncus maritimus*/*Scirpus maritimus* community which is frequently found behind it. *Puccinellia maritima*,

Table 3. *Changes in the vegetation of the observation plot* 1956–1968

The location of the plot, a square of *c.* 16·8 m. side, is shown in Fig. 1.

Species	6.5.56	12·5·57	4.5.58	3.9.59	15.10.63	25.5.68
Agrostis stolonifera	.	.	.	.	.	r
Armeria maritima	.	r	r	.	va	va
Aster tripolium	f	a	a	va	va	f
Carex extensa	.	.	.	.	o	o
Cochlearia officinalis	o	o	la	.	.	o
Festuca rubra	.	r	o	o	f	va
Glaux maritima	la	la	la	la	va	lf
Juncus gerardii	.	.	.	r	la	r
Juncus maritimus	.	.	.	vr	o-r	f
Plantago maritima	.	.	f	f	va	va
Puccinellia maritima	d	d	d	ld	f-a	o-lf
Salicornia sp.	.	o	la	o	o	r
Schoenoplectus tabernaemontani	.	.	.	.	.	r
Scirpus maritimus	r	la	la	la	o	lf
Spergularia media	.	.	r	.	.	.
Suaeda maritima	.	.	.	r	.	.
Triglochin maritima	o	o-f	f	a	f	f
Cladophora sp.	ld	← l sub d			→ } 5	
Bare Ground (%)	10	2	1	5	}	} 4
*Filamentous algae	.	.	.	.	.	
	7	10	12	12	13	16

* Sample taken consisted mainly of *Microspora* and *Oedogonium*, with a very little *Zygnema* and *Oscillatoria*.
The first five observations by D. S. Ranwell.

. = not recorded d = dominant va = very abundant a = abundant f = frequent l = locally
o = occasional r = rare

Armeria maritima, *Plantago maritima* and *Festuca rubra* are very important members of the lower salt marsh sward, while *Triglochin maritima* and *Salicornia* sp. are often prominent. This community could be divided into smaller units for detailed work using objective methods, but the term conveniently describes a vegetation which is quickly recognized in the field, having a characteristic height and being composed of a number of species growing together at various densities (see Table 4).

There are areas of well developed *Festuca rubra* grassland on slightly higher ground at the southern end of the marsh, but elsewhere it is not so easy to divide the lower salt marsh sward into such units as Puccinellietum, General Salt Marsh and Festucetum rubrae, as is possible in the lower regions of other Welsh marshes (Chapman 1964). It may well be that the level of much of the relatively narrow area now occupied by the lower marsh built up rapidly, thus allowing many species to enter within a fairly short period. The fact that 15 species of higher plant became established so quickly in the observation plot discussed below illustrates such a trend.

Above and behind the tall *Juncus maritimus*/*Scirpus maritimus* vegetation is found *Festuca rubra* grassland with varying amounts of *Juncus maritimus*. These two communities grade into each other so the line separating them is somewhat arbitrary. The drift line is found in this upper fescue zone which also contains occasional damp areas occupied by *Scirpus maritimus*. A number of species, e.g. *Rumex crispus*, *Atriplex* sp. are frequently found growing on or near the drift, whose presence favours nitrophiles. Much of the drift consists of *Scirpus maritimus* debris.

The spoil from the artificial drainage ditches is relatively dry so that plants intolerant of excessive moisture are able to grow on it, while some interesting aquatic species are found in the ditches themselves.

At the southern end of the marsh is a considerable area of ground now occupied by *Juncus maritimus* in lower salt marsh sward. Much of this was bare sand less than 20 years ago when a rapid build-up was noticed. An observation plot was set up here by D. S. Ranwell on 6 May 1956, and Table 3 shows the changes in the composition of the vegetation which occurred between then and 1968. The observation site was bare of all flowering plants and macroscopic algae in 1951, when it appeared to be an inter-tidal bare sand area. Pioneer *Puccinellia maritima* entered the plot at some time between 1952 and 1954 and was the first higher plant invader.

Further south and also behind this region is a sand dune covered with *Ammophila arenaria*, a grass which is spreading quite rapidly at present. *Agropyron junceiforme* is well developed on the foredunes in the south. In the early summer of 1968 it was also extensively planted in a bare sand region stretching eighty metres towards the opposite side of the estuary from the southernmost portion of the salt marsh. By September nearly all the plants in the outer 35 m. had died, but the others were growing fairly well.

Halimione portulacoides is found near the bank of one of the more prominent creeks, while *Limonium vulgare* and *L. binervosum* agg. are scattered in a few places to the south of this. A number of species, e.g. *Juncus gerardii*, *Cochlearia* spp. and *Glaux maritima* have a wide, if local, distribution through the marsh. *Schoenoplectus tabernaemontani* is found in a few quite large patches in the wetter areas of the marsh as well as in the artificial pool dug to provide a breeding habitat for birds. Its major stands are usually rather exclusive but it is normally adjacent to *Scirpus maritimus* areas. In one case, where it is protected on the seaward side by a low sandbank, it is growing at the very edge of the shore. A few isolated plants are also present in the drier areas.

Table 4. *Cover records (%) for four plots on the lower salt marsh sward, September 1969*

Plot A was panned and at the highest level of any of the four plots, which were square and had sides 10 m. long. Plot B was much dissected by pans, C was unpanned and D slightly panned. The positions of the plots are shown in Fig. 1. Records were obtained for 200 points in each plot.

	Top cover				Species/point				Cover repetition			
	A.	B.	C.	D.	A.	B.	C.	D.	A.	B.	C.	D.
Armeria maritima	2·5	7·0	16·5	10·0	22·5	32·0	34·0	61·5	37·0	69·0	83·5	146·0
Aster tripolium	13·5	15·0	8·5	35·5	53·5	29·0	14·5	51·5	81·5	42·0	15·5	86·5
Festuca rubra	45·0	0·5	.	.	90·0	2·0	.	.	373·5	5·5	.	.
Glaux maritima	0·5	.	.	.	5·0	.	0·5	2·5	5·5	.	0·5	2·5
Juncus gerardii	.	.	.	0·5	.	.	.	0·5	.	.	.	1·5
Plantago maritima	5·5	24·5	0·5	14·5	17·0	47·0	1·5	27·0	24·0	81·5	3·5	45·0
Puccinellia maritima	.	13·5	53·5	13·0	.	55·0	84·5	43·5	1·0	118·5	229·5	82·0
Salicornia sp.	.	4·5	13·0	0·5	.	5·0	19·5	6·0	.	5·5	22·5	6·0
Spergularia media	.	0.5	0·5	1·0	.	3·5	5·0	7·5	.	5·0	6·0	10·0
Suaeda maritima	.	.	0·5	.	.	.	1·0	.	.	.	1·0	.
Triglochin maritima	31·5	34·5	4·5	23·0	59·5	56·5	8·0	40·0	111·5	123·0	10·5	71·0
Algae	.	.	2·0	.	.	1·5	54·0	11·0	.	1·5	54·0	11·0
Bare ground	1·5	.	1·0	2·0	.	.	.	.	1·5	.	0·5	2·0
Total	100	100	100	100	247·5	231·5	222·5	251·0	635·5	451·5	427·0	463·5

Until 1969 only *Spartina* had been able to establish in isolated positions on the bare sands well to the west of the present shore, but in that year *Salicornia* colonized much of this area. Once *Spartina* achieves a foothold the substrate often builds up quite rapidly even in exposed positions. If Spartinetum is subjected to severe wave-slap or swift running tidal streams it is eventually undercut, as are other types of vegetation. Filamentous algae are often present in the upper two centimetres of apparently bare sand and their importance in stabilizing this material should not be overlooked.

Ruppia spiralis is present in the streams running through the marsh from the Rock Ridge while *Ruppia maritima*, a submerged aquatic herb whose normal habitats are brackish ditches and salt marsh pools, is found in the salt pans near the sea. Its presence along the edge of the shore, often where streams flow into the estuary, is less usual, but in any given area of this marsh it is normally at a lower level than any other angiosperm. The height at which the plant occurs varies, but the positions in which it grows are invariably flooded or very damp on all save exceptional occasions and it is clear that a lack of tolerance to exposure greatly limits the distribution of this species, which is not uncommon in the lowermost regions of the more brackish marshes of continental Europe.

Biotic factors

Flowering plants are the main primary producers present on the marsh, although algae also make a contribution. Later studies should provide an estimate of the general productivity of the area and for this to be done much more detailed information will be required concerning the animals and other heterotrophs, especially decomposer organisms including fungi. Many aspects of the community relationships, ecological energetics and physiology of organisms living in estuaries discussed by Green (1968) have direct application to the Cefni Marsh area.

Even the relatively scanty amount of information now available concerning the sheer numbers of animals is sufficient to indicate the importance of the biotic factors which operate on the marsh. The salt pans often contain small fish together with shrimps, other crustaceans and annelids. As at Scolt Head Island, very big populations of the snail *Hydrobia ulvae* are present. Pitfall and other trapping have demonstrated that many primarily terrestrial invertebrate species, some of which also invade the lower marsh, live in the grassland and *Juncus maritimus*/*Scirpus maritimus* zone. Large numbers of spiders are often present, especially in parts of the lower salt marsh sward, though the number of species is restricted. Dr. P. A. Walker, drawing on his own collections and a preliminary list of Mackie (1964), has provided the list given in Table 5. *Protadia patula*, found in 1969, is particularly interesting as it is a species normally of a more southern distribution.

Of the many insects present one of the most interesting is the minute moth *Coleophora*, whose cigar-shaped silk larval cases can be seen in late summer on the capsules of *Juncus maritimus* and, often very near the shore, *Juncus gerardii*. *Coleophora obtusella* has been recorded on *Juncus maritimus*, while species known to eat the seeds of *Juncus gerardii* include *C. alticolella*, *C. glaucicolella*, and *C. adjunctella* (see Richards and Clapham, 1941). The relationships between *C. alticolella* and *Juncus squarrosus*, a very high proportion of whose seeds may be consumed by the moth, have been investigated by Jordan (1958) and by Reay (1959). Those between *Juncus inflexus*, *C. alticolella* and *C. glaucicolella* are described by Packham (1968). Although coleophorid moths consume large numbers of their seeds they do not appear to limit the spread of *Juncus inflexus* or *J. effusus* and preliminary observations suggest that the

Table 5. *Preliminary list of Cefni Marsh spiders.*
(*Nomenclature after Locket and Millidge, 1951 and 1953*)

Dictynidae	*Protadia patula* (Sim)
Lycosidae	*Lycosa nigriceps* Thor
Theridiidae	*Theridion pictum* (Walck)
	Robertus lividus (Bl)
Tetragnathidae	*Tetragnatha extensa* (L)
	Pachygnatha clerki Sund.
Argiopidae	*Meta segmentata* (Bl)
	Araneus diadematus Cl
	A. quadratus Cl
	A. cornutus Cl
Linyphiidae	*Hypomma bituberculatum* (Wid.)
	Maso sundevalli (Westr.)
	Oedothorax fuscus (Bl)
	O. retusus (Westr.)
	Perimones britteni (Jacks).
	Araeoncus humilis (Bl)
	Erigone arctica (White)
	Bathyphantes gracilis (Bl)
	Linyphia montana (Cl)

same is true of these two maritime rushes. As the food of the moths is so well defined and they usually eat all the seeds in a particular capsule it would be worth studying the ecological efficiency of the producer/herbivore conversion rates (Phillipson, 1966) of the species feeding on *J. maritimus* and *J. gerardii*. An interesting inhabitant of the *Juncus/Scirpus* zone is *Conocephalus dorsalis*, the only bush cricket found on Anglesey, which forms the most northerly station of this species on the west coast.

Relatively little is known concerning the mammals of the marsh. The long-tailed field mouse (*Apodemus sylvaticus*), short-tailed vole (*Microtus agrestis*) and the bank vole (*Clethrionomys glareolus*) have all been taken in traps set in the *Juncus/Scirpus* zone a few metres from the forest fence, while water voles (*Arvicola amphibius*) have been seen near the Marsh Pool. Myxomatosis was reported on the Newborough Reserve in August 1954 (Ranwell, 1960) and the rabbits, which had been farmed for centuries on the Warren, were greatly reduced in numbers. This virus disease flares up again from time to time and we did not observe any rabbits on the Cefni Marsh during the brief periods of our visits (1967–1969). Until 1967 it was not uncommon for cattle to break into the northern part of the marsh, but the fences have since been restored. The droppings of brown hares (*Lepus europaeus occidentalis*) were frequently found on the marsh and these animals were seen well out on the Malltraeth Sands.

Birds have received more attention than any other animals found on the Cefni Marsh, while Malltraeth Pool has for many years attracted a large and interesting bird population with waders being particularly prominent. In the course of time it tends to become overgrown, but in March 1970 was dredged out with the result that a number of birds returned to the area even while dredging was in progress.

Table 6 is based mainly on the observations of Mr. P. Hope-Jones (1965*a*), Mr. R. Arthur and Mr. J. P. Wilkinson. The scientific nomenclature and sequence follow Peterson *et al.* (1966). Some species occur in large numbers and only those which apparently fed, landed or swam on or over the areas are shown. Woodland birds such as tits and siskins occur on the wooded fringes of the marsh and in the willows near the artificial pool where many waterbirds can be seen. Montagu's Harrier originally had a breeding site on the marsh, but was last seen in 1964 when it bred in Newborough Forest. When tides are higher than usual many birds are forced up on to the salt marsh from the tidal flats. The distribution of birds in the estuary is being studied by Mr. R. Arthur, who has found evidence to show that the zonation which exists during periods of spring tides differs from that found during the neaps.

Table 6. *Birds of the Cefni Marsh and Estuary*
(*Nomenclature after Peterson, Mountfort and Hollom*, 1966)

			Marsh	Tidal sand flats
1.	Little grebe	Podiceps ruficollis	×	×
2.	Red-necked grebe	Podiceps grisegena	—	×
3.	Great crested grebe	Podiceps cristatus	—	×
4.	Cormorant	Phalacrocorax carbo	—	×
5.	Little egret	Egretta garzetta	×	×
6.	Grey heron	Ardea cinerea	×	×
7.	Spoonbill	Platalea leucorodia	×	×
8.	Canada goose	Branta canadensis	×	×
9.	Brent goose	Branta bernicla	—	×
10.	Greylag goose	Anser anser	×	×
11.	White-fronted goose	Anser albifrons	×	×
12.	Mute swan	Cygnus olor	×	×
13.	Whooper swan	Cygnus cygnus	×	—
14.	Bewick's swan	Cygnus bewickii	×	×
15.	Shelduck	Tadorna tadorna	×	×
16.	Mallard	Anas platyrhynchos	×	×
17.	Teal	Anas crecca	×	×
18.	Wigeon	Anas penelope	×	×
19.	Pintail	Anas acuta	×	×
20.	Shoveler	Anas clypeata	×	×
21.	Tufted duck	Aythya fuligula	—	×
22.	Common scoter	Melanitta nigraula	—	×
23.	Velvet scoter	Melanitta fusca	—	×
24.	Long-tailed duck	Clangula hyemalis	—	×
25.	Goldeneye	Bucephala clangula	—	×
26.	Red-breasted merganser	Mergus serrator	×	×
27.	Osprey	Pandion haliaetus	—	×
28.	Sparrowhawk	Accipiter nisus	×	—
29.	Hen harrier	Circus cyaneus	×	—
30.	Montagu's harrier	Circus pygargus	×	—
31.	Marsh harrier	Circus aeruginosus	×	—
32.	Peregrine	Falco peregrinus	—	×
33.	Merlin	Falco columbarius	×	—
34.	Kestrel	Falco tinnunculus	×	—
35.	Partridge	Perdix perdix	×	—
36.	Pheasant	Phasianus colchicus	×	—
37.	Water rail	Rallus aquaticus	×	—
38.	Moorhen	Gallinula chloropus	×	—
39.	Coot	Fulica atra	—	×
40.	Oystercatcher	Haematopus ostralegus	×	×
41.	Ringed plover	Charadrius hiaticula	×	×
42.	Golden plover	Pluvialis apricarias	×	×
43.	Grey plover	Pluvialis squatarola	×	×
44.	Lapwing	Vanellus vanellus	×	×
45.	Turnstone	Arenaria interpres	×	×
46.	Little stint	Calidris minuta	—	×
47.	Pectoral sandpiper	Calidris melanotos	—	×
48.	Dunlin	Calidris alpina	×	×
49.	Curlew sandpiper	Calidris ferruginea	×	×
50.	Knot	Calidris canutus	—	×
51.	Sanderling	Calidris alba	—	×
52.	Ruff	Philomachus pugnax	×	—

53.	Spotted redshank	Tringa erythropus	×	×
54.	Redshank	Tringa totanus	×	×
55.	Greenshank	Tringa nebularia	×	×
56.	Green sandpiper	Tringa ochropus	×	—
57.	Common sandpiper	Tringa hypoleucos	×	×
58.	Black-tailed godwit	Limosa limosa	×	×
59.	Bar-tailed godwit	Limosa lapponica	—	×
60.	Curlew	Numenius arquata	×	×
61.	Whimbrel	Numenius phaeopus	×	×
62.	Woodcock	Scolopax rusticola	—	×
63.	Snipe	Gallinago gallinago	×	×
64.	Jack snipe	Lymnocryptes minima	×	—
65.	Avocet	Recurvirostra avosetta	×	×
66.	Grey phalarope	Phalaropus fulicarius	—	×
67.	Little gull	Larus minutus	—	×
68.	Black-headed gull	Larus ridibundus	×	×
69.	Lesser Black-headed gull	Larus fuscus	—	×
70.	Herring gull	Larus argentatus	×	×
71.	Greater black-backed gull	Larus marinus	—	×
72.	Common gull	Larus canus	×	×
73.	Kittiwake	Rissa tridactyla	—	×
74.	Sandwich tern	Sterna sandvicensis	—	×
75.	Common tern	Sterna hirundo	—	×
76.	Arctic tern	Sterna paradisea	—	×
77.	Guillemot	Uria aalge	—	×
78.	Wood pigeon	Columba palumbus	×	×
79.	Stock dove	Columba oenas	×	×
80.	Cuckoo	Culculus canorus	×	—
81.	Barn owl	Tyto alba	×	—
82.	Short-eared owl	Asio flammeus	×	—
83.	Swift	Apus apus	×	×
84.	Kingfisher	Alcedo atthis	—	×
85.	Green woodpecker	Picus viridis	—	×
86.	Shore lark	Ereomphila alpestris	—	×
87.	Skylark	Alauda arvensis	×	×
88.	Sand martin	Riparia riparia	—	×
89.	Swallow	Hirundo rustica	×	×
90.	House martin	Delichon urbicca	—	×
91.	Richard's pipit	Anthus novaeseelandiae	×	×
92.	Meadow pipit	Anthus pratensis	×	×
93.	Rock pipit	Anthus spinoletta	×	×
94.	Grey wagtail	Motacilla cinerea	—	×
95.	Pied wagtail	Motacilla alba s. sp. yarrellii	—	×
96.	White wagtail	Motacilla alba s. sp. alba	—	×
97.	Wren	Troglodytes troglodytes	×	×
98.	Dunnock	Prunella modularis	—	×
99.	Grasshopper warbler	Locustella naevia	×	—
100.	Sedge warbler	Arcrocephalus schoenobaenus	—	×
101.	Reed warbler	Arcrocephalus scirpaceus	×	—
102.	Willow warbler	Phylloscopus trochilis	×	—
103.	Goldcrest	Regulus regulus	×	×
104.	Whinchat	Saxicola rubetra	—	×
105.	Stonechat	Saxicola tarquata	×	×
106.	Wheatear	Oenanthe oenanthe	×	×
107.	Robin	Erithacus rubecula	—	×
108.	Fieldfare	Turdus pilaris	×	×
109.	Blackbird	Turdus merula	×	—
110.	Redwing	Turdus iliacus	—	×
111.	Misselthrush	Turdus viscivorus	×	×
112.	Longtailed tit	Aegithalos caudatus	×	×
113.	Coal tit	Parus ater	×	—
114.	Blue tit	Parus caeruleus	×	—
115.	Great tit	Parus major	×	—
116.	Reed bunting	Emberiza schoeniculus	×	—
117.	Snow bunting	Plectrophenax nivalis	×	—
118.	Chaffinch	Fringilla coelebs	—	×
119.	Greenfinch	Carduelis chloris	×	×
120.	Siskin	Carduelis spinus	×	—
121.	Goldfinch	Carduelis carduelis	—	×
122.	Twite	Acanthis flavirostris	×	—
123.	Linnet	Acanthis cannabina	×	×

124. House sparrow	Passer domesticus	—	×
125. Starling	Sturnus vulgaris	×	×
126. Magpie	Pica pica	×	—
127. Jackdaw	Corvus monedula	—	×
128. Rook	Corvus frugilegus	×	×
129. Carrion crow	Corvus corone	×	×
130. Raven	Corvus corax	×	×

Wigeon, which are normally present for the first three months of the year, graze on the lower salt marsh sward. On one occasion in early 1970 as many as 2,750 were present on the estuary, though only some of these fed on the marsh. During August and early September up to 150 Canada geese graze on the marsh in company with various other birds. Wood pigeons have increased as the forestry plantations have matured and they now join the ducks and geese as important herbivores of the lower salt marsh sward. Observation suggests that the grazing pressure exerted by the birds is considerable and the phosphorus and nitrogen contained in their faeces, which in the case of the geese are often deposited far out on the sands, represent significant additions to the scanty supplies of these elements. Exclosure experiments to observe any changes which might occur if grazing by birds and small mammals were prevented in various parts of the marsh would produce results of considerable interest.

Observations concerning plants growing on the marsh

Effects resulting from height variations and drainage conditions influence marsh plants differentially, a point illustrated by Table 4 and Fig. 5. Three types of cover record are given in Table 4. Top cover favours the tallest species while the species/point column prevents under-recording of such low-growing forms as *Glaux maritima.* Within certain limitations cover repetition is said to provide a measure of yield and the fact that Plot A, which had the thickest vegetative cover, had the highest score supports this view. Plot A had the highest ground level of the four plots and a conspicuously high score for *Festuca rubra.* The salt pans of Plot A were deep and the drainage of the general vegetated surface was good. Plot B had a relatively even surface which was much dissected by salt pans, whose depths were intermediate between those of Plots A and D. Drainage of Plot B was quite good while that of Plot D, which was rather flat, was bad. Plot C had a considerable number of hummocks. Its drainage was not good and the low areas will probably develop into salt pans in the near future. The surfaces of all these plots were uneven, but while the mean altitudes of B, C and D, as determined from a comparison with water levels, appeared to lie within a maximum range of 15 cm., that of A was at least 15 cm. above B.

Two short transects near Plot C, in a region where *Festuca rubra* occurs intermittently, were used for the microtopographic records shown in Fig. 5. The distribution of the plants is influenced by two scales of relief, the relatively minor variations within each transect and a more major rise which accounts for a difference of 148·6 mm. between the transect means, leading to major differences in the numbers of the various species present. The order in which the mean species altitudes occur, with the lowest on the left, is paralleled for the two transects by *Salicornia, Puccinellia maritima, Armeria maritima* and *Festuca rubra.* The distribution of *Armeria* is markedly different from that of *Festuca* however, in that some individuals occurred well below the transect mean, while *Festuca,* which responds very adversely to bad drainage and

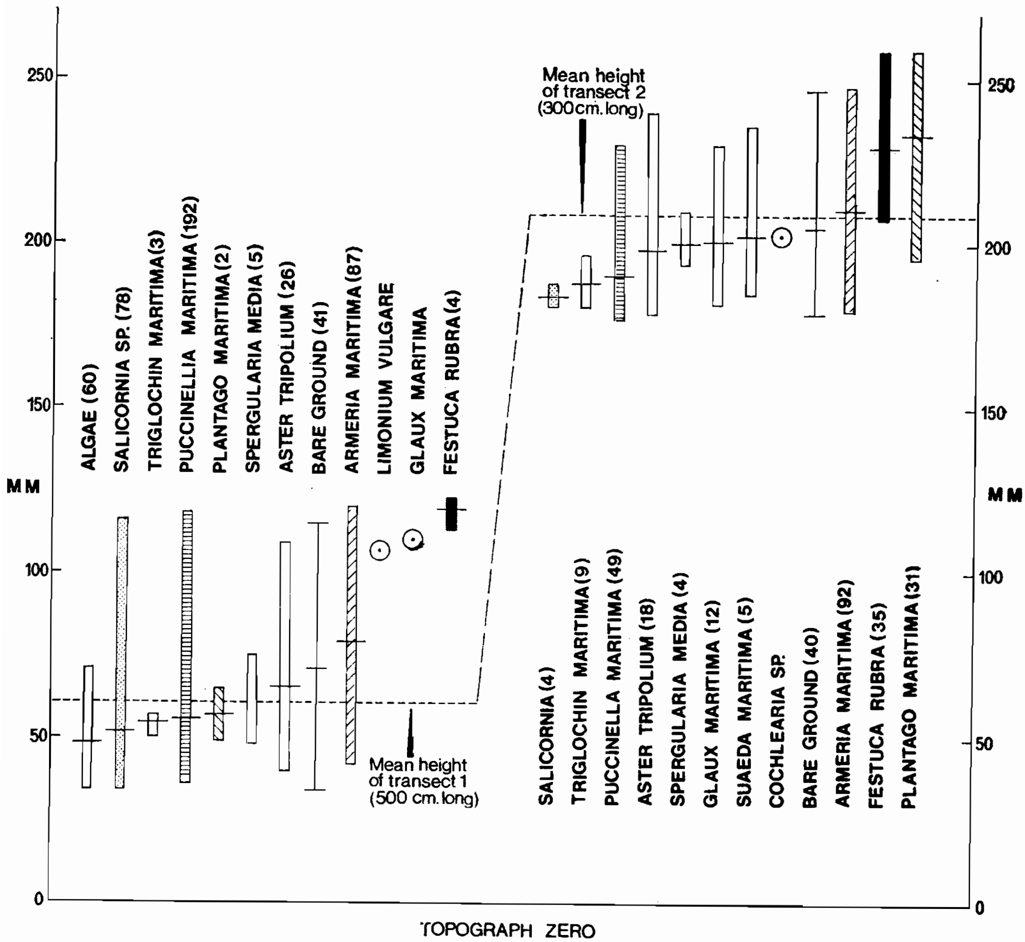

FIG. 5.
Distribution of species in relation to microtopography.
The two transects were both near to plot C (see Fig. 1) and were 12·3 m. apart. A levellng telescope was used to maintain constant topograph zero. The mean transect altitude of each species is indicated by a horizontal line. Where a species predominated in more than one square, the number of 1 cm. squares it occupied is given.

poor soil oxygenation under experimental conditions (Piggott, 1969), is here entirely restricted to the higher levels.

Puccinellia is frequently found in low hollows and is known to be able to endure poor oxygenation, but even this species may be killed if the dark reducing layer, rich in sulphide, which frequently occurs in salt marsh soils rises too near the surface. Ranwell (1956) found that roughly circular patches between 120–150 cm. in diameter developed on the new Puccinellietum in three or four years. When such patches are sectioned with a spade the previous levels of rhizome development can be seen. Differences between successive rhizome levels indicate that the speciesc an easily tolerate an annual accretion rate of 5 cm. The lowermost rhizome levels are sometimes in the black sulphide layer, but from the behaviour of living plants it can be inferred that the substrate surrounding them was better aerated when they were alive. *Puccinellia maritima* is thought to be apomictic (Hubbard, 1968) and to produce few viable seeds in this country, but spreads rapidly by vegetative propagation and tillering.

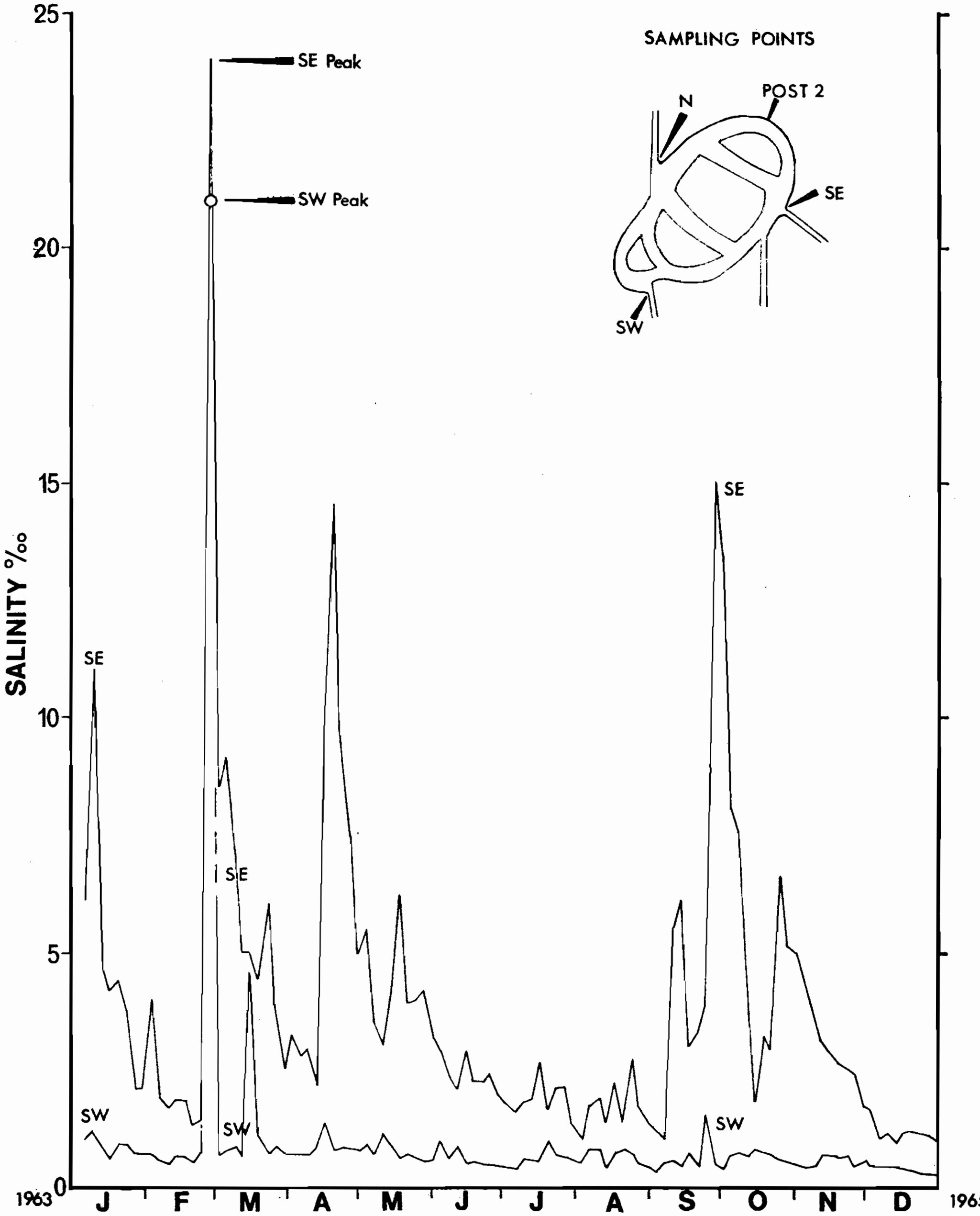

Fig. 6.
Salinity variations for the south-east and south-west positions at the Cefni Marsh Decoy Pool during 1964.

Salinity is one of the major habitat factors and analyses of the water at the Marsh Pool (Fig. 6) and the Dune Slack Pool were made during the whole of 1964 (Hope-Jones, 1965*b*). The salinity of the Dune Slack Pool, which has no direct connection with the sea was low, varying between 0·132 and 0·296 ‰. There appeared to be a good correlation between rainfall and salinity while the tides may have exerted a minor influence. The salinity of the Marsh Pool, where occasional high tides cause sea water to flow up the northern outlet ditch, is greater and of considerable interest as stands of *Schoenoplectus tabernaemontani* and *Scirpus maritimus* in the pool are both able to survive periods when salinity is quite high. Samples were taken at the four points shown in Fig. 6 and the results for the south-east and south-west stations are plotted. Both were thought to receive water draining off the nearby marsh but the results indicate that the south-east station is affected much more strongly by tidal inflows which are, as expected, most extreme near the equinoxes. The diagram brings out the fluctuations caused by the cycle of spring and neap tides that affects the plants of the marsh to differing extents.

The ecology of invasions by animals and plants is a fascinating subject, reviewed by Elton (1958). Two halophytes which have spread rapidly within the marshes of the reserve are the sea rush (*Juncus maritimus*) and cord grass (*Spartina anglica*), both of which reproduce effectively by seed and by vegetative propagation. These plants compete so strongly with other salt marsh angiosperms that under some conditions they produce semi-exclusive and uniform stands in areas formerly occupied by the lower salt marsh sward, an interesting and attractive community containing many species, which can easily be traversed on foot. It would, therefore, be in the interests of conservation to control the spread of both species.

Control of Juncus maritimus *by cutting*

Juncus maritimus has been growing in the area for centuries, but in view of its recent rapid spread a control measure has been sought which will not affect other species too severely. Experiments by the Nature Conservancy have shown that ploughing effectively eradicates sea rush, but has the disadvantages of requiring heavy equipment and causing considerable upheaval of the soil. Cutting, on the other hand does not necessarily need heavy equipment or disturb the soil, and for this reason its use as a control measure was investigated. The area used was on the Braint Estuary and its position is shown in Fig. 1. Two sites, one more exposed than the other, bearing large, fairly homogeneous stands of sea rush were used. Each was divided into ten plots and each of the following treatments was used on four plots:

A. Control.
B. Cutting at 15 cm. above the ground at the end of April.
C. Cutting at ground level at the end of April.
D. Cutting at 15 cm. above the ground at the end of June.
E. Cutting at ground level at the end of June.

Before cutting was carried out 5 random samples of the aerial parts of rush were removed from each plot. The sums of the biomass of these samples were in the order B> D> E> C> A for the various treatments, but only A (control) was significantly beneath the average. The limits of the *Juncus maritimus* stands were plotted using plastic markers in 20 positions per treatment. The average vegetative spread for each, i.e. distance between markers for the end of April and the end of September is shown in Table 7 along with dry weights of the aerial shoots and the number of new stems per rhizome extension.

Cutting at ground level was considerably more effective than at 15 cm. in producing severe reduction in dry weight of aerial shoots at the end of the season. When carried out at the end of June it entirely prevented seed formation, so cutting near to the ground in summer is likely to be an effective means of reducing the rate of spread.

Table 7. *Results of the* Juncus maritimus *cutting experiment on the Braint Estuary. 1968.*

Harvesting carried out at the end of September, 1968
GL = Ground level Sample area per treatment of 20 sq. ft. = 1.858 m².

Cutting treatment	not cut	15 cm. April	GL April	15 cm. June	GL June
Dry weight of aerial shoots g/m.² ..	636·9	556·9	254·9	279·5	127·8
Mean increase in rhizome length (cm.)	5·20	5·56	5·71	3·77	3·72
Mean no. new stems/ rhizome extension	3·40	3·50	3·45	2·45	2·15

Invasion by Spartina

A revised account of *Spartina* species found on British coasts is given by Hubbard (1968), who also provides details of other British grasses. Because of the chromosome numbers described for its various species the relationship between *Spartina* and other members of the Chlorideae was in doubt until Marchant (1963) issued corrected numbers for the British species which fitted into the pattern found in the rest of the tribe. *S. maritima* ($2n = 60$) is a native grass, found in tidal salt marshes,which almost certainly hybridized with the American species *S. alterniflora* ($2n = 62$) to produce the male sterile hybrid S. ×*townsendii* ($2n = 62$), first collected from Southampton Water in 1870. *S. anglica* ($2n = 122$) is a most vigorous amphidiploid which is believed to have arisen naturally from *S.* ×*townsendii* by chromosome doubling. Various derivatives of the *S. alterniflora* and *S. maritima* cross have been used in reclamation schemes in many parts of the world and have been estimated to cover a total area of 21,000 to 27,000 hectares (Ranwell, 1967). *Spartina* was first noticed in the Cefni Marsh in 1957, or possibly a year or two earlier, and was growing in the Puccinellietum. It is very firmly established in the Foryd estuary across the Menai Straits. *S. anglica* is now present in many parts of the reserve and it appears to have arrived by natural means. New colonies of the grass frequently establish from pieces of rhizome swept round the coast, but many of the new plants in established marshes grow from seed.

Control can be achieved on a field scale using a Dalapon (formulation of sodium salt of 2, 2-dichloropropionic acid) spray and a wetting agent, but costs up to £50 an acre (Ranwell, 1967). Cord grass has spread so extensively in the Cefni estuary that to control it now would be uneconomic and very large areas will soon be Spartinetum.

The use of aerial photographs in mapping vegetation is well established and it is often possible to use photographs taken for other purposes, as on this occasion. In 1964, however, an attempt was made to map the distribution of *Spartina* clumps in the Cefni Marsh single handed using conventional ground survey. Despite six weeks labour (Davies, 1965) it was impossible to complete the work, which would have been a useful guide to the rate of spread of the grass. Aerial photography from a low level, using plastic sheets as markers to aid location, would have finished the main task in an hour or two. If such surveys were carried out at three-year intervals a most valuable record would be obtained. When money cannot be provided for such work the most cost effective way of recording invasions by flowering plants seems to be by walking over the ground making general observations, followed by the production of detailed maps and assessments of a few key areas in which the sequence of events is followed closely.

Recent development of the marsh

Drainage undertakings, especially those in connection with Malltraeth Marsh, which extends six miles north-east from Malltraeth Yard to Llangefni have influenced sedimentation in the Cefni Estuary. Works designed to reclaim Malltraeth Marsh were provided for in Acts of Parliament passed in 1788, 1790, 1811 and 1859. The drainage system was often neglected but, as described in the Malltraeth Marsh report (1950), it was put in order during both World Wars when efforts were made to increase agricultural efficiency. Even in 1946, however, the system was virtually a renovation of that produced by Telford. The Afon Cefni runs through the whole of Malltraeth Marsh in a long artificial cut and is prevented from flowing into the marsh by embankments, on either side of which are the Left and Right Main Drains, statutory rivers in themselves, which discharge to the estuary through tidal gates at Malltraeth Yard. The various improvements in draining the Malltraeth Marsh will have increased the amounts of sediment swept into the estuary. The straightening of the river after 1945 diverted more of the channel to the western side of the estuary leaving calm water suitable for rapid sedimentation near the Cefni Marsh. Most of the silt at the northern end of the marsh has been deposited there by water currents.

In 1951 the Forestry Commission built a fence along the south-west dune foreshore in order to recreate a dune barrier which would protect the plantations further inland, and which could later be stabilized with marram. At that time the southernmost track shown on Fig. 1 went westwards through the Commission's land before turning south-south-west over the bare Malltraeth Sands. Within two years occasional plants of *Puccinellia maritima* appeared near where the path ran on to the foreshore, having presumably spread from the main area of lower salt marsh sward to the north-east. In 1956 (Ranwell, 1956) the area of the new Puccinellietum was nearly five hectares. It was some 100 metres wide in places and had grown along the old shore towards the south-west and north-east. Spread towards the south-west continued for some time and there was a slow rise in level associated with the general plant succession in the region of the observation plot.

Fig. 4 shows the position of the forestry fence in relation to the marsh, whose new southern region is now colonized by *Juncus maritimus* in lower salt marsh sward. The foreshore sand ridge which runs out across the estuary from the western corner of the dunes seems to be a relatively recent feature built up by sand drifting along the foreshore from the south-east. This process was almost certainly accentuated by the forestry fences and when the wind is slightly south of south-west sand is moved in a northerly direction towards the area of build up. The movements of sand which occur in this part of Anglesey are very considerable. Ranwell (1958) found that a three-day summer gale, with speeds up to 40 knots, caused changes of level in partially vegetated dunes of 0·4 m. The shelter afforded by the foreshore sand ridge, part of which is the area planted with *Agropyron junceiforme* in 1968, tended to still the movement of the water and sand, thus causing the rate of sedimentation to increase. The rise in level facilitated the rapid spread of *Puccinellia maritima* whose presence further slowed the rate of water movement.

After the gales of March 1968 a great deal of fresh sand was found along the shore near the centre of the marsh where the lower salt marsh sward is widest. Growth is still occurring near this point where fixation is by *Salicornia*, *Puccinellia* and green algae. On 30 March 1968, the vegetation of the previous season was still present, though mainly buried. The 1967 vegetated surface was covered by 8 cm. of sand in many places. Accretions of this order are stabilized by the upward growth of *Puccinellia* clumps or the development of new populations from seed or by vegetative propagation. In 1969 there was a very considerable northerly extension of the area colonized by *Salicornia* and it seems likely that the margin of the marsh will advance rapidly westwards in the next few years.

Salicornia, *Spartina* and *Puccinellia* are the main angiosperm pioneers of the Cefni Marsh and they frequently occur together. In some freshly colonized areas, however, one of these plants occurs alone or at markedly higher cover values than the others. Isolated plants of *Spartina* develop much further from the shore than do new clumps of *Puccinellia*, which are thought to arise when fragments of existing stands are carried relatively short distances along the shore. It is known (Wiehe, 1935) that *Salicornia* requires a threshold time of 2 or 3 days undisturbed by tides if a dense population is to establish from seed. Periods of this length during which the sand remains uncovered may not occur frequently at suitable seasons of the year. When they do occur *Salicornia* is likely to colonize fresh areas, whereas in other years the tides drag seedlings from their anchorages before adequate root systems have developed.

The margin of the marsh gives a good indication of how it is developing now. At the southern end it slopes gradually on to bare sand in most places and this is typical of regions where active colonization is proceeding. The lower salt marsh sward with *Juncus maritimus* area is very low lying and has a gently sloping margin with the sand. Cliffs between 15 and 60 cm. high are frequent in places where erosion is occurring. The cliff edges often slump into the sea and are secondarily colonized by the more halophytic species. Erosion occurs near the mouths of creeks throughout the marsh due to the rapid flow of drainage water from the land, particularly after heavy rain. The mouths of most of the watercourses swing towards the north and erosion is most marked on their northern edges.

The marsh seems to be building out from the shore in most places south of the northernmost fence, which has a large patch of *Schoenoplectus tabernaemontani* (shown in Fig. 1) at its shoreward end. For nearly 500 m. to the north the shore is eroding quite badly with a well-marked cliff and a rapid drop to deeper water from the edge of the shore. In many cases this has caused salt pans to become free draining and they are now being re-colonized. To the north of the erosion cliff is a further area of accretion, although erosion is occurring where the northernmost creek runs out almost parallel to the Cob. The seaward side of the Cob, completed by Telford at the beginning of the nineteenth century, is protected against wave slap by an old cover of lichen-encrusted stones which has been buried beneath the marsh in many places.

The development of the marsh has been characterized by movement of soil particles through wind and water action, modified or halted in areas where colonization by plants has occurred. The waters of the estuary are often very calm, so much so that in winter sheets of ice a few mm. thick may be hundreds of metres long, and under these conditions erosion is minimal. When gales sweep up the Malltraeth Estuary from the south-west the picture is very different. Free sand is actively and rapidly swept over the surface in air or water currents, while water flowing from the creeks is driven north along the shore which it often undercuts. Apart from the summer and early autumn neaps when it sometimes dries out, water is always present in front of the northern erosion cliff so that erosion by water can occur at almost any time. When the tide is rising the wind, driving in from the sea and with a long fetch over the estuary, causes choppy waves to drive into the area which is being eroded near the north of the marsh.

Topography, because it largely controls the periods during which the plants are exposed or submerged, is an important factor in determining the zonation. Drainage is generally good on the sandy areas, but waterlogging in areas of low relief favours *Puccinellia maritima* where it is in competition with *Festuca rubra*. The absence of grazing promotes the continued development of *Juncus maritimus*. The species could be limited by cutting, but the use of sheep would probably afford a satisfactory control and one which could be integrated with the future development of the reserve provided care was taken to leave the decoy pools undisturbed.

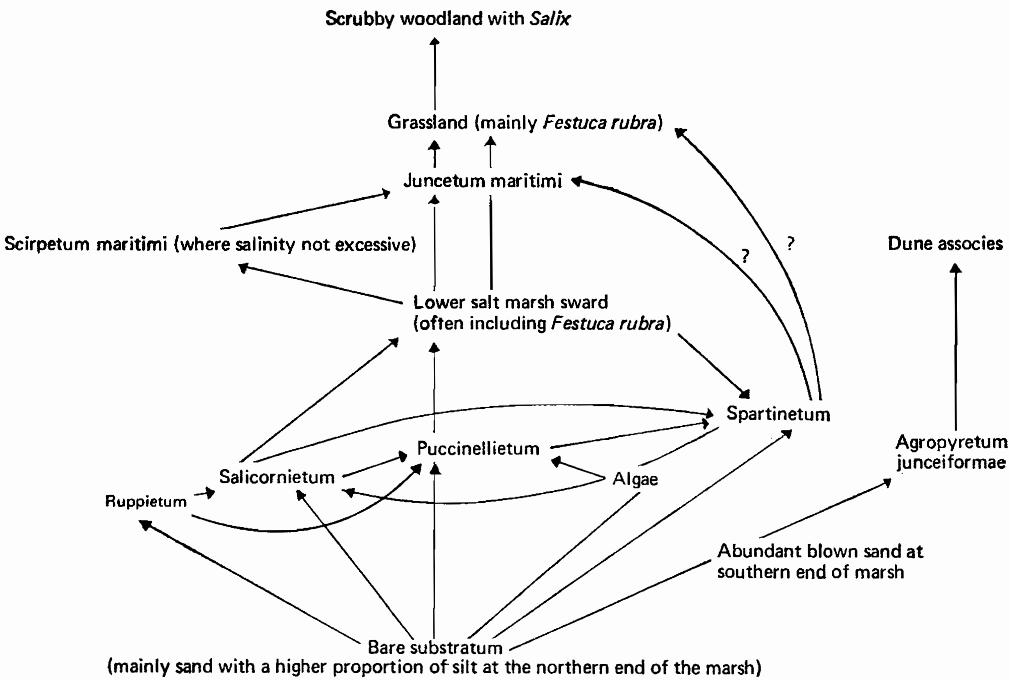

Fig. 7.

Generalized succession for the Cefni Marsh.

In a few parts of the shore where conditions are often brackish *Scirpus maritimus* acts as a primary colonizer.

Under the present system of management the spread of *Juncus maritimus* and *Spartina* is likely to continue and the lower salt marsh sward, as a proportion of the existing marsh, can be expected to diminish. A generalized succession for the Cefni Marsh is shown in Fig. 7. Ranwell (1967) points out that *Puccinellia* is usually overlapped by *Spartina* for the lower four-fifths of its range and that the replacement of the taller grass by *Puccinellia* on areas grazed by sheep at Bridgwater Bay, Somerset, began some 20–30 years after the *Spartina* plantation was established. Had conditions on the estuary side of the Cefni Marsh been as saline as is common in the lower regions of many marshes, this type of replacement could have been expected to occur. On the Cefni Marsh, however, the distribution of the various species makes it clear that the salinity gradient is not so extreme as it is in many marshes while *Festuca rubra* can be found flowering at the edge of the shore in many places. Under these circumstances an exclusive community of *Spartina*, if it develops, will probably be replaced eventually by grassland containing a high proportion of *Festuca* and some *Juncus maritimus*.

Acknowledgements

We wish to thank the Nature Conservancy and the Polytechnic, Wolverhampton, for financial and technical support. Mr. R. Goodier, Mr. M. J. Gash and Dr. D. F. Ball provided facilities and advice. Mr. P. Hope-Jones and Mr. J. P. Wilkinson generously allowed us to make use of their work on the marsh and Mrs. S. Cartwright made the final drawings for the figures. We are particularly grateful to Dr. D. S. Ranwell, Dr. P. A. Walker and Mr. R. Arthur for their comments on the draft of the paper.

References

Ball, D. F. (1964). Loss-on-ignition as an estimate of organic matter and organic carbon in non-calcareous soils. *J. Soil Sci.*, **15**, 84–92.

Boorman, L. A. (1966). *Experimental studies in the genus* Limonium. D. Phil. thesis, University of Oxford.

Boorman, L. A. and Woodell, S. R. J. (1966). The topograph, an instrument for measuring microtopography. *Ecology*, **47**, 869–870.

Chapman, V. J. (1938). Studies in salt marsh ecology. Sections I–III. *J. Ecol.*, **26**, 144–179.

Chapman, V. J. (1960*a*). *The plant ecology of Scolt Head Island.* In: *Scolt Head Island* (ed. J. A. Steers), 85–163. W. Heffer and Sons: Cambridge.

Chapman, V. J. (1960*b*). *Salt marshes and salt deserts of the world.* 1st edition. Leonard Hill: London.

Chapman, V. J. (1964). *Coastal vegetation*, 1st edition. Pergamon Press: London.

Clapham, A. R., Tutin, T. G. and Warburg, E. F. (1962). *Flora of the British Isles.* 2nd edition. University Press: Cambridge.

Davies, C. E. (1965). Spartina *distribution in the Cefni saltmarsh.* Manuscript at Nature Conservancy, Bangor.

Dunning, A. E. (1962). *Survey of the artificial pools on the Newborough Warren—Ynys Llanddwyn National Nature Reserve.* Document at Nature Conservancy, Bangor.

Elton, C. (1958). *The ecology of invasions by plants and animals.* 1st edition. Methuen: London.

Green, J. (1968). *Biology of estuarine animals.* 1st edition. Sidgwick and Jackson: London.

Greenly, E. (1919). *The geology of Anglesey.* 2 vols. 1st edition. Mem. Geol. Surv. H.M.S.O: London

Hope-Jones, P. (1965*a*). Birds recorded at Newborough Warren, Anglesey, June 1960—May 1965. *Nature in Wales*, **9**, 197–215.

Hope-Jones, P. (1965*b*). *Salinity analysis at the marsh and dune slack pools, Newborough, 1964.* Manuscript at Nature Conservancy, Bangor.

Hubbard, C. E. (1968). *Grasses.* 2nd edition. A295 Pelican Books: Harmondsworth, Middlesex.

Jordan, A. M. (1958). The life history and behaviour of *Coleophora alticolella* Zell. (Lep.). *Trans. Soc. Brit. entom.*, **13**, 1–16.

Kershaw, K. A. (1964). *Quantitative and dynamic ecology*, 1st edition. Edward Arnold: London.

LOCKET, G. H. and MILLIDGE, A. F. (1951 and 1953). *British Spiders*. 1st edition. The Ray Society: London.

MACKIE, D. W. (1964). A contribution to the spider fauna of Anglesey. *Naturalist*, **889**, 53–55.

MALLTRAETH MARSH INVESTIGATION REPORT. (1950). H.M.S.O.: London.

MARCHANT, C. J. (1963). Corrected chromosome numbers for *Spartina* × *townsendii* and its parent species. *Nature* (*Lond.*), **199**, 929.

OLSON, D. P. (1964). *The use of aerial photographs in studies of marsh vegetation*. Bull. 13, Tech series. Maine Agricultural Experiment Station.

PACKHAM, J. R. (1968). The influence of *Coleophora* on seed production in *Juncus inflexus*. *Proc. Birm. Nat. Hist. Soc.*, **21**, 109–116.

PETERSON, R., MOUNTFORT, G. and HOLLOM, P. A. D. (1965). *A field guide to the birds of Britain and Europe*. 2nd edition. Collins: London.

PHILLIPSON, J. (1966). *Ecological Energetics*. Edward Arnold: London.

PIGOTT, C. D. (1969). *Influence of mineral nutrition on the zonation of flowering plants in salt marshes*. In: *Ecological aspects of the mineral nutrition of plants*. (Ed. I. H. Rorison), 25–35. Blackwell Scientific Publications: Oxford.

RANWELL, D. S. (1965). Puccinellia maritima *spread in Malldraeth Estuary—Newborough Warren*. Document at Nature Conservancy, Bangor.

RANWELL, D. S. (1958). Movement of vegetated sand dunes at Newborough Warren, Anglesey. *J. Ecol.*, **46**, 83–100.

RANWELL, D. S. (1960). Newborough Warren, Anglesey. III. Changes in the vegetation on parts of the dune system after the loss of rabbits by myxomatosis. *J. Ecol.*, **48**, 385–395.

RANWELL, D. S. (1967). World resources of *Spartina townsendii* (sensu lato) and economic use of *Spartina* marshland. *J. appl. Ecol.*, **4**, 239–256.

RANWELL, D. S., BIRD, E. C. F., HUBBARD, J. C. E. and STEBBINGS, R. E. (1964). *Spartina* salt marshes in southern England. V. Tidal submergence and chlorinity in Poole harbour. *J. Ecol.*, **52**, 627–641.

REAY, R. C. (1959). *A population study on* Coleophora alticolella Zell. (Lep.). Ph. D. thesis, University of Durham.

RICHARDS, P. W. and CLAPHAM, A. R. (1941). *Juncus* L. Biological Flora of the British Isles. *J. Ecol.*, **29**, 362–368.

TANSLEY, A. G. (1939). *The British Islands and their vegetation*. The University Press: Cambridge.

WIEHE, P. O. (1935). A quantitative study of the influence of the tide upon populations of *Salicornia europaea*. *J. Ecol.*, **23**, 323–333.

YAPP, R. H., JONES, D. and JONES, O. T. (1917). The salt marshes of the Dovey Estuary. II. The salt marshes. *J. Ecol.*, **5**, 65–103.