A phytosociological study of Hart Warren Dunes, County Durham, in relation to future management

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A PHYTOSOCIOLOGICAL STUDY OF HART WARREN DUNES, COUNTY DURHAM, IN RELATION TO FUTURE MANAGEMENT.

BY

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CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

Hart Warren Dunes extend northwards along the Durham Coast, from within the Borough of Hartlepool GR 499357 to an area immediately north of the mouth of Crimdon Beck in the Borough of Easington GR 487370. (See Map 1).

The principal dune ridge known as Hart Warren exceeds 15 Metres in height along part of its total length of 3 Kilometres. The dunes are believed to have been formed in a prograding manner by accretion of offshore wind blown sand particles. These are derived, to some extent, from natural Magnesian limestone outcrops which occur inland from the coast.

The dunes have been formed on an underlying clay terrace which became eroded in Post glacial times when the sea level was some 24M higher than now (Smith, 1967).

It appears that a small harbour existed at the mouth of Crimdon Dene in the C18th and the remains of a wooden sailing ship have been found beneath wind blown sand at GR 488368 (Hackett, 1975).

Since as early as 1906, part of the stabilised dunes have been used as golf links (See Map 1) whilst the southern end of the site has come under pressure from industrial development with the building of a chemical plant for extracting Magnesium from seawater in the late 1930's.

Also at this end of the site some 2 acres of this unique Magnesian limestone Dune ecosystem have been irretrievably lost by Local Authority landfill tipping. This practise was begun in 1968/69 between the main dune ridge and the Hartlepool - Sunderland railway embankment but was subsequently discontinued in favour of a site to the south of Hartlepool.

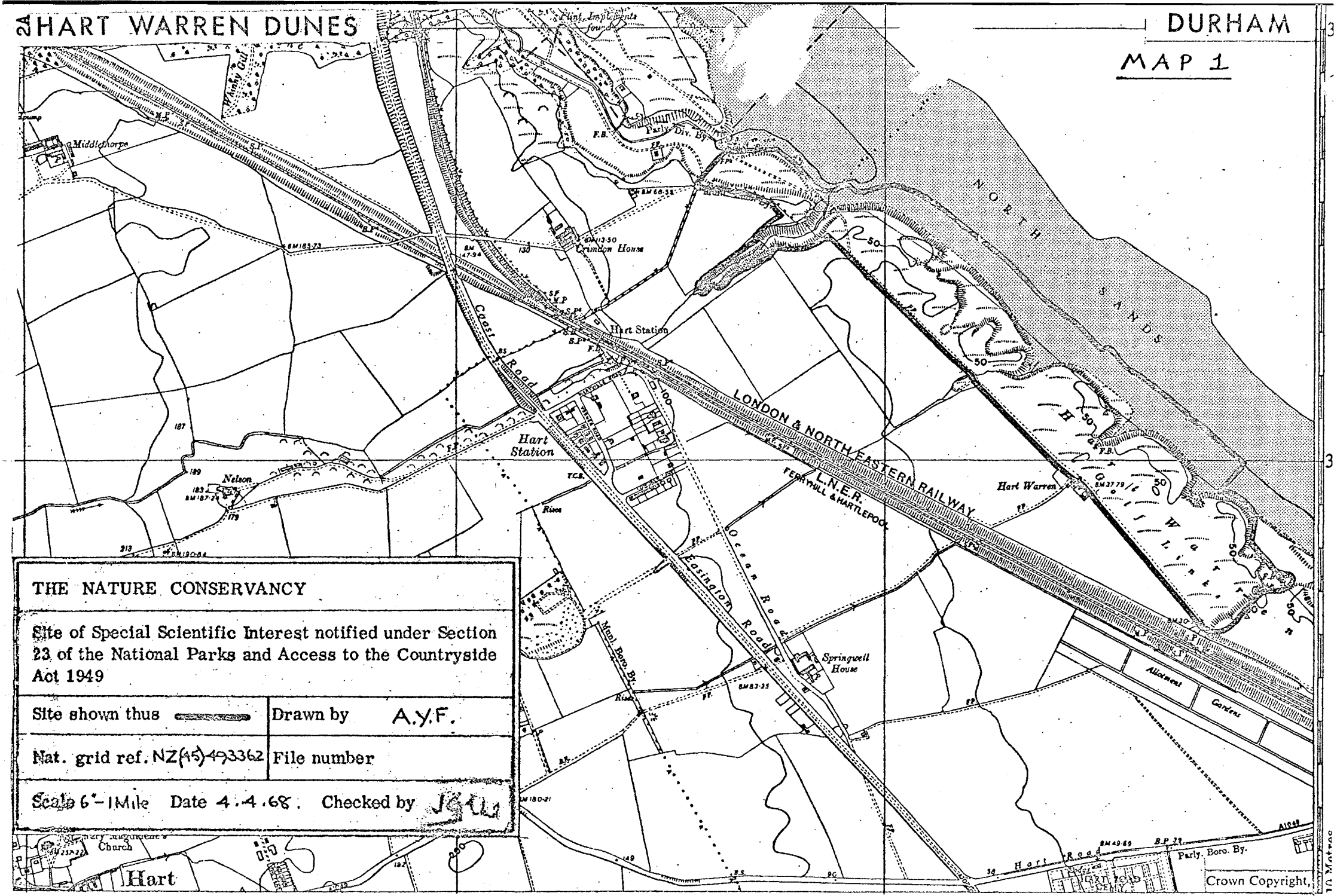
Human pressure on the fragile dune areas at the northern end of the site has increased markedly since 1960, when a million pound Caravan and Holiday Park Development was completed on land to the north of Crimdon Dene.

In 1968, part of the dunes were declared a Site of Special Scientific Interest (see enclosed area on Map 1). Public access to the dunes, however, is not restricted in any way.

The whole area is floristically rich, over 300 species of vascular plant having been recorded. These include species of extremely local distribution notably Astragalus danicus and Orchis ustulata (Graham, Gamon, and Sayers, 1971). In the case of Orchis ustulata, Hart Warren represents one of only 14 northern sites of this predominantly Southern species (Perring F. and Walters S., 1962). It is also the only known site in County Durham. The plant was first recorded in the area in 1797 by a Miss Wharton (Bellamy, 1974). However, it was not rediscovered until 1969, quite close to its original location (See Appleyard in Graham et Al 1971). The reason for the disappearance of this extremely local species in the intervening years must remain a matter of speculation.

Inula conyza has also been found on the dunes north of Hartlepool (Heslop-Harrison, 1956) and more recently within the S.S.S.I boundary at Hart (Appleyard, 1972) thus representing the most northerly location of this species.

In the current phytosociological study, the author has recorded 119 species of vascular plants in 60 aufnahmen. The list included Linaria repens , which was found growing as scattered individuals in partially fixed dunes immediately to the north of the mouth of Crimdon Dene - a new record for the area.



THE NATURE CONSERVANCY

Site of Special Scientific Interest notified under Section 23 of the National Parks and Access to the Countryside Act 1949

Site shown thus	Drawn by A.Y.F.
Nat. grid ref. NZ(45)493362	File number
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OBJECTIVES OF THIS STUDY

1. A total phytosociological survey and mapping of the plant communities within the study area (See Map 2).
2. An association analysis of the phytosociological data obtained, to enable, as far as possible, a classification of the vegetation in syntaxonomic terms, to be obtained.
3. A field description of the plant communities, in essentially phenomenological terms: in an attempt to elucidate the most probable pattern of succession and give further information on certain interesting individual species.
4. Assessment of the validity of the subjective interpretation of the succession sequence and the existence of distinct plant communities by reference to:-
   a) Biotic and abiotic relationships - especially dune soil studies.
   b) Patterns of species blocks obtained by association analysis of phytosociological data.
   c) At least one objective ordination statistical procedure - based on floristic data from the main communities recognised in the field.
5. Supplying the foundations for a suitable management strategy at Hart - with especial reference to the problems of dune erosion and conservation of Orchis ustulata.

2. THE FLORISTIC SURVEY AND SYNTAXONOMY

A number of earlier surveys have been carried out, notably by Doing (1969 unpublished data) using phytosociological methods and by Hackett (1975) using random sampling. In addition, a Durham County check list has been prepared for the whole area (Graham G.G. et Al 1971). However, no total phytosociological study has been carried out.

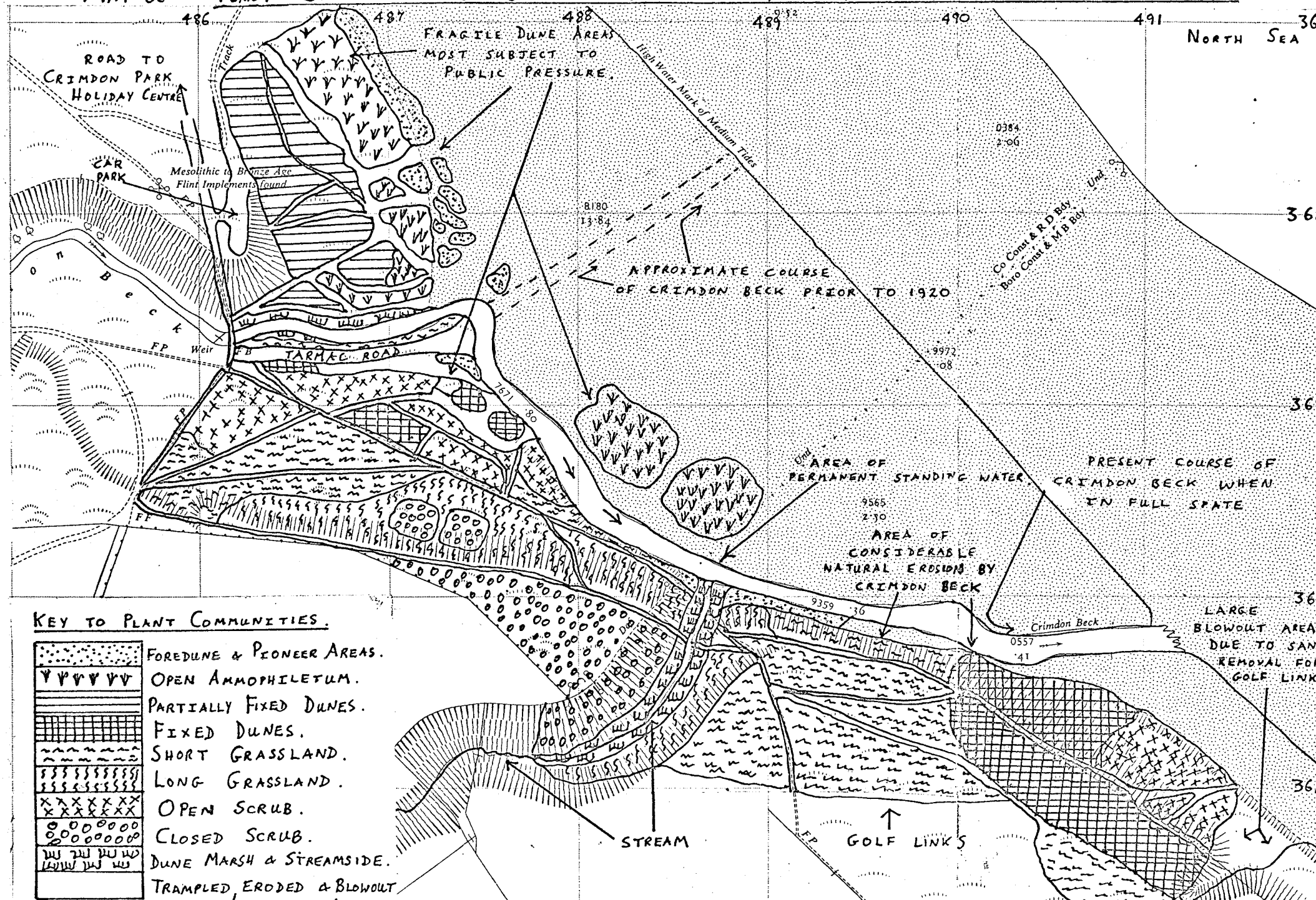
a) THE SURVEY METHOD

Essentially, the method chosen was the classical phytosociological technique of the Zurich - Montpelier School (Braun - Blanquet 1928 and 1964).

The first step was therefore a preliminary reconnaissance of the survey area in an attempt to recognise, subjectively, apparently uniform stands of vegetation which could then be characterised as discrete plant communities. Where possible, stand uniformity was chosen in relation to floristic composition which is most readily assessed at the preliminary stage, in terms of the dominant species. However it should be borne in mind that the apparently uniform distribution of a dominant species may lead to a false impression of total floristic homogeneity (Gounot 1961).

The preliminary reconnaissance was carried out within the boundaries of the survey area shown in Map 2, which also indicates the nature and extent of the main plant communities that were subjectively recognised in the field.

MAP 2 :- PLANT COMMUNITIES OF SURVEY AREA - HART WARREN DUNES SEPTEMBER 1976.



These were found to be:-

	DOMINANT SPECIES
1. FOREDUNE COMMUNITIES	Agropyron junceiforme Elymus arenarius
2. OPEN AMMOPHILETUM	Ammophila arenaria
3. PARTIALLY FIXED DUNES	Ammophila arenaria Hypochaeris radicata Lotus corniculatus
4. TRAMPLED AREAS	Lolium perenne Carex arenaria Festuca rubra (arenaria)
5. FIXED DUNES	Festuca rubra (arenaria) Geranium sanguinaeum Ammophila arenaria
6. * DUNE GRASSLAND (average height-20 cms.)	Festuca rubra (arenaria) Geranium sanguinaeum
7. * DUNE GRASSLAND (average height-40 cms.)	Festuca rubra (arenaria) Geranium sanguinaeum Arrhenatherum elatius
8. OPEN DUNE SCRUB	Rosa spinosissima
9. CLOSED DUNE SCRUB	Ulex europeaus Rubus fruticosa (agg)
10. DUNEMARSH AND STREAMSIDE COMMUNITIES	Equisetum arvense Phalaris arundinacea

*Structural rather than floristic criteria were the main distinguishing features between these communities.

Having completed the preliminary mapping and reconnaissance the next step was to determine the MINIMAL AREA for each community. This is an important concept in phytosociology and is most readily defined as the smallest area which provides sufficient environmental space for a specific community to develop its true species complement and structure.

Minimal area is most rapidly determined by plotting number of species against quadrat area. Initially, a quadrat size is chosen smaller than the minimal area and all the species listed within the plot. The plot area is then increased (usually doubled) and any further species noted. This procedure is repeated until subsequent plots give no significant increase in species number. The region in which the curve begins to flatten off is accepted amongst most plant sociologists as the minimal area. This is the minimum quadrat size necessary to describe the community.

The minimal area curves for the ten communities listed above are given in FIGURE 1.

Six sample plots were subjectively chosen from each community. The size of each plot corresponded to the minimal area of the community being studied. Each sample plot is generally termed a RELEVÉ (French) or AUFNAHME (German) in the literature and constitutes a "picture" of the stand of vegetation which is being studied.

For each relevé a list of species was prepared together with observation on certain vegetational and physiographic characteristics.

ie. % Vegetation Cover

Height of Stand

Plant Vigour
- (E Excellent
- (VG Very Good
- (G Good
- (F Fair
- (P Poor

Angle and Direction of Slope

General Soil Type

The relevés selected in this study occurred within a relatively small area and were marked with small sticks. However, it is more usual to quote the grid reference of the stand being studied. Other factors (e.g. Grazing, parasites, regeneration) were recorded where necessary at the bottom of the raw data sheets.

FIG 1 :- MINIMAL AREA CURVES - MAIN COMMUNITIES - HART DUNES

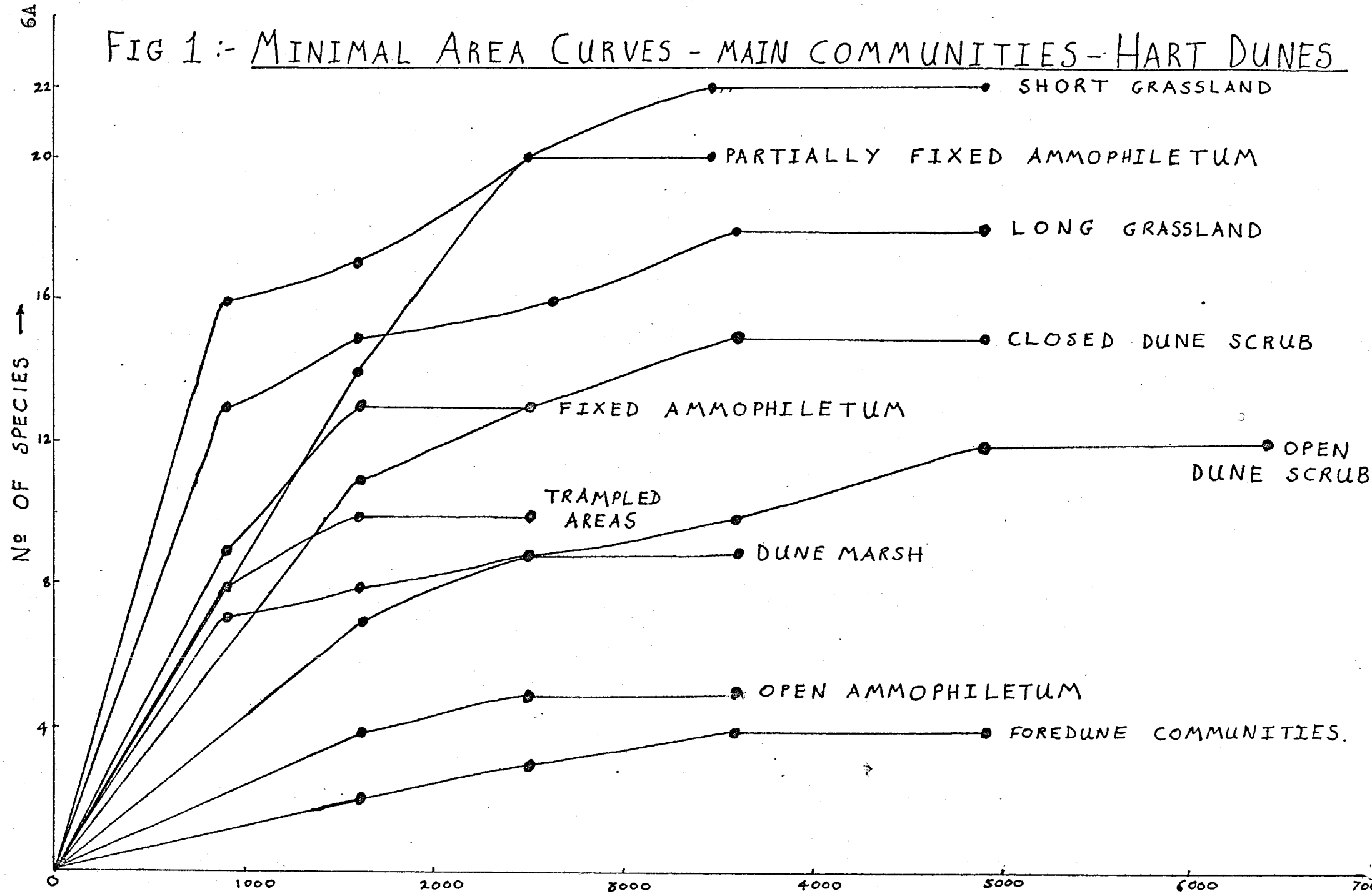


TABLE 1

1. FOREDUNE COMMUNITIES

	Minimal Area 0.36 M^2	1	2	3	4	5	6
	Slope and Direction	2° ENE	5° SE	8° SE	2° E	5° E	12° SW
	Vegetation Cover %	20	25	75	85	90	80
	Height of Stand - cms.	25	25	45	5	15	35
	Plant Vigour	VG	VG	E	VG	G	VG
1	Agropyron junceiforme	13	+3	+2	+2	33	23
2	Agro pyron repens				+2		
3	Armeria maritima				22	+2	
4	Cirsium arvense		11				
5	Elymus arenarius		+1	43	+1	12	23
6	Honkenya peploides				23		
7	Sonchus arvensis					+1	
8	Tussilago farfara		+1				

2. OPEN AMMOPHILETUM

	Minimal Area 0.25 M^2	7	8	9	10	11	12
	Slope and Direction	7° SE	-	8° SW	3° SW	6° SW	10° SW
	Vegetation Cover %	75	85	70	70	70	70
	Height of Stand - cms.	55	40	30	30	50	80
	Plant Vigour	G	G	G	G	E	E
1	Achillea milefolium			+1	+1		
2	Agropyron junceiforme	+2	+1	+1			+2
3	Ammophila arenaria	32	32	12	12	43	43
4	Cerastium diffusum	+1			+1		
5	Erodium dunense				+1		
6	Hypochaeris radicata			+1	+1		
7	Leontodon hispidus			+2	12		
8	Plantago lanceolata			+1			
9	Senecio jacobea			+1			
10	Senecio squalidus	11		12	+1		
11	Senecio vulgaris		+1				
12	Sonchus oleraceus			+2			
13	Taraxacum officinale				+1		
14	Tripleurospermum maritimum		+1				+2
15	Tussilago farfara	+1	11	+1			

3. PARTIALLY FIXED DUNES

	Minimal Area 0.25 M^2	13	14	15	16	17	18
	Slope and Direction	12° NE	7° NE	1° SW	8° E	2° SW	2° S
	Vegation Cover %	100	100	100	95	100	90
	Height of Stand - cms.	30	40	30	25	25	35
	Plant Vigour	G	G	G	VG	VG	G
1	Achillea milefolium	+1		+1			+1
2	Agropyron funceiforme	+2					
3	Agropyron pungens x funceiforme					+2	
4	Ammophila arenaria	12	12	12	+2	+2	22
5	Anacamptis pyramidalis	+1			11	+1	
6	Anthylis vulneraria						11
7	Bellis perennis		+1			+1	
8	Bryum erythrocarpum			+2			
9	Bryum pendulum				22		
10	Camptothecium lutescens	13	+3			+2	
11	Cardus nutans						+1
12	Cerastium diffusum	12	+1	+1	+1		
13	Cerastium semidecandrum		+1	+1	+1		
14	Dactylis glomerata	+2	+1	+2		+1	
15	Dactylorhiza fuchsii	+1				+1	
16	Elymus arenaria						+1
17	Festuca nubra (arenaria)				+2	13	
18	Helictotrichon pubescens	+2					
19	Heracleum sphondyllium	+1			+1		
20	Hypochaeris radicata	+2	11	+2	+2	+2	12
21	Leontodon hispidus	12			+2	+1	
22	Linaria repens	+1					
23	Lotus carniculatus		33		13	13	
24	Ononis repens			22		+1	
25	Plantago lanceolata			+2	+1		
26	Plantago maritima					12	
27	Poa trivialis (attenuated form)	+1					
28	Poa subcaenulea	+1	+1	+1		+1	
29	Poa pratensis				+2	+1	
30	Rumex crispus						+1
31	Senecio facobea		+1			+1	+1
32	Senecio squalidus			+1			
33	Sonchus oleraceus						+1
34	Taraxacum officinale	+1				+1	
35	Trifolium pratense	+1	+1	+2		+1	

3. PARTIALLY FIXED DUNES (cont.)

Minimal Area 0.25 M^2	13	14	15	16	17	18
Slope and Direction	12° NE	7° NE	1° SW	8° E	2° SW	2° S
Vegetation Cover %	100	100	100	95	100	90
Height of Stand - cms.	30	40	30	25	25	35
Plant Vigour	G	G	G	VG	VG	G
36 Tussilago farfara	+1		+1	+1	+1	
37 Vicia satioa					+1	

The following species was observed in this community but did not occur on any of the relevés selected:- Rosa rugosa

4. TRAMPLED AREAS

Minimal Area 0.16 M^2	55	56	57	58	59	60
Slope and Direction	5° SW	6° W	10° N	6° E	8° NW	8° N
Vegetation Cover %	60	50	85	95	90	90
Height of Stand - cms.	6	3	3	10	5	10
Plant Vigour	G	G	F	F	G	F
1 Achillea milefolium						+2
2 Agropyron junceiforme x repens				+1	+1	
3 Agropyron pungens x junceiforme			+2			
4 Ammophila arenaria	12				+2	12
5 Camptothecium lutescens					+2	+2
6 Carex arenaria		+2		+2	12	12
7 Cerastium semidecandrum		+1				
8 Festuca ouina				23		
9 Festuca rubra (arenaria)		+2	23		13	+2
10 Galium verum				+2		
11 Geranium sanguinaeum		+1	12			+2
12 Elymus arenarius					+1	
13 Honkenya peploides					13	
14 Hypochaeris radicata	12					
15 Lolium perrene		+1	+2	13	+2	12
16 Lotus corniculatus			+2			
17 Ononis repens		+2	+1			
18 Pimpinella saxifraga		+2				
19 Plantago lanceolata				+2	+1	
20 Potentilla anserina					+1	
21 Potentilla reptans		12				22
22 Poterium sanguisorba				12		
23 Rosa spinosissima			+1			
24 Taraxacum laevigatum		+1				
25 Thalictrum minus						+2
26 Tortula ruraliformis		+2				
27 Trifolium repens						+1

5. FIXED DUNES

	Minimal Area 0.16 M^2	19	20	21	22	23	24
	Slope and Direction	2° E	1° SW	6° SW	3° SW	4° NE	9° SW
	Vegetation Cover %	100	100	100	100	100	100
	Height of Stand - cms.	30	40	30	17	30	30
	Plant Vigour	VG	VG	G	G	G	VG
1	Achillea milefolium	+1	+2	+2	+1	+2	+1
2	Agropyron junceiforme		+1				
3	Agrostis stolonifera	+2					
4	Ammophila arenaria	+2	12	+2	12	12	12
5	Anacamptis pyramidalis		+1				
6	Astragalus danicus	12					
7	Campanula rotundfolia				+1		+1
8	Carex arenaria	+1					
9	Dactylis glomerata			+2			
10	Festuca rubra (arenaria)	33	23	+2	33	13	+3
11	Galium verum	+1					
12	Geranium sanguinaeum	+2	12	11	11	+1	22
13	Helictotrichon pratense						+1
14	Helictotrichon pubescens		+2	+2	+1	+2	+2
15	Hypochaeris radicata		+1	+1			
16	Lolium perenne			+2			
17	Lotus corniculatus		+1				
18	Ononis repens	+2	+2	12	+1		+2
19	Plantago lanceolata	+1	+2	12			
20	Poa subcaerulea	+1	+1	+1		+1	+1
21	Poa pratensis		+1		+1	+2	
22	Pimpinella saxifraga	+1					+1
23	Primula veris					22	
24	Rosa spinosissima		+2	+2	+1	+1	+1
25	Senecio jacobea			+1			
26	Taraxacum officinale	+1					
27	Thalictrum minus	+1			+2	12	+2
28	Trifolium pratense			+1			
29	Trifolium repens	+1	+1	+1			
30	Trisetum flavescens	+2					
31	Vicia sativa	+1	+1	+1	+2	+1	12
32	Viola hirta				+1	+1	

6. DUNE GRASSLAND ("SHORT GRASS")

	Minimal Area 0.36 M^2	25	26	27	28	29	30
	Slope and Direction	7° N	3° W	11° N	4° SE	8° NW	10° N
	Vegetation Cover %	100	100	100	100	100	100
	Height of Stand - cms.	20	20	20	20	6	20
	Plant Vigour	VG	VG	VG	VG	G	E
1	Achillea milefolium	+1					+1
2	Agrostis stolonifera			+2	12		
3	Ammophila arenaria			+2			
4	Anacamptis pyramidalis	+1		+1			+1
5	Arrhenatherum elatius		+2		+2		
6	Bellis perennis			+1			
7	Briza media				+1	+1	+2
8	Carex caryophylla					+2	
9	Carex flacca					+2	
10	Centaura nigra				+2		
11	Cerastium diffusum			+1			+1
12	Dactylis glomerata		+2	+1			+2
13	Dactylorhiza fuchsii			+1	+1		
14	Equisetum arvense			+1			
15	Festuca ovina						+2
16	Festuca rubra (arenaria)	23	23	13	+2	23	+2
17	Galium verum					+1	+2
18	Geranium sangunaeum	22	23	+2	12	+2	+2
19	Habaneria conopsea			+2			
20	Helianthemum chamaecistus				+2	+2	
21	Helictotrichon pubescens				+2		
22	Holcus lanatus				+2		
23	Hypochaeris radicata			+2			
24	Koelaria cristata (varalbescens)	+2	+2			+1	+3
25	Leontodon hispidus			+2		+1	
26	Linum catharticum						+1
27	Listera ovata				+2		
28	Lolium perenne	+1					
29	Lotus corniculatus	+2	+2	12		+1	+2
30	Luzula campestris	+1		+2		+1	+1
31	Mnium undulatum	+2					
32	Orchis mascula					+1	
33	Orchis ustulata					+1	
34	Plantago lanceolata	+2		+2	+1	+1	+2
35	Poa annua	+1	+1				

6. DUNE GRASSLAND ("SHORT GRASS") (cont.)

Minimal Area 0.36 M^2	25	26	27	28	29	30
Slope and Direction	7° N	3° W	11° N	4° SE	8° NW	10° N
Vegetation Cover %	100	100	100	100	100	100
Height of Stand - cms.	20	20	20	20	6	20
Plant Vigour	VG	VG	VG	VG	G	E
36 Poa subcaerulea	+2					
37 Polygala vulgaris					+1	
38 Poterium sanguisorba		+2			+2	+2
39 Primula veris			+1		+1	+1
40 Ranunculus bulbosus	+2	+1				+1
41 Ranunculus repens			+1			
42 Rhinanthus minor						+1
43 Rosa spinosissima					+2	+1
44 Thalictrum minus					+1	23
45 Trisetum flavescens	+1	+2				+2
46 Trifolium pratense			+2			
47 Trifolium repens	+1	+1				+1
48 Vicia sativa		+1				
49 Viola hirta					+1	

The following species were observed in this community but did not occur in the relevés selected.

TRAGOPOGON pratensis

VERONICA chamaedrys

7. DUNE GRASSLAND ("LONG GRASS")

	Minimal Area 0.36 M^2	31	32	33	34	35	36
	Slope and Direction	3° SE	7° NW	20° NE	20° NE	17° N	17° W
	Vegetation Cover %	100	100	100	100	100	100
	Height of Stand - cms.	45	40	30	50	35	55
	Plant Vigour	VG	E	VG	VG	VG	G
1	Achillea milefolium	+1	+2	+1			
2	Agropyron junceiforme x repens	+2		+1	+2	+1	
3	Agropyron pungens x junceiforme	+2	+1			+1	13
4	Agropyron repens		+1				
5	Agrostis stolonifera	+2		13			
6	Angelica sylvestris			11			
7	Arrhenatherum elatius	+2			13	23	
8	Campanula rotundifolia			+1			+1
9	Carex flacca			+2			
10	Centaura nigra			+2		+1	
11	Centaura scabiosa				+2		
12	Centaurium erythraea			+1			
13	Cerastium diffusum					+1	
14	Cirsium arvense				+1	12	
15	Dactylis glomerata	+1		+2	+2	+2	
16	Equisetum arvense			+1	+1	+1	23
17	Festuca arundinacea				+2	+2	
18	Festuca rubra (var arenaria)	23	13	+3	23		13
19	Galium verum					+1	
20	Geranium sanguinaeum	+1	+1	12	12		+1
21	Helictotrichon pubescens		+3	+1			
22	Heracleum sphondyllium			+1			
23	Holcus lanatus		+2	+2		12	
24	Holcus mollis	+2					
25	Leontodon hispidus				+2		
26	Listera ovata			+2			
27	Lotus corniculatus		+2				
28	Ononis repens	12	12				+2
29	Pimpinella saxifraga					+1	+1
30	Plantago lanceolata	+2	+1	+1		+1	
31	Poa pratensis	+2					
32	Potentilla reptans		+2				
33	Poterium sanguisorba	+2					
34	Primula veris			+2			

7. DUNE GRASSLAND ("LONG" GRASS) (cont.)

Minimal Area 0.36 M^2	31	32	33	34	35	36
Slope and Direction	3° SE	7° NW	20° NE	20° NE	17° N	17° W
Vegetation Cover %	100	100	100	100	100	100
Height of Stand - cms.	45	40	30	50	35	55
Plant Vigour	VG	E	VG	VG	VG	G
35 Reseda lutea					+1	
36 Rosa spinosissima	+2	+2				
37 Senecio jacobea				+1	+2	
38 Silene alba						+2
39 Thalictrum minus				+2		
40 Trifolium repens		+1			+1	
41 Trisetum flavescens	+2	+2				
42 Tussilago farfara			+1			
43 Vicia sativa		+1				

8. OPEN DUNE SCRUB

	Minimal Area 0.49 M^2	37	38	39	40	41	42
	Slope and Direction	14° SW	8° W	7° SW	4° SW	10° W	9° SSW
	Vegetation Cover %	90	95	90	100	100	90
	Height of Stand - cms.	35	30	35	20	30	30
	Plant Vigour	G	VG	G	VG	VG	G
1	Achillea millefolium	+1			+1	+1	+1
2	Agropyron junceiforme	+2					
3	Agropyron junceiforme x repens				+2		
4	Agropyron pungens x junceiforme		+2	+2			
5	Ammophila arenaria	12	+2	12	+2	12	+1
6	Arrhenatherum elatius					+1	
7	Bellis perennis			+2			
8	Campanula rotundifolia						+1
9	Carex arenaria	+2	+2	+2	+2	+1	
10	Cerastium diffusum	+1		+1			
11	Festuca ovina			+2			
12	Festuca rubra		+1		13	13	23
13	Geranium sanguineum	+2	+2	+1	12	+2	+1
14	Helictotrichon pubescens		+2	+2			
15	Heracleum sphondyllium					+1	+1
16	Hypochaeris radicata	+1		+1	+1		
17	Leontodon hispidus				+1		
18	Lotus corniculatus				+2		
19	Ononis repens	+2	+1	+2		+2	
20	Pimpinella saxifraga	+1					
21	Plantago lanceolata	+1	+2	+1			
22	Poa annua	+1	+2		+1		
23	Poa subcaerulea	+2	+2	+2			
24	Poa pratensis	+1			+1		
25	Poterium sanguisorba				+1		
26	Rosa spinosissima	33	33	33	22	23	33
27	Rosa sherardii	+1					
28	Rubus fruticosa (agg')						+1
29	Sonchus oleraceus	+1					
30	Taraxacum laevigatum		+1	+1		+1	+1
31	Taraxacum officinale		+1	+1			
32	Thalictrum minus		12		+2	+2	+2
33	Vicia sativa	+1	+2	+1	+1	+1	

Cover Abundance and Sociability of the individual species within a releve were estimated using the admittedly subjective but relatively effective 1 to 5 scales of Braun - Blanquet (1928). In this study the following scale divisions were found by the author to be most readily applicable in the field.

For Cover Abundance

5		Total Cover 100%
4	Approx	Cover up to 80%
3	"	Cover up to 60%
2	"	Cover up to 40%
1	"	Cover up to 20%
+		Small amounts (ie $\ll$ 10% cover)

For Plant Sociability

5	In pure populations
4	Forming extensive carpets - except for isolated gaps
3	Patches or cushions - tending to form a network
2	Scattered clumps
1	Scattered individuals

b) RESULTS

The raw survey data for each of the releves studied in the ten communities at Hart Warren are given in Table 1. A complete species list, obtained from all 60 releves in the survey, is summarised in Appendix 1.

The raw floristic data from Table 1 were then rearranged manually in a new table with species names written down the left hand side in decreasing order of abundance (See species occurrence figures in brackets in Appendix) and releve numbers arranged horizontally across the top of the table.

The next step was to rearrange the releves horizontally and the species vertically in an attempt to elucidate the presence of mutually exclusive groups of species and obtain a classification (SHIMWELL 1971). This technique of Braun - Blanquet ASSOCIATION ANALYSIS was initially carried out manually, and in terms of producing the differentiating tables, proved very time consuming. In the later stages, therefore,

use was made of the electronic computer to produce the final differentiated tables.

In this case Program SHUFFLE was used which enabled a rapid print-out, from the manual ordering of species - releve matrices to be obtained.

In the operation of the computer the following options were used:-

i) PRESENCE This option automatically arranged the species down the table in a decreasing order of abundance.
It provided a useful check on the species abundance sequence, which as stated earlier, was initially performed manually.

ii) DICTATE This enabled relevés from a predetermined sequence to be printed from left to right across the table. In the manual ordering of the data it was decided to exclude relevés 35 and 49. These rejected relevés therefore appear at the extreme right of the final differentiated table (See Table in cover wallet of binder). The option also enabled species to be printed out in a pre-determined sequence down the table. Any species with fewer than 2 occurrences were printed in conjunction with the "presence" option in a separate list at the bottom of the table.

iii) KUT This printing option was selected to enable spaces to be inserted between groups of selected species.

The final differentiated species blocks are shown in Table FORM (SEE FRONT COVER WALLET).

c) DISCUSSION OF PHYTOSOCIOLOGICAL ASPECTS AND SYNTAXONOMY

On the basis of the small amount of data available, it is impossible to go into detail on the syntaxonomy of the vegetational groups as identified by computer aided sorting using the Zurich - Montpelier method.

The pioneer and foredune communities are allied to the AMMOPHILETUM and are notable, in this case, for the inclusion of a number of "weed" species (viz Senecio squalidus, Tussilago farfara, Sonchus oleraceus and Senecio vulgaris) suggesting some degree of disturbance of these areas of the site, probably largely due to human pressure.

SYNTAXONOMY:- CLASS AMMOPHILETEA (Vegetation of Embryo and mobile dunes)

O ELYMO - Ammophiletalia

ALL Ammophilion borealis

Character species:- Ammophila arenaria
Agropyson funceiforme
Taraxacum officinale
Senecio vulgaris

The grassland communities are referable to

CLASS FESTUCO - BROMETEA (Vegetation of Calcareous grasslands)

O BROMETALIA erecti

ALL Mesobromion

and also to CLASS TRIFOLIO - GERANIETEA (Communities, often calciocolous of scrub/ grassland boundaries)

O Origanetalia

ALL Trifolion medii

The character species for both alliances being:-

Helictotrichon pubescens
Leontodon hispidus
Anacamptis pyramidalis
Primula veris
Koelaria cristata
Ranunculus bulbosus
Helianthemum chamaecistus
Anthylis vulneraria
Geranium sanguinaeum
Thalictrum minus
Pimpinella saxifraga
Viola hirta
Rosa spinosissima
Centaura nigra
Centaura scabiosa
Helictotrichon pratense

Also there is an admixture of species typical of

i) the GALIO - KOELERION

CLASS SEDO - SCLERANTHETEA (± Closed herbaceous vegetation of Sand Dunes)

O FESTUCO - SEDETALIA

ALL GALIO - KOELERION

VIZ:-	Ononis repens	Galium verum
	Hypochaeris radicata	Luzula campestris
	Lotus corniculatus	Taraxacum laevigatum
	Camptothecium lutescens	Bryum pendulum
	Cerastium semidecandrum	Tortula ruraliformis

and ii) CLASS MOLINIO - ARRHENATHERETEA (Vegetation of Meadows, Pastures and adjacent footpaths)

O ARRHENATHERETALIA

ALL ARRHENATHERION elatioris

VIZ:-	Arrhenatherum elatius	Trifolium pratense
	Holcus lanatus	Agrostis stolonifera
	Trisetum flavescens	Anthoxanthum odoratum

Also iii) O TRIFOLIO - AGROSTIETALIA

ALL Agropyro - RUMICION crispi

VIZ:-	Agropyron repens	Lolium perenne
	Potentilla reptans	Rumex crispus

The nearest descriptions in the literature are those of TÜXEN (1967) where he describes dunes from an area of South West Norway. It would appear that the grasslands at Hart Warren Dunes, come closest to the association GENTIANO - PIMPINELLETUM described by TÜXEN, although lacking certain of the character species described in his paper

VIZ:-	Draba incana	Rhytidium rugosum
	Gentiana campestris ssp baltica	
	Gentiana amarella ssp uliginosa	
	Antennaria hibernica	

The dune system at Hart would correspond most nearly to the GALIO - litteralis - Geranietum ass nov of TÜXEN.

Much more work is needed, however, before the actual relationships of these areas of vegetation can be fitted in with both the extensive work on the continent of Europe and Shimwell's (1968) work on the magnesian limestone grasslands of County Durham.

This is true of the dune marsh community which displays a somewhat heterogenous syntaxonomy.

ie. CLASS ARTEMISIETA VULGARIS

O ARTEMISIETALIA VULGARIS

ALL ANGECILION LITORALIS

VIZ. Atriplex hastata
Galium aparine
Agrostis stolonifera (var' palustris)

Also an admixture of species typical of

CLASS PHRAGMITETEA

O NASTURTIO - GLYCERIETALIA

ALL GLYCERIO - SPARGANION

VIZ. Veronica becabunga
Iris pseudacorus

ALL APION NODIFLORI

VIZ. Nasturtium officinale

O MAGNOCARICETALIA

ALL MAGNOCARICION

VIZ. Phalaris arundinacea

3. PLANT SUCCESSION, AND DISCUSSION OF FLORISTIC RELATIONSHIPS

The vegetation in an ecosystem is in dynamic equilibrium with its environment. As such, it will tend to undergo directional changes in time. This will involve a linked series of changes between the biotic and abiotic components of the ecosystem, brought about by storage and utilisation of energy.

The Primary Production of an ecosystem tends to be in excess of its maintenance requirements.

ie. GROSS PHOTOSYNTHESIS > Gross Respiration.

The ecosystem is, therefore, in positive energy balance. The excess energy accumulates in the form of Standing Crop or Biomass. Up to 1% of the 1° production may be utilised by herbivores. The remainder may die and pass into the decomposer chain.

A plant community normally stabilises when some limiting factor results in an energy equilibrium being reached.

ie. GROSS PHOTOSYNTHESIS = Gross Respiration.

This represents the Climax state of the ecosystem. The series of changes (seral stages) between the Pioneer and Climax communities constitute Succession.

In most natural ecosystems - macroclimate is the limiting factor stabilising the climax community. However, succession may not proceed to the ultimate climatic climax but become arrested at a sub-climax stage.

This occurs when some of the stored energy in the standing crop becomes dissipated.

eg. Burning ⟶ Fire climax

Grazing ⟶ Grazing climax

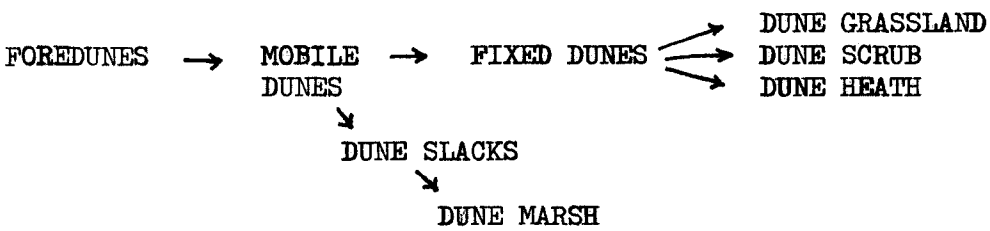
OR where local water/sub-soil conditions prevent establishment of the climax community eg. In Marsh communities.

a) DUNE SUCCESSION

Dune ecosystems have long been popular for studying plant succession as many of the complicating variables are absent, ie. The initial substitute, dune sand, is constant for the area. Also, macroclimate is the same and only a restricted range of flora and fauna can colonise the foredunes. Therefore any differences between dunes should be due to time, succession, colonisation and dispersal. One of the first classic contributions to our knowledge of plant succession was made by Cowles (1899) who worked on the sand-dune vegetation of Lake Michigan.

In Britain, sand dunes are almost always confined to the coast. Tansley (1939) reviews the early research carried out on British coastal dune ecosystems. From these studies, a distinct series of communities characterising the DUNE SUCCESSION SEQUENCE (PSAMMOSERE), can be recognised.

VIZ.



At Hart, communities characterising all of the above successional stages, were recognised in the field - except for Dune Slacks and Dune Heath.

b) FIELD DESCRIPTION OF SUCCESSION AT HARTWARREN

The plant communities subjectively recognised in the field and their spatial distribution in the succession are shown in Map 2. The raw survey data, from each of the 10 communities mapped, are compiled in Table 1. Soil analysis of samples from these communities are summarised in Table 2. (For Description of Soil Analysis methods, see Appendix II).

TABLE 2 SUMMARY OF SOIL ANALYSES

COMMUNITY	Relevé Nº	SOIL PH			LOSS ON IGNITION			CALCIUM*			MAGNESIUM*		
		VALUE	MEAN	SM	%	MEAN	SM	ME/100g	MEAN	SM	ME/100g	MEAN	SM
1 FOREDUNES	1	9·48			1·90			12·05			0·25		
	3	9·45	9·38	0·10	6·44	4·14	1·38	12·85	9·92	2·99	0·24	0·22	0·03
	5	9·22			4·09			4·86			0·18		
2 OPEN AMMOPHILETUM	7	9·07			4·42			6·95			0·10		
	10	9·15	9·29	0·21	1·23	3·08	1·12	6·68	6·34	0·56	0·10	0·11	0·01
	12	9·65			3·60			5·40			0·13		
3 PARTIALLY FIXED DUNES	13	9·00			4·13			4·02			0·12		
	16	9·10	9·07	0·04	1·20	2·19	1·14	10·40	6·25	2·45	0·16	0·12	0·03
	17	9·10			1·25			4·32			0·07		
4 TRAMPLED AREAS	56	8·85			2·29			3·75			0·06		
	58	8·20	8·65	0·27	3·90	2·70	0·71	2·94	3·23	0·32	0·06	0·09	0·04
	59	8·90			1·91			3·50			0·16		
5 FIXED DUNES	19	9·15			4·97			5·05			0·24		
	21	8·50	8·75	0·23	3·77	4·25	0·43	5·10	5·03	0·05	0·10	0·15	0·06
	21	8·60			4·00			4·95			0·10		
6 SHORT GRASSLAND	25	8·30			5·94			7·36			0·23		
	29	8·52	8·32	0·11	7·70	6·22	0·85	4·07	5·38	1·18	0·14	0·23	0·05
	30	8·15			5·01			4·71			0·31		
7 LONG GRASSLAND	31	8·50			5·02			4·05			0·23		
	33	8·00	8·25	0·15	7·31	6·96	1·15	0·74	1·95	1·24	0·15	0·17	0·04
	36	8·25			8·56			1·07			0·13		
8 OPEN SCRUB	37	8·30			2·99			3·20			0·06		
	38	8·70	8·43	0·16	3·60	3·19	0·24	4·00	4·26	0·78	0·22	0·15	0·05
	42	8·30			2·99			5·58			0·16		
9 CLOSED SCRUB	43	8·35			3·67			3·25			0·11		
	44	8·63	8·08	0·49	6·42	5·89	1·31	0·80	1·44	1·07	0·20	0·13	0·04
	45	7·25			7·57			0·26			0·08		
10 DUNE MARSH	49	8·27			16·55			25·27			3·01		
	52	8·60	8·49	0·13	11·95	11·70	3·00	13·60	16·31	5·29	0·52	1·28	1·02
	53	8·61			6·59			10·05			0·32		

NB * EXCHANGEABLE CALCIUM & MAGNESIUM.

(i) FOREDUNE COMMUNITIES

These consist of Sea Couch Grass Consocies (Agropyretum juncei). This community represents the pioneer stage in the psammosere at Hart and is most extensively developed at the North western end of the site. Here, almost pure stands of Agropyron junceiforme characterise the community. This species can penetrate deep into the substratum by means of its rhizomes and can withstand short periods of immersion in seawater (Tansley 1939). This accounts for it forming the most seaward of the communities at Hart, as it is capable of growing to the high-water mark of the Spring tides.

At the northern end of the site, Agropyron junceiforme forms an open sward of vigorous young plants approximately 25 cms. in height. The area colonised is ~10 M x 65 M and consists of a flattened plateau elevated ~2 M above the gently sloping foreshore.

On the seaward side of this plateau, occasional clumps of Ammophila occur, with their subterranean rhizomes exposed on the near vertical dune face. This suggests that Agropyron is stabilising freshly wind blown sand (or a badly eroded surface) on a dune ridge formerly built up by Ammophila. A long shore drift of sand in a predominantly south easterly direction is also suggested by a series of embryo dunes formed some 30 M south of the main Agropyron consocies. Amongst these dunes, a number of other associated species occur viz. Cirsium arvense, Tussilago farfara and Elymus arenarius. At one of these locations, the latter species forms an almost pure stand and is capable of building and stabilising low profile dune areas on the seaward side of the main Ammophiletum.

Due to sand quarrying, vehicles and trampling, a series of blowouts have developed at the end of the tarmac road leading to the beach (GR 487367). A small series of foredunes have resulted on the seaward side and are being stabilised chiefly by Honckenya peploides and Armeria maritima.

The latter species is interesting, being more characteristic of salt marshes and is relatively deep rooting. (YAPP 1917).

Agropyron junceiforme also occurs on the more northerly of the 2 offshore dunes. Here it is co-dominant with Elymus arenarius. It also occurs in a narrow band to the east of the mouth of the small un-named stream shown on Map 2.

The dune sand samples taken from 3 widely separated relevé sites are significantly calcareous (Mean Exchangeable Calcium 9.92 M Eq/100 gms $\pm$ 2.99). This suggests that the mineral particles have largely been derived from a calcereous parent rock (Magnesian limestone). However, the results of the Magnesium analysis are very low (Mean 0.22 M Eq/100 gms $\pm$ 0.03) but these figures are for exchangeable magnesium. In the parent rock, this element would largely be present in the combined form of non-exchangeable Mg CO_3, so that a total Magnesium analysis would have, presumably given higher values.

The pH values are extremely high (Mean 9.38 $\pm$ 0.10) which are in keeping with the highly calcareous nature of the dune particles. LOSS on ignition values (Mean 4.14 $\pm$ 1.38) are considerably higher than one might expect from foredune samples. Coal dust particles were visibly evident on the foreshore and their probable presence in the samples could have contributed to the high losses. The large standard error would suggest that the result should be treated with some degree of caution.

(ii) OPEN DUNE COMMUNITIES

These consisted of Marram Grass consocies (Ammophiletum arenariae). Such a consocies, dominated by Ammophila arenaria represents the second stage in succession at Hart and has resulted in the building of the main dune ridges observed throughout the site.

Open Ammophiletum occurs as a series of dune crests and hollows immediately to the landward side of the Agropyretum juncei at the northern end of the site. It also occurs as almost pure stands (with significantly fewer "weed" species) on the 2 offshore dunes at 488366.

The dune hollows at the northern end of the site have been badly eroded by human trampling and are significantly devoid of vegetation. This renders them especially susceptible to wind erosion.

Tansley (1939) summarises the vegetation of dune "slacks" (ie. Wet hollows between the dune ridges where the water table approaches the surface). Such communities were not found at the Hart site and are more characteristic of wetter sites on the Western coast of Britain. Annual precipitation at Hart is relatively low at < 630 mms. (Smailes 1968).

The mobile Ammophila dunes at Hart are extremely open, being composed of separate tufts with dry, loose sand between. At the northern end of the site, these have been colonised by a number of non-maritime "weed" species viz. Senecio squalidus, Senecio jacobea, Senecio vulgaris, Tussilago farfara, Sonchus oleraceus and Hypochaeris radicata. Calcareous conditions were indicated by the frequency of Leontodon hispidus.

Although these species are frequent associates of the Ammophiletum consocies, their relative luxuriance and (in some cases) high abundance at the northern end of the site must act as a floristic indication of excessive public pressure in this area.

Dune soil analysis from the open Ammophiletum (Mean pH 9.29 $\pm$ 0.21 Mean Calcium 6.34 M Eq/100 gms $\pm$ 0.56) show a slight fall, resulting from loss of Calcium due to leaching. A gradual decline in these values would be expected through the temporal succession sequence.

(iii) PARTIALLY FIXED DUNES

These occur only at the northern end of the site (See Map 2). Although Ammophila is still the dominant species, they are characterised by an almost closed community showing far greater species diversity than the Open Ammophiletum (see Table 1). The thin humus created by decay of former colonisers in the Ammophiletum enables species capable of consolidating the sand surface to gain a hold. Festuca rubra (var arenaria) is significant in this respect.and was found with good cover/sociability values in some releves. Other notable surface consolidaters were the moss Camptothecium lutescens, also Lotus corniculatus and Ononis repens. Both these species carry out nitrogen fixation. The glutinous, sticky prostrate shoots of the latter should assist in colonisation by further species, as wind blown fruits and seeds may adhere and subsequently germinate.

This community was interesting in other respects. Cardus nutans, a calciocolous species was recorded and several perennating shoots of Linaria repens were observed. Final confirmation of this species was provided when the plant reached the flowering stage. A grass which appeared to have a perennating bulb at the base of the shoot was also found. Although this was first believed to be Poa bulbosa (which would have constituted a new northern record for this species), subsequent detailed examination of the inflorescence, showed that it was, in fact, a somewhat attenuated form of Poa trivialis. Such are the joys of Botanical investigation!

The soil analysis showed a decline in pH (Mean 9.07 $\pm$ 0.04) which was to be expected from the successional sequence. (Loss on Ignition and Calcium values showed rather large standard errors).

(iv) FIXED DUNES

The main area occupied by this community is to the west of the large blowout area (See Map 2). Isolated fragments of vegetation of this type also occur south of the tarmac road which leads to the beach.

The community is characterised by total vegetation cover and a decline in both frequency and vigour of Ammophila. Festuca rubra (var arenaria) and Geranium sanguinaeum are the dominant species and are largely responsible for consolidation of the fixed dune surfaces at Hart. Geranium sanguinaeum is a constant species throughout the subsequent communities in the succession but does not appear to occur in the Dune Marsh. This species occurs at a number of locations along the coast, extending northwards from Hart to Northumbria and coastal areas of Eastern Scotland. (Perring and Walters 1962). South of Hart, its east coast distribution appears to be restricted to two locations immediately northwest of Flamborough Head. The factors influencing the distribution of this rather local species are not fully understood. The Hart site approximates to the Southern limit of its range along the east coast of Britain.

Astragalus danicus was observed occasionally in the fixed dune vegetation. In a small segment immediately south of the tarmac road, this local species was found to have a cover value > 20% in one of the releves recorded. This species has been reported from a number of coastal sites extending southwards from Eastern Scotland into Northumbria and County Durham. It would again appear to be approaching its Southern limit on the east coast at Hart, although it has been recorded from the Wash (Perring and Walters 1972).

A number of relatively constant associates were recorded in this community, notably Achillea milefolium, Helictotrichon pubescens, Ononis repens, Poa subcaerulea, Rosa spinosissima, Thalictrum minus and Vicia sativa (ssp segetalis). The latter species is not native and may have originally been introduced into the vicinity as a fodder crop.

Both soil pH (Mean 8.75 ± 0.23) and Calcium (Mean 5.03 M Eq/ 100 gms ± 0.05) show a decline from the corresponding values obtained in the partially fixed Ammophiletum. This can be contributed to progressive loss of Calcium (and other basic ions), due to leaching by rainwater, from the older fixed dunes.

It would appear from the foregoing that the initial succession sequence of the psammosere at Hart, is linear.

VIZ.

FOREDUNE and PIONEER COMMUNITIES (Agropyretum juncei) → OPEN AMMOPHILETUM → PARTIALLY FIXED AMMOPHILETUM ↓ FIXED DUNES

The decline in soil pH and Calcium values, from the pioneer stage, are in accordance with the above sequence.

The Ultimate Vegetation Climax in the succession from fixed dunes can show a range of variation. Tansley (1939) recognises 3 main types.

VIZ:- Callunetum (Dune Heath), Dune Scrub and Dune Grassland. Succession to woodland communities does not occur on fixed dunes in Britain. This may be due to a low density of seed parents in the vicinity of many dune sites. This seed dispersal problem in the establishment of dune woodland is cited by Tansley (1939). Failure of seedlings to withstand violent coastal winds could also be a contributory factor.

Good (1935) describes a complete psammosere for South Haven peninsula Dorset, passing from open Ammophiletum to Callunetum which he regarded as the dune climax vegetation in that area. The author visited this site in the Summer of 1974 and observed that drier areas of the Callunetum were being colonised by Betula pendula which may thus represent a pioneer stage in the succession from Heath to Woodland.

Callunetum will only develop where sufficient Calcium and other basic ions have become leached from the dune soil to allow the establishment of acidophilous species such as Calluna vulgaris and Erica cinerea.

Where the dunes are initially highly calcareous (as at Hart), it is doubtful whether Callunetum could become established. It was significant that, at Hart, the lowest mean pH value was > 8 - in the closed scrub community dominated by Ulex europeaus

(v) OPEN SCRUB

This community was readily recognised at Hart by the dominance of Rosa spinosissima, forming a dwarf scrub up to 35 cms. high, in areas adjacent to the fixed dune communities (See Map 2).

As a community, the Rosa spinosissima associes was found to be somewhat open, with a vegetation cover of 90-95% in most releves. This is rather surprising, as it must represent a definite successional stage from the closed fixed dune community. This is confirmed by the decline in pH values (8.75 to 8.43) and Soil Calcium (5.03 to 4.26 M Eq/100 gms.) when both communities are compared. (These results can be taken as being statistically significant as the standard errors are low).

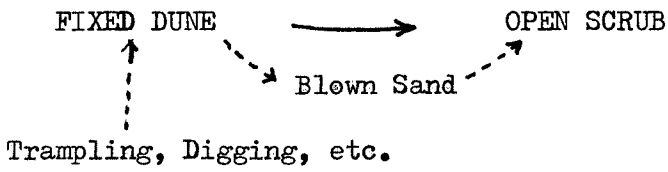
Inspection of Map 2 in fact shows that Rosa spinosissima scrub is developed in areas adjacent to "blowouts" in the stabilising fixed dune sward (See GR 487366 and 491364). This suggests that Rosa spinosissima shows most vigorous development in fixed dune communities inundated by windblown sand originating from previously stable dune areas, in which "blowouts" have been formed.

Although fresh sand deposition in fixed dune areas, would appear to eliminate relatively few species, it would seem that certain of the fixed dune dominants show a slight decline in vigour. Thus Festuca rubra, Geranium sanguinaeum and Ononis repens show a decline in cover/sociability ratings in the Rosa scrub. (See Table 1).

Evidence for the disturbance/sand deposition hypothesis in favouring development of Rosa scrub at Hart comes from:-

a) The spatial relationship of the Rosa spinosissima and Fixed Dune communities to blowout areas. Hence the spatial succession is an indicator of the temporal succession.

ie.



b) The decline in Loss on Ignition value from 4.25% (Fixed Dunes) to 3.19% (Dune Scrub) indicating fresh sand deposition.

c) The more "open" nature of the Rosa spinosissima community. Soil depth profile pH and loss on ignition analyses, involving samples from 3 separate locations in the Rosa scrub also tend to support the above hypothesis. (See Table 3).

(vi) CLOSED SCRUB

Apart from one isolated relevé, this community exhibited 100% Vegetation Cover.

Two distinct layers were recognised.

a) A shrub layer up to 60 cms. high - dominated by Ulex europeaus and/or Rubus fruticosa.

b) A herb layer forming a mosaic between the shrubs, dominated by Agrostis stolonifera, Geranium sanguinaeum and Festuca rubra. Centaura nigra, Festuca arundinacea, Dactylis glomerata, Arrhenatherum elatius and Plantago lanceolata were also frequent associates of this layer.

The main area dominated by this community lies on a high dune plateau immediately west of the stream at GR488365. It also extends down the steep bank to the dune marsh community flanking the stream on either side.

The plateau is elevated ~20 M above the upper shore and except in very high gales, must receive virtually no blown sand deposition. Soil analysis showed a Mean pH of 8.08 ($\pm$ 0.49) and a Mean Calcium (based only on releves 44 and 45 from the high dune plateau) of 0.53 M Eq/100 gms. suggesting that the plateau was the least calcareous area surveyed.

Loss on Ignition (Mean for releves 44 and 45) was found to be 6.99% - a significant increase in humus content from that on the fixed dunes (Mean 4.25 $\pm$ 0.43).

These results suggest that in the absence of biotic and anthropogenic factors (grazing, trampling, cutting, etc.) the Ulex/Rubus closed scrub community represents a climax stage in the succession from fixed dunes at Hart. On the dune plateau, the succession would appear to be aided, physiographically, by its elevation above much of the adjacent site. This ensures that sand deposition from "blowouts" is minimal, which might account for the infrequent occurrence of Rosa spinosissima scrub in this area.

(vii) THE DUNE GRASSLAND COMMUNITIES

These form an almost entirely closed vegetation cover over large areas of the site, most notably the golf links and the grassy valley immediately South of Crimdon Beck.

Dune grassland is widely regarded as a biotic climax, brought about by grazing pressure of livestock or rabbits. (Tansley 1939). Under such conditions, woody plants have little chance of establishing themselves beyond the seedling stage.

At Hart, it was difficult to ascertain the exact source of herbivore pressure. Neither rabbits or their droppings were in evidence and only a single hare was sighted, hardly sufficient to be a serious contributor to grazing pressure. Cattle and horses were observed in the fields to the southwest of the small stream but at no time during the study were they seen feeding on the Dune grassland. Thus the source of grazing pressure remains obscure. The most likely contributory factor in maintaining the short dune grassland in the valley South of Crimdon Beck, is probably anthropogenic, resulting from trampling pressure over a wide area. A number of new footpaths have become established in recent years, (cf Maps 1 and 2) yet in spite of increasing pressures, some closed scrub has become established along the base of the steep slope leading to the high dune plateau referred to earlier.

To the east of the stream marked on Map 2, the golf links extend for some 1.5 Km along the coast. The dune grassland here is almost exclusively maintained by the anthropogenic factor, ie. By an extensive mowing/cutting regime and by trampling pressure of the golfers themselves. In exposed areas nearest the cliffs, a low dune sward may also be partly maintained by the growth inhibiting effect of high winds.

Two main grassland communities were distinguished and mapped. This was based on structural rather than marked floristic differences. ie. a) "Short" Grassland was found to comprise a relatively homogenous sward up to 20 cms. high.

b) "Long"Grassland exhibited more rank and tussocky growth, with stand heights up to 55 cms.

Both communities were found to be, floristically, the most diverse at the site. In species composition they showed marked, although not exclusive similarities. Festuca rubra was the dominant species throughout both communities. Geranium sanguinaeum was a significant component of both communities, although it reached its fullest cover and sociability in the short grassland. Primula veris was also quite frequent in this community. Grasses such as Dactylis glomerata, and Trisetum flavescens appeared to occur with roughly equal frequency in both communities. Holcus lanatus, Arrhenathenum elatius and Agrostis stolonifera were more frequent in the "long" grassland. Two interesting hybrid grass forms were also found frequently in this community. Both forms were found to have sterile anthers and after detailed examination were considered to be Agropyron junceiforme hybrids.

VIZ. a) Agropyron pungens x junceiforme - a robust hybrid form, with prominent ribbing on the upper surface of the leaves.

b) Agropyron junceiforme x repens - with far less prominent ribbing and fine silky hairs on the upper surface of the leaves.

Agropyron pungens has not been recorded further north than Teeside. (Graham et al 1971).

Koelaria cristata (var albescens) and Briza media were found only in the "short" grassland. Both species are generally regarded as good indicators of dry, calcareous pastures. This was borne out by the soil analysis which showed a Mean pH of 8.32 ($\pm$ 0.11) and a Mean Calcium value of 5.38 M Eq/100 gms. ($\pm$ 1.18) for the short grassland. The "long" grassland appeared to be somewhat less calcareous (Mean Calcium 1.95 M Eq/100 gms. $\pm$ 1.24) Soil pH, however, showed little difference (8.25 $\pm$ 0.15). Loss on Ignition values were also quite similar (See Table 2).

Physiographic differences between the 2 communities would also account for the local occurrence of moisture loving species, such as Equisetum arvense and Angelica sylvestris, on the steep, north east facing slope of the dune ridge to the west of the stream (See Map 2).

The dune grassland was also found to be the main site for at least 6 species of orchid. Listera ovata and Dactylorhiza fuchsii occurred occasionally in both "long" and "short" grassland communities. Habaneria conopsea was found on the steep dune slope mentioned above. Also, an interesting form, which appeared to be a hybrid between this species and Dactylorhiza fuchsii. Unfortunately, it was picked at the crucial flowering stage!

Anacamptis pyramidalis was the most ubiquitous species in the "short" grassland - its attractive pink flowery spikes being much in evidence on the short dune sward of the golf links. This species was also frequently recorded on the partially fixed dunes at the northern end of the site.

Both Orchis mascula and Orchis ustulata were found in locally abundant societies on the golf links. The former species, with its conspicuous reddish purple inflorescences, appears to suffer the unfortunate depradations of picking - as some 10-15 discarded flowering spikes were found lying on a nearby footpath. The much rarer Orchis ustulata is far less conspicuous with its smaller brown tipped inflorescences. The golfers, intent on their game, do not constitute a serious threat to it. Excessive trampling is not a problem, at present, as the main pathway used by the golfers is some 3-4 M from the flowering site. In conversation, with the golf course groundsman, the author was informed that this small area was never cut. Presumably, the low sward here is maintained by exposure of the northwest facing slope (See Relevé 29 in Table 1).

to onshore winds plus not excessive human trampling. In any event, some 15 flowering spikes of Orchis ustulata were observed in early June 1976, which appears to have been a very good year for it.

Helianthemum chamaecistus was quite frequent here and is a good indicator of moderately dry, calcareous soil conditions.

(viii) TRAMPLED AREAS

These were found running through all communities on the site, although most frequently dissecting and destroying the vegetation cover of the mobile dunes at the Northern end of the site. Large areas here consisted of bare sand, with occasional stunted clumps of Ammophila and Hypochaeris radicata, as testimony to the degree of trampling pressure.

Lolium perenne and Festuca rubra were found to be frequent constituents of the paths on the dune grassland. The yellowed culms of both these species were adequate testimony of their failure to survive the drought of Summer 1976.

Galium verum, Poterium sanguisorba, Achillea milefolium, Potentilla reptans, Lotus corniculatus and Plantago lanceolata showed relatively good vigour under the harsh drought/trampling conditions. Anderson (1927), in studies on the water economy of the chalk flora, has demonstrated that these species have relatively deeply penetrating root systems. Geranium sanguinaeum and Thalictrum minus also appeared to be quite tolerant of moderate trampling. It was observed that G. sanguinaeum was a pioneer coloniser on bare sand around the large blowout at GR 491364. Hackett (1975) found that recolonisation of bare sand areas was very slow at Hart.

Camptothecium lutescens and Tortula ruraliformis occurred in localised societies of low cover value, on some of the trampled areas. Although mosses and lichens frequently play a significant part in the consolidation of dune surfaces and the formation of closed communities, such Grey Dunes (Tansley 1939) with a high cover

of Bryophytes and lichens, do not occur at Hart. Only 5 species of Bryophyte were recorded during the survey, mainly growing on the partially fixed dunes, although a detailed survey of this group would undoubtedly reveal far more species.

(ix) DUNE MARSH

This somewhat heterogenous community is to be found at GR 488365, where, in the passage of time, a stream has cut deeply through the main dune ridge. A dune marsh flora, composed largely of non-maritime species, has developed as a result of the waterlogged soil conditions.

The community at the mouth of the stream was found to be extremely open and notable for the presence of salt tolerant species such as Triglochin palastris and Atriplex hastata. Agrostis stolonifera (var palustris) appeared to be successfully colonising the muddy dune flats in this area.

Following the stream up the valley from this point, a marked zonation was observed, starting with large tussocks of Oenanthe crocata and Juncus inflexus. The latter is a good indicator of water seepage conditions.

Phalaris arundinacea formed a sizeable stand, with associates of Epilobium hirsutum, Lamium purpureum and Urtica dioica. Behind this zone, Veronica decabunga, Rumex conglomeratus and Tussilago farfara flourished. Further up the valley, Nasturtium officinale, Iris pseudacorus and once again, Phalaris arundinacea became the dominant species. Equisetum arvense was a fairly constant associate throughout the whole community.

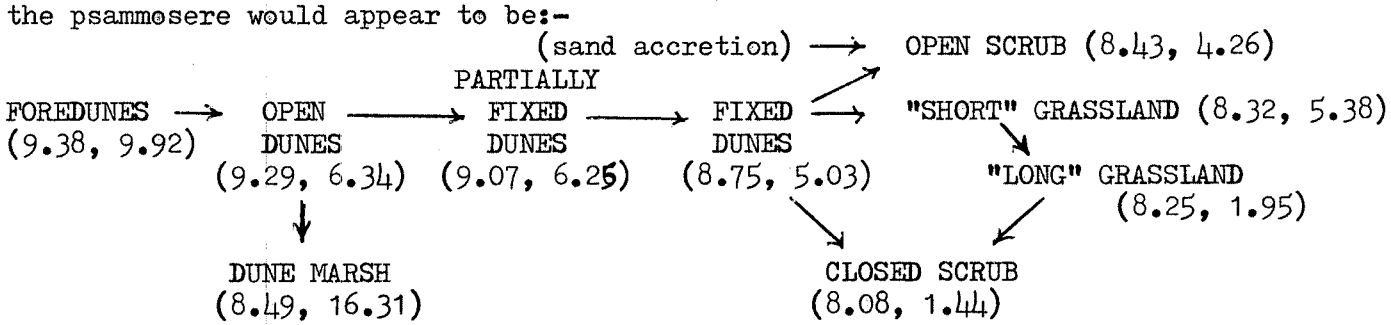
A further narrow strip of dune marsh has become established just below the bridge crossing Crimdon Beck. This area will tend to be periodically inundated by floodwater from the beck,

following heavy rains. It was most notable for the presence of Symphytum uplandicum, Carex hirta, and Cirsium arvense.

The soil at this marsh site (Releve 49) had a high level of exchangeable calcium (25.27 MEq/100 gms.) and Magnesium (3.01 M Eq/100 gms.) when compared with samples from the other dune marsh area, or indeed the rest of the site. (See Table 2). Hackett (1975) reports that the bed of Crimdon Beck lies on Magnesium limestone for much of its length, which would account for the highly calcareous nature of the marsh soil.

c) SUMMARY OF THE MOST PROBABLE SUCCESSION SEQUENCE AT HART

Based on the field description of the vegetation and soil analysis within the subjectively recognised plant communities - the most probable course of the psammosere would appear to be:-



(NB Figures in brackets denote mean Soil pH Values and exchangeable Calcium M Eq/100 gms.)

The above scheme is supported by the Mean Soil pH and Calcium values which show a gradual decline from the embryo dunes to the least calcareous closed scrub community. Loss on Ignition values were less consistent with the above succession sequence but show a broadly similar trend. (See Table 2).

Discussion

From the fixed dune stage in succession - 3 distinct vegetation climaxes would appear to have developed.

VIZ. (i) Open Scrub - dominated by Rosa spinosissima. Reference to map 2 shows that this community is most pronounced in areas of fixed dune most liable to sand accretion from nearby badly eroded areas of stabilised dunes.

Ammophila arenaria was a constant component of the Rosa associes. Both species showed good vigour which is to be expected in areas of rapid sand accretion. The pattern of vegetative growth of R. spinosissima is such that it would be expected to survive relatively rapid sand accretion, which many herbaceous species would find intolerant.

Following a period of high winds in September 1976, it was observed that the Rosa scrub adjacent to the large blowout (See Map 2) had been covered with a sand deposit to a depth of 5-10 cms., whereas dune grassland areas of the site were relatively unaffected. It would be interesting to monitor the recovery rate of Rosa in this area and also attempt to measure the annual rate of sand accretion in the main climax communities developed at Hart.

(ii) Dune Grassland - This would appear to be a sub-climax community maintained largely by the anthropogenic factor (See earlier field description of this community)

The "short" grassland community is significantly calcareous and would appear to be developed in areas subject to (not excessive) public pressure. The less calcareous nature of the "long" grassland suggests that it is formed on older dune surfaces less subject to public pressure. Relaxation of the latter would appear to be a significant factor in the formation of closed scrub. Incipient closed scrub formation can most readily be observed at 487366 (Map 2). This is consistent with the view that the "long" grassland is a transitional stage in the formation of the closed scrub climax.

(iii) Closed Scrub - dominated by the Ulex europeaus/Rubus fruticosa associes. This community would appear to represent the landward limit of the fixed dune succession at Hart (See Map 2.

The community would appear to represent a climax in both the spatial and temporal succession, being developed on the least calcareous dunes of those studied - suggesting that they may be amongst the oldest at the site.

It is interesting to speculate, whether Rosa spinosissima scrub would eventually succeed to Ulex/Rubus scrub, if denied the presence of accreting wind blown sand particles. However, there is no direct evidence to suggest that this has happened at Hart.

Both the Dune Marsh and Trampled Area communities can be regarded as adjuncts to the main succession sequence. The Dune Marsh probably originated by the small stream (See Map 2) cutting down through the main dune ridge when it was at a relatively mobile stage.

Trampled Areas can be regafded as plagioclimax situations which can, in practise, arise from any of the communities studied - should the deflecting factor (ie. trampling) be of sufficient pressure and duration.

d) SOIL DEPTH PROFILE STUDIES

Due to lack of time, soil depth profiles and subsequent analysis were carried out in only two of the main communities. For details of the sampling method - see Appendix II.

Results of soil depth profile analysis at 3 widely separated releve sites within each community, are summarised below.

TABLE 3 pH and Loss on Ignition Values

COMMUNITY		OPEN DUNE SCRUB									
ANALYSIS		SOIL pH					Loss on Ignition %				
SOIL DEPTH - cms.	RELEVE NO.	37	38	42	Mean	Sm	37	38	42	Mean	Sm
0-5		7.40*	8.01*	7.90	7.77	0.22	7.37*	4.89*	2.39	4.88	0.74
10-15		8.60	7.70	8.88	8.39	0.41	1.10	3.22	1.72	2.01	0.68
20-25		8.95	9.15	8.90	9.00	0.09	2.44	1.09	1.36	1.63	0.48

TABLE 3 (cont.) pH and Loss on Ignition Values

COMMUNITY		"SHORT" DUNE GRASSLAND									
ANALYSIS		SOIL pH					Loss on Ignition %				
SOIL DEPTH - cms.	RELEVE NO.	25	29	30	Mean	Sm	25	29	30	Mean	Sm
0-5		8.20*	7.60*	7.49*	7.76	0.26	9.13*	9.74*	8.16*	9.01	0.50
10-15		7.51	8.00*	7.59	7.70	0.18	3.85	6.07*	4.32	4.75	0.78
20-25		8.60	8.92	7.50	8.34	0.50	3.99	2.57	4.93	3.83	0.74

NB Samples marked * were relatively dark in colour, due to humus formation. Thus a dark band of humus at 20-25 cms. depth in releve 25 probably marks a period of temporary stability and relatively marked humus accummulation. No such dark staining bands were evident in the deeper soil layers of the Open Scrub. pH values increase more rapidly with depth in this community. It is significant also that loss on ignition values decline more rapidly with depth than in the grassland community.

Such a pattern of results tends to support the view that the Rosa scrub develops under conditions of continuing wind blown sand accretion rather than from periods of previous temporary stability.

Further work is obviously needed, with fuller depth profile studies, involving the other communities as well, before this hypothesis can be confirmed or rejected with any degree of certainty.

Further depth profile studies might also assist in establishing the approximate ages of the stable dunes at Hart. It is interesting to note that Wilson (1960) recorded 13% Organic matter in the surface soils of dunes estimated to be 300 years old at South Haven Peninsula, Dorset (cf Dune Grassland Analyses in Table 3). Admittedly, this is from an area with significantly higher annual temperatures but markedly similar annual precipitation to the Hart site.

e) PHYTOSOCIOLOGICAL ASSESSMENT OF THE SUCCESSION SEQUENCE

Using the techniques of vegetation mapping and field description the most probably succession sequence has been described in Tansleyan terms. The pattern of this succession shows good agreement with the soil analysis data obtained. The next step must be an assessment of the validity of the succession sequence in phytosociological terms.

This is not a task which can be elucidated in a comprehensive manner at this stage. It has already been pointed out in the discussion on syntaxonomy of the vegetation groups (See 2 (c) page 8) at Hart, that far more work is needed before the exact relationships (especially at the association and sub-association level) can be fully elucidated.

Reference to the final differentiated table obtained (See envelope inside front cover of binder) shows that a number of distinct species blocks or sub-units have been obtained. It would be wrong to infer that these constitute distinct associations (or sub-associations) until more data is available from other geographical locations.

The broad syntaxonomy of the vegetational alliances has already been described (See Section 2 (c)). The alliance character species are indicated on the differentiated table. From these data a broad successional pattern is indicated which corresponds quite closely to that already described in Tansleyan terms.

The pioneer communities are characterised by the Ammophilion borealis alliance. This is represented in species block 1 by a character species of the Alliance - notably Agropyron junceiforme. This plant, in fact, was the dominant species of the foredunes.

Ammophila arenaria is the dominant character species of the alliance, occurring in Block 2, - as does Taraxacum officinale. The synaxonomy shows that this block involves a confluence of character species of several alliances.

VIZ. (1) GALIO - KOELERION

Characterised by:- Ononis repens,
Hypochaeris radicata,
Lotus corniculatus.

These species play a major role in the colonisation and stabilisation of the mobile dune surface.

(ii) TRIFOLION MEDII AND MESOBROMION

Characterised by:- Leontodon hispidus,
Anacamptis pyramidalis,
Helictotrichon pubescens.

These species are typical of calcareous grasslands - but both Leontodon and Anacamptis occurred frequently on the partially fixed dunes. Helictotrichon was more characteristic of the fixed dune and grassland communities.

(iii) ARRHENATHERION Elatioris

Characterised by:- Dactylis glomerata,
Trifolium pratense.

Both these species occurred relatively frequently in the areas showing transition from open to fixed dunes. Although both species are characteristic of neutral grasslands - they can, in fact, colonise a range of rudereal habitats - including footpaths and roadside verges. Disturbance, as a factor, is indicated by the occurrence of "weed" species - notably Tussilago farfara, Senecio jacobea and Sonchus oleraceus.

Block 3 is characterised by further species of the GALIO - KOELERION VIZ Camptothecium lutescens and Cerastium semidecandrum which continue the process of dune surface consolidation. On the more open dues, the "weed" species Senecio squalidus occurs, as well as the maritime Tripleurospermum maritimum.

Block 4 is characterised by a number of Alliances.

VIZ. (i) Trifolion medii and Mesobromion

Characterised by:- Geranium sanguinaeum
Thalictrum minus
Pimpinella saxifraga
Viola hirta

These are calcareous grassland species. Geranium sanguinaeum is the dominant species of the Trifolion medii grassland at Hart.

(ii) Arrhenatherion elatioris

Characterised by:- Arrhenatherum elatius
Holcus lanatus

These species occur more frequently in the less calcareous "long" grassland.

(iii) Agropyro - Rumicion crispi

Characterised by:- Lolium perenne
Potentilla reptans

The presence of both these species indicate disturbance, as a result of trampling pressure, in the grassland communities.

Block 5 consists of:-

(i) Differentials of Primula variant of Trifolion medii (and Mesobromion)

VIZ. Primula veris,
Koelaria cristata,
Ranunculus bulbosus,
Helianthemum chamaecistus,

With the exception of R. bulbosus all the above species occurred in releve 29 which was noteworthy for the presence of Orchis ustulata. This plant is regarded as a good Mesobromion character species in continental Europe (Shimwell 1971).

Orchis ustulata has a distribution throughout central Europe as far North as southern Sweden and southwards to the northern regions of the Mediterranean. To the east it occurs in the Caucasus as far as western Siberia (Summerhayes 1951).

In Britain, it has a markedly southern distribution, being of extremely local occurrence and rare in the north (Perring and Walters 1962).

Summerhayes (1951) reports it as occurring on the chalklands of the south and also on the Oolitic and other Jurassic limestones of the Midlands and southern England. In the north it has been reported from Cumbria, Durham and Yorkshire.- chiefly on the magnesian limestone.

The Hart site is believed to constitute the only record of this species in County Durham (1 of only 14 northern locations) and approximates to its north-eastern limit in Britain.

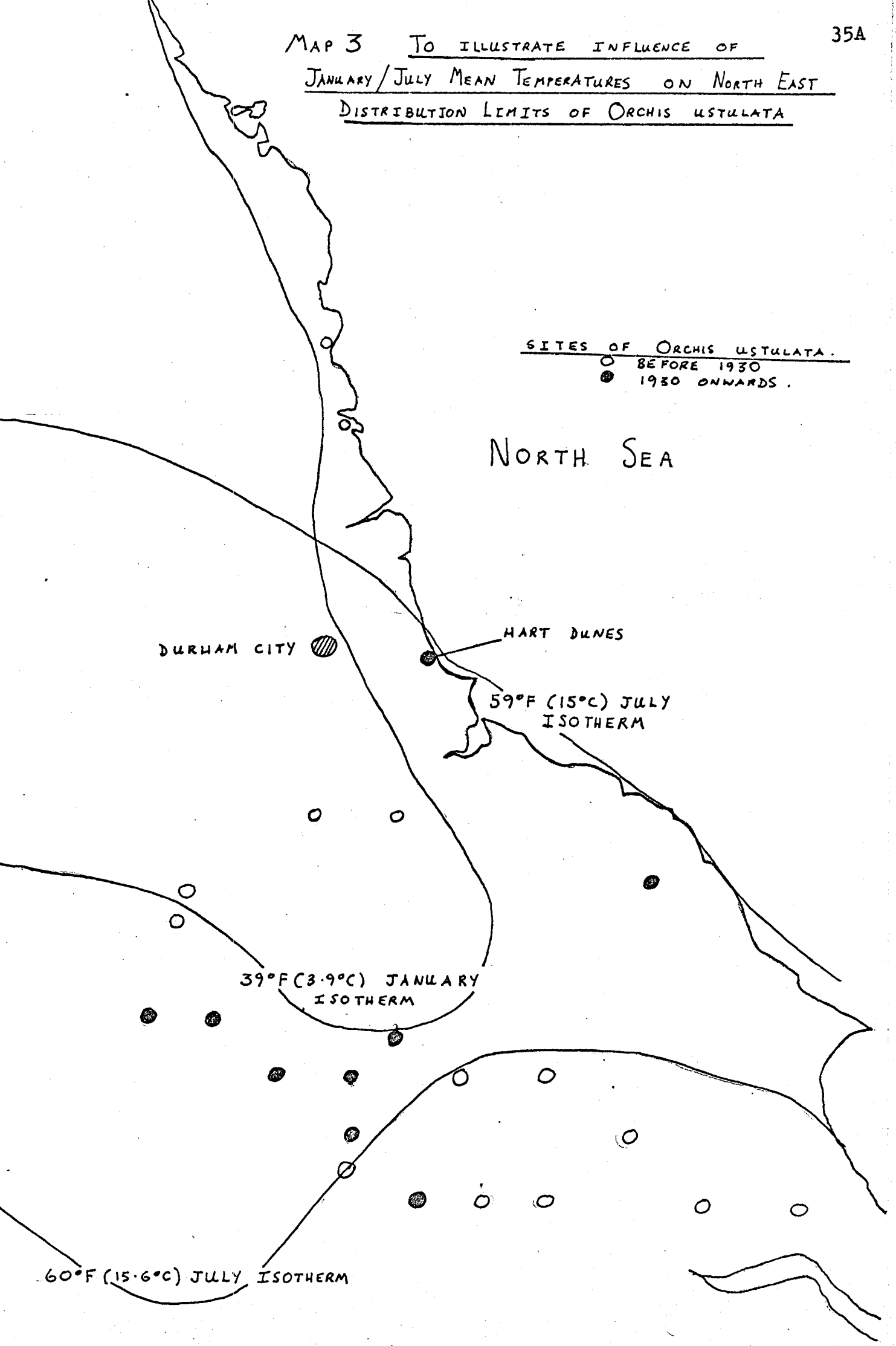
The site data for this species, at Hart, are summarised below:-

Slope and Direction:	8° N.W.
Height of Stand:	6 cms.
Soil pH:	7.60 (5 cms.) 8.00 (15 cms.) 8.92 (25 cms.)
Exchangeable Calcium:	4.07 M Eq/100 gms.
Exchangeable Magnesium:	0.14 M Eq/100 gms.
Soil Texture:	Fine and sandy, dry
Annual Rainfall:	< 630 mms.

Orchis ustulata has a low stature (usually up to 10-15 cms.) and occurs mainly on dry, calcareous grasslands where it does not have to compete with tall growing herbs (Summerhayes 1951). These conditions occur at the Hart site. The short mesobromion grassland sward is maintained partly by trampling (though this is relatively minimal) and partly by exposure of the dry north west facing slope to the growth inhibiting effects of the wind.

The soil analysis indicate calcareous conditions but Orchis ustulata is absent from the Magnesian limestone grasslands inland from this coastal area. The main reason for its restriction to this narrow coastal region of County Durham appears to be Climatic.

MAP 3 TO ILLUSTRATE INFLUENCE OF JANUARY/JULY MEAN TEMPERATURES ON NORTH EAST DISTRIBUTION LIMITS OF ORCHIS USTULATA



Map 3 shows the main sites of Orchis ustulata in the north east - in relation to the mean January/July isotherms. The Hart site lies just within the boundary of the 15°C July isotherm and the narrow coastal strip lies within the limit of the 3.9°C January isotherm. All present distributions of O. ustulata can be seen to be within these isothermal boundaries. Thus temperature appears to be the main factor in limiting the north-eastern distribution of O. ustulata.

Summerhayes (1951) reports that the seedling of this species develops as a cylindrical subterranean rhizome during the first year of its life. Subsequent growth occurs for a period up to 15 years; a new horizontal segment developing on the rhizome each growing season. During this period food is provided by a mycorrhizal fungus association with the rhizome. Usually after 10-15 years the first leafy shoot develops bearing three foliage leaves. Flowers are not normally produced before the plant is 13 years old and the first tuber is formed after the appearance of the leafy shoot.

Although it has not been demonstrated, low temperatures could inhibit one of the above developmental stages of this interesting little plant.

The Galio - Koelerion alliance is characterised in block 5 by Galium verum and Luzula campestris.

Block 6 can be regarded as consisting mainly of differentials of Rosa variant of Trifolion medii (and mesobromion). VIZ. Rosa spinosissima and Centaura nigra. As referred to earlier, the Rosa scrub is believed to be formed under conditions of continuing inundation by wind blown sand.

Block 7 could be regarded as a differential of Anthoxanthum variant of Arrhenatherion elatioris. Characterised by Anthoxanthum odoratum which is present in the herb layer beneath a closed scrub community dominated by Ulex europeaus.

Block 8 contains Rumex crispus, a character species of the Agropyro - rumicion, although Equisetum arvense, appears dominant throughout. This species thrives especially on damp soils and is a constituent of the dune marsh community.

Block 9 appears to show a confluence of several alliances

VIZ. i) ANGELICION LITORALIS:- Galium aparine, Atriplex hastate.

ii) MAGNOCARICION:- Phalaris arundinacea

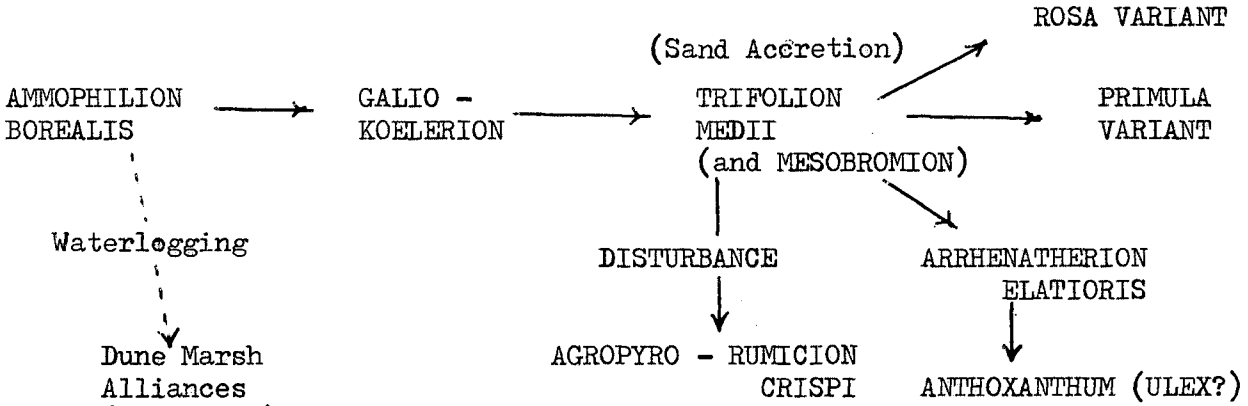
iii) APION NODIFLORI:- Nasturtium officinale

iv) GLYCERIO - SPARGANION:- Veronica becabunga

Block 9 is syntaxonomically somewhat heterogenous.

By reference to the sytaxonomy and the final differentiated table, it is possible to construct a scheme of the broad seral relationships in phytosociological terms.

VIZ.



This pattern is broadly similar to the succession sequence already described in subjective terms.

f) OBJECTIVE ORDINATION OF FLORISTIC DATA

Floristic data have been used to described the most probable succession (psammosere) at Hart in subjective terms (See page 28). This sequence tends to be confirmed by both soil analysis and phytosociological methods.

The final step must therefore be to attempt an objective assessment of the succession sequence using statistical methods based on floristic criteria (ie. presence and absence of species).

For this study, two statistical techniques have been employed. The first is the ordination technique of Kulczyinski (1949) based on floristic co-efficients of similarity between the 10 communities described at Hart. The second method

was a modification (Newsome and Dix 1968) of the ordination technique developed by Bray and Curtis (1957).

(i) KULCZYINSKI ORDINATION

This procedure relies on calculation of the Index of Similarity (IS) between two communities.

This was defined by Sorensen (1948) as

$$I.S. = \frac{2c}{a + b}$$

Where a = Number of Species in first community

b = Number of Species in second community

c = Number of Species common to both communities

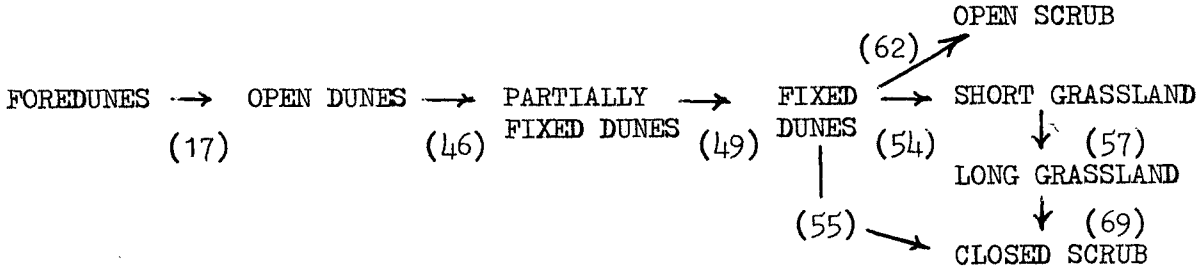
Imdices of similarity between the communities at Hart were calculated using the formula

$$I.S. = \frac{2c}{a + b} \times 100$$

The results are summarised in Table 4. This matrix of coefficients was then rearranged to give the best pattern with the highest I.S. values towards the centre.

The rearranged matrix is shown in Table 5. Greatest similarities occur between communities 3, 4, 5, 8, 6 and 9 (especially 5, 7, 8 and 9). The most dissimilar communities are 2 and 10, 1 and 10 and 2 and 1. The trampled areas (4) show greatest similarity to the fixed dunes (5) and open scrub (8). The pattern of I.S. values in Table 5 tends to confirm the subjective model of the succession.

VIZ.



NB Figures in brackets refer to I.S. values between communities.

ABLE 4

RAW MATRIX OF COEFFICIENTS OF SIMILARITY - PLANT COMMUNITIES - HART DUNES

	1	2	3	4	5	6	7	8	9	10
1		17	13	11	5	0	12	5	16	12
2	17		46	19	30	19	21	38	28	5
3	13	46		34	49	38	38	54	36	10
4	11	19	34		53	32	14	59	35	0
5	5	30	49	53		54	63	62	55	3
6	0	19	38	32	54		57	46	26	11
7	12	21	38	14	63	57		53	69	15
8	5	38	54	59	62	46	53		54	0
9	16	28	36	35	55	26	69	54		15
10	12	5	10	0	3	11	15	0	15	

ABLE 5

REARRANGED MATRIX - TO ILLUSTRATE KULCZYINSKI SQUARE FLORISTIC SIMILARITY.

		1	2	4	3	5	8	7	9	6	10
EDUNES.	1		17	11	13	5	5	16	16	0	12
AMMOPHILETUM.	2	17		19	~~46~~	30	38	21	28	19	5
PLED AREAS.	4	11	19		34	~~53~~	~~59~~	14	35	32	0
LLY FIXED UNES.	3	13	~~46~~	34		~~49~~	~~54~~	38	36	38	10
D DUNES.	5	5	30	~~53~~	~~49~~		~~62~~	63	~~55~~	~~54~~	3
DUNE SCRUB	8	5	38	~~59~~	~~54~~	~~62~~		~~53~~	~~54~~	~~46~~	0
GRASSLAND.	7	16	21	14	38	~~63~~	~~55~~		~~69~~	~~57~~	15
DUNE SCRUB.	9	16	28	35	36	~~55~~	~~54~~	~~69~~		26	15
GRASSLAND.	6	0	19	32	38	~~54~~	~~46~~	~~57~~	26		11
IE MARSH.	10	12	5	0	10	3	0	15	15	11	

>40 =

>50 =

Although the results in Table 5 cannot claim to be a complete analysis - it would appear that both the communities recognised in the field and the succession outlined above, constitute ecologically meaningful entities.

(ii) CURTIS ORDINATION

The traditional ordination procedures of Bray and Curtis (1957) select reference stands that represent the end points of known environmental gradients. The method adopted here, however, is that described by Newsome and Dix (1968) which attempts to select reference stands without bias towards any known gradient.

This method is essentially a modification of one employed by Beals (1960), in which the first reference stand on the X axis, is selected as one with a low sum of similarity indices ($\leq$ I.S.). It is assumed that this represents an end point of floristic variation within the overall community being sampled. The second reference stand is then chosen as one having a high dissimilarity index (I.D.) to the first one. The second stand is thus assumed to represent the opposite extreme of the floristic gradient.

Dissimilarity indices were calculated from the data given in Table 4, using the formula

$$I.D. = 100 - I.S.$$

Table 6 shows reference communities A and B which were selected from the X axis.

The dA values show the dissimilarity (ID) of a given community to community A, whereas dB values show the dissimilarity of a given community to community B. The x values denote the position of a community along the X axis. These were calculated using the formula

$$x = \frac{L^2 + (dA)^2 - (dB)^2}{2L}$$

(where L = ID between communities A and B)

TABLE 6

SUMMARY OF DATA USED IN ORDINATION OF

VEGETATION COMMUNITIES - HART WARREN (for explanation see text)

REFERENCE COMMUNITIES	SIMILARITY INDICES IS	DISSIMILARITY INDICES ID 1	2	3	4	5	6	7	8	9	10	Σ ID	Σ IS	dA	dB	x	e^2	dA'	dB'	y
A	1		83	87	89	95	100	88	95	84	88	809	91	0	100	0	0	88	83	54.2
B'	2	17		54	81	70	81	79	62	72	95	677	223	83	81	51.6	4222	95	0	95.1
	3	13	46		66	51	62	62	46	64	90	582	318	87	62	68.6	2860	90	54	75.9
	4	11	19	34		47	68	57	41	65	100	614	286	89	68	66.5	3501	100	81	67.2
	5	5	30	49	53		46	37	38	45	97	526	374	95	46	84.5	1077	97	70	72.5
B	6	0	19	38	32	54		43	54	74	89	617	283	100	0	100	0	89	81	56.8
	7	21	21	38	43	63	57		47	31	85	529	371	88	43	79.5	1428	85	79	54.9
	8	5	38	54	59	62	46	53		46	100	529	371	95	54	80.5	2538	100	62	74.1
	9	16	28	36	35	55	26	69	54		85	566	334	84	74	62.2	4049	85	72	60.2
A'	10	12	5	10	0	3	11	15	0	15		829	71	88	89	49.1	5332	0	95	4.9

A measure of the fit of a community to the axis is given by e. e^2 values were calculated for each community using the theorem of Pythagores (See figure 3).

ie. $$e^2 = (dA)^2 - x^2$$

These values were used to compute the second (Y) axis.

VIZ. Community A' was selected as that with the greatest e^2 value on the X axis and community B' was selected as that having the greatest ID to A'. (See Table 6).

dA' values show ID of a community to A'

dB' values show ID of a community to B'

y values were calculated from

$$y = \frac{L^2 + (dA')^2 - (dB')^2}{2L}$$

(where L = ID between A' and B')

There were no conditions for the third (Z) axis which was not computed.

Figure 2 shows the final ordination of the ten plant communities based on the corresponding x and y value plots from Table 6.

In effect, the ordination has distributed the communities (stands) in space in such a way that intercommunity distances are inversely proportional to floristic similarities between community pairs.

Based solely on floristic similarities - four distinct groupings are shown by the ordination. Soil pH and Calcium have been correlated with these groupings on the floristic gradient - although the most likely parameter segregating community 10 (viz. Soil Moisture) was not measured. The groupings, in fact, show good agreement with the floristic similarity pattern obtained by the Kulczyinski ordination. (See Table 5)

FIGURE 2 ORDINATION OF VEGETATION COMMUNITIES – HART WARREN & THEIR CORRELATION WITH DISTRIBUTION OF SOIL pH & EXCHANGEABLE CALCIUM.

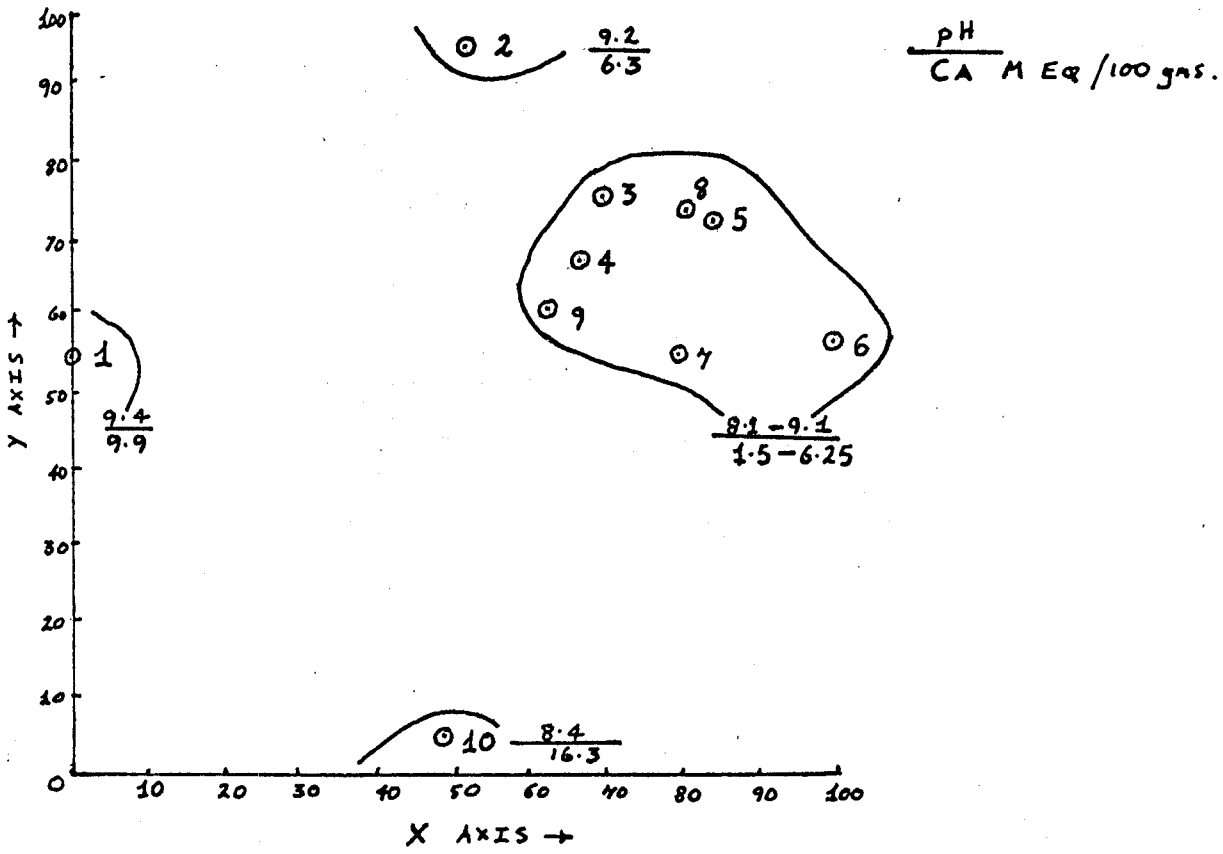
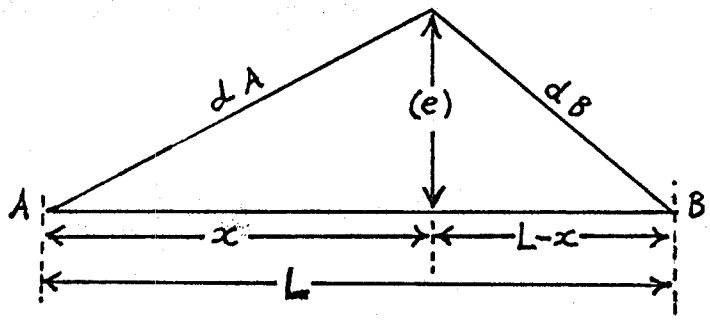


FIGURE 3 GEOMETRIC MODEL USED TO POSITION COMMUNITIES ALONG ORDINATION AXES (FOR EXPLANATION – SEE TEXT).



A correlation of the groupings with the known syntaxonomy of the vegetation at Hart is summarised below:-

COMMUNITY	FIELD DESCRIPTION	ALLIANCES	POSSIBLE ASSOCIATIONS (after Tüxen 1967)
1	Foredunes		
2	Open Ammophiletum	Ammophilion borealis	
3	Partially Fixed Dunes	Trifolion medii	Gentiano - Pimpinelletum?
4	Trampled Areas	Mesobromion	
5	Fixed Dunes		
6	Short Grassland	Galio - Koelerion	Galio -
7	Long Grassland		littoralis -
8	Open Scrub	Arrhenatherion elatioris	Geranietum
9	Closed Scrub	Agropyro - Rumicion crispi	ass Nov? (Tüxen)
10	Dune Marsh	Glycerio - Sparganion Apion - Nodiflori Magnocaricion Angelicion litoralis	

In conclusion, both ordination procedures utilised, would appear to offer a meaningful objective assessment of the validity of the plant communities, as distinct floristic units, within the overall successional pattern which was observed in the field.

CONSERVATION OF HART WARREN DUNES - SOME MANAGEMENT RECOMMENDATIONS

a) VALUE OF THE SITE

From a Conservation viewpoint, the greatest importance must be attached to certain floristic components of the site. That the Mesobromion grasslands of the Hart site represent the most probable North Eastern limit of the predominantly Southern Orchis ustulata, due to a fortuitous combination of climatic, edaphic and anthropogenic circumstances, has already been discussed in the previous section. In addition, a number of other plant species of somewhat restricted distribution would appear to be approaching their Northern limit at Hart. These include Inula conyza (Appleyard P 1972), Cardus nutans (Bellamy 1970) and Agrimonia odorata (Graham et al 1971).

By contrast the extremely local Astragalus danicus would appear to be approaching its Southern coastal limit at Hart (Perring and Walters 1962). Coastal records become increasingly infrequent further South. This is also true for Geranium sanguinaeum which forms the dominant character species of the Trifolion medii alliance at the Hart site. Two alien species are also worthy of note :- Vicia sativa ssp segetalis which occurs frequently throughout the Trifolion medii and Mesobromion grassland communities and the large flowered Rosa rugosa which appears to be spreading vegetatively in the open Ammopheletum at the Northern end of the site. The author has also recorded Linaria repens and Graham et Al (1971) cites the extremely rare Potentilla tabernaemontani as occurring in small mats on fixed dunes at Hart.

The relatively small area enclosed by the S.S.S.I (See Map 1) displays considerable floristic diversity. Hackett (1975) lists 102 vascular plant species. In the present phytosociological study, the author, working in a slightly larger area (See Map 2) recorded 119 species in 60 aufnahmen. Map 2 also shows the 10 main Plant Communities recognised by the author in the field. Each of these will provide a supportive series of ecological niches for the diverse animal communities at the site. The 2 main wetland areas of Dune Marsh

shown on Map 2 are a most desireable feature which should be maintained - providing a valuable refuge for animal species intolerant of the dry arid conditions of the main dune ecosystem.

The animal communities at Hart have not been extensively studied. Virtually nothing is known of the invertebrates. Hackett (1975) lists 6 species of mollusc obtained during half an hour's collecting. He lists Hygromia hispida as the dominant species which he reports as being very variable and possibly including several subspecies. During the floristic survey the author observed Burnet Moths (Zygaena sp) feeding in clusters on the inflorescences of Centaura nigra and colonies of a small unidentified spider on the rolled leaves of Ammophila arenaria.

Hackett (1975) reports Meadow pipit (Anthus pratensis) as the bird species most commonly associated with the dunes. He also records that Hedge Sparrow (Prunella modularis) and Skylark (Alanda arvensis) were seen frequently. During the survey, the author observed two pairs of Reed Buntings (Emberiza schoeniclus). Two nests were also found. One was situated in a thick clump of Ammophila at the northern end of the site which is subject to greatest public pressure. It was here that one pair successfully raised a brood of four chicks. The other nest was situated in the Rosa spinosissima scrub at the southern end of the site. Here the parents were less fortunate, only 1 fledgling surviving from an initial clutch of 4 eggs. These observations fully illustrate the value of both the Open Ammophiletum and Rosa spinosissima scrub as nesting cover. Conservational management must attempt to maintain these communities.

The author observed both Mole (Talpa europaea) and Hare (Lepus capensis) but no rabbits or their droppings were seen. This is interesting, as in the absence of these opportunist herbivores, one would expect the succession to Dune Scrub to have proceeded over larger areas than is, in fact, shown by Map 2. Presumably the dune grassland at (GR 486366) is being maintained by human trampling pressure. At the southern end of the site the grassland is more exposed. Nearest the cliff, the sward is probably maintained to some extent by trampling pressure - although a major factor may possibly be

exposure to onshore winds - producing the physiological effect of stunted growth forms in many species. On the golf links themselves - the intensive management necessary for such an amenity would serve to maintain the grassland sward in its present condition.

The site has considerable educational potential as a study area for students of environmental sciences. However, because of the essentially fragile nature of dune ecosystems it should be borne in mind that large parties (ie. > 10 students) continually visiting such a relatively small area offered by the site, could further accelerate the relatively serious erosion problems already created by excessive public pressure. The value of the dune binding grass Ammophila arenaria is not always fully appreciated. Should this vegetation cover be destroyed by excessive trampling or burning, then the subsequent wind erosion can rapidly lead to a large "blowout" with many tons of sand carried away over the surrounding land. The most fragile dunes occur at the northern end of the site which is subject to greatest public pressure. It is here that a number of new "blowouts" have developed in recent years. (See Map 2). At the southern end of the site, natural erosion is the major problem. Valuable amenity land forming part of the golf links could soon be irretrievably lost unless remedial measures are taken.

In short - Hart Warren Dunes comprises a site of both considerable Scientific and Amenity value and is worthy of serious Conservation Committment. It would be unfortunate to allow the character of this unique Magnesian Limestone Dune ecosystem to be destroyed by ill conceived or laissez-faire management methods.

b) CONSERVATION PROBLEMS

The following account describes the main problems observed by the author during fieldwork carried out at Hart Dunes between May and July 1976. Reference is also made to previous work carried out by Hackett (1975).

The problems described are such that if allowed to continue unchecked, can only result in a deterioration of both amenity value and wildlife potential of such a site. The report concludes with some future management suggestions for the site in an attempt to minimise these problems.

(i) Natural Erosion

Observations at the site show that the greatest natural erosion is occurring along the seaward facing slope of the principal dune ridge at GR 489-91/365. (See Map 2). The map clearly shows the present course of Crimdon Beck, which during the last 60 years has gradually moved in a south easterly direction from the outflow position shown by Ordnance Survey maps prior to 1920. The North Sea coastal currents flow predominantly southwards in this area and it is most probable that long shore drift of sand has resulted in the gradual movement of the river mouth to occupy its present position. Surface water flow down Crimdon Beck is far more intermittent than formerly, due to the decline in activity of local coal washeries. This has probably been a contributory factor in accelerating the southward movement of the river mouth in recent times, as any sand accretion from the northern side would only be flushed away after heavy rains. Present surface flow is therefore more intermittent than formerly but appears to be the causative factor in the undercutting of the principal dune ridge with subsequent loss of sand and vegetation to the open sea.

At any time large rafts of stable dune vegetation can be observed along the eroded northern face of the dune ridge. These rafts gradually sink downwards under gravity, where they become disintegrated by the scouring action of the river at the base.

Hackett (1975) measured the site of natural erosion along the dune face, using metal markers placed 30 metres apart in a straight line. By reference to fixed points and repeated measurements, he estimated that approximately 284 square metres of land were eroded between March 1973 and February 1974. He concluded that the greatest erosion was occurring on the highest part of the ridge and that this was likely to continue indefinitely until a large part of the stable dune had been irretrievably lost.

(ii) Man Induced Erosion

This is also a major problem at the site resulting from a) Trampling Pressure b) Sand Quarrying.

Trampling Pressure This is a problem which has increased markedly in recent years. With the development of the Crimdon Park Holiday Centre and the proximity of the site to the industrial connurbations of Sunderland and Hartlepools, this form of pressure must inevitably continue. The most popular area for visitors would appear to be the dunes immediately to the south east of the Holiday Centre. (See Map 2) -together with some overspill on the newly formed dunes at GR 488366. Unfortunately, these are the most fragile areas of the whole ecosystem and already large trampled areas, relatively devoid of vegetation and tending to form blowouts have developed (See GR486368) and (487366/67). Most public pressure comes during the relatively short, warm, dry holiday season which, of course, corresponds to the maximum growth period of the dune binding plants!

The author observed that the trampled paths between the partially fixed dunes, at the North West end of the site consisted largely of bare sand. Only stunted clumps of Ammophila arenaria and the flattened rosettes of Hypochaeris radicata appeared to be relatively trample resistant. By contrast, the trampled paths in the Mesobromion and Trifolion medii dune grasslands showed less severe erosion. The survey was carried out during the hot, dry Summer of 1976 and it was noticed that species with relatively high Cover/Sociability values, such as Lolium perenne and Festuca rubra, had been unable to survive the drought. However, Geranium sanguinaeum, Potentilla reptans, Plantago lanceolata, Galium verum, Poterium sanguisorba and Thalictrum minus proved to be relatively trample/drought resistant.

Hackett (1975) reports that Galium verum, Achillea milefolium, Ononis repens and Festuca ovina were the pioneer colonists of an area of bare sand resulting from illcut turf removal in the dune grassland. Recolonisation however was very slow. Between 1969 and 1975 only 50% plant cover had developed over the original denuded area of $\sim$ 2 square metres.

Sand Quarrying At the highest point of the main dune ridge, a large blowout has been created as a result of sand quarrying activities at GR 491365 (See Map 2). The author observed sand being dug manually from this area for use on adjacent golf course bunkers. Because of the (not insurmountable) problems of sand transportation from the lower shore, it would appear that sand has been quarried from the blowout for many years - for use on the golf course.

The cumulative effect is that a large sand crater has formed in a once stable dune ridge. The northern face has a slope of $\sim 30^{\circ}$ to the horizontal and is exposed to the full force of the onshore winds. No estimate has yet been made of the annual movement of sand, as a result of wind erosion, from this area but it must be the major contributory factor which has led to numerous complaints regarding excessive deposition of windblown sand on the greens and fairways of the golf course.

The author has also observed sand bags being filled by military personnel with material dug from fixed dunes at GR487366. Whilst this may not be an extensive practise, it can only hasten the deterioration of the site by further aggravating the erosion problem.

(iii) Litter

Litter is not only visually offensive but in the form of broken glass, rusting cans and aluminium "pull" rings can be positively injurious to both humans and wildlife. Such offensive items assume a new lethality when carelessly discarded on sand dunes, where they may lie partly buried and thus unnoticed by the unfortunate victim.

With the rash of modern "convenience" packaging, much of it non-biodegradeable, it is hardly surprising that litter is a major problem in picnic areas. This was confirmed by a visit to the dunes at the North west end of the site in September 1976. Cans, bottles and plastic packaging left by careless picnic parties were much in evidence. There must come a point when the visual amenity aspect of an area of natural beauty becomes so marred by these offensive items that it may well deter the more discriminating visitor.

It was noticed that no litter bins were provided near the car park or dune entrance areas at this end of the site.

(iv) Other Problems

During the early part of the survey, it was noticed that large areas of fixed Dune and Rosa spinosissima scrub had been burned at GR 487366 (See Map 2). Whether this was deliberate or accidental was difficult to establish but it must have occurred prior to May 1976 (ie. Before the hot, dry Summer period). It has been already emphasised that retention of Ammophila and Rosa spinosissima vegetation cover at the site is essential - if only to maintain dune stability and provide ecological niches for animal communities - especially nesting birds. The thorny nature of Rosa spinosissima is also an excellent deterrent of excessive public pressure on the stabilised dunes.

An area of almost permanent standing water was observed at GR 488366 throughout the survey period, although surface flow along Crimdon Beck was only evident after periods of heavy rain. Hackett (1975) believes that the area of standing water is caused by the salt water table rising to the surface at this point and that retention of water by clay underlying the sand is less probable. However, the author observed that even during the drought period, a continual feed of water from the unnamed stream at GR 488365 supplied the standing water area. This is further confirmed by the fact that the sand at this point, has accumulated both silt and peaty matter, presumably flushed down the stream after heavy rains.

The area has recently been marred by rubble dumping in an alleged attempt to fill in the water hollow. This hardly serves to enhance the visual amenity aspect and is no proper answer to the problem.

A somewhat disquieting feature which was observed on several occasions during the survey involved the presence of numbers of youths discharging air rifles in the direction of the open shore and offshore dune systems much frequented by visitors.

Besides the obvious risks to both wildlife and the general public, these incidents should emphasise the need for greater official surveillance of the area.

c) MANAGING THE PROBLEMS

Any overall Conservational management strategy for Hart Warren Dunes must clearly define the roles the site is intended to fulfill.

Three main roles would appear to be demanded of the site.

i Conservation of the main Plant Communities with a recognition of their floristic uniqueness in the North East and their subsequent Scientific and Educational potential. (This was the main reason the site was declared an S.S.S.I in 1968).

ii To provide a golf links as a local amenity.

iii To provide an open space amenity for relaxation by the general public.

There is no reason why these roles should be antagonistic and with intelligent management they could be complementary. A management plan for the site must therefore attempt to minimise the major problem of erosion and endeavour to maintain the plant communities shown on Map 2 thus allowing continued existence of maximum floristic diversity. In this way it may be possible to realise the dual aims of both Amenity and Wildlife Conservation at the site.

In conclusion, the author outlines some management recommendations, which it is hoped would minimise the problems already described.

(i) NATURAL EROSION

Bearing in mind that the present course of Crimdon Beck will continue to undercut the main dune ridge, thus causing valuable land to be lost, the only practical solution would be to excavate the approximate course of the river shown prior to 1920. (See Map 2). Hackett (1975) in the conclusion of his survey, is also of the same opinion. Much of the excavated sand could then be used as landfill in the area of permanent standing water between the two newly formed offshore dunes and the main dune ridge at GR488366.

It would also be essential to stabilise both this landfill area and the north and south banks of the newly excavated course with dune stabilising grasses. Although Ammophila is widely planted for this purpose, it tends to build high dunes, the slopes of which may become readily eroded by wind and trampling pressure (Ranwell 1973).

Studies at the coastal Ecology Research Station, Norwich, show that Elymus arenarius is preferable in situations liable to intense trampling. This species builds low profile dunes and can colonise areas nearer to the sea more readily than Ammophila. Furthermore Elymus is already well established among the foredune communities at Hart.

Ranwell (1973) gives details of field trials carried out using Elymus in areas of extensive trampling at Caister (Norfolk). Greenhouse reared seedlings were planted out at the High Water Mark of Spring Tides during May 1972. A simple wire fence erected round the plantings and a notice explaining the activities was sufficient to keep most holidaymakers from the plot. By Autumn 1972, most plants had established vegetative growth but were still too small to trap sand.

Such a planting regime should minimise the long shore drift of sand which has pushed the mouth of Crimdon Beck some 460 metres to the South east during the past 50 years. It would also be desireable to fence off the newly planted areas so as to minimise trampling and give the dune vegetation a chance to become established.

With the present intermittent flow of water down the beck, some periodic sand clearance would be necessary to keep the excavated channel clear. This should not be required more than once or twice a year. It would be essential to ensure that the excavation method would not destroy any stabilising dune vegetation along the river banks, otherwise the whole objective would be defeated. Alternatively the channel might be kept clear by periodic flushing with waste mine water down the beck. One attractive aspect of the excavation method is that the sand dug out could be used for golf course bunkers! This should alleviate the quarrying for sand at the large blowout area referred to earlier.

(ii) MAN INDUCED EROSION

The dune sward at the North western end of the site has become badly damaged by heavy trampling. Once the sward is destroyed, rapid erosion can occur, leading to an inundation of inland developments with blown sand. These problems were observed by the author at Hart in September 1976 - following a period of high, but not excessive, winds. Sand lay piled in drifts up to 50 cms. deep and was deposited over a wide area of the Crimdon Holiday Centre. At one point, the road leading to the beach was completely blocked. Much of this sand came from the badly eroded dunes below the Caravan Park. Thus the subsequent loss of amenity and clean up costs involved must constitute a serious financial problem.

Following very serious dune erosion at Camber (Sussex) it became necessary to institute a dune restoration programme involving seeding and fertilising coupled with protective fencing (Boorman L.A. 1973). Studies by the Coastal Ecology Research Groups have shown that fertilisation of trampled areas produces small but significant increases in the regrowth of a damaged sward (Boorman L. 1973).

Studies by Hackett (1975) of natural regeneration of Dune grassland at Hart shows that it is an extremely slow process. In badly eroded areas this will be hampered by drought, wind blasting and low availability of minerals. It is recommended that the badly eroded areas at the North western end of the site (and at GR 487366) be fenced off and a dune stabilisation program implemented involving planting and fertilisation. Provided explanatory notices are set up, human interference should be minimal. Large areas of foreshore would still be available for recreational activities.

Sand Quarrying from areas above the High Water Mark should be forbidden and it is recommended that notices be displayed to this effect. Also the driving of tracked vehicles through the partially fixed dunes at the Northern end of the site should be discouraged.

If possible, the golf course management should be dissuaded from continuing their quarrying activities at GR 491365. They should be encouraged to obtain sand from the lower shore, pointing out that the large blowout area is the main source of wind blown sand problems on the golf course! It is recommended that the steep slopes of the blowout be thatched and planted with Ammophila. The lower, flatter slopes nearer the sea could be stabilised with Elymus arenarius.

(iii) LITTER

This is a major problem on the dunes at the North west end of the site.

It is recommended that litter bins be installed at the car park, Crimdon bridge and other dune access points. The bins should be regularly emptied and notices displayed warning that littering is an offence carrying a £100 maximum fine.

Even with these precautions it will still be necessary to have periodic litter clean ups from the dune areas, if both safety and visual amenity aspects at the site are to be maintained. Some discarded items may have a market value. Durham Friends of the Earth group organise collections of metal cans for recycling.

(iv) PUBLIC EDUCATION AND CO-OPERATION

With its close proximity to both urban areas and the Crimdon Park Holiday Centre, the Northern end of the site will continue to experience pressure from visitors. Whilst, admittedly, it is impracticable to exclude the public from large areas of duneland, in the interests of conservation - much could be done to maximise public co-operation at this unique site.

It is recommended that:-

a) A notice be displayed at the Crimdon Park entrance with some brief information about the dunes and requesting the public (i) To avoid walking over young dunes as excessive trampling results in serious wind erosion;

(ii) Not picking any wild flowers however common they may appear.

b) A small booklet be produced which could be purchased by individuals wishing to learn more about the dunes and the plants and animals found there.

c) A part-time warden be appointed to carry out conservation tasks throughout the year and public liaison duties at weekends during the busy holiday period.

The author has seen such a system work quite successfully at a coastal dune site (Eskmeals) in South Cumbria.

At Hart, much of the site is occupied by the golf links which is already subject to intensive management. Whilst golf courses do restrict floral diversity (HEPBURN, I. (1952)) it is without doubt that the one at Hart is an excellent amenity feature from the Conservation point of view. Although the golfers produce some trampling, disturbance to isolated clumps of rare plant species is minimal. In the case of Orchis ustulata this is noteworthy as without the presence of the golf links, it might have disappeared for ever from the Durham Flora.

APPENDIX 1

HART WARREN DUNES - SPECIES LIST July 1976

NB THE FIGURE IN BRACKETS DENOTES THE TOTAL NUMBER OF OCCURRENCES OF EACH SPECIES WITHIN THE RELEVES

Achillea milefolium (24)
Agropyron junceiforme (14)
Agropyron junceiforme x repens (7)
Agropyron pungens x junceiforme (8)
Agropyron repens (3)
Angelica sylvestris (2)
Agrostis stolonifera (10)
Agrostis stolonifera (palustris) (1)
Ammophila arenaria (29)
Anacampis pyramidalis (7)
Anthylis vulneraria (1)
Anthoxanthum odoratum (2)
Armeria maritima (2)
Arrhenatherum elatius (9)
Astragalus danicus (1)
Atriplex hastata (3)
Bellis perennis (4)
Briza media (3)
Campanula rotundifolia (6)
Cardus nutans (1)
Carex arenaria (10)
Carex caryophylla (1)
Carex flacca (4)
Carex hirta (1)
Centaura nigra (7)
Centaura scabiosa (1)
Centaurium erythraea (1)
Cerastium diffisum (11)
Cerastium semidecandrum (4)
Crataegus monogyna (1)
Cirsium arvense (6)
Dactylis glomerata (15)
Dactylorhiza fuchsii (4)
Elymus arenarius(7)
Epilobium hirsutum (2)
Equisetum arvense (11)
Erodium dunense (1)
Festuca ovina (3)
Festuca arundinacea (5)
Festuca rubra (arenaria) (33)
Galium aparine (2)
Galium verum (5)
Geranium sanguinaeum (32)
Habaneria conopsea (1)
Helianthemum chamaecistus (2)
Helictotrichon pratense (1)
Helictotrichon pubescens (12)
Heracleum sphondyllium (7)
Holcus lanatus (7)
Holcus mollis (2)
Honkenya peploides (2)
Hypochaeris radicata (15)
Juncus inflexus (1)
Koelaria cristata (albescens) (4)
Lamium purpuraeum (1)
Lathyris pratensis (1)
Leontodon hispidus (11)
Linaria repens (1)
Listera ovata (2)
Lolium perenne (6)

APPENDIX 1 (cont.)

Lotus corniculatus (14)
Iris pseudacorus (1)
Nasturtium officinale (2)
Oenanthe crocata (1)
Ononis repens (17)
Linum catharticum (1)
Luzula campestris (4)
Orchis mascula (1)
Orchis ustulata (1)
Phleum nodosum (1)
Phalaris arundinacea (2)
Pimpinella saxifraga (8)
Plantago lanceolata (23)
Plantago maritima (1)
Poa annua (5)
Poa subcaerulea (10)
Poa trivialis (2)
Poa pratensis (8)
Polygala vulgaris (2)
Potentilla reptans (3)
Potentilla anserina (1)
Poterium sanguisorba (7)
Primula veris (6)
Prunella vulgaris (1)
Ranunculus Bulbosus (3)
Ranunculus repens (2)
Reseda lutea (1)
Rhinanthus minor (1)
* Rosa rugosa
Rosa spinosissima (17)
Rosa sherardii (1)
Rubus fruticosa (6)
Rumex acetosa (1)
Rumex crispus (3)
Rumex conglomeratus (1)
Senecio jacobea (8)
Senecio squalidus (4)
Senecio valgaris (1)
Silene alba (1)
Sonchus arvensis (1)
Sonchus oleraceus (3)
Symphytum uplandicum (1)
Taraxacum laevigatum (5)
Taraxacum officinale (5)
Thalictrum minus (13)
Trifolium pratense (6)
Trifolium repens (9)
* Tragopogon pratensis
Triglochin palustris (1)
Trisetum flavescens (6)
Tripleurospermum maritimum (2)
Tussilago farfara (11)
Ulex europeus (5)
Urtica dioica (1)
Veronica becabunga (2)
* Veronica chamaedrys
Vicia sativa (14)
Viola hirta (5)

BRYOPHYTA

Bryum erythrocarpum
Bryum pendulum
Camptothecium lutescens
Mnium undulatum
Tortula ruraliformis

* Indicates a species not recorded in the releves

APPENDIX II

THE DUNE SOILS

A series of soil samples were collected from each of 3 relevé sites within each plant community. A total of 30 samples were collected using a hollow tube of dimensions 16 cms. x 2.7 cms. This was driven in flush to the ground and the sample core was then removed. The samples were labelled with the community and relevé number and then transported in polythene bags to the laboratory for subsequent analysis.

Methods

The soil samples were broken up and ground separately in a mortar and pestle. Each sample was then shaken through a fine 30 mesh sieve to remove root fibres and other coarse matter. The following analyses were subsequently performed on each sample.

i SOIL pH Approximately 50 gms. of air dried soil were weighed into a 100 ml. beaker, 50 mls. distilled water were then added to the sample which was left to stand, with occasional stirring, for 1 hour. The pH was then determined using a meter and glass electrode, whilst stirring was continued.

ii LOSS ON IGNITION Each soil sample was first dried for 5-6 hours in an oven at 110°C, removed and allowed to cool in a dessicator. Approximately 2 gms. of sample was then weighed into a tared porcelain crucible. The crucible was then heated in a muffle furnace at 700°C for 30 minutes. It was then removed, cooled in a dessicator and re-weighed. The % loss in weight was taken as being equal to the Loss on Ignition.

iii EXCHANGEABLE CALCIUM AND MAGNESIUM These are most readily extracted from soil samples by a process of cation exchange, utilising $^{n}/_{1}$ ammonium acetate solution.

ie. $Ca^{++} + 2\ CH_3\ COONH_4 \longrightarrow Ca\ (CH_3COO)_2 + 2NH_4^{+}$

APPENDIX II (cont.)

The Calcium exchanged can then be analysed most accurately using the atomic absorption spectiometer.

The main difficulty with the straightforward ammonium acetate cation exchange procedure is that soils of pH > 7 may give erroneous results - due to non-exchangeable Calcium and Magnesium being leached out. (DURHAM UNIVERSITY, GEOGRAPHY DEPARTMENT 1972).

The Hart Warren soil samples, without exception, had pH values in excess of 7. The following procedure was therefore adopted:- Two solutions were prepared, one containing 48.8 gms. of Barium chloride/litre. the other containing 50 mls. triethylamine plus 180 mls. $^{n}/_{1}$ hydrochloric acid/litre. These solutions were then mixed in equal volumes. 250 mls. of the resultant solution were then allowed to filter through 5 gms. of soil sample at a rate of ~ 200 drops per minute. For convenience, the soil sample was packed between layers of cotton wool in a vertically clamped tube. The filtrate was discarded. 250 mls. of $^{n}/_{1}$ ammonium acetate (buffered to pH 7 using ammonium hydroxide solution or acetic acid) were then allowed to filter through the sample at the rate of 200 drops per minute. The resultant filtrate was collected and analysed for Calcium and Magnesium using the atomic absorption spectrometer. The above procedure was repeated for all the other samples. A blank run was done on the unused $^{n}/_{1}$ ammonium acetate and also on the double distilled water used for the atomic absorption analysis. Any calcium or magnesium values obtained were then subtracted from the final results.

The results from the atomic absorption spectrometer gave exchangeable Calcium and Magnesium values as parts per million (ppm) of sample analysed. These values were converted to milliequivalents (me)/100 gm. of soil, using the formula:-

$$\text{ppm} \times \frac{1}{EW} \times \frac{1}{4} \times \frac{100}{W}$$

Where EW is equivalent wt of Element (Ca = 20, Mg = 12)

$\frac{1}{4}$ is dilution figure for leachate

W is weight of soil used (5 gms.)

SUMMARY

1. Vegetation communities subjectively recognised at the more northerly end of Hart Warren Dunes have been extensively mapped.

2. These communities have been intensively surveyed for floristic characteristics, using the phytosociological technique of the Zurich:Montpelier school and a detailed association analysis carried out to produce a classificatory pattern of species groupings.

3. From the differentiated table obtained an attempt has been made to elucidate the syntaxonomy of the vegetation groups. It was not really possible to differentiate these beyond the Alliance level - on the basis of the small amount of data available - although broad similarities have been shown to Associations described in the literature from a dune area of South west Norway.

4. Field descriptions of the plant communities have been given both in terms of traditional British plant Ecology (after Tansley) and Continental phytosociology. This has included some discussion of the autecology of Orchis ustulata together with the most probable factors influencing its location at Hart.

5. Using field observations, description and the phytosociological table - the main successional patterns have been summarised in both traditional British and Zurich:Montpelier terms. These have shown good correlations and the succession sequence has been further confirmed by detailed soil analyses and by limited soil depth profile studies.

6. Evidence has been presented which suggests that the Rosa spinosissima scrub climax may have been formed under conditions of continuing sand accretion resulting from erosion of nearby dune surfaces.

SUMMARY (cont.)

7. Two statistical procedures, each involving ordinations of the available floristic data, have been carried out. The results of these objective procedures have tended to confirm the validity of the vegetation communities and the succession sequence as ecologically meaningful entities.

8. The adverse pressures on this floristically valuable site have been described together with a detailed discussion of a suitable Conservation strategy - aimed principally at minimising the serious problem of dune erosion, and maintaining the existing floristic communities within the broad framework of wider amenity usage.

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University College,

The Castle,

Durham.

September 1976.

PRINT OUT

Alliance	No.	Species	FOREDUNES						OPEN AMMOPHILETUM						PARTIALLY FIXED DUNES						TRAMPLED AREAS						FIXED DUNES						"SHORT" GRASSLAND						"LONG" GRASSLAND						OPEN DUNE SCRUB						CLOSED SCRUB					DUNE MARSH					REJECTED RELEVÉS	
			001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	016	017	018	055	056	057	058	059	060	019	020	021	022	023	024	025	026	027	028	029	030	031	032	033	034	036	048	037	038	039	040	041	042	043	044	045	046	047	050	051	052	053	054	035	049
Ab	12	AGRO JUNC	1	+	+	+	3	2	+	+	+			+	+													+															+	+																		
Ab	28	ELYM AREN		+	4	+	1	2												+				1																																	
	37	CIRS ARVE		1																																							+										+										1	+
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TM	61	RANU BULB																															+	+				+																										
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	80	SYMPHYTUM UPLANDICUM.																																																												4

KEY TO CHARACTER SPECIES OF ALLIANCES

Ab = AMMOPHILION BOREALIS.
TM = TRIFOLION MEDII (& MESOBROMION).
K = GALIO - KOELERION.
A = ARRHENATHERION ELATIORIS.
A/R = AGROPYRO - RUMICION CRISPI.
A/L = ANGELICION LITORALIS.
M = MAGNOCARICION.
A/P = APION NODIFLORI.
G/S = GLYCERIO - SPARGANION.