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THE GRAZING MANAGEMENT OF SAND DUNES

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Contents

Summary

This handbook on the grazing management of sand dunes represents the results and conclusions of a three year study funded jointly by the Nature Conservancy Council and the Institute of Terrestrial Ecology. It combines a review of the processes that control and affect the development of vegetation on sand dunes with a field survey of the present situation regarding the grazing management, or non-management, of British sand dunes. It is concerned with the use of grazing as a management tool for the maintenance or increase of plant species diversity within the various sand dune communities.

Sand dunes are formed when wind blown sand becomes stabilised by the arrival and growth of vegetation. In the early stages of this process the critical factor is the ability of the early colonisers to withstand sand accretion, to withstand burial by sand. Once the rate of accretion drops the area is colonised by a wide range of plant species forming various different plant communities.

The nature of the community formed is determined by the prevailing environmental conditions, both physico-chemical and biological. The physico-chemical factors include climatic factors such as temperature, humidity, and rainfall, and soil factors, moisture content, water holding capacity and ground water level, mineral nutrient status, and organic content. The biological factors include such diverse properties and processes as the presence of nitrogen fixing algae, bacteria and fungi, on the one hand, and the presence of grazing animals on the other.

Grazing principally affects grassland communities, here used in its widest sense to include all terrestrial plant communities not dominated by tall woody vegetation. Five habitat groups are recognised: yellow dune communities, damp slack communities, wet slack communities, dune heath communities and grassland communities not included in any of the above.

Forty eight dune sites were visited and studied through the recording of information on the vegetation and grazing status of 777 quadrats. Vegetation parameters included height, cover and abundance of vascular plants, bryophytes, and lichens. The grazing status was inferred from animals and their signs in the quadrats and within various zones up to 50 m away.

Data was also used from the survey of Scottisn coastal dune sites by the Institute of Terrestrial Ecology under a commision from the Nature Conservancy Council. Detailed information was used from eighteen representative sites. More general information was taken from the survey as a whole.

The results of the present survey confirm that the dominant grazing animal in the British sand dunes is the rabbit. Over 70% of the quadrats are regarded as being rabbit grazed directly and over 98% of the dune sites sampled appeared to be affected by rabbit grazing to some extent. Just over a third of the sites were grazed by cattle and a similar proportion by sheep. Generally it was one or the other although there were five sites that were grazed by both. There was only site where there was significant grazing by ponies although a number of other sites

were grazed occasionally by passing ponies.

The intensity of the grazing pressure was very variable. Out of the forty eight sites, four were virtually ungrazed and a further ten only lightly grazed, while nine sites were considered to be heavily grazed. However the remaining twenty five sites were recognised as being intermediate only to the extent of not being obviously overgrazed or undergrazed. It was further recognised that the present state of the vegetation tended to reflect the grazing management of the vegetation in the recent past rather than reflecting the current management. A change in the grazing management often took many years to effect a permanent change in the vegetation.

Certain sites were selected to illustrate key points in dune management and then these points were combined with information from various dune grazing experiments and from practical dune management studies that had been made on similar dune communities in the Netherlands, to formulate some general guidelines for the future grazing management of the British sand dunes.

The grazing requirements to promote species diversity are very different for the five habitat groups. In the yellow dunes the plant community is open with bare ground for colonisation and plant competition is not great. There is thus little need for the control of plant growth by grazing. In addition yellow dune communities are particularly vulnerable to damage from trampling and grazing animals should thus be excluded.

Dune grassland, in the narrow sense, needs to be grazed to maintain species diversity. The purpose of grazing is to remove excess vegetation growth to reduce competition from the vigorously growing plant species. In general a grazing intensity of between 0.2 and 0.5 beasts per Ha or perhaps better 0.5 to 1.5 sheep per Ha is likely to give the best results. These rates can be exceeded when grazing is first applied to an area or as a permanent measure for limited periods of the year only.

It is important to limit the rate of stocking to that which can be maintained by the dune vegetation itself. If there is insufficient food on the dunes the animals should be removed and fed elsewhere. Supplementary feeding on the dunes causes damage from soil nutrient enrichment and from excessive trampling and is to be avoided. If the area grazed is large (>100Ha) lower stocking rates can be used and a rich vegetation mosaic created.

Dune slacks are generally best grazed by cattle and with the higher soil moisture levels this can sometimes be at intensities as high as 1 beast/Ha. Anything above this is likely to cause serious damage to both the soil and the vegetation especially in the wetter areas.

Dune heath vegetation has a low productivity and its own special management problems. It needs to be grazed (or cut or burnt) to maintain the internal mosaic by the successful regeneration of the main species, but too much grazing will leads to its conversion to a species-poor acid grassland. The sucessful management of heath vegetation can best be achieved by sheep grazing at rates of between 0.2 and 1.0 sheep/Ha although cattle

grazing has also been used successfully at rates of between 0.1 and 0.3/Ha. The point made about the benefits of grazing large areas to maintain the vegetational mosaic is particularly true for heathland communities.

Finally it is emphasised that any dune management regime must be accompanied by an effective programme of long term monitoring so that undesirable changes can be detected at an early stage and appropriate adjustments can be made.

Author's Preface

This handbook on the grazing management of sand dunes represents the results and conclusion of a three year study funded jointly by the Nature Conservancy Council and the Institute of Terrestrial Ecology. However it is more than just a final report on that contract as I have drawn extensively from my experiences of working on various aspects of sand dune ecology over the past seventeen years.

The seeds of this project were sown in the early years of my time at the then Coastal Ecology Research Station, Colney Lane, Norwich, where, under the expert guidance of Derek Ranwell, I acquired a deep and lasting interest in the ecology of coastal sand dunes and especially in their care, management and restoration. In parallel with this a series of visits over the years to the Netherlands, and in particular to the Instituut voor Duinonderzoek 'Weever's Duin' at Oostvoorne and to the Rijksinstituut voor Natuurbeheer at Leersum, gave me considerable insight into the very positive approach to the complexities of dune ecology and management adopted by our Dutch colleagues. Both during this period and during the course of this study I gained much from discussions, often in the field, with those concerned with the practical implementation of sand dune management, with wardens, estate workers and others. I have tried to make this a practical handbook and if I have succeeded at all then it is thanks to these practical and stimulating discussions.

The timing of this handbook is, I think, singularly appropriate. The 1970's were a fruitful period for sand dune research, as indeed they were for many other lines of ecological research. The early 1980's saw something of a contraction and retrenchment of the position but despite this there is now very much a renewal of interest in coastal ecology and coastal management. Two conferences in 1987 on coastal ecology, at Hull and at Leiden, effectively set the seal on this process. As a sign of this two new groups appeared, a Coastal Research Group in Britain, and more significantly the international European Union for Dune Conservation and Coastal Management. In addition to all this the impending threat to all coastal ecosystems from a major rise in sea level as a result of the greenhouse effect is generally acknowledged. While it is the salt marshes that will take the brunt of the attack, the impact on our dunes will be considerable and will demand a nationally co-ordinated and research-based management programme if their rich and diverse floras and faunas are to survive.

As I have already indicated I owe much to the very many colleagues who have contributed in many different ways to this report and I am sure they will appreciate that it is not possible to thank them all individually. I would however like to express my special thanks to Pat Doody, the NCC's nominated officer for the contract, for his help and support in so many ways, and to Mary, my wife who accompanied me on many field trips in this country and abroad, for her continued encouragement and interest. It is sad that Derek Ranwell, from whom I learnt so much is no longer with us. In recognition of the tremendous debt dune ecology and management owe him I should like to dedicate this handbook to his memory.

1. Introduction

The term 'grassland' is generally used in this handbook in its broadest sense as including all those terrestrial plant communities of coastal sand dunes that are not dominated by tall woody vegetation. Strictly grassland is composed of those plant communities where grass species are dominant, but species rich grassland of high conservation interest may well be dominated by broad-leaved species. In some circumstances climatic and biotic stress may produce communities that are dominated by bryophytes and lichens. Except where there is further clarification, the term 'grassland' is used in contrast to shrub and woodland, to indicate those communities where herbaceous species are dominant, and woody species, if present, are of low stature.

The main body of this handbook begins by considering the processes involved in the development of the various sand dune plant communities. Herbaceous sand dune vegetation can be divided into five distinct groups of communities, yellow dune, dune grassland, damp dune slack, wet dune slack and dune heath. Each of these has its own special environmental and biological properties. The mechanisms that control plant species diversity, including the grazing of domestic and farm animals, interact differently with these different groups of sand dune plant communities. These matters are all discussed in Section 2.

The next section is concerned with methods used in the course of the survey of the grazing situation in British sand dune sites. The criteria used for the selection of sites are discussed. Then the methods used in the survey are described. This handbook has a broader base than just the survey results so this section concludes by describing the various different sources of information that have been used.

Section 4 is concerned with the presentation of the results of the survey. It attempts to answer the following questions:-

1. What are the current levels of grazing by both domestic and wild animals on the selected British dune systems ?
2. What problems are there in relation to the maintenance of the floristic diversity of the dunes ?
3. What are the effects of the different grazing regimes on the structure and composition of the dune vegetation ?

This section also considers the effect on the results of seasonal changes during the course of the survey as well as considering regional trends. It concludes by considering what lessons can be learnt from various grazing experiments.

While the results from all the sites are summarised in various ways it is only possible to consider a selection of these in detail. Section 5 takes 28 sites as examples to illustrate various general points concerning their grazing management. It is emphasised that the inclusion or exclusion of particular sites was purely on the basis of the existence at these sites of special points of general interest. It was not intended to be judgmental in any way although suggestions are sometimes made with regard to the management of particular sites.

The remainder of this handbook is concerned with the interpretation and utilisation of all the information obtained in order to draw up more effective grazing management plans. Section 6 is concerned with the practical assessment of various different grazing situations. This includes an appreciation of the present grazing position with regard to both farm and wild animals and the interactions between them. It includes the assessment of the comparative effects of combined stocking rates and the question of the incidental and interactive effects of trampling from both grazing animals and humans. The section concludes with a consideration of the difficult problems associated with the interpretation of the effects of the past grazing history.

Section 7 is the section of the report with practical guidelines for the formulation of effective grazing management programme for specific sites. It includes the assessment of the current situation, the interpretation of what is needed, the practical implications and finally emphasises the need to monitor future changes in the vegetation. While the essentials are contained in this section they are best seen against the background of the handbook as a whole.

The text finishes with some general conclusions and a discussion of a number of points of uncertainty where some further research is needed (Section 8). Finally there is a bibliography including some recommendations for further reading (Section 9) and an Appendix summarising the results on a site by site basis (Section 10).

2. The effect of grazing on dune grassland communities

2.1 Grazing and the plant community

A study of the effect of grazing on vegetation might well be taken to be a study of grassland vegetation itself, since the prime effect of grazing on any plant community is to inhibit the natural tendency for taller woody plants, shrubs and trees, to gain dominance. This succession will take place unless inhibited by certain factors of natural or man-made origin. Natural inhibitors of successional development may be geophysical, climatic or biotic.

The development of woody plant communities may be prevented by continued sand movement limiting plant growth to those species able to withstand sand burial. It may be prevented by climatic stress; for example, drought maintains grassland steppe communities, and low temperature produces tundra vegetation, or a combination of factors, for example, salinity and temperature interact to produce the typical temperate and sub-polar salt marsh vegetation.

The biotic limitation of successional development of a plant community is through the presence of sufficient numbers of herbivores to inhibit the growth of woody plants. This can occur naturally or it can be the result of man's intervention. A somewhat similar effect can also be brought about artificially by mowing or cutting the vegetation.

The term 'grassland' is generally used in this report in its broadest sense, to include all those terrestrial plant communities that are not dominated by tall woody vegetation (trees or shrubs). Strictly grassland is composed of those plant communities where grass species are dominant, but species-rich grasslands of high conservation interest may well be dominated by broad-leaved species. In some circumstances climatic and biotic stress may produce communities that are dominated by bryophytes and lichens. Unless there is further clarification the term 'grassland' is used in contrast to shrub and woodland, to imply those communities where herbaceous species are dominant, and woody species, if present, are of low stature. In the sand dune context, this will include a very wide range of plant communities, from the pioneer dune-building communities, through both the wetland vegetation of dune hollows and the dry lichen-dominated communities, to mature grassland and also the heathland communities where species of the Heath family Ericaceae are dominant.

Before we can consider the effect of grazing on these dune 'grassland' communities it is necessary to examine the processes that are involved in the growth and development of all the vegetation types involved. The word community itself is used in different senses reflecting different perceptions of the way the plants that make up that grouping interact.

On one hand it may be thought that the assemblage of species that is characteristic of a particular area is purely and simply a reflection of the local environment and the propagules that are available for plant colonisation, with no suggestion of plant-

plant interactions.

On the other hand a plant community can be seen almost as an organism in the sense that the component species interact with each other to form a distinctive coherent whole, rather in the same way as the different component cells form a living organism. It is upon this quasi-organismic concept that the Zurich-Montpellier system of vegetation classification, of phytosociology, is based. While in some ways it represents a complete contrast to the mathematically formal classification systems used in Britain and the United States the practical outcomes of the two approaches are remarkably similar.

Certainly the differences that there are can be attributed to differences of methodology rather than reflecting the differences of fundamental concept. After all if a particular assemblage of plant species is readily recognisable is this not more important to the ecologist, let alone to the manager of a nature reserve, than the deeper relationships between the species involved ? Certainly in recent years the tendency has been for conservation management to be based on the preservation of the whole plant community rather than on the preservation of single species.

2.2 The development of sand dune vegetation

The sand dune communities where the grazing impact has been studied include the pioneer communities of the fore dunes and of areas where there has been dune erosion and secondary vegetation development; the vegetation of dune hollows, dune slacks, where the water table is a dominant factor; dune heath where Ericaceous species are important; together with all the remaining dune grassland communities as outlined above (Boorman, 1977).

The pioneer stages in sand dune succession are characterised by high levels of active sand accretion. They are dominated by plant species that are capable of extended vertical growth as the sand surface rises. In Britain the dune building species are grasses, notably Sand Couch-grass Elymus farctus, Lyme-grass Leymus arenarius and Marram grass Ammophila arenaria. Thus the pioneer yellow dune stage is dominated by grassland in the narrow sense. The switch from yellow dune to the other forms of dune grassland is one characterised by a decrease in sand accretion and the corresponding changes in species dominance. In the yellow dune stage sand mobility, giving both accretion and erosion, is the dominant factor determining the species composition. In dune grassland however there is only very limited sand movement and any major erosion/accretion cycles represent a reversion to the yellow dune stage.

The absence of sand movement allows non-dune building species to become dominant. For example Fescue Festuca rubra often replaces Marram. The emphasis then changes from dune building to dune stabilisation. The dune builder Marram has a considerable capacity for extended vertical growth but rather limited capabilities for horizontal spread. Fescue on the other hand has strictly limited capabilities for vertical growth but it can produce abundant creeping rhizomes and lateral tillers so

that it can rapidly cover the ground surface. Thus the distinction between the yellow dune stage and dune grassland is one of the change from vertical development, the response to sand accretion, to horizontal development; the development of a more mature, more complete and more complex vegetation cover. The shrub species that invade dune grassland are usually excluded from the foredune communities by the occurrence of active sand accretion, as are other potentially invasive species and thus grazing is not necessary for community survival. In fact the consequential effects of grazing, particularly the effect of trampling, can have serious consequences for the survival of the vegetation on steep unstable slopes. All the dune pioneer communities are particularly sensitive to damage by trampling in any form.

2.3 The development of dune soils

While the transition from vertical development to horizontal development represents the change in the dominant habitat factor, there are many other changes also taking place in this transition. The beach sand that forms the primary dunes is low in mineral nutrients and low in organic matter. Typically the soils of the yellow dunes have a humus content of 0.5% or less compared with 1.0 - 1.5% for dune grassland and around 5% for dune woodland. The effects of the gradual build-up in organic material are considerable. The water holding capacity of sandy soils is increased by even small increases in organic content. This greatly increases the possibility of further successful plant colonisation.

The origin and nature of the sand can greatly affect the course of the vegetational development. Sand deposits are largely composed of grains of silica which is chemically inert. While such sands are chemically neutral, leaching, by rainfall, can rapidly lead to acidification with the corresponding effect on the flora. Many beach sands include a proportion of shell fragments that are almost pure calcium carbonate. indeed some of the beach sands of the Western Isles are entirely of this origin. The soils that develop from these sands are naturally markedly calcareous and support a distinctive flora. They are also very resistant to acidification by leaching; this process only occurs very slowly. In addition calcareous sand, reworked by wind blow or the burrowing of rabbits, can restore alkaline conditions in older dune areas where a degree of acidification has taken place. The increase in soil variability will have its effects on the diversity of the flora.

The build-up of organic material through the dune succession is accompanied by a general increase in the major nutrients. However there is an unequal distribution in the overall level of these nutrients. The lower, damper areas are enriched at the expense of the higher sites as a result of leaching and water movements under the influence of gravity. Initially nutrient enrichment is the result of the accumulation of tidal litter but as the dunes develop in height the input of tidal debris becomes less and other sources of nutrients become important. Because the nutrient levels in young dune soils are so low even small inputs can have a considerable effect. Nitrogen fixation by bacteria and blue-green algae plays a part in the supply of

nutrients for Marram. Even the small quantities of nitrogen and phosphorus in rain-water can make a significant contribution particularly when taken over a period of years.

The distribution of nutrients within the dunes varies from place to place and it is likely that the local patterns observed in dune vegetation are at least in part due to differences in nutrient levels. An overall raising of nutrient levels favours those species with a high potential growth rate. These species can then out-grow the otherwise more numerous species that can better tolerate low nutrient levels. It is easy to see that in a dune community on richer soils shrubs can readily become dominant, but this dominant role can also be fulfilled by herbaceous species although the change is far less obvious. It can however be just as devastating from the point of view of the potential loss of species diversity. High nutrient levels mean an increase in the growth of the most vigorous species; while at low nutrient levels all species are at least equal, indeed many of the weakly competitive species are actually at an advantage.

Once scrub or woodland has developed the change in soil characteristics is marked. Certain key woody species such as Sea Buckthorn Hippophae rhamnoides or Alder Alnus glutinosa have root nodules and are able to fix atmospheric nitrogen. The nutrient build-up under stands of these two scrub species has important consequences if they are ever cleared to encourage the spread of species-rich grass and herb communities.

2.4 Dune soil water levels

The dune grassland communities, in the broad sense but excluding the pioneer dune building communities, can be subdivided on their relationship to the level of the ground water below the soil surface, the water table. Dune slacks, also called lows or dune valleys were defined by Tansley (1949) as "damp or wet hollows left between the dune ridges where the ground water reaches or approaches the surface of the sand". On a coast where the shoreline is advancing rapidly seawards a new line of dunes can enclose an area of beach plain, sand that is at beach level. Shut off from incursions of sea water and from further sand accretion, a rising fresh water table results in the development of either dune lakes or wet slacks. This rise in the water table results from drainage from the high dunes around which raises the overall level of the water table. These primary dune slacks can be seen at places like Ainsdale, Lancashire, or Tentsmuir, Fife. They are called primary dune slacks in contrast to the secondary dune slacks which are formed by the erosion of existing dunes.

Once the cover of vegetation over existing dry dunes is broken, sand erosion can take place rapidly until the layer of wet sand, associated with the ground water, is reached. The cohesion of these wet sand grains is sufficient to halt the process of erosion. The flatness of the bottom of a dune slack reflects the profile of the water-table at the time of erosion. The level of the ground water in the dune is not static but varies by a metre or more between the summer and winter. Characteristically there is a winter and a summer level with a rather rapid transition in the spring and autumn.

Above the ground water there is a zone where the sand remains damp as a result of capillary action. The height of this zone will depend both on climatic factors and on the physical properties of the sand. If the climate is relatively damp there will be less drying out of this layer of damp soil which will thus be of a greater vertical height. The other factor relevant here is the rooting depth of the sand dune plant species.

These two factors taken together determine the depth at which the influence of ground water on the vegetation ceases. The actual depth varies between 1 and 2 m depending on soil and climate. Where the rainfall is higher the annual fluctuation in ground water level is greater and thus its influence is extended. Dune slack communities are only found when the ground water in the summer is within 2 m of the soil surface, or within 1 m in the winter.

An alternative definition of dune slack communities can be derived in terms of the plants themselves; a dune slack community being a plant community with a high proportion of those species that are known to be dependent on the ground water for some or all of their life cycle (Londo, 1975). Conversely dune grassland (dry) can be defined as being of plant communities made up primarily of those species known to be independent of the ground water level. In practical terms these definitions can be readily applied to an area, quadrat, or other record, as the species composition of the area will reflect the average ground water level over some considerable period of time. This was the approach used in this study to subdivide the quadrat information (see 3.2).

2.5 Yellow dune communities

Sand mobility, as we have seen, is the characterising feature of the yellow dune stage, and it is the ability to withstand the effects of sand mobility that will determine the plant species that grow on yellow dunes. The yellow dunes are dominated by one or more of the dune building grasses, Marram, Sand Couch or Lyme-grass but with a number of other species at low frequencies. These can include both shingle beach or drift line species persisting from earlier stages, species such as Sea Kale Cakile maritima or Sea Bindweed Calystegia soldanella, and also certain aggressive ruderal species like Spear Thistle Cirsium vulgare or Ragwort Senecio jacobaea. In the older yellow dunes, as the rate of sand accretion decreases, dune building species become less vigorous and non-dune building species are able to invade. This process is often quite gradual and communities intermediate between the yellow and the grey (stable) dune stage are common. As far as this study is concerned dune communites were treated as yellow dune either if pioneer species were still dominant or if there was extensive bare sand indicating continued sand mobility. It is was on this latter criterium that dune communities dominated by exotic species, such as Hottentot Fig Carpobrotus edulis or Garden Rose Rosa rugosa, were recognised as yellow dune communities. As well as the primary dune building stage, there are also, not infrequently, secondary yellow dune communities as a result of erosion and recolonisation.

With such a powerful limiting factor as sand movement the species composition of yellow dunes is strictly limited and it is only when this factor is reduced in magnitude that other external influences can have any effect. Vegetation management in yellow dunes has to be concerned, almost exclusively, with the preservation of the integrity of the dunes themselves against the major forces of erosion by wind and water. The influence of grazing animals at this stage is largely one of direct physical damage to the surface of the dunes which can lead to destructive erosion, although generally the rather small quantities of green vegetation of low palatability mean that they are not particularly attractive to most grazing animals. As the grey dune stage is approached then other management factors come in but these will be considered in terms of the grey dune stage itself.

2.6 Dune grassland communities

The dune grassland communities have been defined as those predominately herbaceous communities that are able to grow up independent of the ground water table. In practice they are recognised by the absence of species known to be dependent on the ground water, species such as Common Sedge Carex nigra or Water Mint Mentha aquatica. However, even though the dune grassland species are essentially drought tolerant or drought avoiding species, there is nevertheless a differentiation within these grasslands based on the relative availability of water. Even small quantities of water can have considerable influence on the vegetation of dry dunes and local variations in the supply of water can come about in one of two ways. Except under still conditions the distribution of the rainfall will be influenced by variations in topography. Topography also produces differences in soil moisture through slope and aspect affecting the input of solar-radiation, and thus soil temperature which influences evapo-transpiration. Micro-relief is thus a major cause of variation within dune grassland.

Just as soil water is in short supply, so are soil nutrient levels low in dune grassland and indeed may often be an important limiting factor. Soil nutrients are by no means uniformly distributed and thus can be an additional cause of spatial variation in dune grassland (Boorman & Fuller, 1982).

The third main source of variation in dune grassland comes under the general heading of biotic factors especially grazing and trampling. Variations in the nature and intensity of these two factors can make a considerable contribution to the diversity of dune grassland. Not only is plant species diversity dependent on the range and diversity of environmental and biotic sub-units but the range of niches available is further increased by the interaction of factors in the transition zones, the so-called ecotones. Many ecotones are considerably richer than either of the communities that they separate.

Dune grassland communities can be subdivided into open dune grassland and closed dune grassland. While the extent of bare ground is of an order of magnitude less than that in yellow dunes, there is still sufficient ground available for plant colonisation. This is as a result of extreme environmental

factors limiting the development and extent of plant cover. It is this that makes dry dune grassland distinct from inland grasslands where environmental factors are less severe and where there is very little bare ground available for plant establishment (Maarel, 1981). This corresponds to the closed dune grassland which is to be found particularly in dunes in the damper north and west of Britain. A similar situation also exists in dune slack vegetation but for different reasons (see 2.5).

A distinctive component of the flora of arid or semi-arid areas is the therophyte, the species that survives unfavourable conditions as a seed. Effectively therophytes are annual species mostly belonging to that group called winter annuals. On a world scale therophytes form about 13% of the flora, as they do in dry grasslands (Whittaker 1975). In chalk grassland they only constitute about 8% of the flora reflecting that it is a rather more closed community (Wells, 1975). Both these figures are low compared with the 30 - 40% found in dune grassland. The high proportion of dune annuals gives emphasis to the open nature of the vegetation.

There are two other growth forms that are prominent in dune grassland, solitary perennials and perennials with long rhizomes. The solitary perennials, such as Hairy Hawkbit Leontodon taraxacoides, are mainly long-lived rosette species with deep roots. The rosette habit enables them to maintain their niche despite competition from other species and the deep root enables them to exploit the slightly higher moisture levels at some depth. The long rhizomes of other perennial species, such as Sand Sedge Carex arenaria, enables them to exploit local gaps in the vegetation cover. The rhizomes also contribute to the stability of the sand surface.

The proportion of biennial species in the dune grassland flora is low. There are niches that enable annual species to regenerate year by year which might suggest that biennials could do the same. Their problem is one of the survival of the vegetative plant. The dune biennials that there are, such as Hound's Tongue Cynoglossum officinale, show a notable mortality at the onset of the summer drought (Boorman & Fuller, 1983).

So far we have only considered higher plants but ferns, bryophytes and lichens also play a part in the dune grassland community. The ferns are relatively drought intolerant species often limited to the damper conditions on the north slopes well sheltered by the surrounding dunes. There are two groups of bryophytes in the dune flora, a xerophytic (drought resistant) group characteristic of dry open situations and a more mesophytic group of mosses and liverworts that are found in damp hollows and among the stems of taller herbs and grasses. The xerophytic bryophytes, like Tortula ruraliformis, and the lichens associated with them are vulnerable to outside influences such as trampling, particularly in their normally dry state. They are able to withstand some sand accretion and appear also to be associated with areas having a particularly low nutrient status. The mesophytic group occurs in moderately tall grassland and also in areas where the grass cover is reduced by local rabbit grazing to which they are resistant. They are however vulnerable to rabbit scratching which occurs mainly at high rabbit densities.

In the north and west of Britain where the climate is cool in the summer and mild in the winter, and where the weather overall is dominated by strong winds and high rainfall, a distinctive form of dune grassland develops called 'machair'. It is very much a grassland in the strict sense with grasses dominant over mosses and lichens. Machair pastures have a gentle topography with slopes normally less than 5°. They are heavily grazed, particularly by sheep, and the vegetation is uniformly short or very short. The soils are usually based on shell-sand and are thus lime-rich and support a rich flora of vascular plants. While the machair surfaces are stable in the short or medium term, the exposure of the situations in which they occur means that they are subject to periods of instability, when old surfaces are eroded and new ones laid down.

Machair forms a more or less continuous fringe along the western seaboard of the Outer Hebrides with smaller patches in other locations. The machair grasslands are frequently cultivated to a greater or lesser extent thus changing the natural patterns of vegetation. The developmental relationship between dune and machair is a complex one with complex links in both space and time (Dickinson and Randall, 1979; Basset & Curtis, 1985).

2.7 Dune slack communities

With the ground water providing an adequate water supply for most species there is far less open ground in dune slack vegetation than in dry dune grassland. One consequence of this is a very much lower proportion of annual species, often it is less than 10% (Willis et al., 1959, Watkins, 1973), comparable with that found in woodland or chalk grassland (Whittaker, 1975). The main exception is for the pioneer dune slack communities where there is considerable open ground and thus opportunities for annual species (Ranwell, 1960). The slacks at Newborough Warren come in this category and the flora of the slacks has 16% of annuals. However, even though inter-specific competition is important in dune slack vegetation, the dominant factor is the reaction of the plant species to the ground water level. The closeness of the relation of certain species was recognised as early as 1924 when Goethart et al. showed, for example, that while the Marsh Orchid Dactylorhiza incarnata would only grow at levels of up to 0.3 m above the water table, the Wild Pansy Viola tricolor would only grow at levels of at least 0.8 m above the water table. Subsequently whole floras have been classified and sub-divided on the response of each species to ground water levels (Londo, 1975). While the proximity of the water table can mean an adequate supply of water, very often the benefit of this is offset by the problems that are created by the soil being water-logged.

The interaction of these factors is brought out well by the studies of Jones and Etherington (1971) who compared the behaviour of three dune slack species Common Sedge Carex nigra, Carnation-grass Carex flacca and Common Bent-grass Agrostis capillaris with the dune grassland species Red Fescue Festuca rubra. Under dry conditions Red Fescue could outgrow the other three species. Red Fescue was, however, intolerant of even partially water-logged conditions and its growth rate was

drastically reduced. Under partial water-logging Common Bent-grass was little affected and it could outgrow Red Fescue. Increased water-logging killed the Red Fescue and reduced the growth of Common Bent-grass while Common Sedge and Carnation-grass were not affected and thus became dominant. Carnation-grass did best under partial water-logging while the growth of Common Sedge was actually stimulated by complete water-logging The latter species has a specific requirement for water-logged conditions while the former only had a degree of tolerance to these conditions. Thus in these four species we have four contrasting responses to the level of the ground water and this is shown by their zonation, Common Sedge in the bottom of the wet slack, then Carnation-grass, Common Bent-grass in the damp slack and finally the Red Fescue in the dry dune.

A further effect of the damp or wet conditions in dunes slacks is seen in the increased proportions of stoloniferous species such as Water Mint or Common Sedge. In dune grassland stoloniferous species only account for 7 - 9% of the total flora while in dune slacks they amount to 20 - 40% of the total. There are also a considerable number of species with long rhizomes in the dune slack flora. The possession of long stolons or long rhizomes enable a species to form a network throughout the community and by it to exploit the local areas where there is less competition from other species. Both the stolons and the rhizomes are associated with relatively shallow root systems that avoid the deeper permanently water-logged layers of the soil. This view is supported by the virtual absence of deep rooted perennial special species from dune slacks.

While dune grassland involves little more than a single stage of development between the pioneer yellow dune communities and the dune scrub communities, there is a range of dune slack communites from those that colonise the bare wet sand through to the mature dune slack communities that precede scrub development (Ranwell, 1972; Laan, 1978). There is a further complication in that acidification can occur leading to the development of damp or wet dune heath communities.

The primary colonisers of dune slacks are usually the Creeping Willow Salix repens or Creeping Bent-grass Agrostis stolonifera, but under wet conditions this role could be filled by tne Jointed Rush Juncus articulatus or Shore-weed Littorella uniflora the latter often in association with Brookweed Samolus valerandi. The vegetational development and the relationship between the various communities within dune slacks is complex. The main factors are the degree of wetness of the primary slack surface, the rate of acidification of the soil and the rate of drying out of the soil either as a result of further sand accretion or by a lowering of the water table.

The consequence of the interaction of these factors is that from any pioneer slack community, a very wide range of secondary communities can arise. Sand accretion can lead to the formation of secondary dunes, or to a range of dune grassland communities and then on to scrub. Acidification can produce wet, damp or dry heath communities depending on the extent of accretion or lowering of the water table. The maintenance of wet base-rich conditions will lead to fen formation with bryophyte species of the genera Drepanocladus and Calliergon. In the absence of

any of of these possibilities the slacks will eventually develop in wet or damp scrub communities with Birch Betula spp. or Alder Alnus glutinosa. With all these different possibilities the seral relationships of natural dune slacks is complex. There can also be further divergences from this general scheme as a result of grazing or mowing pressures altering species balance or preventing succession through to scrub.

2.8 Dune heath communities

It is highly likely that any formal classification of sand dune plant communities will not include consideration of heath vegetation as there is a close similarity between dune heath and lowland heath elsewhere inland. This can be attributed to the common factor of soil acidity resulting from the acid, usually sandy, soils on which heath vegetation is based. Inland sand deposits tend to acidity, a tendency accentuated by the effect of leaching which removes soluble calcareous material and thus decreases the pH.

Coastal sands very often have a high proportion of calcareous material in the form of shell fragments - almost pure calcium carbonate - and acidification by leaching, if it ever occurs, is a very slow process. Dune heath vegetation is limited to dunes formed from neutral or acid sands. The dunes at Studland, for example , are formed from reworked Bagshot Sands. The process of acidification is also facilitated when there is only a thin layer of sand with underlying acidic rocks. The dune heath communities at Great Bay, St. Martin's in the Scillies are an example of this. Of the forty eight sites visited during the survey only seven had examples of heath vegetation.

The dune heath communities can be divided on the basis of the influence of the water water table into wet and dry communities (Webb, 1986). The dry dune heath is similar to the dry heaths inland in the Breckland of East Anglia and the Dorset heaths. Heather Calluna vulgaris, Bell Heather Erica cinerea and Sheep's Fescue Festuca ovina together with a range of bryophytes and lichens are characteristic. In the south east particularly the Grey Hair-grass Corynephorus canescens often occurs in more open areas perhaps associated with a local degree of sand mobility. The occurrence of the Cross-leaved Heath Erica tetralix indicates increasing soil moisture levels which enable this species to compete successfully with Heather and Bell Heather. In the wettest areas Sphagnum species are common with the development of peat. Purple Moor-grass Molinia caerulea and also Deer Grass Scirpus caespitosus are characteristic wet heathland species. Bog Myrtle Myrica gale is notable locally, for example at Studland where it forms a distinctive scrub community with Birch. Birch, especially Betula pubescens, readily invades damp slacks in acid dunes leading to the development of a rather species poor acid woodland.

2.9 The control of plant species diversity

As any gardener will testify there are weed species that, if left unchecked, will smother all the crop or ornamental species he was trying to grow. Abandoned farmland soon becomes dominated by a

rather small range of vigorous growing species that only decrease as the area is invaded by woody species of shrubs and trees. And yet we can find grassland on lowland chalk, mountain limestone or sand dunes with perhaps twenty or more species in a square metre. The maintenance of species diversity is naturally of crucial importance for nature conservation therefore we should consider some of the mechanisms involved in this process.

It is a relatively straightforward, if time consuming, exercise to determine the maximum potential growth rate of various plant species (Boorman, 1982). Most grassland plant species have rather low maximum growth rates compared with the maxima obtained by a few species. A common component of grassland is Red Fescue and its maximum growth rate is higher than that of the many species that can be found associated with it. The key to this enigma is that under natural conditions plants are performing well below their maximum potential. This is because some environmental factor is limiting. This may be water, a particular mineral nutrient, or some other physical or biotic factor. Under these sub-optimal conditions a high maximum growth rate loses its value and the species loses its competitive ability.

Sea Lavender Limonium vulgare is a common plant in salt marshes where it dominates large areas. It will, however, grow more vigorously under non-saline conditions. Individual plants grown in a fertile garden soil achieve a size many times that of marsh grown plants. Sea Lavender is only weakly competitive, individuals planted into grassland are soon smothered by other more vigorous species and die. In the salt marsh these competitors are unable to grow and so Sea Lavender is the dominant species.

This same principle applies not just to salt marshes but to most natural plant communities. There is some factor keeping the vigorous species in check and thus maintaining species diversity. In sand dunes this limiting factor is usually a matter of low levels of soil moisture or low levels of mineral nutrients, although, as we have seen, sand mobility can be the determining factor. If the controlling factor is not fully effective then the biomass of one or more species will increase at the expense of the less vigorous species and thus diversity will be reduced. If this process is to be inhibited then either the controlling factor will have to be increased - that is to say the soil moisture or nutrient levels will have to be decreased - or the extra biomass produced will have to be removed.

A productive grass sward can produce an aerial biomass of 1.5 Kg or more per m^2, but it will be virtually a monoculture. Species rich grassland has an annual shoot biomass of around one fifth of this. Various workers have shown that species diversity is inversely proportional to biomass, the lower the biomass the greater the species diversity. At very low levels of productivity the process is reversed (Klinkhamer & de Jong, 1975; Kutiel & Danin, 1987). At very low soil moisture levels there are only a very few plant species that can survive, so the species diversity is low. It would appear that for sand dune communities maximum species richness is reached under conditions that correspond to an aerial biomass of about 300 g per m^2. Above this figure the more vigorous species such as Red Fescue Festuca rubra will be

dominant. Below this figure few species can survive. If, for example, the figure is low because of low soil moisture, then only xerophytes like Biting Stonecrop Sedum acre or the bryophyte Tortula ruraliformis can survive.

This situation represents one of the two categories of dune grassland - open dune grassland. This category includes both the earliest stages of dune vegetation development as well as those later stages where environmental factors, particularly low soil moisture levels, limit the degree of plant cover. This situation is generally only applicable to exposed dune sites in the south and east of Britain. In the north and west dune plant growth is not so moisture limited. In open dune grassland bare ground is a significant feature of the vegetation and shoot competition is not a key factor. Under these conditions the vegetation will contain a high proportion of drought tolerant species, together with the drought avoiding winter annuals.

As the dunes mature soil nutrient levels and water holding capacity increase with the build up of organic matter enabling more or less complete vegetation cover to develop - closed dune grassland. The closed vegetation means that there is no bare ground available for plant colonisation. Under these conditions shoot competition becomes the key factor and, unless the excess plant growth is kept in check, then diversity will fall. The grazing of plant biomass by herbivores can provide this check. In theory the control of diversity is relatively simple, in practice the situation is complex. First this optimum biomass figure I quoted is an estimate from limited data and must be used with great caution. Secondly grazing animals are selective in their choice of food and certain species are eaten and others may be untouched. Fortunately the grass species that tend to dominate dune grassland are generally palatable and are thus more readily kept in check. In addition the determination of biomass or standing crop is slow and time consuming and the process has to be repeated at intervals through the growing season to allow for seasonal differences between the various species.

During the planning stages of this study consideration was given to the measurement of biomass as a parameter in assessing the various dune grassland communities. Its undoubted value was outweighed by the difficulty of biomass determination. To determine biomass is time consuming and costly. It was decided that very limited data obtainable would be less useful than that obtainable by rapid, but indirect, methods such as the use of vegetation height.

The tall grass dune communities often do have a low herb layer with scattered etiolated individuals among the grass stems. Many of these perennial herb species are only just surviving in the vegetative state. They are unable to reproduce effectively until there is an increase in the openness of the sward as a result of some form of disturbance. The persistence of perennials under unfavourable conditions results in a very slow rate of response of the vegetation to changes in the intensity of the impact of grazing. The absence of grazing will result in the gradual development of a tall grass community but several of the perennial herbs may often survive for many years. Thus, because of the slow rate of response, it is not feasible to make periodic small adjustments in management in response to

observed changes in species composition. Any reassessment of the nature of the vegetation and modification of the management regime has to be of necessity on a very long term basis.

Dune grasslands, like other grasslands, can be divided into climax grassland, where any further succession to scrub or woodland is limited by climatic considerations and seral grassland representing a stage in the succession to woodland. The open dune grassland generally falls into the first category and the closed dune grassland into the second. This latter type can be maintained as a plagioclimax (deflected climax) more or less indefinitely by grazing or mowing which prevents the growth of woody species. Thus positive management is required for the survival of closed dune grassland. The vegetation of dune slacks falls into this category except for the pioneer communities. The rate of development of scrub and woodland communities in dune slacks is also affected by the water table. Any drying out of a wet slack will greatly increase the rate of invasion by woody species.

2.10 The impact of rabbits on sand dunes

The grazing animal that has had the greatest influence on sand dunes is undoubtedly the rabbit. The loose, well drained, soils of the dunes provide the rabbit with an ideal substrate for their burrows and even in midsummer the damp slacks provide grazing. The rabbit has been with us since Roman times, and in Medieval times it was deliberately cultivated on sand dunes. Up to the early 1950's the rabbit population was high on most sand dune areas but with the spread of the virus disease, myxomatosis, in the mid-1950's there was a dramatic decrease almost to the point of extinction. Since then, however, the number of rabbits has increased steadily up to the present day, with numbers now approaching those of the pre-myxomatosis days, although notably fewer in certain areas.

The impact of rabbits is considerable both through their burrowing activities and through the effect of rabbit grazing on the vegetation (Hulsbos, 1974). While rabbits are normally found mainly in the older stable dunes, they can also affect dune colonisationand dune building (Harris & Davy, 1986). Rabbit burrows can be the focal point for the occurrence of blowouts that can result in serious erosion depending on the overall stability of the dune system and the size and situation of the area involved. The impact of the rabbits on the vegetation depends very much on the density of the rabbit population and also on the spatial distribution of their burrows. Rabbit grazing tends to be restricted to areas around active burrows and over a wide range of rabbit population densities there will be a mosaic of areas with different intensities of grazing.

At low densities rabbits help to maintain species diversity by checking the growth of the more vigorous grasses, herbs and shrubs (Zevalking & Fresco, 1977). Near the burrows can be found more open plant communities with dune annuals exploiting the reduced competition from the perennials. As the densities of rabbits increase the increased grazing pressure produces a close, dense sward of annual and perennial species together with mosses and lichens, a sward often only one or two centimetres

tall. However there is a delicate balance between this stage and the next, which is represented by the progressive breaking up of the sward with increasing areas of bare sand. Once the turf has been destroyed, recovery is very slow and there may well be a long period of sand mobility. A much lower rabbit population density can maintain sand mobility than is necessary to initiate the process.

2.11 The use of dunes for grazing farm animals

Sheep, cattle and ponies have all been grazed on sand dunes, although the heavier foot pressures exerted by these larger animals tend to damage the sward with the consequent risk of erosion. The well established turf of old dune pasture is able to withstand trampling better than the early stages in the dune succession, and thus these former areas can provide useful grazing without any significant risk of erosion.

Areas with a long history of grazing are often very species rich. In Britain, in recent years however, there has been a decrease in the utilisation of relatively marginal grazing areas as part of a general movement away from extensive stock farming, partly as a result of the increase in labour costs making the supervision of low return grazing uneconomic. With the current levels of agricultural over-production this trend seems certain to continue.

The present agricultural use of sand dune areas for the grazing of stock centres on the 'improvement' of the sward by the addition of farmyard manure or artificial fertilizers. The effect of this is to increase the productivity of the sward at the expense of plant species diversity. This loss of floristic diversity will occur whether or not reseeding takes place. The other agricultural use of sand dunes is as a holding area for stock in the winter. This involves the importation of hay and straw for feed. Eutrophication of the dunes takes place through the deposition of the nutrient-rich faeces and very often this is accompanied by the development of a species-poor ruderal flora from seeds brought in with the feed. This process of degeneration is further enhanced by the effect of the intensive trampling that occurs around the areas where the stock is fed.

2.12 The increase of species diversity

While we are primarily concerned with the maintenance of existing plant species diversity, it is important to note that grazing has been used effectively to re-create species rich grassland from species poor abandoned arable land (Gibson et al., 1977). The same principles also apply to the re-creation of species rich dune grassland from areas degraded by bad management, or recently restored grass swards in areas that had suffered from erosion. The prime need is to establish plant cover without raising soil nutrient level any more than necessary.

3. Study methods

3.1 Selection of study sites.

The study area covered England, Wales and Scotland including the adjoining islands from the Scillies to the Shetlands. The Channel Islands of Jersey and Herm, although not in the main study area, were also visited. In Britain there are something like 500 sites with some vegetation growing on wind blown sand of marine origin; many of these sites are,however, very small. There are some 50 - 60 sites of 100 hectares or more. The largest dune site, Culbin Sands in North-east Scotland, covers 3180 Ha, although most of this area is now pine plantation. There are three other dune sites of more than 1000 Ha - Baleshare and Morrich More in North Scotland, and Newborough Warren in North Wales.

The area of a particular dune site is difficult to define for a number of reasons. Dune grassland can be brought into various stages of cultivation especially in the wetter north and west of Britain. Where cultivation only involves improving the grass sward the area may still be considered to be part of the dune site, but clearly a sown ley can hardly be treated as semi-natural dune vegetation. The same remarks also apply when afforestation has taken place.

The greatest difficulty arises from the way high winds can carry sand considerable distances inland. At Forvie in East Scotland sand dunes have travelled up to 6 km from their point of origin around the estuary of the river Ythan and dunes of sorts occur on land surfaces up to 46 m above sea level. Sand dune vegetation can be found on sites where there is underlying bedrock at heights well above sea level. The area of sand dune given makes no distinction as to whether there is sand or rock beneath. The difficulty comes in defining the landward boundary. If the underlying rock is of a contrasting pH there is usually a recognisable vegetation boundary but very often the boundary can only be defined by soil investigations.

A range of sites was selected to cover the major contrasts, including geographic variants, acidic and calcareous sites, predominately wet and predominantly dry sites, as well as sites grazed by various animals and ungrazed sites. An attempt was made to strike a balance between large and small sites and between sites considered to have a high conservation interest and those sites with a lower conservation interest. Overall emphasis was given to those sites where comparisons between different grazing regimes could be made. During the course of the visits a number of new sites of significant interest were located and added to the original selection, when it was clear that they could give information significant to the study. Some of these extra sites had unusually high intensities of grazing, others unusually low, while yet others had a particular grazing intensity which contrasted with that of a nearby site on the original list.

At the end of the study a total of 48 sites had been visited covering all regions except West Scotland (Fig. 3.1). The regional distribution of the sites visited in relation to the

total number of dune sites is given in Table 3.1. The boundaries between the regions generally reflect natural phytogeographic areas. The inclusion of St. Cyrus, less than forty km south of Aberdeen, in South-east Scotland, reflects the numbers of southern species that reach their northern limit there. Down the east coast of England Flamborough Head was taken to represent the natural boundary between the cooler damper north-east and the more continental south-east. Along the south coast the oceanic south-west is considered to begin at Portland Bill. The two Channel Island sites visited were included with South-west England as they are climatically similar. The Channel Islands experience oceanic conditions and lack the winter and spring cold that is characteristic of South-east England. The boundary between the south-west and the north-west was drawn at Aberystwyth, Cardigan Bay.

Within each of six of the seven regions at least four sites were visited. The exception to this was the west of Scotland. The original plan was to cover this region in the second or third year but when it became clear that it could only be achieved at the expense of other aspects of the study it was decided to omit the whole region rather than study it incompletely. An outline is given of the grazing situation in eighteen of the west coast sites based on the Nature Conservancy Council's Scottish Survey and other data (Ranwell D. S. - unpublished). The details of this information are given in 3.3 and the conclusions in 5.8.

A full list of the sites visited in given in Table 3.2 and Figure 3.1 together with the approximate area of each site. The site reference number provides a cross reference to the Appendix Tables where tabulated data for each site will be found. Table 3.3 gives the Regional distribution of the range of site areas. The large number of smaller sites in North-east Scotland reflects the occurrence of small isolated sites along the rocky coasts in the Northern Isles. The limited number of small sites in south-east England can be explained by the nature of the coast with much larger sandy areas; also under the intense pressure from holiday makers in this region small sites are often destroyed or severely degraded.

Initially the sites were visited in sequence from south-west to north-east to minimise the differences due to seasonal change. However repeat visits were made, early and late in the growing season, to two widely separated sites, Aberlady Bay, East Lothian and Winterton, Norfolk. These showed that while the species composition varied through the season the species diversity changed little and thus the timing of site visits was not considered critical. In addition dune grassland at one site, Strathbeg, Aberdeenshire, was visited in 1985 and in 1987 to get some idea of any changes with time.

Table 3.1 Regional distribution of British sand dunes and numbers of sites visited during survey.

Region	Dune sites	Sites visited	% visited
North-east Scotland	110	10	11
South-east Scotland	31	4	13
West Scotland	229	0	0
North-east England	20	6	30
South-east England	22	6	27
South-west England and South Wales	60	11(+2)*	18
North-west England and North Wales	35	9	26
Totals	507	46(+2)*	9

* - 2 Channel Island sites.

Table 3.2 Alphabetic list of the 48 sites visited during survey.

Site, location, county	Number	Area (Ha)
Aberffraw, Anglesey, Gwynedd	21	355
Aberlady Bay, East Lothian	07	150
Ainsdale, Lancashire	09	800
Alnmouth, Northumberland	39	35
Bamburgh Links, Northumberland	37	40
Bar Point, St. Mary's, Isles of Scilly	01	2
Braunton Burrows, Devon	12	800
Breakon, Yell, Shetland	27	25
Brownslade Burrows, Dyfed	34	250
Cabin Hill, Lancashire	10	40
Conninghole, Sanday, Orkney	29	70
Druridge Bay, Northumberland	38	40
Earlshall Muir, Fife	08	370
Fidge, Sanday, Orkney	28	120
Forvie, Aberdeenshire	48	800
Gibraltar Point, Lincolnshire	22	240
Great Bay, St. Martin's, Isles of Scilly	03	10
Herm, Channnel Islands	47	35
Holkham, Norfolk	04	218
Kenfig Burrows, Glamorgan	17	480
Kilpaison Burrows, Dyfed	32	150
Levenwick, Shetland	43	10
Lindesfarne, Northumberland	35	100
Llangennith Burrows, Glamorgan	19	100
Morfa Dyffryn, Gwynedd	15	450
Morfa Harlech, Gwynedd	14	410
Newborough Warren, Anglesey, Gwynedd	20	650
Newton Links, Northumberland	40	25
North Walney, Cumbria	23	150
Oxwich, Glamorgan	18	75
Pentle Bay, Tresco, Isles of Scilly	02	15
Quendale, Shetland	26	80
Quennevais, Jersey, Channel Islands	46	740
Ross Links, Northumberland	36	225
St. Cyrus, Aberdeenshire	41	40
St. Ninian's, Shetland	45	10
Saltfleetby, Lincolnshire	13	110
Sandscale, Cumbria	24	300
Scolt Head, Norfolk	42	200
Scousburgh, Shetland	44	25
South Walney, Cumbria	25	100
Stackpole, Dyfed	33	80
Strathbeg, Aberdeenshire	31	380
Studland, Dorset	05	160
Tentsmuir, Fife	06	60
Whiteford Burrows, Glamorgan	16	220
Whitemills, Sanday, Orkney	30	40
Winterton, Norfolk	11	325

Figure 3.1 Map of the British Isles showing the sites visited during the survey. Site numbers are given in Table 3.2.

Table 3.3 Regional distribution of sites by size

Region	Area (Ha) 0-50	51-100	100-250	250+
North-east Scotland	6	1	1	2
South-east Scotland	0	2	1	1
North-east England	4	1	1	0
South-east England	0	0	6	0
South-west England and South Wales	4	4	2	3
North-west England and North Wales	1	1	1	6
Totals	15	9	12	12

3.2 Survey methods used

The basic unit of recording was a quadrat 2 m x 2 m, as used in many other surveys including the National Vegetation Classification. These quadrats, made out of four pegs and nylon line around the outside and across the diagonals, were located regularly on a grid basis to cover the whole of each site, excluding those areas covered by dense scrub, woodland or open water. Each site was sampled by 3 - 6 transects set perpendicularly to the beach and running landwards. The number of transects was determined by the shape of the site, long narrow sites having the higher number. Along each transect the quadrats were spaced regularly at a distance that gave a total of 15 - 20 quadrats for most of the sites (Figure 2). Some of the small sites had fewer quadrats especially where the vegetation was fairly uniform. Generally sites under 50 ha had 7- 14 quadrats. A total of 777 quadrats were recorded giving an average of 16 quadrats per site.

The first quadrat of each transect was located at the top of the primary dune ridge. Subsequent quadrats were located by pacing out the distance from the first one, on the basis of of one pace equalling 0.9 m (this was checked periodically). The direction of a transect was either interpreted from a map or taken by compass bearing. After one transect had been completed the next transect line was located by pacing out the calculated distance from the first quadrat of the preceding transect. The sampling grid was recorded on a 1:50 000 map and the grid reference to each quadrat was also recorded.

At each quadrat a record was made of all species of vascular plants, bryophytes and lichens present, together with an estimate of their cover/abundance, based on the Domin scale as modified by van der Maarel (1977) and also of the extent of the bare ground. This scale was found to be relatively easy to use and occasional back checks suggested that with the same observer there was little variation in application. The categories used are given in Table 3.4. Five measurements were made of the height of the vegetation (in millimetres to the nearest 10 mm) within each quadrat at 'randomly' selected points.

Estimates were then made of the nature and intensity of the impact of grazing. A set procedure was used for each type of grazing animal. The numbers of the animal present in the quadrat, visible within 5 m, within 10 m, and within 50 m, were counted and recorded on a five point scale (Table 3.5).

Following this, a similar method was used to record the density of the faeces of that species of animal. These observations were repeated for each species of animal present. A record was also made of the apparent impact of grazing animals present using a 5-point scale (Table 3.5). Following the formal recording, notes were made on any salient features not otherwise covered. A series of photos was taken at each site to show the general nature of the site, the impact of grazing and any special features.

Table 3.4 Cover/abundance scale used for recording plant species

Cover/abundance	Domin Value
Single individual - cover <5%	1
Few individuals - cover <5%	2
Many individuals - cover <5%	3
Very abundant - cover <5%	4
Cover 5 - 12%	5
Cover 12 - 25%	6
Cover 25 - 50%	7
Cover 50 - 75%	8
Cover 75 - 100%	9

Table 3.5 Coding of field information

ANIMAL CODES

1 - PONIES*	2 - CATTLE	3 - SHEEP	4 - GOATS
5 - DEER	6 - RABBITS	7 - HARES	8 - OTHERS

ANIMAL NUMBERS	ANIMAL DAMAGE
0 - 0	0 - NONE VISIBLE
1 - 1	1 - SOME PLANTS EATEN
2 - 2-10	2 - VEGETATION SHORT
3 - 11-50	3 - SOME BARE GROUND
4 - 50+	4 - >25% BARE GROUND.

ANIMAL DROPPINGS

RABBIT TYPE (maximum per m^2)	CATTLE TYPE (total number in area)
0 - 0	0 - 0
1 - 1-10	1 - 1-4
2 - 10-50	2 - 5-10
3 - 50+	3 - 11-50
4 - 2 or more x50	4 - 50+

* - strictly the term pony refers to a horse less than 1.57m tall at the shoulders. In this report ponies includes all equines although they were mostly ponies in the strict sense.

After the data had been collected the individual quadrat records were examined and those quadrats that represented areas where there was scrub or woodland with a cover value of greater than 50% (Domin value 8), or permanent open water, saline habitats, shingle beach, driftline or improved arable land, were rejected if this had not already been done. Incidentally the rejection of quadrats containing woody vegetation meant that losses of herbaceous dune communities to scrub and woodland, as a result of low grazing intensities, are not included.

The remaining quadrats were then divided into 5 habitat groups on floristic criteria (Table 3.6 and 3.8). It will be clear from the way the dune grassland category is reached that it will be a rather varied category and therefore especial caution is needed in the interpretation of results in this group. The possibility of the occurrence of quadrats intermediate in character exists in any of the groups.

Table 3.6 Key to the subdivision of quadrats

1. Bare ground or **Ammophila arenaria** or **Elymus farctus** or **Leymus arenarius** => 7 (cover = > 25%) YELLOW DUNE

1a. Not as above 2

2. **Calluna vulgaris** or **Erica** species =>6 (cover =>12%) DUNE HEATH

2a. Not as above 3

3. **Mentha aquatica** or **Carex riparia** or **Filipendula ulmaria** or **Hydrocotyle vulgaris** => 5 (cover =>5%) WET SLACK

3a. Not as above 4

4. **Salix repens** or **Carex nigra** =>6 (cover =>12%) DAMP SLACK

4a. Not as above DUNE GRASSLAND

3.3 Data from the Scottish Survey

Between 1975 and 1977 the Institute of Terrestrial Ecology under a commission from the Nature Conservancy Council, surveyed 94 coastal sand dune sites in Scotland (Shaw, 1985). As it had not proved possible to visit the west coast of Scotland during the present survey, data from the Scottish Survey was used, relating to 18 of the west coast sites (Table 3.7, Figure 3.2). Certain items were taken from the whole data set of 3327 quadrats from 94 sites. Where data refers to the whole data set this is indicated, otherwise the data is from the 18 selected sites. The format of data in the two surveys differed in a number of respects but, as some sites were covered by both surveys, an assessment was possible of the comparability of the two data sets. The main differences centre upon the size of quadrat used and the assessment of the grazing impact on the vegetation. While species cover/abundance was assessed from 2m x 2m quadrats in the present survey, this was done in the 5m x 5m quadrats in the Scottish Survey. This enabled the quadrats to be classified into the five habitat types in the same way as in the main survey (Table 3.8). However the relationship between the number of species per quadrat and the quadrat area was not close enough to allow a direct calculation of the one from the other. However relative comparisons were still possible.

Vegetation height, measured directly in the 2m x 2m quadrats in the present survey was categorised in the 25m x 25m quadrats in the Scottish Survey, however the results each gave a fair indication of the general state of the vegetation. For example dune grassland quadrats at Tentsmuir had a mean vegetation height of 81 mm in comparison with 15 % of the quadrats having some vegetation 500 mm or more. When the dune grassland vegetation had a mean height of 31 mm there were no quadrats with vegetation of 500 mm or more.

The impact of grazing on the vegetation was assessed in a similar way in both surveys and it was possible to calculate a comparable site figure for each vegetation habitat type. It would seem reasonable to attribute differences in the impact assesment either changes occurring in the ten years between the two surveys or to differences in the site boundaries that were used.

The percentages of each habitat type in West Scotland were broadly similar to those in other areas (Table 3.8) although there tended to be rather more yellow dune quadrats at the expense of dune grassland. This may reflect a higher level of erosion as a consequence of local heavy grazing and extreme exposure.

Table 3.7 Alphabetic list of the 18 Scottish Survey sites from which data was used.

Site, location, county	Number	Area (Ha)
Baleshare, North Uist	28	512
Ballevullin, North Tiree	13	320
Balranald, North Uist	35	524
Barvas, Lewis	43	240
Faraid Head, Sutherland	56	228
Farr Bay,Sutherland	58	29
Gruinart, Islay	6	560
Loch Bee, South Uist	25	752
Macrihanish, Kintyre	2	353
Monach Islands, North Uist	30	336
North Barra, South Uist	20	240
Oldshore More, Sutherland	53	117
Oronsay, Argyllshire	7	352
Pabbay, North Uist	38	250
Redpoint, Wester Ross	50	122
Sandwood, Sutherland	64	91
Totamore, Coll	16	144
Torrs Warren, Galloway	1	1200

Figure 3.2 Map of Scotland showing the Scottish Survey sites from which data was used. Site numbers are given in Table 3.7.

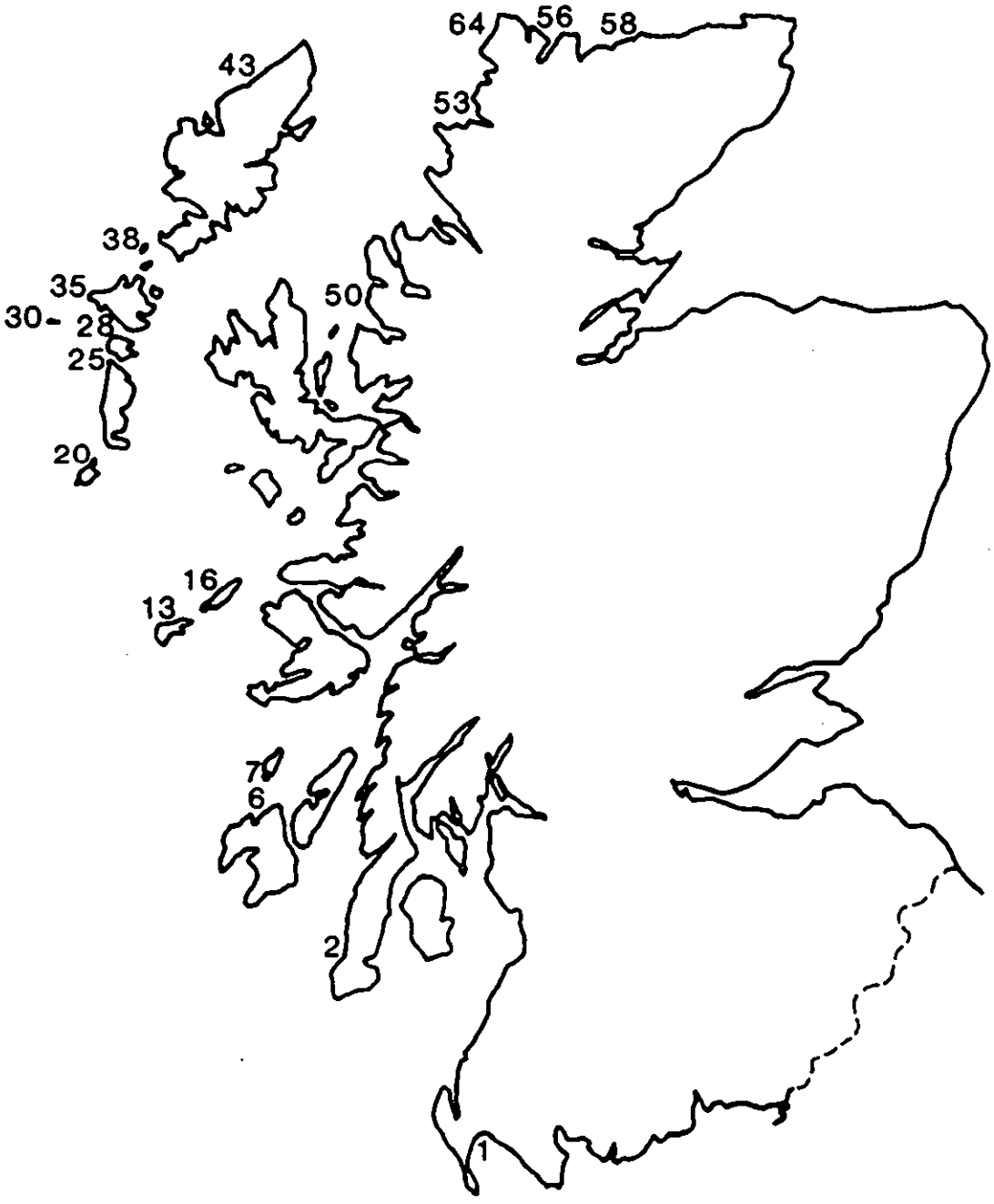

Table 3.8 Regional distribution of quadrat habitat types

Region	Number of quadrats in each habitat type				
	Yellow dune	Dune grassland	Damp slack	Wet slack	Dune heath
North-east Scotland	25	116	8	0	8
South-east Scotland	22	43	5	1	6
North-east England	19	30	3	4	0
South-east England	37	71	1	4	18
South-west England and South Wales	55	122	13	7	11
North-west England and North Wales	25	86	25	10	2
Totals	183	468	55	26	45
%	23.6	60.1	7.1	3.4	5.8
West Scotland (Scottish Survey)	234	415	39	32	56
%	30.2	53.5	5.0	4.1	7.2

3.4 Other sources of information

There were two sources of information that were drawn upon in the course of this study, apart that is from the not inconsiderable amount of published information. In the Netherlands nature conservationists and research workers in the field of dune ecology have accumulated over the years a vast quantity of useful information on dune management including much on the grazing management of dunes. While there have been many papers in the scientific literature much remains unpublished or only available in local sources.

Two visits to the Netherlands yielded much information from personal discussions, from field visits and from various reports and memos not available outside the country and or not available in English. The Dutch experience is relevant to the British situation because the dunes are very similar floristically, physiographically and climatically. The Dutch experience is also relevant because of the positive line that has generally been taken in the field of dune management. Considerable emphasis has always been placed on practical methods of proven efficacy (Bakker et al., 1979, Bink et al, 1979). The reasons for this approach stem from a combination of three factors: the importance of the dunes for sea defence, a passionate interest in nature conservation, and, because of the high population density, extreme human environmental pressures on all coastal areas.

The other source of information is from past and present experimental work on sand dune grazing. It has the great advantage of giving a degree of depth to a study that was extensive in the spatial sense but restricted in the temporal. The degree of information obtained varied from casual observation on grazing exclosures long abandoned through to current studies such as the large mixed grazing exclosures at Saltfleetby, the sheep grazing studies at Newborough (Hewett, 1985) and the goat studies at Tentsmuir (Bullock & Kinnear, 1988). In addition the author has maintained rabbit exclosures at Holkham, Norfolk for seventeen years. The current results underline the very slow rate of change that can occur and the consequent need for taking a long term view of any floristic changes that result from a change in management or changes in circumstances.

4. Survey of British sand dunes

4.1 Seasonal changes

The potential problem of seasonal changes was a serious worry as it would have quite impossible to sample vegetation over so wide an area in a short time span. Two sites, Aberlady, East Lothian, and Winterton, Norfolk, were visited in May and August of 1985, the first year of the study. Twelve grassland quadrats were recorded during each visit to Aberlady and the mean number of species per quadrat was 16.1 and 17.7 respectively. The difference was not significant. The grass heights at 73 mm and 86 mm were not significantly different. The same held for the species and vegetation height for the yellow dunes. The assessment of impact overall did not differ either. Thus for Aberlady dunes there were no differences that were significant in the vegetation between May and August.

Dune grassland at Winterton was less species rich than that at Aberlady, but the two figures of 6.3 and 7.2 again did not differ significantly and neither did the vegetation height (84 & 103 mm). The same was also true for the species diversity and vegetation height of the dune heath (6.8 & 6.3 and 146mm & 168 mm). However there were differences in the vegetation of the yellow dune. The vegetation height in August at 277 mm was significantly greater than the height of 135 mm in May ($p<0.001$). The number of species per quadrat was lower, 4.0 compared with 5.9. The difference was, however, only just significant ($p=0.053$). The lower August figure can be explained by the loss of annual species during the summer drought. In the more closed grassland and heath vegetation the proportion of annuals is lower and rather more moisture is available. In addition the sand mobility in the yellow dunes would rapidly obscure the remains of small annual species. Despite the differences observed in the yellow dunes there was no significant difference between the two impact assessments at Winterton.

The two visits to Strathbeg gave very similar results at least for the dune grassland. The mean number of species per quadrat was estimated to be 15.0 in 1985 and 14.2 in 1987. The mean height of the vegetation was 45 mm in 1985 and 48 mm in 1987. The impact was assessed at 1.4 in 1985 and 1.5 in 1987. None of these were significantly different. The only difference between the two visits was in the number of rabbits seen. On the first visit over 150 were seen compared with 15 over approximately half the area in 1987. The size of the difference may partly be explained by the rainy weather during the latter visit although there were significantly fewer signs of rabbits.

It was concluded from the data from these three sites that data from the various sites collected at different times could be validly compared, given a degree of caution with regard to species number and more especially the height of the vegetation in quadrats on yellow dune. It became clear during the course of the collection of the data that actual species of plants that were recorded did vary during the course of the season even if the number of species per quadrat did not differ very much. Early in the season the winter annuals were particularly noticeable During the course of the summer these species gradually disappeared but generally their loss was made up for by the

appearance of later flowering perennials including various orchid species. The yellow dune habitats tended to have more winter annuals than late flowering perennials hence the differences observed. The other dune categories tended to have approximately similar proportions of annuals and late perennials resulting in little change to the overall number of species per quadrat.

4.2 The present grazing situation

The limitation imposed by a single visit to most sites meant that only a general picture of the grazing situation could be obtained. This was particularly true of the assessments based directly on the number of animals seen during the course of the visit. On a warm dry evening the number of rabbits seen would be very much closer to the total present than on a cold wet day when the majority would be sheltering underground. The larger grazing animals tend to remain together in a group or groups which move around the site. In the case of the larger sites it was quite possible for considerable numbers to be missed completely. On the other hand the animal droppings, while not giving an accurate indication of the total number present did at least indicate what the average situation over the last few months had been. It was clear from discussions with local people that the droppings observed represented the current year, that is the majority of rabbit pellets, cow pats etc., relating to the previous year had decayed during the winter, although in one or two of the drier sites traces could be found dating back to the previous season. The grazing situation as it appeared during the site visits is given on a quadrat basis in Table 4.1 and on a site basis in Table 4.2 .

As might have been expected the role of the rabbit as the dominant grazing animal on British dunes was largely confirmed. Rabbits had recently been present in 55.7 % of the quadrats and if those quadrats within grazing range of rabbits (that is within 50 m) are included as well then 69.5 % of the quadrats could be regarded as being rabbit-grazed. The situation was similar in West Scotland where 72.1 % of the quadrats could be regarded as being rabbit-grazed. Bearing in mind that rabbits tend to graze an area for some time and then move on to another area it is very likely that the total number of quadrats affected by rabbits at some time or other is even greater.

Only two sites appeared to be completely free of rabbit grazing, Alnmouth, Northumberland and St. Ninian's in the Shetlands, and there were only very limited signs of rabbit grazing at Oxwich, Glamorgan and Druridge Bay, Northumberland. The latter site was however grazed by cattle. These ungrazed sites were, however, all small sites amounting in total to only 160 Ha. In West Scotland only Fabbay was virtually ungrazed by rabbits but this site was heavily grazed by sheep and cattle. Thus while 92 % of the sites showed signs of rabbit grazing within the quadrat, with a further 2 % with signs within 50 m: on an area basis something like 98.5 % of the dunes sampled appeared to be affected by rabbit grazing to some extent.

The picture was very different in the case of the other grazing

animals. Around fifteen per cent of quadrats had signs of cattle within 50 m and 35 % of sites were cattle grazed to some extent. Generally speaking the effect of the larger grazing animals was distributed more evenly over a site than was the case with rabbits, except that in a number of cases sheep, cattle, or ponies were physically restricted to specific areas.

The grazing situation regarding sheep was similar to that for cattle but often involving different sites. Five sites were extensively grazed by both sheep and cattle with a further site where both grazers were present but on different parts of the site (Fidge, Sanday) and another site where there were grazing experiments with both sheep and cattle (Saltfleetby, Lincolnshire).

In West Scotland the majority (84%) of sites were sheep grazed or cattle grazed. Cattle grazing affected 45 % of quadrats to some extent, while 38 % of quadrats were affected by sheep grazing.

Grazing with horses or ponies was limited to two sites - Whiteford, Glamorgan and Bar Point in the Scillies. It is also possible that some grazing by native ponies occurs from time to time on some of the Shetland sites although this was not recorded during this study. However in West Scotland pony grazing was relatively common affecting 18 % of the sites although less than 1 % of quadrats were affected.

Grazing by hares was only recorded from four quadrats involving two sites Kenfig, Glamorgan and Aberffraw, Anglesey. Grazing by hares is likely to have been underestimated since it was difficult to distinguish between the droppings of rabbits and hares, especially when there was an abundance of rabbit droppings in an area. Hares were also seen at Llangennith, Glamorgan and Holkham, Norfolk.

No deer grazing was recorded in the present survey but in West Scotland 13 % of sites and 2.7 % of quadrats were affected. The degree of influence generally appeared to be small in relation to other grazing animals.

While four sites were recognised as being virtually ungrazed a further ten sites were only lightly grazed. Especially notable were those in North-east England (Bamburgh, Druridge Bay, Alnmouth and Newton Links) and in Wales (Kenfig, Oxwich, Llangennith and Newborough).

At the other end of the scale nine sites could be regarded as being heavily grazed with St. Martin's, Scillies and Stackpole, Dyfed being particularly notable. The grazing pressure from rabbits at Gibraltar Point seemed to be very high, in the course of a day's visit over 200 rabbits were seen. The recorded impact was not particularly high and the average height of the vegetation was over 180 mm corresponding to that of some of the lightly grazed sites. This anomaly can be attributed to the dominance of inedible ruderal plant species such as nettles and thistles. A similar situation exists on parts of Stackpole where the heavy rabbit grazing is concentrated further by dense stands of Bracken Pteridium aquilinum.

With fourteen lightly grazed sites and nine heavily grazed sites one might assume that the grazing situation was about right for the remaining twenty five sites. The reality of the situation was that these twenty five sites were identified as neither being overgrazed to the extent of having very short vegetation with patches of bare ground; nor being undergrazed with extensive tall vegetation. This assessment may or may not relate to species diversity. This will be considerably affected by the nature of the vegetation concerned, the plant species and communities involved. The relative impact of the different forms of grazing on the various vegetation types is considered in the next five sections.

Table 4.1 Number of quadrats (out of 777) with signs of grazing animals found in the quadrat and found within 50 m of the quadrat

Animal	Within Quadrat		Within 50 m		Total		S.S.
	Q's	%	Q's	%	Q's	%	%
Ponies	10	1.3	10	1.3	20	2.6	0.9
Cattle	59	7.6	57	7.3	116	14.9	45.3
Sheep	68	8.8	49	6.3	117	15.1	37.9
Deer	0	0	0	0	0	0	2.7
Rabbits	427	55.0	113	14.5	540	69.5	72.1
Hares	4	0.5	4	0.5	8	1.0	-
No signs	233	30.0	114	14.7	233	30.0	10.9

S.S. = Scottish Survey data from 3327 quadrats.

Table 4.2 Number of sites (out of 48) with signs of grazing animals within one of the quadrats and within 50 m of the quadrat

Animal	Within Quadrat		Within 50 m		Total		S.S.
	Sites	%	Sites	%	Sites	%	%
Ponies	1	2.1	1	2.1	2	4.2	18
Cattle	15	31.3	2	4.2	17	35.4	84
Sheep	15	31.3	3	6.3	18	37.5	84
Deer	0	0	0	0	0	0	13
Rabbits	44	91.6	1	2.1	45	93.8	100
Hares	2	4.2	1	2.1	3	6.3	-
Ungrazed	4	8.3	1	2.1	4	8.3	0

S.S. = Scottish Survey data from 94 sites.

4.3 Yellow dune communities

All but two sites had some yellow dune quadrats. The total of 183 quadrats indicated an average of 3.8 yellow dune quadrats per site. Site averages are given in Table 4.3. Within the limits of the small sample size the proportion of yellow dune quadrats gave an indication of the mobility of the site. Frequently this reflected the way the older parts of the site had been lost to housing, industry or agriculture rather than an inherent difference in the dune system. All seven quadrats of the 2 Ha Bar Point dunes were in the yellow dune category but more significant was the 8 out of 18 at Morfa Dyffryn, the 450 Ha of which include extensive areas of secondary dune activity. This is in contrast with the situation at South Walney where no quadrats of yellow dune were recorded in a heavily grazed 100 Ha site.

Although the average number of species per quadrat was quite low at 8.1 the site means varied greatly from 16.0 at Lindesfarne to 2.7 at Strathbeg. One quadrat from Morfa Harlech had 21 species and several quadrats had 20. The species rich yellow dune quadrats represented two distinct situations. In sites where the primary dunes were relatively stable the plant species diversity would slowly build up as new species colonised the open space available thus increasing the number of species from four or five up into the teens.

Sometimes, when secondary mobility occurred, the area of mobile sand and associated pioneer species also included fragmentary areas of old turf of high species diversity that seemed to be able to survive considerable periods.

Generally the yellow dune vegetation was tall, the average height was 340 mm with a quadrat maximum of 86 mm , but there was a proportion of closely grazed quadrats with a vegetation height of 100 mm or less. The correlation between height and species diversity was not particularly good. This was mainly because while no quadrats with tall vegetation had a high species diversity short vegetation was no guarantee of high diversity. The sites with an above average species diversity generally had vegetation that was 300 mm or less in height, at least in patches.

The rabbit was the main grazing animal to be found on the yellow dunes; only 7% were grazed by any other animal. This is partly a reflection of the poor grazing value of the yellow dunes and partly a realisation by the grazier of the vulnerability of yellow dunes to damage by trampling. Generally the impact of rabbit grazing on yellow dunes was quite light but heavy grazing by rabbits was noted at Gibraltar Point, Herm, and Morfa Harlech. The yellow dunes at 30 sites were ungrazed or only lightly grazed (impact < 1.0) usually by rabbits.

The mean number of species per quadrat for the seven ungrazed sites of 6.9 was just below the overall mean: while the mean for the seven sites that were heavily grazed was 9.0, just above the mean. The big difference lay in the variability of the heavily grazed sites as compared with the ungrazed ones. On the one hand there were sites like Morfa Harlech with a rich yellow dune flora (14.5 species/quadrat) in marked contrast with sites like Breakon with a limited yellow dune flora (4.3). Field

Table 4.3 Site summary of yellow dune quadrats

Site	Q's	Species	Height (mm)	Impact	Animals
Aberffraw	3	4.3	505	0.3	6,(2)
Aberlady Bay (A&B)	8	7.6	424	0.5	6
Ainsdale	3	7.7	257	0.7	6
Alnmouth	3	9.7	500	0.0	0
Bamburgh Links	3	11.0	457	0.7	6
Bar Point	7	9.7	385	0.6	6,(1)
Braunton Burrows	5	10.4	214	0.0	(6)
Breakon	3	4.3	203	2.0	6,3
Brownslade Burrows	4	12.5	438	0.5	6
Druridge Bay	2	5.0	604	0.0	0
Earlshall Muir	2	9.0	470	0.0	(6)
Fidge	1	9.0	378	1.0	2,6
Forvie	1	7.0	480	1.0	6
Gibraltar Point	1	10.0	224	3.0	6
Great Bay	6	8.8	366	0.3	6
Herm	1	9.0	10	3.0	6
Holkham	7	13.3	197	1.3	6,2
Kenfig Burrows	2	9.5	148	0.0	(6,3,7)
Kilpaison Burrows	6	7.5	450	0.0	(6)
Levenwick	3	9.7	370	0.7	3
Lindesfarne	3	16.0	225	0.7	6
Llangennith Burrows	4	6.3	341	0.0	0
Morfa Dyffryn	8	6.3	276	1.5	6
Morfa Harlech	2	14.5	265	3.0	6
Newborough Warren	4	7.8	380	0.0	0
Newton Links	4	7.5	484	0.0	0
North Walney	3	10.0	215	0.7	6
Oxwich	3	8.5	258	0.0	0
Pentle Bay	8	10.1	435	0.6	6
Quendale	4	6.0	427	0.0	0
Quennevais	7	10.0	186	2.0	6
Ross Links	4	10.8	521	0.0	(6,2)
St. Cyrus	6	7.5	498	1.0	6
St. Ninian's	2	6.0	338	0.0	0
Sandscale	2	5.5	217	0.0	(2)
Scolt Head	7	7.3	242	0.3	6
Scousburgh	4	8.0	562	0.3	3
Stackpole	1	8.0	386	2.0	6
Strathbeg (A&B)	6	2.7	517	0.3	6
Studland	5	7.2	257	1.2	6
Tentsmuir	6	10.7	235	0.5	6
Whitemills	1	7.0	-	2.0	6
Whiteford Burrows	1	13.0	216	1.0	1,(2,6)
Winterton (A&B)	17	5.0	202	0.8	6
Means (se) (183 quadrats)		8.1(0.3)	339(14)	0.9(0.1)	

Animals:- 1 = ponies, 2 =cattle, 3 = sheep, 6 = rabbits, 7 = hares. Figures in brackets refer to signs of that animal in the vicinity of the quadrat. se = standard error.

observations indicate that while limited grazing, particularly by rabbits, can increase the species diversity of yellow dunes. These communities are particularly susceptible to overgrazing and the consequent species impoverishment.

The Scottish Survey data from West Scotland gave a broadly similar picture (Table 4.4), although there was a higher proportion of sites that were noticably grazed. However a comparison of sites covered by both surveys (Table 4.5) also showed a higher grazing impact index in the yellow dune communities for the earlier survey. This would suggest either an overall decrease in grazing on yellow dunes or a difference in the assesment of grazing impact or a combination of both.

The mean number of species per quadrat for the sites in common was 18.1 (Scottish Survey) compared with 7.0 (present survey). It would thus seem that the mean of 20.1 for West Scotland corresponds with the mean of 8.1 for all other sites. It is concluded that the West Scotland sites have a similar plant species diversity to that of the other sites. The high range of diversity was also similar with the most diverse site (Fabbay) having over twice the diversity of the least diverse site (Sandwood).

The picture that emerges, regarding grazing in yellow dune communities, is a very variable one, often intermittent in space or time, but with quite high intensities of grazing. As a result there is a considerable variability in species diversity. The enhancement of diversity following grazing results from an acceleration in the natural processes of succession from yellow dune to dune grassland. Grazing helps to transfer part of the high quantities of organic material tied up in the standing crop, both living and dead, into the organic content of the soil. This, together with the more open habitat created by grazing, enables many plant species to colonise successfully. The dangers of grazing lie in the sensitivity of yellow dune swards to trampling and to the overall reduction in the ability of the vegetation to respond to natural or man-induced dune mobility once non-dunebuilding species form a significant part of the flora. If yellow dunes are overgrazed, non-dune building species can increase before the dunes are fully developed. This produces an unstable situation with a greatly increased risk of serious erosion.

The increased diversity found in yellow dune quadrats in grazed areas is usually exceeded by the diversity to be found in the corresponding dune grassland quadrats. There is thus no advantage, in terms of the overall plant species diversity of a site, in permitting the grazing of the yellow dunes. Against this there is a markedly greater erosion risk when yellow dunes are grazed.

Table 4.4 Site summary of yellow dune data from Scottish Survey.

Site	Q's	Species ($25m^2$)	Height (% >500 mm)	Impact	Animals ($200m^2$)
Baleshare	8	20.3	13	1.9	6,2,3
Ballevullin	6	17.8	17	1.3	2,3,6
Balranald	10	17.6	0	0.8	2,3,6
Barvas	9	17.7	33	1.3	6,3,2
Faraid Head	15	22.5	80	0.9	3,6,2
Farr Bay	19	25.4	58	2.1	6,3,2
Gruinart	19	17.3	32	1.6	6,3,2,1
Loch Bee	7	24.0	0	1.3	2,6,(3,1)
Macrihanish	18	22.7	83	1.3	2,3,6
Monach Islands	13	24.9	77	0.9	6,3
North Barra	9	15.6	11	0.9	2,6,(3,1)
Oldshore More	11	24.0	36	1.7	6,3,2(1)
Oronsay	6	19.2	50	2.3	6,3,(2)
Pabbay	8	30.3	75	1.4	3,2,(5,6)
Redpoint	10	14.4	0	0.9	3,6,2
Sandwood	19	11.2	53	1.0	6,3
Totamore	3	16.7	67	1.0	2,3,(6)
Torrs Warren	46	19.8	30	1.3	6,5,3,(2)
Means(se)	(236 quadrats)	20.2(1.2)	-	1.3(0.1)	

Animals:- 1 = ponies, 2 = cattle, 3 = sheep, 5 = deer, 6 = rabbits/hares. Figures in brackets refer to animals elswhere on site. se = standard error.

Table 4.5 Site comparison of yellow dune data.

Site		Q's	Species	Height	Impact	Animals
Aberlady	a	7	23.3	86	1.4	6
	b	8	7.6	424	0.5	6
Breakon	a	7	16.6	0	1.1	3,6,(2)
	b	3	4.3	203	2.0	6,3
Fidge/Overbister	a	5	15.6	60	1.0	6,2,(3)
	b	1	9.0	378	1.0	2,6
Forvie	a	25	13.4	60	0.9	6
	b	1	7.0	480	1.0	6
Quendale	a	13	21.3	8	1.4	3,6,2,1
	b	4	6.0	427	0.0	0
St. Cyrus	a	4	23.0	75	1.3	6,2,3
	b	6	7.5	498	1.0	6
Scousburgh	a	11	22.3	0	1.5	3,6,1,2
	b	4	8.0	562	0.3	3
Strathbeg	a	21	10.2	95	0.9	6,3,2,(5)
	b	6	2.7	517	0.3	6
Tentsmuir	a	20	17.3	15	1.5	6,2,3,(5)
	b	6	10.7	235	0.5	6
Scottish Survey	a	113	18.1(1.6)	-	1.2(0.1)	
Present Survey	b	39	7.0(0.8)	-	0.7(0.2)	

Animals:- 1 = ponies, 2 = cattle, 3 = sheep, 5 = deer, 6 = rabbits/hares. Figures in brackets refer to animals elswhere on site. se = standard error.

Height a = per cent of quadrats with some grass >500 mm

b = mean height in mm

4.4 Dune grassland communities

The dune grassland communities formed by far the largest group of quadrats; the 468 grassland quadrats recorded represented 60% of the total. The results from these quadrats are given on a site basis in Table 4.6. The most notable feature is the wide range in the mean number of species per quadrat on a site basis, with a range from 6.7 at Winterton to 21.5 at Aberffraw. The actual quadrat minimum was 4 in a quadrat from Winterton and the maximum was 31 species in a quadrat from Great Bay, St. Martin's, in the Scillies. The mean number of species per quadrat for all the grassland quadrats at 14.8 was the highest of the five vegetation categories.

The range of species diversity formed a spectrum reflecting the soil alkalinity or acidity. At one end of this spectrum was Aberffraw, in Anglesey, which showed the highest dune grassland diversity with 21.5 species per quadrat. While at the other end there was Winterton with 6.7 species. Thirteen sites had a mean of sixteen or more species per quadrat while twelve sites had less than thirteen species per quadrat. In general there seemed to be a link between species diversity and vegetation height. The thirteen richest sites (mean number of species = 17.5) had a mean vegetation height of 103 mm; while the twelve poorest sites (mean number of species = 10.1) had a mean vegetation height of 184 mm. The vegetation height of the species poor quadrats was usually high (e.g. Alnmouth with a mean vegetation height of 553 mm and a mean of 10.3 species per quadrat) but there was a number of quadrats with a short but species poor vegetation. At Winterton the explanation could be found in the dry acid soil conditions; while phytogeographic considerations could explain the paucity of species at Breakon, on Yell, the most northerly site. The relatively short but species poor vegetation at South Walney could be attributed to the combination of grazing and eutrophication by the large population of nesting gulls present on the site.

If the sites were compared on the basis of impact assessment the picture obtained was generally similar but on the whole vegetation height seemed to be a better indicator of the grazing situation regarding species diversity. There is however one important exception and that is when there is a significant proportion of inedible species in the vegetation. A tall inedible herbaceous species will remain ungrazed. This will put up the mean height of the vegetation with the implication that the grazing pressure is low. The reality is very different when the very occurrence of that species is a more or less direct result of excessive grazing.

The most notable feature of the data from the dune grassland quadrats is the existence of sites where the grazing pressure is low, as indicated by the visual absences of grazing animals, by the lack of signs, or as indicated indirectly by vegetation height or impact assessment. Out of the thirteen sites with the highest mean number of species per quadrat, three had taller vegetation than might have been expected from the species diversity. One of these, Stackpole, had a high grazing impact index and the tall vegetation resulted from the occurrence of of extensive shoots of an inedible species - Bracken. The low

Table 4.6 Site summary of dune grassland quadrats

Site	Q's	Species	Height (mm)	Impact	Animals
Aberffraw	12	21.5	58	1.8	6,3,2
Aberlady Bay (A&B)	24	16.9	80	2.1	6
Ainsdale	8	16.0	109	2.1	6
Alnmouth	6	10.3	553	0.0	0
Bamburgh Links	4	14.8	412	0.3	6
Braunton Burrows	14	17.9	114	0.9	6
Breakon	9	9.9	31	1.8	3,6
Brownslade Burrows	11	16.7	86	1.7	6
Cabin Hill	3	15.7	61	2.0	2,6
Conninghole	14	13.6	54	1.7	6,2
Druridge Bay	8	14.4	284	0.4	2,(6)
Earlshall Muir	9	14.1	92	1.4	6
Fidge	19	14.7	64	2.0	6,3,2
Forvie	4	13.5	136	1.0	6
Gibraltar Point	12	12.5	183	1.8	6
Great Bay	6	19.8	37	2.6	3,1
Herm	10	11.6	49	2.0	6
Holkham	16	17.4	105	1.2	6,2
Kenfig Burrows	8	19.4	183	0.5	3,7,(6,1)
Kilpaison Burrows	13	14.9	105	1.5	2,6
Levenwick	5	9.2	174	0.8	3
Lindesfarne	8	14.3	161	1.1	6
Llangennith Burrows	11	16.0	164	0.3	3,6,(7)
Morfa Dyffryn	5	16.6	31	2.0	6,2
Morfa Harlech	9	17.3	96	2.0	6,2
Newborough Warren	10	15.1	199	0.3	6
Newton Links	4	13.8	305	0.5	6
North Walney	10	13.7	210	0.5	6
Oxwich	13	13.2	186	0.0	0
Pentle Bay	3	13.0	85	1.7	6
Quendale	13	14.9	43	1.9	3,6
Quennevais	8	13.8	31	2.5	6
Ross Links	9	13.8	202	1.1	2,3,6
St. Cyrus	6	14.5	293	1.3	6
St. Ninian's	4	9.8	269	0.0	0
Saltfleetby (grzd)	17	15.2	155	1.1	(2,3,6)
Saltfleetby (ungr)	6	8.2	397	0.0	(6)
Sandscale	13	15.5	72	1.5	6,2,3,1
Scolt Head	9	12.0	182	0.4	6
Scousburgh	6	12.5	50	1.5	3,6
South Walney	16	9.9	160	1.8	6,3,2
Stackpole	15	16.0	199	2.0	6,(3)
Strathbeg (A&B)	19	14.6	45	2.0	6,(3,2)
Tentsmuir	4	16.8	81	1.3	6
Whitemills	14	12.1	74	1.7	6,(2)
Whiteford Burrows	10	14.9	142	1.1	6,1,3,2
Winterton (A&B)	11	6.7	91	0.9	6
Means (se) (468 quadrats)		14.5(0.2)	131(7)	1.4(0.04)	

Animals:- 1 = ponies, 2 =cattle, 3 = sheep, 6 = rabbits, 7 = hares. Figures in brackets refer to signs of that animal in the vicinity of the quadrat. se = standard error.

grazing status of the two other sites was confirmed by the few animals that were seen, the few signs seen and by a low impact index. These two sites were both in Glamorgan, Kenfig and Llangennith. Kenfig was the third richest site with a mean of 19.4 species per quadrat but a mean vegetation height of 183 mm. The dunes extend over some 490 Ha but the grazing is restricted to some 100 sheep and a few rabbits and hares. The high species diversity can best be explained by reference to the previous management with very much higher grazing intensities and the slow rate of species loss following the marked reduction in grazing. The situation at the other site is essentially the same with probably the same explanation but background information was not available.

At two sites it was possible to separate the grassland quadrats into grazed and ungrazed and to make direct comparisons. At Saltfleetby there was a series of large grazing enclosures contrasting with the largely ungrazed open areas. The differences from the quadrat data was striking; the ungrazed quadrats had a mean vegetation height of 397 mm and a mean of 8.2 species per quadrat, while for the grazed quadrats the height was 155 mm and there were 15.2 species per quadrat. The intensity of grazing was low; the impact was assessed at 1.1. At Stackpole the grassland quadrats were divided into 'grazed' and 'ungrazed' on the height of the vegetation and the two groups of quadrats had a mean of 18.4 and 11.2 species per quadrat respectively. As previously mentioned the tall vegetation included the unpalatable Bracken and the vegetation classified as 'ungrazed' was in fact lightly grazed; the grazing impact was assessed at 1.4 compared with 2.3 within the grazing enclosures. Nevertheless the figures show that even heavy grazing can maintain a high species diversity.

Data from the 420 quadrats from the 18 West Scotland sites are given in Tables 4.7. Site comparisons were possible for 9 sites (Table 4.8). There was general agreement between the two data sets for dune grassland, with similar vegetation heights, impact assesments and, given due allowance for the effect of quadrat size, species diversity. The eighteen West Scotland sites were similar to the other sites in terms of the grazing impact but several of them showed an unexpectedly high species diversity. Particularly notable was Oldshore More and Sandwood, both moderate to heavily grazed, although the latter site was only represented by two quadrats. The sites with the tallest vegetation and lowest grazing impact also had the lowest species diversity.

Considering the grazing situation of dune grassland overall fourteen sites were undergrazed to a point where the species diversity had been significantly reduced or was likely to be reduced. Three sites were apparently without any significant grazing notably Alnmouth, Oxwich and St. Ninian's. Eleven sites were heavily grazed but few of them gave any real indication that the species diversity had suffered although the risk of serious erosion as a result of trampling damage was increased. While it might be expected that the grazing situation at the remaining twenty two sites was about right, in general terms, this assumption overlooked two important factors. Firstly there was the possibility of the existence of incipient species decline where the grazing management had changed but there had

Table 4.7 Site summary of dune grassland data from Scottish Survey.

Site	Q's	Species ($25m^2$)	Height (% >500 mm)	Impact	Animals ($200m^2$)
Baleshare	33	33.7	0	2.4	6,2,3
Ballevullin	29	28.0	17	2.1	3,2,6
Balranald	22	31.8	5	1.6	2,6,3
Barvas	16	27.6	6	2.0	6,3,2
Faraid Head	13	35.7	15	2.0	3,2,6
Farr Bay	19	30.1	16	2.3	6,2,3
Gruinart	30	33.5	7	2.3	6,2,3
Loch Bee	52	33.7	0	1.6	2,6,3,1
Macrihanish	17	24.1	65	1.5	2,6,3
Monach Islands	23	23.0	30	1.0	6,2
North Barra	35	24.9	0	1.9	6,3,2,1
Oldshore More	21	44.1	24	2.2	3,6,2,1
Oronsay	18	29.7	6	2.5	6,2,3
Pabbay	30	35.0	13	1.7	3,2,5,6
Redpoint	10	33.5	0	1.4	3,2,6
Sandwood	2	39.5	0	3.0	2,6
Totamore	29	39.4	0	1.8	2,3,6
Torrs Warren	16	21.4	31	1.3	6,5,2,(3)
Means (se)	(415 quadrats)	31.6(1.4)	-	1.9(0.1)	

Animals:- 1 = ponies, 2 = cattle, 3 = sheep, 5 = deer, 6 = rabbits/hares. Figures in brackets refer to animals elswhere on site. se = standard error.

Table 4.8 Site comparison of dune grassland data.

Site		Q's	Species	Height	Impact	Animals
Aberlady	a	10	30.8	70	2.1	6
	b	24	16.9	80	2.1	6
Breakon	a	14	20.2	0	2.1	3,6,2
	b	9	9.9	31	1.8	3,6
Fidge/Overbister	a	26	25.4	4	2.0	6,2,3
	b	19	14.7	64	2.0	6,3,2
Forvie	a	24	21.4	58	1.1	6
	b	4	13.5	136	1.0	6
Quendale	a	21	26.7	0	1.8	6,3,2,1
	b	13	4.9	43	1.9	3,6
St. Cyrus	a	26	17.7	31	1.7	6,2,3
	b	6	14.5	293	1.3	6
Scousburgh	a	18	26.4	0	2.2	3,6,2,1
	b	6	12.5	50	1.5	3,6
Strathbeg	a	35	19.7	71	1.5	6,2,3,5
	b	15	16.0	199	2.0	6,3
Tentsmuir	a	41	27.2	15	2.4	6,2,3,5
	b	4	16.8	81	1.3	6
Scottish Survey	a	215	23.9(1.5)	-	1.9(0.1)	
Present Survey	b	100	13.3(1.3)	-	1.7(0.1)	

Animals:- 1 = ponies, 2 = cattle, 3 = sheep, 5 = deer, 6 = rabbits/hares. Figures in brackets refer to animals elswhere on site. se = standard error.

Height a = per cent of quadrats with some grass >500 mm

b = mean height in mm

not been time for the species composition to respond. Secondly the assumption concealed the prospect of enhancing the plant species further by judicious manipulations of the grazing regimes.

None of the sites in West Scotland could be regarded as seriously undergrazed, and, although nine of the 18 sites were heavily grazed, there was little sign of this reducing species diversity, even though there were signs of erosion damage locally.

At Gibraltar Point the impact of the rabbits was only estimated to be moderate, and the vegetation, at 183 mm, was slightly taller than average. The mean number of species per quadrat, at 12.5, was only slightly below average. All this rather concealed the truth of the situation in a way that illustrates the need for caution in the interpretation of grazing data. There are extensive stands of Sea Buckthorn Hippophae rhamnoides on this site. This has produced problems even though Sea Buckthorn is probably native in this situation. The nitrogen fixation by the root nodules of Sea Buckthorn coupled with the activities of the rabbits has resulted in the general eutrophication of the site with the spread of inedible ruderal species such as Nettles and Thistles. The spread of Sea Buckthorn has also restricted the grazing area available to the rabbits. The combination of the partly concealed overgrazing and the effects of eutrophication have resulted in a moderate species diversity in an area with a potential for a high species diversity. This site indicated the need for caution in interpreting the interactions between grazing pressures and floristic change.

Dune grassland is very much a transient seral community on the route between the yellow dune communities, involved in dune building, and dune scrub and woodland. Without grazing a species-poor rough grassland is formed and this is then colonised by various woody species and transformed into scrub and ultimately woodland. Grazing is essential for the survival of dune grassland especially the damper calcareous areas. Dry acid grassland can persist for quite a long time even with little or no grazing, although it too will eventually be colonised by woody species. Some grazing is better than no grazing at all. Overgrazing is generally less damaging to dune grassland than undergrazing. The deleterious effects of overgrazing are usually obvious, with an increase in the proportion of bare ground. The effects of undergrazing may be relatively apparent in the form of an increase in the average height of the vegetation but the lasting effects on species diversity may only become apparent after many years. At this stage the rectification of the situation will be difficult if not virtually impossible.

4.5 Damp slack communities

Damp slack communities were only recorded at 20 of the 48 sites but their general characteristics were similar to those of the grassland communities despite the differences in species composition (Table 4.9). There were however contrasts in that sites with species rich grassland often had dune slack vegetation that was relatively species-poor and conversely some of the sites with a high species diversity in the damp slacks had grassland communities that were rather poor in species. Of the six sites with the highest species diversity in the damp slacks, only two were in the top six grassland sites and two were not even in the top thirteen grassland sites.

In general the level of grazing impact associated with species rich damp slack vegetation was rather less than that for grassland communities but at low grazing intensities the species diversity showed a more rapid increase with increasing vegetation height. The quadrats with a species diversity of 16 or more all had a vegetation height of 200 mm or less, with the exception of one quadrat from Kenfig with 31 species and a mean vegetation height of 254 mm. The anomalies associated with this site have already been discussed.

The species poor quadrats in the damp slack category are generally associated with the taller vegetation but there are exceptions. Relatively short vegetation but with a low species diversity is often associated with Dwarf Willow Salix repens either in the pioneer stage colonising damp sand or in the mature phase where the density of shoot growth inhibits colonisation by other species. The relationship between the growth of Dwarf Willow and the maintenance of the species diversity of damp slack communities is a complex one. This matter is considered further in Section 7.

Cattle grazing seemed to occur more in damp slacks than in other dune communities. Eight out of the twenty sites with damp slacks were cattle grazed (40%) while only four were sheep grazed (10%). It was clear that the dense close sward that developed on damp sand as well as the cohesion of the sand resulted in damp slack communities being well able to stand the normally damaging trampling of the cattle, or horses although this only occurred on one site.

Twelve of the eighteen West Scotland sites had quadrats representing damp slack communities (Table 4.10). There were three sites that were covered by both surveys (Table 4.11). The West Scotland damp slack sites generally had more grazing, shorter vegetation, and a higher diversity. Particularly notable in this respect was Gruinart and Oldshore More. Barvas, in Lewis, was a notable exception. The one quadrat of the damp slack habitat type had a background of tall aquatics more usually associated with wet slack or open water. As in the present survey there was more cattle grazing in damp slacks than in other habitat types. This was particularly true of the West Scotland sites; cattle were the dominant grazing animal in damp slacks in eight out of twelve sites compared with five out of twenty in the present survey. Sheep were the dominant grazing animal in only two West Scotland sites and one other Scottish site.

Table 4.9 Site summary of damp slack quadrats

Site	Q's	Species	Height (mm)	Impact	Animals
Aberffraw	2	16.5	99	1.5	6,(2)
Ainsdale	2	15.0	166	1.0	6
Braunton Burrows	2	15.5	99	0.5	6
Cabin Hill	4	10.5	380	0.5	2,(6)
Conninghole	2	11.0	94	0.6	2,6
Forvie	1	8.0	32	2.0	6
Holkham	1	11.0	156	1.0	2,(6)
Kenfig Burrows	3	19.7	246	0.3	6,(3)
Lindesfarne	1	10.0	142	0.0	6
Llangennith Burrows	2	16.5	127	0.0	(6)
Morfa Dyffryn	5	11.0	146	1.2	6
Morfa Harlech	2	13.0	94	2.0	2,(6)
Newborough Warren	5	14.2	162	0.4	6
North Walney	1	6.0	320	0.0	0
Ross Links	2	11.0	241	0.0	(2)
Sandscale	4	16.8	131	1.0	6,3,(2)
Strathbeg	3	22.0	53	1.7	3,6,(2)
Tentsmuir	5	16.8	81	1.3	6
Whitemills	2	14.0	95	1.0	6
Whiteford Burrows	6	16.2	117	1.1	6,1,(3)
Means (se)	(55 Quadrats)	14.1(0.7)	151(15)	1.0(0.1)	

Animals:- 1 = ponies, 2 =cattle, 3 = sheep, 6 = rabbits. Figures in brackets refer to signs of that animal in the vicinity of the quadrat. se = standard error.

Table 4.10 Site summary of damp slack data from Scottish Survey.

Site	Q's	Species ($25m^2$)	Height (% >500 mm)	Impact	Animals ($200m^2$)
Baleshare	2	34.0	0	1.5	2,3,6
Balranald	3	37.0	0	1.0	2,(6,3)
Barvas	1	44.0	100	2.0	6,3
Faraid Head	1	42.0	0	1.0	2,3,6
Gruinart	1	69.0	0	2.0	2,3,6,(1)
Loch Bee	13	44.7	0	1.3	2,6,1,(3)
Macrihanish	2	44.5	0	2.5	2,3,6
Monach Islands	2	25.0	0	1.0	6,3
Oldshore More	1	53.0	0	3.0	3,6,(2,1)
Pabbay	7	37.7	0	1.4	3,2,5,(6)
Totamore	2	46.5	0	2.0	2,6,3
Torrs Warren	4	32.3	0	1.0	6,(5,3,2)
Means (se)	(39 quadrats)	42.5(3.3)	-	1.6(0.2)	

Animals:- 1 = ponies, 2 = cattle, 3 = sheep, 5 = deer, 6 = rabbits/hares. Figures in brackets refer to animals elswhere on site. se = standard error.

Table 4.11 Site comparison of damp slack data.

Site		Q's	Species	Height	Impact	Animals
Forvie	a	5	27.8	40	2.0	6
	b	1	8.0	32	2.0	6
Strathbeg	a	1	21.0	100	0.0	(6,2,3,5)
	b	3	22.0	53	1.7	3,6,(2)
Tentsmuir	a	7	26.3	29	2.6	6,2,(3,5)
	b	5	16.8	81	1.3	6
Scottish Survey	a	13	25.0	-	1.5	
Present Survey	b	9	15.6	-	1.7	

Animals:- 1 = ponies, 2 = cattle, 3 = sheep, 5 = deer, 6 = rabbits/hares. Figures in brackets refer to animals elswhere on site. se = standard error.

Height a = per cent of quadrats with some grass >500 mm

b = mean height in mm

4.6 Wet slack communities

The wet slack communities were few and varied. They were found on 15 sites but usually only to the extent of one or two quadrats at each site (Table 4.12). The division between open water with aquatic vegetation, including some emergent species, and wet slack vegetation, with all the species emergent, was necessarily somewhat arbitrary. It rather depended on the water level at the time of the site visit. The aim was to exclude those areas with more or less permanent flooding. There was a marked contrast between the species-rich short turf at Aberffraw and Newborough Warren and the much taller fen vegetation dominated by Sedges Carex spp. at Saltfleetby or Bamburgh Links.

Wet slack vegetation was also scarce in West Scotland. With 33 quadrats from nine sites it was the least common habitat type (Table 4.13). There were insufficent quadrats to make comparisons with the present survey. It would appear that the wet slack vegetation of West Scotland was rather shorter and more heavily grazed than elsewhere. Despite this the species diversity appeared to be higher than average. Notable in this respect was Baleshare with both the highest species diversity and the highest grazing impact.

There was something of a division of wet slack vegetation into two more or less distinct height categories. The short vegetation was generally species rich, with the exception of one moss dominated quadrat at Whiteford. The tall vegetation was generally species poor, often markedly so, but again Kenfig provided the exception. The wet slacks were generally less grazed than the damp slacks. This can partly be explained by the non-availability of wet slack vegetation which is largely submerged during the winter period when adjacent areas are being grazed. The accumulation of peat and the wet sand as opposed to damp sand makes the wet slack vegetation rather more vulnerable to damage from trampling than the damp slacks. At one site, Saltfleetby, accounting for four quadrats, the vegetation was maintained by annual mowing.

The other problem that affects slacks, but especially the wet ones, lies in the control of the water table. The regular alternation in water levels between the summer and the winter is an integral part of the system but drifts from the mean, particularly a lowering of the water table, can lead to a reduction in species diversity. The small number of quadrats with damp slack vegetation might be considered to be indicative of this situation. Not only were there relatively few sites with damp or wet slacks but the number of quadrats per site was very much less. Slack vegetation was recorded in less than half the dune sites visited, and overall only 10% of the quadrats represented slack vegetation. Only one third of this was wet slack vegetation. The problem of the management of slack vegetation is as much one of managing water levels as that of vegetation management.

Table 4.12 Site summary of wet slack quadrats

Site	Q's	Species	Height (mm)	Impact	Animals
Aberffraw	1	20.0	46	2.0	6
Ainsdale	2	11.5	99	0.5	6
Bamburgh Links	1	8.0	638	0.0	0
Braunton Burrows	1	16.0	62	0.0	(6)
Brownslade Burrows	1	15.0	606	0.0	0
Cabin Hill	2	13.5	163	2.0	2,(6)
Earlshall Muir	1	12.0	330	0.0	0
Kenfig Burrows	3	15.0	242	0.0	(3,6,7)
Lindesfarne	3	16.6	104	0.7	6
Morfa Harlech	2	9.5	208	1.0	6
Newborough Warren	2	17.5	45	1.0	3
Oxwich	1	8.0	354	0.0	0
Saltfleetby	4	4.0	556	0.7	(2,3)
Sandscale	1	14.0	50	2.0	2,(3,6)
Whiteford Burrows	1	7.0	46	2.0	6,1
Means (se)	(26 quadrats)	12.1(1.1)	246(42)	0.8(0.2)	

Animals:- 1 = ponies, 2 =cattle, 3 = sheep, 6 = rabbits, 7 = hares. Figures in brackets refer to signs of that animal in the vicinity of the quadrat. se = standard error.

Table 4.13 Site summary of wet slack data from Scottish Survey.

Site	Q's	Species ($25m^2$)	Height (% >500 mm)	Impact	Animals ($200m^2$)
Baleshare	10	48.9	0	2.8	6,2,3
Ballevullin	2	46.0	0	2.0	2,3,6
Balranald	4	32.5	25	1.3	2,3,6
Gruinart	6	43.2	0	2.1	2,3,6,(5)
Loch Bee	5	35.0	0	1.4	6,2,(3,1)
Monach Islands	2	42.0	0	1.0	3,6
Oronsay	2	26.0	0	2.0	3,2,6
Totamore	1	50.0	0	0.0	2,(3,6)
Means (se)	(32 quadrats)	40.5(3.0)	-	1.6(0.3)	

Animals:- 1 = ponies, 2 = cattle, 3 = sheep, 5 = deer, 6 = rabbits/hares. Figures in brackets refer to animals elswhere on site. se = standard error.

4.7 Dune heath communities

Dune heath was the scarcest of the five dune vegetation communities, but as the occurrence of the heath is, at least partly, related to the acidity of the dune sand it was hardly surprising that when heath did occur it was relatively extensive. There were only seven sites with dune heath vegetation but these seven sites were represented by no less than 45 quadrats (Table 4.14). The occurrence of the acid sand necessary for the formation of dune heath vegetation can be a direct reflection of the parent material e.g. at Studland where the dune sand is acid sand of Eocene origin, or it can be where neutral sands have become acid and nutrient-poor over a period of time as a result of the leaching away of mineral nutrients and residual basic material as is the case at North Walney. This latter process is further facilitated when the rocks underlying the sand are acidic in reaction as at Great Bay or Pentle Bay in the Scillies.

Dune heath vegetation is generally rather tall and, like other heath communities, comparatively species poor. The mean height and animal impact assessment was similar to that from the wet slack quadrats but the species diversity of dune heath was only 8.6 compared with 12.1 for wet slack quadrats. The lack of diversity within the quadrat is further enhanced by the relative uniformity of the vegetation over large areas. The very definition of dune heath based on the presence of Calluna vulgaris or Erica spp., two moderately vigorous shrub species, would suggest that the species diversities is not likely to be very high. Although in sites where there is also non-acidic vegetation, the extra species that are found in the acidic areas will contribute to the diversity of the area as a whole.

Apart from the large acid dune site at Torrs Warren dune heath vegetation is uncommon in West Scotland (Table 4.15). There were two sites that were covered by both surveys, Forvie and Tentsmuir (Table 4.16). Again there appears to be rather less grazing now than at the time of the Scottish Survey. Torrs Warren had tall vegetation and a low species diversity. The five other West Scotland sites only had two quadrats of dune heath vegetation each. Two had low grazing impact and low species diversity, while three were heavily grazed with rather a high species diversity. This latter situation may be explained by the vegetation being a mosaic based on a thin layer of calcareous sand over acidic rock. The larger size of quadrat included acid heath vegetation with other vegetation types thus increasing the overall species diversity.

There is a fine balance involved in the relationship between dune heath and acidic dune grassland. While there were not enough quadrats of dune heath vegetation to reach firm conclusions it is interesting to compare dune grassland and dune heath in sites with both. Generally the dune heath vegetation is taller and the grazing pressure, whether defined by signs visible or impact assessment, is less.

The species diversity of the dune heath is similar or lower than that of acidic grassland, itself generally species poor. An excess of grazing can lead to the loss of heath to the species poor acidic grassland. The dune heath sites were all lightly

Table 4.14 Site summary of dune heath quadrats

Site	Q's	Species	Height (mm)	Impact	Animals
Earlshall Muir	6	12.5	146	1.2	6
Forvie	8	9.0	171	0.5	6
Great Bay	6	12.8	173	1.7	6,(3)
North Walney	2	6.5	162	0.0	(6)
Pentle Bay	5	13.0	49	1.8	6
Studland	9	5.6	410	0.1	6
Winterton (A&B)	9	6.6	157	1.0	6
Means (se) (45 quadrats)		8.6(0.6)	226(24)	0.7(0.1)	

Animals:- 3 = sheep, 6 = rabbits. Figures in brackets refer to signs of that animal in the vicinity of the quadrat. se = standard error.

Table 4.15 Site summary of dune heath data from Scottish Survey.

Site	Q's	Species ($25m^2$)	Height (% >500 mm)	Impact	Animals ($200m^2$)
Gruinart	2	47.0	0	2.0	2,3,6,(1)
Oronsay	2	27.5	0	1.0	3,2,6
Pabbay	2	41.5	0	2.0	2,3,(5,6)
Redpoint	2	27.0	0	1.0	3,6,(2)
Sandwood	2	48.5	0	2.0	3,6
Torrs Warren	46	20.9	25	1.1	6,5,(3,2)
Means (se)	(56 quadrats)	35.4(4.8)	-	1.5(0.2)	

Animals:- 1 = ponies, 2 = cattle, 3 = sheep, 5 = deer, 6 = rabbits/hares. Figures in brackets refer to animals elswhere on site. se = standard error.

Table 4.16 Site comparison of dune heath data.

Site		Q's	Species	Height	Impact	Animals
Forvie	a	30	13.3	27	1.0	6
	b	8	9.0	171	0.5	6
Tentsmuir (Earlshall Muir)	a	3	25.0	33	1.7	6,2,(3,5)
	b	6	12.5	146	1.2	6
Scottish Survey	a	33	19.2	-	1.4	
Present Survey	b	14	10.8	-	0.9	

Animals:- 1 = ponies, 2 = cattle, 3 = sheep, 5 = deer, 6 = rabbits/hares. Figures in brackets refer to animals elswhere on site. se = standard error.

Height a = per cent of quadrats with some grass >500 mm

b = mean height in mm

grazed, usually by rabbits, or virtually ungrazed. This situation may reflect the poor grazing value of the heath vegetation as much or more than indicating an appreciation by the land owner of the optimum management of the vegetation. It was clear from certain sites that the existence of grazing was an important factor in inhibiting the invasion of woody species..pa

4.8 Species diversity

The basic recording unit used in this study was the 2 m x 2 m quadrat and the mean number of species in such quadrats was used as a measure of species diversity. What is also important from the conservation viewpoint is the total number of species present. The number of species in a quadrat may be a reasonable indication of the species richness of the vegetation that is being sampled but it does not tell us anything about the species themselves. Consequently two quadrats each with the same number of plant species present may contain an identical species list or have no species in common. In other words a high mean number of species per quadrat does not necessarily indicate a long list of species for the site as a whole and conversely a diverse site could have a high total species list but a low mean number of species per quadrat.

In most herbaceous dune plant communities the pattern of distribution of the individuals of each plant species is relatively small scale and while no area/diversity studies were done in this project both previous experience and observations during the course of the project suggested that increases in quadrat area would not have greatly increased the number of species recorded, most of the species present were found in the first metre square to be recorded. A major change in species content indicated that a new community was being sampled. However as the number of quadrats per site was limited no attempt was made to sample the various plant communities that occurred within the five main habitat types and comparisons were made of the species total per quadrat without regard to the species involved.

In practice this seemed to work out quite well. When there were several communities present within a habitat type, the component communities appeared to have comparable diversities. This was taken to indicate that species diversity was controlled by the management of the area as well as by its general characteristics. The main value of the total species list was in the indication it gave of the range of diversity within a site. In general the larger sites tended to have a relatively shorter total species list than some of the small sites with a higher degree of small scale diversity. Certainly the range of species present in the large sites was not picked up by the intensity of sampling used.

It might be expected that all the habitat types would benefit in those sites with optimum grazing management. Sites with a high species diversity in one habitat type might be expected to have relatively high diversity in their other habitats. A comparison was made of the diversity of other habitats in the 25 % of sites that had the most diverse dune grassland, the commonest habitat type. The list of the twelve sites in this category also included 60 % of the sites with the most diverse damp slacks and

60 % of sites with the most diverse damp slacks. Clearly if the management is favourable for species diversity in one habitat it is very like to be favourable for species diversity in other habitats, at least for these three habitat types. The fact that there was not a 100 % correspondance may indicate that optimal management for one habitat type may be sub-optimal for another, or it may reflect that the grazing animals have preferences for a particular habitat. Thus even if two habitats have the same grazing requirements optimum grazing will not occur if there is free access to both habitats. Dune heath and yellow dune habitats were excluded from consideration because of their known special requirements.

4.9 Regional trends

The theoretical number of plant species to be found in a particular dune community will depend on the geographical location, the local climatic situation and the physical and chemical properties of the substrate. The actual number of species present will reflect the local opportunities for plant dispersal and the biotic influences that are present and operative. Because of these and associated factors it is difficult to make useful comparisons between widely scattered sites but an awareness of the problems involved can make possible some observations on regional trends.

A breakdown of regional trends in the species diversity of dune grassland communities is given in Table 4.17. Floristically the northern sites are potentially species poorer than the sites in the south-west. Results from this survey do show sites in north-east Scotland to be less diverse than south-west or north-west England. Not surprisingly many more species are found in association with the warm temperate maritime conditions of the south-west of England than are found associated with the extreme climatic conditions of the Northern Isles. With the exception of some sites in south-east Scotland the low species diversity is associated with sites right down the east coast. The low diversity of some sites in eastern England, both north and south, can be attributed, at least in part, to a lack of adequate grazing. The sites of West Scotland are somewhat intermediate with respect to their potential species diversity. The oceanic influence compensates for the northern situation. The large size of many of these sites also includes a particularly wide variation in habitat types. While direct comparisons are not possible the indications are that the species diversity of many of these sites is as high or higher than in other parts of Britain. Two major factors here are the generally high intensities of grazing and a high degree of habitat variation, with complex mosaics of acidity and alkalinity, wet and dry, nutrient rich and nutrient poor.

Some indication of the management potential can be obtained from a comparison between the regional means and the mean for the best site in that region. A major difference suggests the possibility that the diversity of some of the sites in that region could be improved by more effective management. This would seem to be the case for sites in eastern England, both north and south and also for sites in the north west of England and north Wales.

Table 4.17 Regional trends in species diversity and grazing impact.

Region	Species Diversity	Grazing Impact
North-east Scotland	12.5 (0.7)	1.4 (0.2)
South-east Scotland	15.6 (0.7)	1.5 (0.2)
North-east England	11.9 (1.7)	0.6 (0.2)
South-east England	12.0 (0.7)	0.9 (0.3)
South-west England & S. Wales	15.4 (0.8)	1.5 (0.3)
North-west England & N. Wales	15.7 (1.0)	1.6 (0.2)
West Scotland	20+ (est)	1.9 (0.2)

Bracketed figures are standard errors.

4.10 Grazing experiments

Four 4 m x 4 m rabbit exclosures were set up on heavily overgrazed dune grassland at Holkham, North Norfolk, in 1971, and they have been recorded together with two adjacent control areas, at somewhat irregularly intervals since. Over the seventeen years there have been considerable changes, the most notable being the loss of two of the original exclosures to scrub in the late 1970's. The scrub invasion of one of these followed the appearance of a single seedling of Tree Lupin Lupinus arboreus in 1973. By 1975 40% of the central recorded area of the quadrat had been obscured and by 1983 there were only the dead remains of the Lupin bush but the whole exclosure was a dense growth of Bramble Rubus fruticosus agg. and some Privet Ligustrum vulgare, up to 2m high. The other plot was invaded by scrub spreading across from outside the plot. Originally at least a metre clear of the plot, over a period of twelve years the scrub had spread some five metres to obscure the whole of the exclosure. In this case the scrub was mainly Privet together with some Honeysuckle Lonicera periclymenum and Bramble. In both cases the ground flora was limited to a few species around the edge of the scrub.

The exclosures initially showed a small increase in diversity which can be explained by the resurgence of species particularly sensitive to grazing by rabbits. This increase was maintained for at least four years, but after a period of eight years without any recording the diversity had markedly decreased in both plots that had not succumbed to the invasion of scrub. The total number of species in the four square metres had fallen from 23.5 to 12 and the mean number of species in a 100 mm x 100 mm sample quadrat had fallen from 7.5 to 2.8. In the following four years the situation remained much the same except for signs of a shrub invasion. In 1987 there were seedlings of Honeysuckle and Privet but by 1987 there were also seedlings of Pines Pinus nigra and Wild Rose Rosa canina.

All these changes have to be viewed against a background of changing rabbit grazing pressures. For the first five years there was very heavy grazing by rabbits, so great that the control areas were largely denuded with the number of species in 100 mm x 100 mm falling to less than two, although overall the odd individual of most of the species managed to survive thus keeping up the total number of species. Since then the rabbit numbers and their grazing impact have fallen considerably with a limited revegetation of the denuded areas.

There were two groups of species that exploited the conditions immediately following enclosure. First there were the dune annuals like Sand Cat's Tail Phleum arenarium and Early Hair Grass Aira praecox, then there were the rosette perennials like the Hairy Hawkbit Leontodon taraxacoides and Cat's Ear Hypochoeris radicata. Both groups were able to thrive as they were able to exploit the open conditions that persisted for a while after enclosure provided freedom from rabbit grazing. However, in the absence of grazing, the vegetation became more dense and competition increased. The rosette perennials could withstand this but the annuals lacked the space they need for their annual establishment and started to decline. Thyme-leaved Sandwort Arenaria serpyllifolia and Little Mouse-ear Chickweed Cerastium semidecandrum had started their decline after three

years but the decline of Sand Cat's Tail and Early Hair Grass was only recorded after a further eight years (after the gap in the recording).

The study of these plots continues, two further areas were enclosed to replace those lost to scrub, but certain conclusions can be drawn. In the years immediately following exclosure, or the removal of grazing animals, there may well be an increase in floristic diversity, but this is unlikely to persist for more than five or, at the most ten, years. It is then followed by a period of a gradual decline in species diversity. This process is only likely to be broken by the invasion by woody species as the first step in the colonisation by scrub that will effectively eliminate the remaining grassland species. Grazing is essential for keeping a species rich open grass sward and for inhibiting invasion by woody species. The increase of diversity that occurs when grazing pressure is reduced indicates the benefits that can accrue when grassland is subjected to fluctuating and spatially variable grazing intensities.

The experiments at Holkham were based on the use of exclosures to prevent access by grazing animals within an area normally grazed. The opposite approach was used at Newborough Warren, Anglesey where sheep at various densities were kept in enclosures on a dune system that is otherwise largely ungrazed (Hewett, 1987). The grazing experiment had a stocking rate equivalent to one or two animals to 0.3 Ha paddocks which were grazed for four months, eight months or the whole year. The grazing generally increased the floristic diversity. The largest mean number of species was for plots grazed for eight months of the year at the higher grazing level.

The plots grazed for the whole year had fewer species and the author concluded that the grazing density of two animals to 0.3 Ha was too great when applied all the year round. At low levels of grazing it did not seem to make much differences which third of the year the grazing was applied.

The grazing appeared to operate by controlling the normally dominant grass species particularly Tall Oat Grass Arrhenatherum elatius and opening up the sward allowing the spread of grassland herbs such as Birdsfoot-trefoil Lotus corniculatus. The author concluded that sheep grazing could be beneficial in increasing or maintaining species diversity in sand dune grassland without the risk of the complete destruction of the sward that can occur with highly intensive rabbit grazing. At the same time sheep grazing can provide the possibility of animal production. The disadvantage is that the control of the grazing animals requires considerable manpower and capital for fencing.

The other benefit of grazing dune grassland is the control of woody species, that is the control of scrub development. At Tentsmuir, Fife, dune slack vegetation is threatened by the rapid invasion of Birch Betula pendula. Previously this species has been controlled by a combination of rabbit grazing and winter flooding both of which have decreased recently. Scrub development had taken place to such an extent that hand pulling was no longer practical and that the grazing of the young shoots by sheep would not have controlled it to any extent. What was

clearly needed was a browsing animal that would consume the woody growth. Goats have been used for scrub control in both New Zealand and the Netherlands as well as to control rushes on hill pasture in Britain. After a trial run with two domestic goats a much larger trial was started using the hardier feral goats. Grazing was not possible during the winter when the slack floods and the goats were wintered away on a farm. Preliminary results suggest that even thought the birch is not a preferred food species a useful degree of control of scrub could be anticipated. Where the birch density was high, the density of goats required to cause 100% defoliation by the end of July was estimated to be between 25 - 41 goats/Ha. This stocking rate is very high and it was suggested that control during the growing season (May - July), when the Birch is vulnerable to browsing, should be attempted before the Birch density became too high (Bullock & Kinnear, 1988). The goats needed careful fencing, the right kind of shelter and good husbandry. It is hoped that after the initial control of the scrub with goats, other grazing animals, such as sheep or even a spontaneous invasion of rabbits, could then inhibit further invasion by woody species and maintain the open vegetation.

5. Site assessments and recommendations

5.1 Introduction

The intention of this section is to consider, in some detail, a selection of the sites that were visited, in order to illustrate particular points regarding grazing management and especially those points of more general significance. It is not intended to make any kind of merit assessment of the flora of individual sites or of their management. In many cases there are physical or biological factors that are outwith the control of the immediate site manager if indeed there is any site management. Any management options suggested are made primarily with reference to the control of plant species diversity through the grazing management. It is acknowledged that there may be various justifiable local reasons for the use of particular sub-optimal management regimes or for the non-use of optimal ones.

Where possible actual numbers of grazing animals are quoted directly, together with the density per hectare. Where there is mixed grazing it is often helpful to calculate an index of the overall stocking rate. This is not easy but a rough figure can be obtained by equating one cow with one pony or with three sheep and quoting a cattle equivalent figure. This can be further refined by making an allowance when smaller breeds or young individuals are involved. The figures quoted in this study for cases where grazing is by cows and calves are based on equating two calves with one cow. This may sound like an overestimate of the grazing by calves but this is probably offset by the increased food intake of the lactating adults.

The boundaries of the areas referred to are the biological boundaries of the grazed (or ungrazed) dune grassland studied. These boundaries are not necessarily the same as those of any SSSI, NNR, LNR, nor are they any physiographic boundaries. The choice of sites for inclusion in this section was made on the basis of the existence of points of special interest at that site consequently some very small sites are included and some of the major large sites are excluded. Omission of a site reflects the limited space available within this report rather than implying anything, favourable or unfavourable, about the state of that site. Just as the regions will be considered in clockwise sequence round the coast from the north-east corner of Scotland southwards, the sites in each region will be described in a similar sequence.

5.2 North-east Scotland

The sites in this region are of two contrasting types, the relatively small island sites of Orkney and Shetland and the large mainland sites represented by Forvie and Strathbeg. While the area is slightly less exposed to the severe weather conditions experienced by the north-west, it lacks much of the gulf stream influence that ameliorates the western climate. It also lacks the continental influence that produces dry warm summers further south. The climate of this area can best be described as cool maritime.

Quendale, Shetland

Quendale, at the south end of the mainland of Shetland, is fairly typical of the northern island sites. The 80 Ha of dune grassland is grazed by sheep and rabbits and occasionally by native ponies (Appendix Table 11.32). There is a sheep fence that divides the site into a seawards portion and a landwards portion where the majority of grazing animals were seen. However neither the height of the vegetation nor species diversity were significantly different between these two areas suggesting that there was probably little difference in grazing pressure taken on a long term basis.

Rabbit numbers have increased onsiderably over the past decade. In 1972 little evidence was seen of rabbit activity. However during the present survey forty were seen during the course of a one day visit including some brown and white ones. Although the grazing pressure was assessed as being high and the vegetation was short there was no evidence that species diversity was reduced by overgrazing. The threats to the flora came from two sources. To the north-west of the semi-natural area studied there was an area of semi-improved grassland where increased agricultural productivity had reduced plant species diversity. At the south east end the natural vegetation was destroyed by sand extraction over a considerable area. There was little or no attempt to restore the vegetation following extraction or to exploit the opportunities for habitat creation.

Fidge, Sanday, Orkney

As implied by the name, much of the Orkney island of Sanday is sand covered, amounting to a total of about 1800 Ha. Most of this is now improved or semi-improved agricultural land and the semi-natural dune grassland is relatively limited.

The largest single area of dune grassland is the Plain of Fidge amounting to some 120 Ha, mostly of a species-rich short turf with Eyebright Euphrasia confusa and Felwort Gentianella amarella. The whole area is heavily grazed by rabbits, more than fifty were seen during the visit (Appendix Table 11.14). The eastern half of the area is used as a golf course and is closely grazed by over a hundred sheep (1.6 sheep/Ha or 0.6 cattle equivalent). Apart from the greens themselves the area is not otherwise managed. The stocking rate is relatively high but it is not known what happens to the sheep in the winter. The western half is grazed by cattle but the grazing intensity is variable with several smaller paddocks. There was no significant difference between the two areas with regard to either species diversity or vegetation height although the varied grazing regimes in the western half did seem to be giving a rather greater floristic diversity. As with Quendale there was no evidence that there was any floristic loss due to the high grazing intensity. The site would be a good one for experimental studies into the effect of grazing on species diversity. The only threat to the area at present would be from agricultural improvement of the grassland.

Strathbeg, Aberdeenshire

Strathbeg, at 380 Ha one of the larger dune sites, lies to the north of Rattray Head and is bounded to landward by the large freshwater Loch of Strathbeg. It is the best preserved section of a dune area that formerly extended with only minor rocky interruptions from Peterborough to Fraserborough. Strathbeg has well developed frontal ridges of mobile yellow dunes with a steep seaward face, extensive dune grassland and, especially towards the loch, well developed dune slack communities with a diverse flora (Appendix Table 11.43). At the north end there are interesting transition communities between salt marsh, freshwater marsh and dune slack.

The dominant grazing animal at the time of the first visit was the rabbit but sheep were also plentiful. There were some signs of cattle especially at the southern end but no beasts were seen. The vegetation was generally short and the grazing pressure seemed to be near the optimum. A further visit, two years later, confirmed these findings.

The main problem seems to lie at the south end where there has been some grassland 'improvement' with drainage, re-seeding and the use of fertilisers. This was largely in the area between the southernmost transect line and the access road and was therefore not covered by the survey. There are also areas of enhanced soil nutrient levels scattered across the southern half of the dunes, reported to be as a result of the use of poultry manure. This would explain the occurrence of areas of taller and coarser vegetation. There would seem to be a case for increasing the grazing pressure especially to control and limit this vegetation growth but also to increase the plant species diversity overall. Any such plan would need careful long term monitoring . The maintenance of the floristic diversity also depends on stopping any use of fertiliser, manure or artificials, on the areas of botanical interest. The areas worst affected by eutrophication could also be improved by a programme of late summer mowing with the removal of the cut material.

Sands of Forvie, Aberdeenshire

The Sands of Forvie, another large site (800 Ha), is notable for the extent to which sand dunes the mobile dunes around the mouth of the river Ythan have moved considerable distances inland and upslope. They are also notable for the extensive heathland plant communities (Appendix Table 11.15). The whole area is no more than lightly grazed by rabbits: four of the fourteen quadrats were recorded as ungrazed. The vegetation was generally tall or rather tall with a rather low species diversity even for heathland.

There are two very different management problems, the heathland and the more limited areas areas of dune grassland. The heathland could benefit from positive management to increase regeneration at least locally. This could be through the use of grazing, burning or cutting with aim of creating a mosaic of vegetation types and thus increasing the opportunities for plant diversity. The dune grassland presents a very different problem. Some of it is quite short and species rich but much of it is very

tall and tussocky, and generally species poor. There is a real potential for species enrichment by fencing such areas to enable them to be subjected to heavy sheep grazing in the late summer and autumn. Once these areas have been grazed down closely it may be possible to maintain them and the heathland communities at the same time by extensive light sheep grazing, as had been practiced up to 1959. The grassland areas would require more grazing than the heathland but the grassland areas should themselves be sufficiently attractive for this to be achieved without the use of permanent fencing.

5.3 South-east Scotland

The sites in this region differ from the those in the north of Scotland both in the climate they experience and also the human environmental pressure are that much greater further south. The climate is similar to that of north-east Scotland only rather less severe. There are a number of small dune sites in the south of the region, the largest being Aberlady Bay, East Lothian. In the north there two large dune sites at the mouth of the river Tay. Tentsmuir, Fife, to the south is now largely under a forestry plantation, and Barry Links, Angus, to the north is now part Golf course and part a military training area. The northernmost site in this region is St. Cyrus in Aberdeenshire. While on superficial inspection of the map it would appear to lie in the north-east region the physiography of the site gives such a degree of shelter that climatically and botanically it is much closer to sites further south.

St. Cyrus, Aberdeenshire

St. Cyrus is particularly notable for the plant species, such as the Clustered Bellflower Campanula glomerata, that reach their northern limit at this site. This results from the sheltered position of the dunes in the lee of high cliffs to the north-west. Despite the absence of freshwater habitats or even damp slacks there is a considerable botanical diversity in the 40 Ha of this site.

The site is lightly grazed by rabbits and the vegetation is tall but nevertheless quite diverse (Appendix Table 11.35). The local high diversity of the areas of shorter vegetation indicate that an increase in the grazing pressure would be beneficial. Another consequence of the low grazing pressure is the spread of dense scrub particularly along the landward edge of the dunes. With the present levels of grazing the present areas of species rich grassland are likely to be reduced by the further spread of scrub and tall herbaceous vegetation.

With the use of the area by people and dogs sheep grazing does not seem to offer a practical possibility. The alternative would seem to be a carefully planned programme of scrub removal and the cutting, in late summer, of the tallest areas of herbaceous vegetation, in both cases with the removal of the cut material to reduce the nutrient status. In addition the rabbits should be encouraged; it is likely that they would exploit new areas of short grass created by cutting thus limiting the need for repeated cutting.

6. Assessment of grazing situations

6.1 Introduction

It will be clear from the comments already made on the results of the survey that the assessment of present grazing situations in different sites is not an easy task given variation in both space and time and additionally the relatively slow rate of response of the vegetation to any changes in grazing pressures. In view of the importance of obtaining the necessary information as the basis for the formulation of future grazing management plans, a few comments are appropriate.

6.2 Grazing by domestic animals

Grazing, as far as dune management is concerned ,is the removal of excessive vegetation growth by herbivorous mammals. In order to quantify grazing we have to determine what animals are present, in what numbers and for how long. On the face of it, this is relatively easy to do for domestic stock, for ponies,cattle aand sheep (Table 6.1). Even so there are various complications.

Firstly, it became clear from the present studies, that, in typical dune terrain, a direct count of sheep, ponies or cattle was not as easy as might be expected. Even dune hillocks of moderate size could conceal significant numbers of ponies or cattle let alone sheep.

Secondly the stock numbers declared by the farmer or grazier tended to reflect the numbers that were permitted rather than actual numbers. At several dune sites the area grazed included significant areas of non-dune grassland along the inland borders or of saltmarsh grazing to seaward. How much of the grazing therefore was actually on the dune grassland ? Given that a site is subject to a particular grazing intensity, there can be great variation in the grazing pressure across that site. In an area of 100 Ha of grassland, grazed free-range by ponies at a density of 0.3/Ha, Oosterveld (1981) showed that 3% of the area was heavily used, 70% moderately used and 27% was little or never used.

Finally in certain circumstances it was found that overgrazing in the past had resulted in the growth of coarse inedible species which reduced the food available. Thus even though the height of the vegetation and, by the same token, the impact assessment, indicated that the site was undergrazed, in reality there was excesive grazing.

As well as spatial variations in the pattern of grazing there are frequently temporal variations. There are a very few sites grazed by the same numbers of stock throughout the year. In the majority of sites grazing is seasonal and really needs defining in terms of grazing days at a particular time of year. The seasonal aspect is important because of the different effects of a given grazing intensity at different times of the year. In addition there is the complication of the variation in the size and appetite of individuals of a given species. Grazing may be

Tentsmuir, Fife

The present NNR represents a tiny fragment of the former huge area of dunes that existed east of a line from Tayport to Leuchars and that are now largely farm land or covered by pine forest. The afforestation of Tentsmuir has brought its own special problems to the remaining dune area. This area of special botanical interest is at the north end where there has been very rapid accretion with new ridges enclosing areas of dune slack (Appendix Table 11.45). The influence of the forest is at the south end of the open dune area. The pine trees themselves have great powers of water extraction and have resulted in a lowering of the water table by at least 270 mm (Ovington, 1951). In addition drainage ditches have been dug to improve the conditions for tree growth. The massive lowering of the water table has resulted in the drying out of dune slacks with consequent vegetation changes including the spread of scrub, particularly Birch, as well as pine seedlings (Hobbs & Grace, 1981).

The low rabbit numbers of recent years have allowed scrub development to continue unchecked to a stage at which grazing could no longer be considered to be a controlling factor. For this reason experiments with goats, that should control scrub by browsing, have been started (see Section 4.10).

There are areas at Tentsmuir where the dominant vegetation is a distinctive mosaic of foliose lichens and bryophytes. The relationship of this type of vegetation to grazing levels is a complex one. Bryphytes are often abundant around rabbit burrows as they are not generally eaten by rabbits. Lichens are not usually eaten by rabbits but they are sensitive to damage by trampling, even by small animals such as rabbits. A rabbit track through a mixed lichen/bryophyte community can be picked out by the absence of lichens along the line of maximum rabbit trampling. Such communities are readily colonised by higher plants if the soil nutrient status is raised. This process of colonisation is facilitated by any form of disturbance to the normally closed carpet of lichens and mosses. It would seem that these lichen communities are formed as a result of a combination of surface stability and low soil nutrient levels rather than from a control of vascular plants by grazing.

The problems at Tentsmuir illustrate how the management of dune vegetation by grazing cannot be considered in isolation from other aspects of dune management.

Earlshall Muir, Fife

Earlshall Muir is situated at the southern end of the Tentsmuir system and with 370 ha of lime-poor dunes it is the largest area remaining un-afforested in south east Scotland. Areas of acid grassland alternate with areas of wet heath and dry heath (Appendix Table 11.13). At the time of the survey the area appeared to be fairly lightly grazed by cattle, also some sheep and rabbits. Historically the grazing level over most of the area has been between 0.2 and 0.4 cattle/Ha or the sheep equivalent. The present grazing is largely by cattle at 0.3/Ha (Leach, 1985). Both the dune heath and the acid grassland had a relatively high

species diversity, the heath particularly so. There appeared to be rather more of the acid grassland than dune heath. The present stocking rate has been estimated at 0.3 cattle per Ha all the year round but with winter feeding. Available evidence suggests that in the past the rates have been similar or even lower, with the exception of a period of heavier grazing in the 1950's. Excessive grazing and/or a lack of burning encourages the development of acid grassland, often species poor, at the expense of dune heath. Thus to ensure the survival of the species-rich dune heath communities the present low levels of grazing must not be exceeded. Preferably they should be limited to 0.2 cattle/Ha for the areas of scattered dune heath and grassland and to 0.5 sheep/Ha for the main heath areas.

5.4 North-east England

While the north-east still experiences something of the northern maritime influence there is also a distinct continental influence at times, both in terms of summer warmth and winter cold. The most striking feature of the dunes of the north east in the general absence of grazing particularly on the numerous small sites. The increasing human environmental impact, mentioned in the previous section, continues southwards, both in terms of industrialisation and holiday developments. There is a large dune complex comprising Lindesfarne (Holy Island), Ross Links and Budle Bay, and a series of mostly very small sites that are largely ungrazed.

Lindesfarne, Northumberland

About half the area of Lindesfarne or Holy Island is made up of calcareous sand dunes forming a peninsula westwards from the north-west corner of the rock core of the island. Between high dune ridges there are extensive damp and wet slacks while at the eastern end of the dunes there is sand over Boulder Clay and rock. It is the damp slacks that are of special interest with no less than six orchid species including the rare Dune helleborine Epipactis dunensis and the Coral-root Corallorhiza trifida (Garson, 1985). The rabbit is the only grazing animal in the dunes where its effects are to be seen mainly in the old dune grassland. At the time of the survey the slacks were only lightly grazed. The grazing situation on the dune grassland was very variable (Appendix Table 11.23). Out of eight quadrats five were heavily grazed with a short turf while three quadrats were virtually ungrazed with vegetation up to 500 mm tall. There was a mean of over sixteen species in the grazed quadrats while the three ungrazed quadrats had 13, 11 and seven species respectively. Recent studies have shown that the rabbits breed in warrens on the dune slopes adjoining the slacks which provide food for the juveniles (Garson, 1985). In wet years flooding can greatly limit this food source and incidentally give the vegetation something of a respite from grazing. The patchiness of the grazing of the dune grassland reflects the reluctance of the rabbits to travel far from the shelter of their warrens. While at certain times and in certain places the pressure of rabbit grazing is sufficient to prevent many plant species from flowering, there is no evidence of any long term damage from over-grazing. Under-grazing that follows the periodic outbreaks

of myxomatosis is a very real threat to the dune flora. Most species can survive episodes of heavy grazing but are eliminated by even short periods of competition from tall ungrazed vegetation. With the mosaic of of high and low grazing pressures and the corresponding short and tall vegetation that exists at Lindesfarne there seems no reason for any action to modify the present grazing regime at Holy Island. It has to be recognised that interpretation needs to be reviewed from time to time.

Ross Links, Northumberland

On the mainland coast immediately to the south of Lindesfarne are Ross Links, 225 Ha of dunes grazed by cattle, sheep and rabbits (Appendix Table 11.34). The survey showed that the dunes overall were moderately grazed with a moderate species diversity. This statement however conceals a range of complex management problems. The comments that will be made here are intended to reflect general principles rather than providing definitive answers to specific local problems.

The area is presently winter-grazed by some 400 cattle and 300 sheep. In the summer it is lightly cattle grazed. The winter stocking rate is high amounting to 1.8 beasts and 1.3 sheep per Ha, equivalent to well over 2 beast per Ha. This is achieved by considerable supplementary feeding during the winter months. As well as the severe damage around the feeding areas there has been a widespread eutrophication of the dunes from the dunging by the stock. This has resulted in the increased growth of coarse vegetation with a corresponding reduction in species diversity. The increase in vegetation growth has meant that more grazing is needed to keep the vegetation short, and this has made the problem worse. This situation well illustrates the undesirability of any form of supplementary feeding of stock grazing on sand dune vegetation.

Any dune site that appears to be under-grazed despite high stock numbers is likely to be suffering from this problem. Rectification of this situation requires much more that just cessation of supplementary feeding. The urgent need is to reduce the nutrient status while maintaining a sufficient intensity of grazing. Where the terrain permits mowing with removal of the 'hay' crop can help to improve things. The key to the optimum grazing management of sand dunes is that the grazing animals should only be present for long enough, in time or numbers, to remove the excess vegetation growth in the dunes themselves. At other times they need to be taken off the dunes completely.

A further point is illustrated by the Ross Links situation and that is the need to consider the site as a whole. The site was judged on the situation regarding the yellow dune,dune grassland and dune slack vegetation described in the survey. Ross Links also has some notable areas of dune heath. These were not picked up by any of the quadrats in the survey but require special attention for their management. Levels of grazing that are barely adequate for dune grassland can result in heathland degenerating into species-poor acid grassland. Heathland requires some form of disturbance, including cutting, turf cutting or burning, to create the spaces for the regeneration of

heathland species together with the appropriate low level of grazing. This is all very different from the management of nearby dune grassland within the same area.

Alnmouth, Northumberland

As well as the large dune systems of Lindesfarne and Ross Links there are a number of small dune systems along the north-east coast; typical of these are the dunes at Alnmouth. There are 35 Ha of yellow dune and dune grassland. The system is completely ungrazed with tall coarse vegetation (the average height of the vegetation was over 500 mm - Appendix Table 11.4) As might be expected the plant species diversity was low. The most diverse areas were found adjoining the paths where light trampling helped to reduce competition. Grazing would certainly increase diversity, although the extent to which this could be achieved would be less and slower because it is a small isolated site. The optimum grazing management would be for the site to be heavily grazed for a short period.

5.5 South-east England

The continental climatic influence is greatest in the South-east with low annual rainfall and extremes of temperature in both summer and winter. The concentration of population in this region also means that there is a high recreational pressure on coastal habitats, although somewhat less so for north Norfolk and Lincolnshire than further south.

Saltfleetby, Lincolnshire

From the Humber to the Wash there is a predominantly dune coastline, with the dunes particularly well developed at Saltfleetby and at Gibraltar Point to the south. The dunes at Saltfleetby are highly calcareous with extensive wet Slacks. In the southern part of the dunes there are stands of dense, very old, areas of scrub. This is mostly Sea Buckthorn Hippophae rhamnoides but there is some Elder Sambucus nigra and Hawthorn Crategus monogyna, indicating the possibility of succession through to woodland, rare in Britain as a natural dune habitat. The area was formerly used as grazing land but at the present there is only limited natural grazing by rabbits (Appendix Table 11.37).

Grazing experiments have been initiated to maintain the diversity of the area. The difference between the grazed and ungrazed areas of dune grassland illustrates very well the relationship between grazing and species diversity. The ungrazed (really lightly rabbit grazed) had a mean vegetation height of 40 +- 5 cm and a mean number of species per $4m^2$ of 8.2 +- 3.1. In contrast the grazed plots had a vegetation height of 16 +- 2 cm and 15.2 +- 2.1 species per $4m^2$. There were plots grazed by different combinations of cattle and sheep but it was not possible to draw firm conclusions at a comparatively early stage in the experiment. It was clear however that when an area had been under-grazed (or ungrazed) for some time there was a build-up in coarse and dead vegetation that the animals were very

reluctant to eat even when short of food. Where ever possible it was better to remove this by mowing before introducing the grazing animals. Even with this there remained the problem that natural vegetation rarely provided adequate food for fattening cattle or sheep. It was perhaps unreasonable to expect to be able to use the animals in a dual role for conservation oriented grazing and commercially. It was noted that rabbits seem to favour areas previously grazed down by the larger animals, an effect noted elsewhere.

Gibraltar Point, Lincolnshire

The dunes at Gibraltar Point are somewhat less calcareous than those at Saltfleetby. There is a moderately rich flora despite the extensive development of scrub following the post-myxomatosis reduction in rabbit numbers (Appendix Table 11.16). However the species diversity is, in part, due to the number of weedy ruderal species associated with the most heavily grazed areas. The dune grassland can be divided into two categories, a short heavily grazed turf and a tall rough vegetation of weedy species. On the basis of any assessment of grazing based on the mean height of the vegetation the grazing pressure is little more than moderate. Despite this more rabbits were seen here than on any other site (over 200 were seen during the middle of the day). The areas of short vegetation provide the clue. The very short vegetation with patches of bare ground indicates heavy grazing pressure. The tall vegetation indicative of relatively ungrazed areas is made up of species that are not eaten by rabbits, thistles, nettles and ragwort. Any assessment of the impact of grazing based on vegetation height is only valid if inedible species are excluded.

There was a great invasion of scrub at Gibraltar Point following the myxomatosis outbreak. Subsequent efforts at scrub clearance have had little impact and the area of dune grassland is limited. The subsequent recovery in the rabbit population has thus resulted in very heavy grazing pressure. This has been accentuated by the development of the ruderal communities of inedible species. This process has been partly as a direct result of the very heavy grazing pressure and partly through eutrophication from both rabbit dung and urine and from nutrient-rich drainage water from the ridges covered with the nitrogen-fixing Sea Buckthorn.

In this situation there is rather little that can be achieved by grazing management. A major reduction in grazing pressure is likely to result in the spread of the more vigorous species, as a result of the relatively eutrophic conditions. Control of the ruderal communities by cutting and removal would certainly be of value, both directly by the removal of competitively vigorous species and indirectly by the creation of more grazing. Some control of the rabbit population would certainly be desirable if difficult to expedite. If however the rabbit population decreased too much then the eutrophic conditions would ensure the speedy development of coarse species-poor vegetation.

Scolt Head Island, Norfolk

Scolt Head Island is a classic barrier island with extensive dunes that have built up on the underlying shingle ridges. While the flora overall is diverse and varied the diversity of individual quadrats is relatively low reflecting the low intensity of rabbit grazing on the island (Appendix Table 11.39). The height of the vegetation is similar to that at Kenfig (q.v.) but the latter site still has a species diversity nearly twice that at Scolt. Unlike many dune areas there has only been a very limited recovery of the rabbit population, thus thirty years of very limited grazing has had its effect on species diversity. A higher grazing intensity should benefit the flora but the achievement of this without introducing a new grazing species is difficult to see. Fortunately the area is still relatively nutrient poor and this coupled with a low rainfall has limited the impact of the near absence of grazing. Perhaps it is a case where no action, except for regular monitoring, is the best answer.

Holkham, Norfolk

The dunes at Holkham, north Norfolk can be divided into two main sections, the open grassy dunes to the west, and the predominately forested dunes to the east. The dune grassland is notably species rich, but it is tall and relatively lightly grazed (Appendix Table 11.19). The dunes are only lightly grazed by rabbits, except for a narrow strip at the back of the dunes where there is also cattle grazing. This site indicated the problems and benefits of relying on rabbit grazing. The grazing experiments at Holkham have already been referred to (Section 4.10). When the experiment was set up in 1971 there was a high density of rabbits and the grazing pressure was locally intense. Despite this there were still some parts of the dunes that were relatively lightly grazed, partly perhaps because the rabbits could feed on the grassland on the reclaimed marsh adjacent to the dunes. It seems also that the rabbits had their preferred areas for feeding and areas that they tended to avoid. Despite periodic outbreaks of myxomatosis the rabbit population remained high for several years.

From the late 1970's onward the number of rabbits has declined considerably. Whereas, formerly, during a day's visit a dozen live rabbits might have been seen, by the mid 1980's numbers had decreased until the situation where it is a notable day when a single rabbit is seen. As might have been expected from the grazing experiments there has been a time lag in the response of the vegetation to these changes. There was one species that seemed to flourish in the early days of reduced grazing, and that was Goat's beard Tragopogon pratensis.

The species diversity has remained high even though the vegetation is relatively tall. Over the last two years there has, however, been a reduction in the number of individuals of certain dune annuals as the vegetation density has increased - a clear sign of changes to come. If there is not a recovery in rabbit numbers very soon, other grazing animals, probably sheep, would have to be introduced if the diversity of plant species is

to be maintained. The choice of the optimum stocking rate would probably have to be determined experimentally, and its effect carefully monitored. It is quite likely that an increase in sheep or cattle grazing would encourage the return of rabbits.

Winterton, Norfolk

The dunes at Winterton provide an interesting contrast in many ways with the Holkham dunes. The most notable difference is the acidity of the Winterton dunes with dune heath and acid grassland communities (Appendix Table 11.48). The dunes are relatively lightly grazed by rabbits and occasionally also by hares. The height of the vegetation is very much less than might be expected from either animal signs or apparent impact. The combination of low rainfall and acid soils has produced a system rather less dynamic than other comparable ones. Competition from other species appears to be far less of a limiting factor to plant establishment and growth than the limited supply of water and nutrients. This has been shown both by the lack of response when grassland was mown experimentally and by the extent of communities with incomplete ground cover. While the area can only be described as being under-grazed, an increase in present levels of grazing are unlikely to have a major effect.

Studland, Dorset

The dunes at Studland, Dorset, are notable for the well developed heath vegetation, indicating both the acidity of the sand of which the dunes have been built and the rapidity with which further acidification can take place. The site is grazed by rabbits but only very lightly. The vegetation is consequently very tall and it is also species-poor (Appendix Table 11.44). It is doubtful whether plant species diversity would increase very much if there was to be more grazing. The limited diversity within a particular habitat is compensated for by the range of habitat types, particularly wet slack and aquatic communities. The diversity is also supported by the strategic situation of Studland, resulting in the flora having both western oceanic and south-eastern continental elements. These, however, would not be affected very much by an increase in the intensity of grazing, although the lack of grazing may well have contributed to the extent of scrub and woodland present.

5.6 South-west England and South Wales

The climate of this region is very much warm maritime, temperatures are relatively high and so also is the rainfall and humidity. The Isles of Scilly represent the extreme of this effect and they support many exotic species. The whole area, however, is relatively mild and spring generally comes early. The Channel Islands are included in this region. The climate they experience is intermediate between the continental climate of the South-east and the mild oceanic climate of the south-west.

Braunton Burrows, Devon

Braunton Burrows has a rich and varied flora and it is also notable for the species that reach their limits there as well as a number of local species (Willis 1985). The site appeared to be only moderately to lightly grazed by rabbits and the vegetation was generally rather tall (Appendix Table 11.7). It was estimated that only about 50% of the area was significantly affected by rabbit grazing. Nevertheless the area was more heavily grazed than either Newborough Warren or Kenfig, the two areas where the lack of grazing was beginning to affect the floristic richness of the area.

It became clear that the present rabbit population is less than is used to be and it was likely that the situation was at or near the point at which significant floristic losses could occur in the near future. This could come about both through an increase in the dominant grasses and through a further increase in the areas affected by scrub (Hope-Simpson, 1985). The answer appeared to lie in the use of sheep to graze the dunes for limited periods in the autumn, although cattle or pony grazing throughout the growing season might be the optimum management in the areas of old grassland at the back of the dunes. The introduction of grazing animals should lead to an increase in rabbit numbers and in the intensity of rabbit grazing. The control of existing scrub would have to be tackled directly but an increase in grazing could inhibit further scrub invasion.

The lichen rich communities pose a special management problem as these are being invaded by clumps of grass. Grazing at a sufficient intensity to eliminate the grass would effectively destroy the lichens as well. It appears that the only answer to this problem would be physically to remove the clumps of grass and the associated nutrient rich soil and replace it with an appropriate mixture of nutrient poor sand and shingle

Great Bay, St. Martin's

Like all the dune sites in the Isles of Scilly the total area of the dunes is quite small (10 Ha) but within this area is a considerable degree of diversity and interest. On the north side of St. Martin's at Great Bay the sand has blown up over the granite slope, in a way reminiscent of many of the exposed Scottish sites. Much of the vegetation is in the form of a close-cropped species-rich sward (Appendix Table 11.17). The dune grassland samples were exceeded in species diversity only by the grassland at Aberffraw, Anglesey. This diversity was associated with heavy rabbit grazing. The vegetation height and the impact assessment indicated a grazing intensity as high as that on any site. The dune heath occurred behind the grassland where the acid bedrock began to exert an effect through the decreasing depth of calcareous sand and where the effect of leaching was at its greatest. The dune heath vegetation was also notably species rich but was, apparently, very much less grazed than the grassland. Nevertheless the dune heath was more heavily grazed than any of the mainland dune sites.

Kenfig, Glamorgan

The South Wales coast had many extensive dunes systems in the pre-industrial era. Margham Burrows must have originally covered over 2000 Ha but we can only get some idea of what they were like by reference to the Kenfig dunes on the other side of the river of that name. The site is large and varied (480 Ha) with dune grassland, dune slacks and a substantial freshwater lake (Appendix Table 11.20). Kenfig is unique among the sites studied for the combination of high species diversity and tall vegetation. The grassland vegetation at Kenfig is as tall as that at Oxwich but with nearly twice the species diversity. The vegetation of the damp slacks at Kenfig is nearly as rich as that at Strathbeg but it is five times as tall.

At the time of the survey there was some sheep grazing, by 100 crossbreeds especially in the north-western corner, and some grazing by rabbits and hares; very little for a site of that size. The sheep grazing is only 0.2 sheep/Ha giving a cattle equivalent of 0.07 per Ha. This has been the situation since 1977 and it is remarkable how the diversity of the vegetation has persisted through a decade of very reduced grazing. It appears that the area is now at the point where a reduction in species diversity is inevitable unless there is a substantial increase in grazing across the whole area.

Whiteford, Glamorgan

To the west of Swansea the Gower peninsula has several dune systems the largest of which is at Whiteford. The dunes are in the form of a spit extending north across the Bury estuary for some 2.5 km, effectively continuing the dune coast running north from Worm's Head. The dunes at Whiteford are grazed by all the major grazing animals (Appendix Table 11.46).

It was difficult to assess the relative impact of the different animals. Officially grazing is by ponies and sheep but from time to time cattle enter illegally. Rabbit numbers are controlled but at the time of the survey there were several areas where rabbits appeared to be the dominant grazing animal. The last count of numbers of stock was in 1983 when there were 64 ponies and 33 sheep together with a further 33 ponies on the salt marsh nearby. This amounted to 0.3 (0.4) ponies and 0.15 sheep per Ha or cattle equivalent of between 0.3 and 0.4 per Ha. The grazing situation at the time of this survey was assessed as intermediate, neither heavy nor light. There was no evidence that an increase in grazing would be particularly beneficial, probably the extra trampling would lead to an increase in bare ground, possibly excessively so. The height of the vegetation suggested that any decrease in grazing pressure could eventually lead to some losses in plant species diversity.

Stackpole, Dyfed

Physiographically there are some similarities between the Angle peninsula and the Gower. Both have extensive dunes especially along the west-facing coasts but with small systems on the south

and east. The Angle peninsula is more exposed than the Gower and the sand has been blown considerable distances up the rocky slopes inland. This has even happened at Stackpole on the more sheltered south east side (Appendix Table 11.42).

The vegetation on the site falls into the grassland category, apart from very limited areas of yellow dune. This 'grassland' can be divided into two contrasting types:- tall vegetation dominated by bracken Pteridium aquilinum and a very short 'grass' sward, the latter also includes some areas with particularly rich lichen dominated communities. The short grass sward is heavily grazed by rabbits with only inedible species like Ragwort Senecio jacobaea or invading shoots of bracken reaching more than a few centimetres high. Rabbit grazing is largely limited to the short grass and has little effect on the spread of bracken which poses a major threat to the dune grassland and lichen communities. The area has been grazed by cattle and sheep in the past, but there is now no cattle grazing and sheep only graze the eastern half in the winter (Evans, pers. comm.). There is little prospect of controlling the bracken by any form of grazing, which would in any case damage the lichen communities. Cutting would seem to offer the best hope of controlling the bracken and the associated spread of scrub.

5.7 North-west England and North Wales

While this region still experiences the warmth from the gulf stream there is an increasing cool northern influence. There is a contrast with comparable sites on the east coast. Corresponding sites on the west coast are significantly wetter and rather less cold. The sites are generally quite large with moderate environmental pressures, which become locally high near large centres of population.

Morfa Harlech, Gwynedd

The northern part of Cardigan Bay is dominated by two very large dune sites, Morfa Dyffryn and Morfa Harlech. Morfa Harlech forms a broad triangular sandy foreland on the south side of the confluence of the Afon Glaslyn and Afon Dwyryd. It is based on a shingle ridge that has grown north-westwards from the old coastline. This ridge is marked by high dunes while to landwards there is a relatively flat plain of wind-blown sand. The area is relatively heavily grazed by cattle and by rabbits who seem to be exploiting the areas eaten down by the cattle (Appendix Table 11.26). The intensity of the grazing seemed to be at or near the optimum level. While the vegetation was generally short there was still a mosaic of different vegetation heights with patches of taller vegetation scattered across a mainly short sward. The generally satisfactory situation was enhanced by the large size of the site and by the occurrence of areas of damp and wet slack among the dry dune grassland. Thus there was great variation in the grazing pressure through time and space, even during dry spells there were still areas of green vegetation.

Newborough Warren, Anglesey

The island of Anglesey (Ynys Mon) supports two large dune systems on its south-west side, Newborough Warren and Aberffraw. Newborough Warren is probably the third largest dune system in the British Isles, and, although the western half has been planted with conifers, it still has a fine range of dunes and dune slacks with a rich and diverse flora not entirely covered by the sampling methods used (Appendix Table 11.27). The situation at Newborough is not dissimilar to that at Kenfig. The grazing pressure is low, the vegetation is tall, but the species diversity is high, although notably less than at Kenfig. Up to the arrival of myxomatosis Newborough was heavily grazed by rabbits, but since the crash in rabbit numbers and its impact on the vegetation, there has not been the gradual recovery in the rabbit population seen elsewhere. The effect of the low grazing pressure can be seen in various different ways. There are extensive stands dominated by coarse grasses and with an impoverished flora. There are other areas where the combination of a degree of eutrophication and lack of grazing has produced stands dominated by ruderals. There are other areas where the lack of grazing is made manifest by the occurrence of considerable numbers of individuals of species that seem to be especially indicative of lack of grazing, for example Goat's beard Tragopogon pratensis: perhaps such species are especially sensitive to damage from grazing animals.

A build up in rabbit numbers may or may not occur naturally at Newborough; however, there are disadvantages in reliance on the rabbit to maintain an adequate grazing pressure, not the least of which is the difficulty in controlling rabbit numbers. Experimental grazing plots were set up recently using Soay sheep, accompanied by mowing experiments (Hewett, 1985). The number of species was significantly increased by grazing with the optimum effect for those plots grazed at the higher intensity for part of the year. This was the equivalent of seasonal grazing with 6 sheep per ha (recognition must be given to the small size of the Soay sheep used). The results from the mowing experiment were less clear. It appears that mowing can be beneficial for certain situations. Mowing, being non-selective, does not create the diversity that comes from grazing animals. The Newborough experiment clearly showed the disadvantages of grazing in terms of the capital cost of fencing and stock and the manpower required for its supervision. The dune grazing survey clearly showed that if the floristic diversity of Newborough is to be maintained then there will have to be more grazing.

Aberffraw, Anglesey

Aberffraw is much smaller than Newborough but it still has notable calcareous dune slack and dune grassland communities (Appendix Table 11.1). The dune grassland at Aberffraw was noted as being the richest of the survey floristically, with 21.5 species per 4m². The area is grazed by cattle, sheep, rabbits and hares, although the cattle and rabbits are the dominant grazing animals. At the time of the survey there were 42 cows and their calves grazing some 100 ha south of the road. This would be equivalent to 0.2 beasts per Ha. Together with the

rabbits they kept the vegetation predominantly short although with patches of taller vegetation. Fairly extensive bare patches on the tops of some of the dunes suggested that the cattle density was at or near its sustainable maximum. There was no evidence to suggest that these bare areas represented a threat to the dunes at the time; rather than reverse, as certain dune annuals were only to be found at the edges of these areas. Any major extension of bare ground would indicate over-grazing and the need for remedial measures.

Ainsdale, Lancashire

From the Mersey to the Ribble sand dunes are the dominant feature of the coastline. The dunes are best developed in the Ainsdale-Formby area and, while much of the area has been planted with pines, the dunes still retain a rich flora and associated fauna (Appendix Table 1.3). The present vegetation of the Ainsdale dunes reflects the widespread problem of the spread of scrub as a result of the lowering of grazing pressure following myxomatosis. Before the disease the rabbit population was very large and inhibited scrub development and even kept the creeping willow to a short carpet. In the years immediately following myxomatosis the spread of scrub was rapid. There are two stages of significance. The first stage is reached when the young scrub grows beyond the reach of rabbits. The second, and most serious stage is reached when the scrub species are old enough to produce seed, usually at about 10 to 20 years (Rothwell, 1985). At the time of this survey the grazing pressure at Ainsdale was assessed as being relatively high, but the present area of grassland is quite small especially in the south and east of the reserve.

Ainsdale illustrates very well the complexity of the grazing management problem. Grazing is, or can be, used for three distinct objectives; the control of plant species diversity in grassland, the inhibition of the spread of scrub, and the management of Creeping Willow. The grazing requirements of these three objectives are quite different. The addition to that of the problems associated with the use of particular grazing animals on places effectively open to the public and the whole question of the optimum balance between grassland, scrub and woodland on dune reserves, shows the complexity of the situation. One solution that has been suggested is to couple the control of existing seedlings, by pulling, cutting and spraying, with the selective removal of the trees adjacent to the slacks, that are a source of seeds, to reduce future recolonisation (Rothwell, 1985).

The impression gained from the survey visit was, however, that of a series of more or less isolated small areas each with their own special requirements regarding the optimum grazing management. A partial answer might be the use of mowing on areas of special need. This might at least encourage more grazing by rabbits. Dependent upon the outcome of the Tentsmuir experiments, goat grazing might well be applicable and beneficial in the control of younger scrub.

South Walney, Cumbria

Walney Island has the appearance of a barrier island but it is in fact composed of boulder clay with dunes systems over shingle deposits at both the north and south ends. South Walney is particularly notable for the very large breeding colonies of the Herring gulls and Lesser black-backed gulls. These high bird numbers have resulted in extensive eutrophication. Although the total number of plant species is quite high there is a low species diversity (9.9 species per $4m^2$) despite moderate to heavy grazing (Appendix Table 11.41). An area of 100 Ha is summer-grazed by 140 cattle (cows and calves) and 200 sheep. This amounted to 1 beast and 2 sheep per Ha or a cattle equivalent of 1.6 per Ha. Despite this the mean height of the vegetation at 160 mm is comparable with that of ungrazed or lightly grazed sites. Again this is partly explained by the occurrence of stands of ruderal species such as Ragwort, Thisties and Nettles. With the continued eutrophication of the area the present grazing regime seems to be the appropriate management of the area, given that there is incompatibility between the bird populations and a higher plant species diversity.

North Walney, Cumbria

The dunes at the north end of Walney Island contrast with those at the south. Firstly they lack the enormous colonies of nesting gulls and secondly they are virtually ungrazed. The species diversity of the dune grassland, at 13.7, is intermediate between that at South Walney and at Sandscale (Appendix Table 11.29). It seems likely that the species diversity at North Walney is limited by the extent of tall vegetation and that some form of grazing by sheep or cattle could be beneficial. This could be either in the form of a short spell of grazing by a large number of cattle or sheep in the late summer or it could be by lightly grazing the area throughout the growing season.

Sandscale, Cumbria

The Sandscale dunes lie just to the north of Walney Island, but at Sandscale the dunes lie directly over boulder clay rather than shingle, and in consequence are much less well drained with well developed slacks. In addition the sand at Sandscale is more calcareous than at Walney. There are well developed dune slack communities with a higher species diversity than the dune grassland, despite the abundance of creeping willow Salix repens (Appendix Table 11.38). The dune grassland at Sandscale is moderately diverse with a moderate level of grazing.

At the time of the survey there were 70 cattle and 32 sheep grazing 300 Ha, together with some rabbit grazing in most parts. It is understood that in the winter the intensity of sheep grazing is much higher with about 150 sheep but with only about 40 cattle. The winter grazing amounted to 0.1 beasts per Ha and 0.5 sheep per Ha, a cattle equivalent of 0.3 per Ha, and summer grazing 0.2 per Ha. Cattle were excluded from the high dunes and were restricted to the central area of dune slacks. The general

impression gained was that the grazing intensity was about right, possibly slightly too high with half the grassland quadrats with a vegetation height of 50 mm or less. Reduced grazing pressure has been observed to increase the flowering of Wintergreen Pyrola rotundifolia. The scattered bushes on the older dune areas suggested that scrub growth, although little changed over the past 25 years, could be a problem if the grazing intensity was very much lower than at present. Sandscale illustrated the benefits of a mixed grazing regime when applied extensively to a large site, creating a varied mosaic of vegetation heights and habitat types.

5.8 West Scotland

This region is characterised by relatively cool and moist conditions; many of the sites are extremely oceanic. Many of the sites are large or form part of a very large system. Many of the sites are closely grazed and have the distinctive 'machair' vegetation with large areas of gently undulating short grassland. It should be noted that the comments here are based mainly on the results of the Scottish Survey and the situation may well have changed considerably over the intervening ten years or so.

Torrs Warren, Galloway

The southernmost of the west Scotland sites is Torrs Warren, among the ten largest British dune sites. It differs from most other west coast sites in two major ways; the sand is mainly lime-poor, with extensive acid soils, and the site as a whole is relatively sheltered. The dunes in the north-east of Torrs Warren are considered to be part of an older dune system (Idle & Martin, 1974). The site is notable for the extensive development of dune slacks and for the great variety of interacting gradients of salinity, soil moisture, soil type and topography. All these factors contribute to the diversity of its flora.

Historically the area was predominately sheep-grazed, but now the rabbit is the main grazing animal, together with some grazing by deer. After myxomatosis rabbit grazing declined and although rabbits are now abundant the grazing impact is low, which, when taken with the height of the vegetation, and the number of species per quadrat, suggests a need for increased grazing. While the site overall is species rich the quadrat diversity for the grassland and dune heath were the lowest, and damp slack the third lowest, for any of the west coast sites. The mean grazing impact did not exceed 1.3 for any of the habitat types. This is similar to the situation at St. Cyrus, for example, where it was concluded that unless grazing was increased, there would be a reduction in species diversity. True, a large site like Torrs Warren is more tolerant of sub-optimal grazing intensities but nevertheless the warning signs are clear, both in terms of the mean height of the vegetation and in the spread of scrub and also bracken.

Gruinart, Islay

There is a complex of two distinct dune systems either side of the mouth of Loch Gruinart. The main area of dunes is on the east shore of the loch (Killinallan), but on the west sand from eroding dunes has blown high over the rocky peninsula of Ardnave Point. The sand is highly calcareous in origin although there are areas where acidification has occurred. Both areas are relatively dry, except for the area around Ardnave Loch.

The flora is rich in both vascular plants and bryophytes with several notable species including Spiranthes rommanzoffiana. The damp slack quadrats are the most diverse of the West Scotland sites and the dune heath quadrats are also notably diverse. The diversity is associated with relatively high overall grazing intensities by cattle sheep and rabbits. While the dunes at Killinallan are probably at or near their optimum grazing intensities, the combined effects of excessive grazing, vehicle damage, and spreading eutrophication at Ardnave represent a considerable management problem. As the dune system is based on rock its long term survival depends on the stability of the machair surface through the retention of adequate vegetation cover. As well as this species diversity will fall if habitat eutrophication continues.

Ballevullin, Tiree

Ballevullin dunes, on the north-west coast of Tiree, are extremely exposed, so much so that at the seaward edge there are only low foredunes with Sand Couch-grass Elymus farctus. Further inland there are mobile Marram dunes but these do not build to any height. There are both areas of relatively dry and stable machair grassland and wetter areas associated with streams and flushes. The site is based on almost pure shell sand and it is moderately rich in vascular plants and rich in bryophytes.

The area is rather heavily grazed mainly by cattle and sheep although rabbit grazing was also recorded. 120 cattle and 60 sheep were seen on a site of over 300 Ha, and the machair surface was damaged by trampling and some areas had become eutrophic from accumulations of cattle dung with the development of coarse vegetation. The site would seem to illustrate a common problem On the one hand the grassland quadrats appeared to be no more that moderately grazed, with some tall vegetation remaining; while on the other hand the sward showed definite signs of damage. It was noted at the time of the survey that the area was divided up into paddocks. In the interests of maintaining species diversity stock should be allowed free access to the whole area to produce a mosaic of grazing intensities. Stock, especially cattle, should be excluded from the foredune and strandline. The rate of stocking during the winter months isnot known, but there can be no justification, from a management viewpoint, for having animals present outside the growing season.

Baleshare, North Uist

The island of Baleshare lies to the south west of North Uist and the whole of the western part of the island is predominately dune-covered although there is some machair. The western edge is extremely exposed but the eastern sides of the sand spits at the north and south ends are very sheltered. There are quite high Marram dunes in the western areas, while to the east there is low dune and hummocky machair. To the east the topography is generally low and the water table near the surface. Baleshare is moderately rich in vascular plants and rich in bryophytes. There are notable populations of the Frog Orchid Coeloglossum viride and the Adder's Tongue Fern Ophioglossum vulgatum. The dune grassland is short and fairly diverse floristically with a heavy grazing impact. The limited areas of damp slack were less heavily grazed but only moderately diverse. In contrast the wet slack areas at Baleshare were the most diverse of any West Scotland site with a heavy grazing impact.

Grazing at Baleshare was by cattle and sheep together with some rabbit grazing. At the time of the original visit 60 cattle and 80 sheep were seen on the southern half of the 512 Ha site. There were signs of grazing damage to the strandline vegetation and grazing had also reduced the numbers of flowering shoots of orchids. It would seem that overall the grazing intensity was near the optimum for all areas except the foredune and strandline which would benefit from some protection from grazing.

Balranald, North Uist

Balranald lies on the north-west corner of North Uist and unlike Baleshare it is predominately machair. It is however notable for the extensive wetland areas with herb-rich fen and bryophyte communites surrounding the extensive machair lochs. There is also a remarkable range of soil types from highly calcareous to sufficiently acid to support Heather Calluna vulgaris. Overall the vascular plant flora is rich but the bryophyte flora is very rich. The grassland is moderately diverse with a light to moderate grazing impact. Both the wet and damp slacks are moderately diverse with light grazing.

Grazing is by cattle, sheep with only a few rabbits. The area could probably benefit from a moderate increase in grazing pressure, with perhaps the exception of the strandline and foredunes.

Monach Isles, North Uist

The Monach Isles lie some 16 km to the west of North Uist. These low-lying islands are almost completely blanketed with dune and machair. The islands are extremely exposed and salt-spray affects the vegetation. The flora is poor in vascular plants but rich in bryophytes. The grassland of the Monachs is floristically the poorest of all the calcareous dune grassland in West Scotland and it is only lightly grazed, mainly by rabbits. The damp slack and wet slack communities are also species poor and lightly grazed.

The grazing history of the Monachs is varied. Overgrazing at the beginning of the nineteenth century led to the virtual loss of the vegetation and a decline in the human population. Subsequently the vegetation recovered and the islands were inhabited and cultivated up to 1949. Since then they have been lightly grazed by cattle and sheep and more heavily by rabbits.

Although the figures indicate only a light grazing impact there are areas locally where excessive rabbit grazing is causing erosion. This illustrates the difficulties implicit in using rabbit grazing as a management tool, however in isolated sites like the Monachs there is little in the way of an alternative solutions.

Oldshore More, Sutherland

Oldshore More lies on the north-west coast of mainland Scotland set in a bay between high rock ridges. There are Marram dunes along the seaward edge while inland there is a complex of hillocks and dune plains with damp hollows. The sand is extremely calcareous but at the landward edges of the site there are transitions to acid moorland and bog.

Although only just over 100 Ha in area the site is floristically diverse in both vascular plants and bryophytes. The dune grassland is the richest of the West Scotland sites and the damp slack the second richest. The grazing impact is moderate to heavy. Grazing is mainly by sheep and rabbits and a few cattle. At the time of the survey there were 200 sheep and 16 cattle grazing there for most of the year. There are extensive erosion scars on the machair but these are attributed to by the local people to rabbits. From what was seen elsewhere sheep are important for perpetuating areas of bare sand, especially when the erosion cliff gives shelter.

From the evidence grazing intensity can not be far from the optimum, although as we have seen elsewhere there is not a great difference between the best grazing intensity for the maintenance of species diversity and the intensity that can cause the onset of erosion in the most sensitive areas.

Sandwood, Sutherland

Sandwood Bay lies just to the north of Oldshore More in a similar position between high rocky headlands. The headland to the south gives sufficient protection for the development of Marram dunes to a height of 20m. At the north end however, exposure limits frontal dune development while at the same time enabling a carpet of dune and machair to extend up the rocky slopes to altitudes of 100 m. At the back of the dunes is Sandwood Loch which drains seaward through the sand and shingle. The system is a highly dynamic one with extensive areas of mobile dune. Despite this the site is rich in vascular plants, bryophytes and lichens.

The dune grassland quadrats were only exceeded in diversity by those of Oldshore More and the dune heath quadrats were the

richest of the West Scotland sites. The diversity of the dune heath quadrats can be attributed, at least in part, to the mixture of sand with rock and bog with extensive transitional habitats. The whole area is grazed by sheep and rabbits as well as a few hares. While the grazing intensity is only moderate it is probably nearly optimal in view of the high degree of mobility of the site.

Faraid Head, Sutherland

Faraid Head lies on the north coast of Scotland some 12 km to the east of Cape Wrath. The headland is joined to the mainland by a low rocky isthmus . On the west side there are high Marram dunes but the wind has also blown calcareous sand over most of the isthmus with transitions to blanket bog. The site is moderately rich in vascular plants and lichens but very rich in bryophytes. Considering the location on the north coast, the diversity of the grassland and damp slack quadrats is remarkably high. There are light to moderate grazing intensities by sheep and cattle and a few rabbits. Although the areas of damp slack vegetation are mostly closely grazed, the grazing intensity is probably rather on the low side but the trampling pressure from visitors means that erosion damage could occur even with sub-maximal grazing intensities. This question of the interaction of the trampling associated with increasing visitor pressure is probably relevant to many of the West Scotland sites.

6. Assessment of grazing situations

6.1 Introduction

It will be clear from the comments already made on the results of the survey that the assessment of present grazing situations in different sites is not an easy task given variation in both space and time and additionally the relatively slow rate of response of the vegetation to any changes in grazing pressures. In view of the importance of obtaining the necessary information as the basis for the formulation of future grazing management plans, a few comments are appropriate.

6.2 Grazing by domestic animals

Grazing, as far as dune management is concerned ,is the removal of excessive vegetation growth by herbivorous mammals. In order to quantify grazing we have to determine what animals are present, in what numbers and for how long. On the face of it, this is relatively easy to do for domestic stock, for ponies,cattle aand sheep (Table 6.1). Even so there are various complications.

Firstly, it became clear from the present studies, that, in typical dune terrain, a direct count of sheep, ponies or cattle was not as easy as might be expected. Even dune hillocks of moderate size could conceal significant numbers of ponies or cattle let alone sheep.

Secondly the stock numbers declared by the farmer or grazier tended to reflect the numbers that were permitted rather than actual numbers. At several dune sites the area grazed included significant areas of non-dune grassland along the inland borders or of saltmarsh grazing to seaward. How much of the grazing therefore was actually on the dune grassland ? Given that a site is subject to a particular grazing intensity, there can be great variation in the grazing pressure across that site. In an area of 100 Ha of grassland, grazed free-range by ponies at a density of 0.3/Ha, Oosterveld (1981) showed that 3% of the area was heavily used, 70% moderately used and 27% was little or never used.

Finally in certain circumstances it was found that overgrazing in the past had resulted in the growth of coarse inedible species which reduced the food available. Thus even though the height of the vegetation and, by the same token, the impact assessment, indicated that the site was undergrazed, in reality there was excesive grazing.

As well as spatial variations in the pattern of grazing there are frequently temporal variations. There are a very few sites grazed by the same numbers of stock throughout the year. In the majority of sites grazing is seasonal and really needs defining in terms of grazing days at a particular time of year. The seasonal aspect is important because of the different effects of a given grazing intensity at different times of the year. In addition there is the complication of the variation in the size and appetite of individuals of a given species. Grazing may be

Table 6.1 Observed grazing intensities

Site	Ponies /Ha	Cattle /Ha	Sheep /Ha	Total Ceq/Ha	Season	Rabbits	Grazing Impact
Kenfig	0	0	0.2	0.07	A	+	0.3
Aberffraw	0	0.2	0	0.2	?	+++	1.5
Sandscale	0	0.2	0.1	0.2	S	++	1.3
Sandscale	0	0.1	0.5	0.3	W	++	-
Earlshall Muir	0	0.3	0	0.3	P	++	1.2
Whiteford	0.3	0	0.15	0.4	A	++	1.2
Baleshare	0	0.3	0.4	0.4	?	+	2.4
Ballevullin	0	0.4	0.2	0.5	?	+	1.7
Fidge	0	0	1.6	0.6	?	+++	2.0
Oldshore More	0	0.2	2.0	0.8	A	++	2.1
Conninghole	0	1.4	0	1.4	W	++	1.7
South Walney	0	1.0	0.5	1.6	S	++	1.8
Ross Links[5]	0	1.8	1.3	2.2	W	++	1.1

Notes:- 1. Ceq = cattle equivalent assessed in terms of 1 pony = 1 cow = 2 calves = 3 sheep.

2. Rabbit Numbers + = some rabbit grazing, ++ = moderate rabbit grazing, +++ = heavy rabbit grazing.

3. Sites are arranged in order of increasing grazing intensity as determined by cattle equivalent.

4. S = summer, W = winter, A = all the year, P = part of year, ? = extent unknown.

5. Substantial supplimentary feeding in the winter.

by Soay or Southdown sheep or it may be by Dexter calves or Hereford cross steers. Due allowance needs to be made for the size of the grazing animal involved.

6.3 Grazing by rabbits

If the assessment of the grazing intensity of domestic animals is difficult, assessing the grazing intensity of wild rabbits is almost impossible. There is an imperfect relationship between observed rabbit numbers and the total of rabbits actually present on a site. The proportion observed varies drastically with the time of day and with the weather. Generally counts at dawn or dusk in fine weather give the most reliable estimates of rabbit numbers both in terms of the proportion of the total observed and in terms of the reliability of the results (Wallage-Drees, 1987). Alternative methods including counts of active warrens and counts of rabbit droppings can also be used but are generally regarded as being less reliable. It must also be remembered that rabbits are selective grazers both in terms of the selection of one plant species in preference to another and also in the way that they move out from their warrens to favoured areas for feeding. These preferences can vary in space and time. An area favoured one year may be largely ignored the following.

6.4 Grazing interactions

As well as all this there is also the question of interactions between the various grazing animals as well as their own specific food preferences. Horses are more selective that cattle, and cattle are more selective than sheep. Horses and cattle tend to be selective, grazing some areas short while leaving other areas tall. To some extent mixed grazing by cattle and horses produces a more even result than either animal on its own. This is partly a result of differences in food preferences, what one animal leaves the other eats, and partly each species avoids vegetation soiled by its own urine or droppings but not by the other (Putman, 1986).

Horses tend to have definite stamping areas where they remain when they are not grazing and where they defaecate, the so-called latrine areas. . The soils of these areas become enriched with mineral nutrients and organic matter with the growth of coarse vegetation in marked contrast to the very short vegetation of the grazing areas.

Cattle tend to defaecate at random but graze selectively. However, as cattle cannot graze as closely as horses, they are forced to graze the coarse vegetation in the latrine areas. As cattle defaecate where they are grazing, their presence reinforces the nutrient enrichment of the horse latrine areas, in contrast to the low nutrient horse grazing areas. All this contributes to the spatial heterogeneity in plant community structure.

Sheep also defaecate at random but they tend to graze the vegetation uniformly short. This results in a rather uniform vegetation structure.

Rabbits also graze areas uniformly short but they will often favour those areas kept short by the larger grazing animals. In addition rabbits favour areas where short vegetation has been produced by trampling or by mowing. Paths where short vegetation had been produced by experimental trampling remained distinct for several years after the trampling had ceased, simply because of selective grazing by rabbits. An increase in grazing by sheep or cattle can be augmented by a corresponding increase in the rabbit grazing.

In areas where there are both cattle and sheep, there tends to be heavier grazing by sheep in the drier parts and by cattle in the wetter. Variations in grazing behaviour generally contribute to the creation of environmental pattern that increases plant species diversity but at the same time it increases the difficulties of assessing grazing pressures.

6.5 Assessment of combined stocking rates

It may be helpful to consider some of the stocking rates observed during this survey. With virtually all the sites being grazed by rabbits to a greater or lesser extent and with the difficulties of estimating rabbit numbers and their grazing impact accurately, any comparisons between sites with different densities of domestic animals must be considered with due caution.

In terms of cattle equivalents stocking rates varied between 0.07 and 2.2 units per Ha (Table 6.1). Those areas where the grazing pressure seemed to be about right, in terms of maintaining plant species diversity, had rates that were between 0.2 and 0.5. This was usually for areas grazed for most or all of the year. Densities of up to 1.0 units per Ha apparently caused little damage if applied for part of the year only. This was especially the case on old dune grassland in areas of high rainfall, that is where the sward was better able to withstand the trampling pressure.

Higher densities of stock, when maintained for any length of time, almost invariably involved some form of damage with supplementary feeding and or sward 'improvement' with reseeding and fertilisers. This resulted in eutrophication and the development of coarse ruderal vegetation, encouraged by the arrival of the seeds of coarse species in the fodder, or in the replacement of native grasses with vigorously growing cultivars that excluded most of the natural flora.

6.6 Effects of trampling

As well as grazing the dunes, ponies, cattle and sheep also trample the sward. The foot pressures exerted by grazing animals are considerable. At low intensities a degree of trampling is beneficial creating new patterns and increasing diversity. At higher intensities significant areas of bare ground appear and diversity decreases with, in many cases, the threat of damaging erosion. The density at which damaging erosion occurs depends both on the species of animal involved and the nature of

the habitat. It has been suggested that under average conditions dune turf can physically support annual grazing intensities of 0.5 cattle/Ha and 4 sheep/Ha (Ranwell, 1986).

Damage to dry dune grassland was observed to occur at Aberffraw even at low cattle densities, densities at which there would be little or no discernible damage to the grassland of damp slacks. Sheep have the advantage of lightness of foot compared with cattle and are thus more suitable for grazing dry dune grassland especially in steeply sloping terrain. Even sheep can cause trampling damage when they regularly use certain areas as stamping grounds while sheltering.

The lower damper areas of the dunes, damp slacks, are usually best grazed by cattle. They are better able to withstand the heavier foot pressure and generally are favoured by cattle and avoided by sheep. Wet slacks are particularly sensitive to trampling especially around the margins of any permanent or semi-permanent water bodies. In these circumstances damage will be least if the grazing is limited to summer periods when the water table is low.

Trampling by humans at low intensities can benefit plant species diversity, but at even moderately high intensities it causes loss of diversity and direct damage through erosion (Boorman, 1977). Trampling at low to intermediate densities can produce a short sward that is attractive to rabbits and this can maintain or increase the initial effect of trampling (Sothern et al., 1985). The main benefit from trampling by humans occurs in those areas where there is very limited grazing. In these circumstances the greatest species diversity will be found along the edges of the paths. However this is generally a very local effect and no substitute for grazing. Where there is light trampling over the whole area combined with extensive light grazing, the combination may be adequate for the maintenance of species diversity particularly where growth is limited by low nutrients or low soil moisture.

The effects of trampling depend on the ability of the sward to repair damage. There are thus geographical factors to consider. The most important factors are temperature and soil moisture, particularly the latter. Thus although the growth potential is greater in the south, often there is insufficent soil moisture for this to be realised. Many southern dune sites are therefore particularly sensitive to the effects of excessive trampling. Generally the dune grassland in the cooler but damper sites is more resistant to trampling. The significance of trampling damage can be greatly increased by the effects of exposure; what would be considered minor damage in a sheltered site could precipitate serious erosion in a more exposed site.

6.7 Effect of past grazing history

The final problem in the assessment of grazing situations is the historic one. It is clear from various observations, notably from Kenfig and Holkham, that there can be a considerable time lag, perhaps as much as ten to twenty years, between a change in the grazing regime and the establishment of a new equilibrium. Moreover the first changes that occur can be radically different

from the eventual equilibrium. If, for example a site had been grazed in a certain way for fifty years and then in another way for ten years, the present situation would be approaching that of the equilibrium; certainly something very close to the equilibrium would be reached over the next five to ten years. If on the other hand the new grazing regime was only two or three years old, then not only would the long term trend hardly be established, there could well be short term changes in a completely different direction.

The situation is, however, rarely as simple even as this. Frequently very little is known about the past grazing regime beyond a few broad generalisations such as 'the area was regularly grazed by sheep'. Clearly every effort should be made to obtain all possible grazing information at least for the past twenty years and preferably for longer. In addition attempts should be made to relate this information to the realities of the present situation as they apply to that particular site. The question needs to be asked as to whether the present situation regarding the vegetation corresponds with the alleged grazing situation. It may be useful in this connection to make some comparisons with nearby dune areas where the past grazing management has been established more precisely. As the benefits from grazing come through the removal of excess vegetation growth, factors that affect the growth of vegetation, such as the levels of soil moisture and mineral nutrients, will have an influence on the required intensity of grazing. The grazing required is thus not a static figure, but will depend on factors that can and do change. While changes in climate will have only limited effects in the timescale of grazing management, soil moisture and even soil nutrient levels can change under the influence of factors both within and outside the dune system. There can be changes in the vegetation, either the result of changes in physical or chemical conditions or from the effect of grazing itself, that can alter the current and future grazing management requirements. For dune slack vegetation past depths of the water table under the surface will have been crucial to the vegetational development. The grazing management of dune slacks thus has to be integrated with the management of the water table, past, present and future.

7. Formation and implementation of management procedures

7.1 Introduction

This section is concerned with the question of how to apply our present knowledge to the practical management problems that occur in British sand dune systems. All the necessary information that is available has been given in the preceding sections, but in a rather discursively. An attempt is made here to provide a summary in a practical form; that is to bring together the most important points regarding the grazing management of the British sand dunes. This must include the selection and implementation of the appropriate management procedures as well as considering the problems of long term monitoring.

The chapter begins with an assessment of the current grazing situation, first of all in a general sense and then specifically, both directly and indirectly. The indirect effects are deduced from the vegetation. From these it should be possible to interpret what management is needed for each of the component habitats of a site.

The second half of this chapter then goes on consider the practical implementation of the chosen management techniques. This includes both the monitoring of future change and the difficult problems involved in the interpretation of the management significance of the changes that are observed.

7.2 General assessment of the grazing situation

The general principles of the site assessment of the grazing situation from the animal side has been considered in the preceding section. From this it should be possible to answer the questions of what animals are present, in what numbers and for what part of the season. For the larger sites it should also be possible to define the areas favoured by the various grazing animals; both the areas used for feeding and for resting or sheltering. This assessment can usually be done by eye, by observing the animals directly and by the interpretation of various signs and tracks. It does need to be done at intervals over a reasonable period of time, at least over a full growing season, and preferably over a full year.

It is also necessary to define the situation with regard to the state of the vegetation. The experienced manager can probably assess the vegetation by eye but if a quantitative assessment is required the section on study methods (Section 3) gives some ideas. If regular assessments are to be made on a particular site then quadrat locations should be securely marked for future reference. There are considerable advantages to be gained by the use of quantitative methods. Not only does it make it much easier to assess changes but it also ensures that there are records available that can be readily used in the future.

While the survey methods described are only concerned with species number individual species may require special attention. There may be rare species that merit individual attention.

There may be species that are indicative of special circumstances. The presence of large numbers of ruderal weedy species suggests that the site may be or has been, overgrazed and that a degree of eutrophication has occurred. There are certain species that are particularly sensitive to grazing and their presence may suggest that the area is undergrazed. Goat's beard Tragopogon pratensis and False oat grass Arrhenatherum elatius are examples of this. The presence of seedlings of the various species of shrub can also be indicative of a low grazing intensity. Often however, the complete control of scrub development only occurs at grazing intensities that are higher than those optimally required for the maintenance of species diversity.

7.3 Survey of vegetation and species

Once the general assessment has been completed then consideration must be given to what are the appropriate management procedures for the different components, plant communities and habitats, of the site. For all but the smallest sites these and thus the grazing requirements will vary across the site. It is appropriate to consider what the best options would be generally and then to consider what specific modifications need to be made in relation to the habitats present and in the light of the practical implications.

Much can be deduced from consideration of the mean height of the vegetation during the growing season. From the point of view of the maintenance of plant species diversity a favourable situation is implied when the mean vegetation height of herbaceous communities, other than heath or Marram dominated communities, is less than 150 mm or where there are extensive areas where the vegetation height is 100 mm or less. If the mean vegetation height is over 200 mm then there is a clear need to consider an increase in the grazing intensity. The occurrence of intermediate situations suggests that action may be needed but that the situation is not urgent.

The situation is rather different for Marram, dune heath and dune slack communities; each of these may have a proportion of taller growing species. The Marram dominated communities are very sensitive to trampling and generally grazing is not required and indeed it is usually undesirable. The nature of Marram is such that even with moderate grazing, which can still be damaging, it can have a mean vegetation height of over 200 mm.

With the dune heath some grazing is usually desirable. Some judgements can be made on the basis of the grazing impact on adjoining communites without these taller species but with similar grazing pressures. Generally the grazing impacts should be assessed from the grazing intensities that the communities themselves are subjected to. Dune heath vegetation is generally taller than most grassland or slack communities. Even quite heavily grazed heathland vegetation may have a mean height of 150 mm or more, although mean heights of over 200 mm probably imply a need for a degree of grazing.

The situation with regard to the vegetation height of dune slacks is complicated by the existance of two distinct types of

communities, those with one or more tall species and those without. This is particularly the situation in wet slacks where there can be vegetation dominated by low growing species such as Water mint Mentha aquatica or by taller species such as Meadowsweet Filipendula ulmaria. Under the same grazing regimes the two communities would have very different vegetation heights. Again reference should be made to the comparable effect of the grazing intensity on adjoining communities and species.

A lightly grazed damp slack will have vegetation with a mean height of 100 mm or more although with taller species dominant the height might be over 250 mm. A moderate to heavily grazed dune slack will probably have vegetation with a mean height of less than 100 mm, often around 50 mm. Thus a vegetation height in excess of 100 mm would indicate a need for increased grazing, especially in the absence of tall species.

The height of vegetation in wet slacks will generally be similar, although in the absence of tall emergent aquatics or semi-aquatics the vegetation is likely to be rather shorter, under both heavy and light grazing. When tall species are present the mean height is often more than 500 mm even with some grazing.

7.4 Survey of grazing patterns

Assessments can also be made on the basis of past and present stocking rates (see Section 6). In terms of cattle equivalents annual rates of between 0.2 and 0.5 per Ha imply that the grazing management is at or near the optimum. Lower rates suggest that the area may be undergrazed unless the area is also grazed by significant numbers of rabbits. Where the site is large (over 100 Ha) stocking rates as low as 0.1 cattle equivalent per Ha may be adequate through habitat differentiation producing a mosaic of vegetation types and grazing intensities.

At these low grazing intensities scrub encroachment can be a real problem although the diversity of the grassland is maintained. Generally it may be better to adopt a policy of scrub management where needed than increase grazing intensities unnecessarily. There is a complex relationship between the size of the area grazed, the grazing animals present, and the stocking rates on the one hand, the local intensity of use and the creation of a suitable vegetation structure pattern on the other. The stocking rate also affects the time taken for a stable situation to be reached or the rate of development of seral stages through scrub to woodland (Oosterveld, 1985).

Higher rates of stocking, especially those over 1.5/Ha, suggest that something is wrong unless the grazing is for short periods only. The need to avoid supplementary feeding has already been mentioned but the damaging effect of supplementary feeding on plant species diversity cannot be over emphasised. If stock can not obtain sufficient food from the dunes themselves then the stock should be removed and fed elsewhere. Rates below 1.5 may be sustainable under certain circumstances, such as on well established damp dune grassland in areas of high rainfall. In general sustained rates of stocking above one beast or its equivalent per Ha should be avoided.

The recommended rates can be exceeded as a preliminary short term measure when introducing grazing animals to a previously un- or undergrazed area. A necessary first step in setting up a new equilibrium is the removal of rank old growth; unless high stocking rates are used this component of the vegetation will remain largely untouched.

After the grazing intensity and the stocking rate, have been selected, there is then the matter of choosing the most suitable grazing animal (Table 7.1). For grassland communities the choice between ponies, cattle and sheep depends on the nature of the terrain particularly soil moisture and steepness of the slope.

Well established grassland on level or gently undulating terrain is equally suitable for grazing by any of the usual grazing animals. Where the terrain is steep there is risk of serious trampling damage if either ponies or cattle are used. Thus in grey dune areas sheep grazing must be the choice.

Where the soil moisture is high, in the damp slacks, cattle are the choice. Such areas are not favoured by sheep and can cause foot problems in both ponies and sheep. With higher soil moisture and soil nutrient levels there is usually sufficient plant growth to support up to 1 beast or 3 sheep per Ha but this density may cause serious damage to the soil and vegetation. However, lower densities are usually more appropriate, except initally on a sward that has had too little grazing, and then only for short periods. Dune slacks in north Holland were grazed by young cattle at densities of between 0.75 and 0.5 beasts/Ha all round the year (approximately 0.5 - 0.3 cattle eq/Ha). Over a period of six years there was an increase in the diversity of the vegetation structure, even trampling created new communities; overall nine species were lost but 25 were gained. The grazing also inhibited the spread of scrub (Klomp, pers. comm.).

Dune heath vegetation presents its own special problems for grazing management. Productivity in such communities is low and high rates of stocking are neither sustainable or desirable. Overgrazing of heathland vegetation can rapidly lead to its conversion to species-poor acid grassland. Heathland vegetation is composed of a mosaic that is maintained by its own internal succession. This can best be maintained by low rates of stocking applied to large areas so that there is a mosaic of different grazing intensities. This increases the possibility for this internal regeneration.

Generally stocking rates of between 0.06 and 0.3 cattle equivalents per Ha are appropriate. The higher rates are only applicable to very large areas (greater than 200 Ha) where the stock can range free. Any overgrazing in these circumstances will tend to be local producing discreet bare patches in the vegetation which will tend to regenerate the heathland communities. In marked contrast to the general overgrazing in smaller sites which will lead to the formation of acid grassland. While sites like Earlshall Muir are apparently successfully maintained by cattle grazing Dutch experience suggests that sheep are more suitable and should be used on dry dune heath at the

Table 7.1 Selection of animal for dune grazing

Habitat type	Yellow Dune	Dune Heath	Wet Slack	Damp Slack	Dune Flat	Grassland Hilly
Animal						
Ponies	no	no	no	pos	yes	no
Cattle	no	pos	yes	yes	yes	no
Sheep	pos	yes	no	pos	yes	yes
Rabbits	pos	pos	pos	pos	pos	pos
Goats	no	no	no	pos	pos	no

NOTES:-

no - not at all

pos - sometimes satisfactory, apply with great care

yes - normally satisfactory, but monitor progress

rates of between 0.2 and 1.0 sheep per Ha. Damp heath can easily be damaged by overgrazing and this is especially true of the wetter areas with peatmoss Sphagnum spp. Light intensities of sheep grazing can be useful for the drier areas and if damp heath occurs in patches within dry heath the whole can well be managed by lightly grazing within large areas. Because of the complexities and variability of the situation thought should also be given to supplementing grazing management by the use of other management procedures such as burning, mowing, turf cutting and direct scrub control.

The selection of the most appropriate grazing management regime is a complex process in which all relevant factors have to e carefully considered. It is possible however, to summarise some of the key decisions that have to be made in the form of a series of questions (Table 7.2). The key given is intended as an indication of some of the main principles involved in the selection of appropriate dune management regimes. It must be emphasised that it is intended for general guidance and the management options should not be implimented without a full appraisal of available information.

7.5 The practical implementation

Having described the benefits of grazing for vegetation management of sand dunes we now have to consider the practical difficulties that have to be overcome. Suitable grazing animals have to be found and then they have to be looked after carefully. They have to be contained within the area and supplied with fresh water.

Generally the food intake of stock maintained on dune grassland is lower than the optimum for growth or lactation demanded by modern husbandry. This means that it will rarely be possible to organise dune management on the basis of letting (selling) grazing on a commercial basis. It may prove possible to 'borrow' agricultural stock for limited periods but generally it is better if the stock is under the full control of those responsible for the grazing management of the area. Checks in growth or even actual weight loss, during periods when the animals are being encouraged to graze down coarse rank vegetation, can be accepted. However acceptance of the full control of the grazing animals does carry with it expenses and responsibilities.

The first problem is the need to contain the animals within the desired area. In the case of large varied areas it may be possible to allow free, open range grazing over the whole area with fencing, if any, limited to the landward boundary. If this is not possible then the answer is probably to have a ring fence around the whole area. Initially the expense is high but with suitable materials the fencing will last for many years. Selective internal fences, restricting access to certain areas, can also be set up permanently. Fences can also be selective for particular grazing animals limiting them to particular areas. A large dune site with an area of high dunes might have a stock-proof fence across the inland boundary and a fence around the high dunes that would allow the passage of sheep but not cattle.

Table 7.2 Selection of dune grazing management options.

Below is a key to the major dune management options. The different habitat types are each considered separately. This table is intended as an indication of some of the main principles involved in the selection of appropriate dune management regimes.

The information given is for general guidance and should not be implimented without a full appraisal of all relevant information.

KEY TO MANAGEMENT OPTIONS

1. What is the habitat type ? (see Table 3.6)	Yellow Dune	2
	Dune heath	6
	Wet Slack	12
	Damp slack	18
	Dune grassland	23
2. Grazing not usually necessary - if area is grazed		3
- if ungrazed		37
3. What grazing animals present ?	Cattle or ponies	EXCLUDE
	Sheep	4
	Rabbits	5
4. What is the vegetation height ?	<250 mm	REDUCE/EXCLUDE
	>250 mm	5
5. Eroded bare areas more than 10 % ?	Yes	REDUCE NUMBERS
	No	37
6. What is the vegetation height ?	>150 mm	7
	<150 mm	8
7. Present grazing (cattle eq/Ha) ?	>0.1	30
	<0.1	INCREASE NUMBERS
8. Present grazing (cattle eq/Ha)	>0.2	9
	<0.2	30
9. Present grazing (cattle eq/Ha) ?	>0.3	REDUCE NUMBERS
	<0.3	10
10. What is the size of area grazed ?	<200 Ha	11
	>200 Ha	30
11. What is the main grazing animal ?	Cattle	REDUCE NUMBERS
	Sheep	30
12. Are tall species abundant ?	Yes	13
	No	14
13. Vegetation all tall, few open gaps		GRAZE OR CUT
Vegetation height variable, many open gaps		15
14. What is the vegetation height ?	>75 mm	15
	<75 mm	16

Table 7.2 (continued)

15. Present grazing (cattle eq/Ha) ?	>0.2	16
	<0.2	INCREASE NUMBERS
16. Present grazing (cattle eq/Ha) ?	>0.5	DECREASE NUMBERS
	<0.5	22
17. Are tall species abundant ?	Yes	18
	No	19
18. Vegetation all tall, few lower gaps		GRAZE OR CUT
Vegetation height variable, some open gaps		19
19. What is the vegetation height ?	>100 mm	20
	<100 mm	21
20. Present grazing (cattle eq/Ha) ?	>0.2	22
	<0.2	INCREASE NUMBERS
21. Present grazing (cattle eq/Ha) ?	>0.5	DECREASE NUMBERS
	<0.5	22
22. Trampling damage arounds pools ?	Yes	GRAZE SUMMER ONLY
	No	30
23. What is the vegetation height ?	>150 mm	24
	<150 mm	28
24. Weedy species (ruderals) present ?	No	25
	Yes	35
25. Present grazing (cattle eq/Ha)	>0.1	26
	<0.1	INCREASE
26. What is the size of area grazed ?	>100 Ha	37
	<100 Ha	27
27. Present grazing (cattle eq/Ha) ?	>0.2	37
	<0.2	INCREASE NUMBERS
28. Lichens or bryophytes dominant		EXCLUDE LARGE ANIMALS
Vascular plants dominant		29
29. Present grazing (cattle eq/Ha) ?	>1.0	REDUCE NUMBERS
	<1.0	30
30. Extent of eroded bare areas ?	>5%	31
	<5%	34
31. Nature of terrain - slopes > 1 in 4		EXCLUDE PONIES/CATTLE
slopes < 1 in 4		32
32. Are many rabbits present ?	Yes	REDUCE NUMBERS
	No	33
33. Is the area heavily trampled ?	Yes	CONTROL ACCESS
	No	34

Table 7.2 (continued)

34. Weedy species (ruderals) present ?	Yes	35
	No	37
35. Is extra fodder fed to stock ?	Yes	REDUCE/STOP
	No	36
36. Is fertilizer/manure added ?	Yes	STOP
	No	CONTROL WEEDS
37. Is scrub invading the area ?	Yes	38
	No	NO ACTION
38. Goat grazing possible ?	Yes	GRAZE
	No	CUT SCRUB

NOTES:-

Exclude = prevent these animals from entering this area.

Reduce = reduce the numbers of this animal in the area.

Graze or cut = reduce vegetation height by introducing grazing animals or by regular cutting at or towards the end of the growing season with the removal of the cut material.

Exclude large animals = prevent ponies, cattle and sheep from entering the area.

Control access = limit the entry of people and or wheeled vehicles to the area.

Control weeds = use appropriate methods to reduce or eliminate weed species present.

Cut/control = use appropriate methods to reduce or prevent invasion of the woody species.

No action = no immediate action needed but monitor change and reassess the situation periodically especially if the management is changing or has changed in the recent past.

Eroded bare areas = areas of bare sand other than from natural sand mobility.

The alternative approach, especially suitable for grazing small areas for limited periods is the use of portable electric fencing that is set up as required. Whatever the fencing it will require regular inspection, ideally daily for electric fencing and weekly for permanent fences.

Stock also require an adequate supply of fresh water. There may already be a suitable stream or lake or a suitable pool could be dug, bearing in mind the need for the stock to have safe access to the water. Otherwise water will have to be brought in either by the use of a trailer mounted water tank to fill a trough or by laying a alkathene pipe to a water trough on a semi-permanent basis. The question of water supply needs considering when fence lines are being selected as it may well be possible to have a common watering point for several enclosures.

If stock are purchased for the job consideration needs to be given to the care of the stock at times when they are not required on the dunes. Is there any non-dune grazing that can be used or are there buildings where they can be housed temporarily and if so what about feed? Stock, particularly sheep, need rounding up for health care from time to time. This can be made much easier if there are suitable holding areas. There are times when it can be very useful to have the use of a suitable building for housing sick or injured animals. While many problems can be solved by a competent stockman there will inevitably be times when professional veterinary care will have to be sought and paid for.

While sheep are often the most suitable grazing animal they do have their own special problems. Not only do they require a greater degree of health care that cattle or ponies, they are very vulnerable to the activities of uncontrolled dogs. The use of sheep can not be recommended in areas where the public are allowed to exercise their dogs. The use of Soay sheep, which are relatively dog-proof can sometimes get over this problem, but there are special problems in their management as they are very mobile and difficult to fence in.

Nothing has yet been said about the selection of suitable breeds of the animals chosen. This may well be determined by local availability, but in general the more traditional native breeds of sheep or cattle are likely to be the most successful. It must be remembered that although the upland breeds of sheep do well on rough grazing they require higher and more secure fencing than do the downland breeds.

The short term borrowing or hire of stock avoids the cost of purchase and of looking after the animals during periods when they are not needed for dune management. The availability of stock for this purpose will depend very much on local circumstances and on the goodwill of the local farmers. Unless they are sympathetic to the aims of dune management they are hardly like to hire or lend stock in a situation when the benefits are likely to be marginal.

What is to be done if the use of stock it impossible ? In some cases there may be sufficient natural instability or potential instability for the regeneration of habitats. Using instability is only likely to be a practical solution on large isolated sites

where dune mobility will not cause problems with adjacent landowners. Exceptionally controlled instability may be applicable locally or on small sites. The use of erosion as a management technique needs the utmost care in planning and execution.

If rabbits are already present on a site or nearby, it may prove possible to encourage them on to communities where grazing is needed. Rabbits are attracted by areas of short vegetation. Short term grazing or mowing can encourage rabbits to move into an area and the rabbits themselves may maintain the short vegetation.

If all else fails then mowing is the only alternative although it is no real substitute for grazing. Generally the dune terrain will preclude the use of tractor mounted machines. The exception here may be the larger dune slack, provided that access can be gained without too much damage. Mowing with hand machines can be applied to most terrains. With a width of cut of less than one metre it use is effectively limited to restricted areas. However a mosaic of small areas of mowing can often provide the most natural solution, with various different areas that are variously cut annually, biannually, triennially or just occasionally. The best results are obtained by mowing at the end of the growing season and removing the cut material. The removal of the cuttings is particularly important to avoid smothering delicate herbaceous species and to reduce the nutrient status of the soil.

Mowing, as described above can also be used very effectively to remove excess growth and standing dead material before introducing a new grazing regime. It can also be used as an occasional measure to control the growth of scrub that may occur under low grazing intensities. Scrub management needs carefull planning (Marrs, 1985; Ranwell & Boar, 1986). Many species readily regenerate when cut. It is usually better to remove the stumps, using mechanical assistance if necessary. This may involve some considerable local distrubance of the soil but is worthwhile in the long term. The woody material, branches and stumps, must be removed. This is best achieved by collecting them up and burning them on a site where a fire, and the nutrient enrichment of the soil will cause the least harm. Even when the main bulk of the scrub has been eliminated there will still be the risk of spread by seedlings, either from seeds already in the soil or from neighbouring seed sources.

7.6 Monitoring future change

However carefully the management regime is chosen its effects, both good and bad, may only become apparent over a period of some years. There is thus an on-going need for careful monitoring of the vegetation and any changes that take place. As this monitoring will also be used for the fine tuning of the management procedures it needs to be as accurate as possible within the limits and skills of the available manpower.

The simplest method is through the use of annual photographs taken from a series of fixed points. However these points need to be chosen carefully and the photos taken with some suitable

indication of scale included in each one. It is usually better to include the necessary details, location, date etc., on a board within the area covered by a photo than relying on a notebook to label the prints subsequently.

A further problem is the question of the seasonal timing of the photos. It might appear that they need to be taken at the same date each year but seasonal variations do occur from year to year. The use of the same calendar date can be confusing (Hope-Simpson, 1985). Every attempt should be made to take the photos at the same state of flowering each year, at least for the important species. The problem can also be eased by supplementing the photos with carefully recorded observations and notes.

Permanent quadrats are probably the most accurate approach but they are also the most time consuming. As they cover a relatively small area a considerable number of quadrats may be needed to cover the range of communities within a given dune site. This will be particularly true when due consideration is given to the range of variation that can occur within a single community. It is very difficult to indicate the number of quadrats that a particular site will require but an idea can be obtained on the basis of allowing at least five quadrats for each major vegetation type; major that is in terms of its extent in area or its biological significance.

The question of quadrat location is also very important. Unless there are good reasons to the contrary, stratified random sampling is usually the best; that is to place the quadrats at random within each particular plant community although of course one has to know the community boundaries .

Quadrat size needs to be considered in terms of the scale of pattern within the vegetation - for most herbaceous dune vegetation types it will generally be between 1 and 4 m^2. Careful thought also needs to be given to the method of recording the quadrat. In the grazing situation the height of the vegetation is as important as the species involved.

Where the vegetation pattern is in zones across some environmental gradient then a transect may be more cost-effective and more informative than a quadrat. It is worth remembering that a transect is really no more than an elongated quadrat.

In many dune areas certain plant species may be of special interest. If this is the case then it may be appropriate to have a separate monitoring system for such species. Very often the general monitoring procedures will not adequately reflect changes in rare species that only occur at low frequencies. In such a case some form of mapping of individuals may be appropriate.

Finally a few comments on the interpretation of the results of monitoring may be helpful. The question of the often very slow rates of change and of the possibility of changes in the direction of change in the course of time has already been referred to.

A further problem is the difficulty of assigning causal relationships especially as there is often a lag period between the change in some envronmental factor and the appearance of a visible effect on the vegetation. Relating cause and effect is particularly difficult when the information is from the whole dune area that has been treated in a particular way rather than from a replicated series of experiments. It has to be accepted that the latter, however desirable, will rarely be possible.

However there may be ways in which some element of control can be incorporated into the management procedures, some way in which comparisons that can be made. This may be in the form of an adjoining area of dune which is still under the original management, or it may be that small areas can be excluded from the revised management system. In addition long practical experience of vegetation management may be able to fill in gaps in the available information and thus assist in the interpretation of the situation.

8. Conclusions and discussions

The purpose of this short final section is to bring together some general thoughts and to comment on a few points of importance that have not been covered elsewhere. The study certainly confirmed the importance of grazing for the maintenance of plant species diversity. At the same time the wide range of existing grazing regimes, in areas of considerable floristic diversity, showed the tolerance of the dune vegetation to mismanagement, at least in the short term. This tolerance, or leeway in terms of action, exists both in space and in time. Certainly some grazing is almost always needed but after that the vegetation will withstand mismanagement for varying periods of time. A dune area will also withstand mismanagement in parts without losing too much as a whole.

This touches on one of the key problems in the grazing management of sand dunes, or of other areas of grassland for that matter, and that is the relatively slow rate of response of the vegetation to a new grazing situation. Indeed this situation is even more complex in the way that the initial changes, over the first two to four years, can be very different to the long term trends. Because of this a dune manager has to make something of an act of faith in setting a new grazing management programme. His superiors must appreciate that he is initiating a process that may take anything from ten to twenty years to achieve the desired result. Hence there is the the very real need for adequate long term monitoring to detect unfavourable changes as soon as possible.

It has to be recognised that in many, if not most, of our sand dune areas, there are external constraints that limit the scope of action that is open to the dune manager. It is to be hoped that this handbook will help to give him sufficient backing to get over at least some of these external constraints. Even when that is not possible there may be alternative ways of reaching a satisfactory compromise. While there are many difficulties and obstacles involved, dune management in general, and dune grazing management in particular, should always be active and positive, rather that passive and rather negative as it has too often been in the past. The positive approaches made in the Netherlands show what can be achieved. Many of the obstacles that appear to stand in the way of positive management can be successfully overcome by the right blend of knowledge and enthusiasm.

The various statements and recommendations that have been made are based on the interpretation of existing knowledge of the processes involved in the maintenance of dune species diversity, and of the effects of existing dune management techniques. This process has necessarily been made within certain limits of both funds and time. There are four major limitations that determined the scope of the present studies. These are:- the number and location of the sites visited, the coverage of sites themselves, particularly in terms of time, the methodology applied and the lack of long term experimentation.

Of these four factors the number and location of the sites was perhaps the least significant. The 48 sites visited represent

only 9% of the total number of sites in Britain but the majority of site differences were covered in one away or another. It is accepted that there the lack of direct coverage of the many large machair sites in the north-west of Scotland does represent a significant gap but probably the geographical gap is greater than the information gap created by the limited information that was available for these sites.

The time factor, which limited repeat visits to all but a few sites, was a serious limitation although the nature of the recording meant that the results obtained were rather more than just a snapshot taken at a single point in time. The vegetation recorded in some ways represented the integration of several years management conditions. The animal signs too, represented at least something of the average of the grazing pressures over the past few months.

While there are limitations imposed by a survey being limited to a single short visit, much can still be achieved. A single visit obtains a snapshot of one point in time just as the use of data from a single quadrat will give a picture of one point in space. This can be extended by the use of background knowledge and experience of the observer; it can also be extended by the use of supplementary information from various sources. While due caution is needed in the comparative interpretation of snapshots, often in terms of the relative effort involved a surprisingly useful comparison can be made.

The impact of the grazing on the vegetation was assessed largely on the basis of the height of the vegetation. This itself was the result of three interacting factors: the productivity of the vegetation, the growth habits of the vegetation and the removal of parts of the vegetation by grazing. The use of height as a parameter was largely on the basis of ease and speed of measurement. From the point of view of the maintenance of species diversity what is important is the control of excessive vegetation growth.

Diversity can be related to an optimal level of standing crop and thus what is needed is the removal of this excess vegetation growth. For this to be achieved we need to know the productivity of the community and the optimal standing crop. If a particular community has naturally low productivity only limited grazing is needed to produce this optimum standing crop. If a community has a high productivity heavy grazing is needed to remove the excess. A high productivity can occur in slack communities under the influence of abundant supplies of mineral rich ground water, or it can occur in dune grassland where soil organic matter and mineral nutrient levels have been increased by the supplementary feeding of cattle in the winter.

There is a great need for long term monitoring. Part of the need is the lack of long term experimentation on the interaction of grazing by different animals at different intensities on various dune plant communities. What experiments there are or have been have very definite limitations. Many of them were local experiments to solve particular short term problems. Often limited funds meant that they were on a very small scale and often too, they lacked the controls needed for the satisfactory interpretation of the results. Moreover because

of variations in recording methods, plot size, grazing animals used or excluded, and plant communities involved it was almost impossible to make any direct comparisons. There is a clear need to use standard procedures over a range of sites to establish more clearly the effects of existing and proposed grazing procedures over a nation wide range of dune sites.

Finally a further field of study is sugested This is the use of individual plant species as indicators of the grazing status. While, as we have seen, the majority of species only respond to a change in grazing management after many years there may well be more species, like Goat's beard, that respond in advance of the majority of species and could thus be used as early indicators of change.

9. Bibliography

The first part of this section is a short anotated list of key references on the subject of the grazing management of sand dunes. After that there is a full bibliography including a list of references referred to in the text. The latest publication on a particular topic is usually the one cited unless earlier papers are of particular significance. As many of the key references are referred to in the text they are all included in the main bibliography as well as being in the selected list.

List of key references

Boorman, L.A., 1977. Sand dunes. In: The Coastline, edited by R.S.K.Barnes, 161-197. Chichester: John Wiley.

Provides a concise summary of the processes involved in sand dune ecology and management.

Doody, P., 1985. Sand dunes and their management. Focus on Nature Conservation No. 13. Peterborough: Nature Conservancy Council.

A up-to-date summary of various aspects of dune management.

Hewett, D.G., 1985. Grazing and mowing as management tools on dunes. Vegetatio, 62(1-3), 441-448.

A useful supplement to the previous publication.

Klinkhamer, P.G.L., & Jong , T.J. de, 1985. Shoot biomass and species richness in relation to some environmental factors in a coastal dune area in the Netherlands. Vegetatio, 63, 129-132.

Important for the insight it gives into the relationship between biomass and species diversity.

Putman, R.J., 1986. Grazing in temperate ecosystems. Large herbivores and the ecology of the New Forest. London: Croome Helm.

Much useful information on habitat diversity and grazing patterns.

Maarel, E. van der, 1977. Environmental management of coastal dunes in the Netherlands. In: Ecological Processes in coastal environments, edited by Jefferies, R.L. & Davy, A.J.,543-570. Oxford: Blackwell.

A useful summary of the Dutch experience.

Ranwell, D.S., & Boar, R.R., 1986. Coast Dune Management Guide. Huntingdon: Institute of Terrestrial Ecology.

An important general guide on dune management.

Main bibliography

Bassett, J.A., & Curtis, T.G.F., 1985. The nature and occurrence of sand dune machair in Ireland. Proceedings of the Royal Irish Academy Section B (Ireland) 85(1), 1-17.

Bakker, T.W.M., Klijn, J.A., & Zadelhoff, F.J. van, 1979. Duinen en duinvalleien - een landschapsecologische studie van het Nederlandse duingebied. Wageningen: PUDOC.

Bink, F.A., Meltzer, J., Molenaar, J.G. de, Rossum, T.A.W. van,& Saaltink, G.J., 1979. Levensgemeenschappen. Wageningen: PUDOC.

Boorman, L.A., 1977. Sand dunes. In: The Coastline, edited by R.S.K.Barnes, 161-197. Chichester: John Wiley.

Boorman, L.A., 1982. Some plant growth patterns in relation to the sand dune habitat. Journal of Ecology, 70, 607-614.

Boorman, L.A., & Fuller, R.M., 1977. Studies on the impact of paths on the dune vegetation at Winterton, Norfolk, England. Biological Conservation (England) 12(3), 203-216.

Boorman,L.A., & Fuller, R.M., 1982. Effects of added nutrients on dune swards grazed by rabbits. Journal of Ecology, 70, 345-355.

Boorman, L.A., & Fuller, R.M., 1983. The comparative ecology of two sand dune biennials: Lactuca virosa L. and Cynoglossum officinale L. New Phytologist, 69, 609-629.

Bullock, D.J., & Kinnear, P.K., 1988. The use of goats to control birch in dune systems: an experimental study. Aspects of Applied Biology, 16, 163-168.

Burggraaf-van Nierop, Y.D. & Meijden, E. van der, 1984. The influence of rabbit scrapes on dune vegetation. Biological Conservation, 30, 133-146.

Dickenson, G. & Randall, R.E., 1979. An interpretation of machair vegetation. Proceedings of the Royal Society of Edinburgh B, 77, 267-278.

Garson, P., 1985. Rabbit Grazing and the dune slack flora of Holy Island, Lindesfarne NNR. In: Sand dunes and their management. Focus on Nature Conservation No. 13, edited by P. Doody, 205-216. Peterborough: Nature Conservancy Council.

Gibson, C.W.D., Watt, T.A., & Brown, V.K., 1987. The use of sheep grazing to recreate species-rich grassland from abandoned arable land. Biological Conservation, 42, 165-183.

Goethart, I.W.C., Tesch, P., Hesselink, E., & Dijt, M., 1924. Cultuur en waterleidingbelangen, uittreksel uit het rapport inzake het verband tussen wateronttrekking plantengroei. Den Haag: Mededeling Rijksbosbouwproefstation.

Harris, D, & Davy, A.J., 1986. Strandline colonization by Elymus farctus in relation to sand mobility and rabbit grazing. Journal of Ecology, 74, 1045-1056.

Hewett, D.G., 1985. Grazing and mowing as management tools on dunes. Vegetatio, 62(1-3), 441-448.

Hobbs, R.J., & Grace, J., 1981. A study of pattern and processes in coastal vegetation using principal components analysis. Vegetatio, 44(3), 137-153.

Hope-Simpson, J., 1985. Monitoring by photographs on Braunton Burrows: relevance to nature conservation purposes. In: Sand dunes and their management. Focus on Nature Conservation No. 13. edited by P. Doody, 175-186. Peterborough: Nature Conservancy Council.

Hulsbos, K., 1974. In de duinen. Amsterdam: Elsevier.

Jones, R., & Etherington, J.R., 1971. Comparative studies of plant growth and distribution in relation to waterlogging. IV. The growth of dune and dune slack plants. Journal of Ecology, 59, 793-801.

Klinkhamer, P.G.L., & Jong , T.J. de, 1985. Shoot biomass and species richness in relation to some environmental factors in a coastal dune area in the Netherlands. Vegetatio, 63, 129-132.

Kutiel, P. & Danin, A., 1987. Annual species diversity and above ground phytomass in relation to some soil properties in the sand dunes of the Northern Sharon Plains, Israel. Vegetatio, 70, 45-59.

Laan, D. van der, 1978. Fluctuations and successional changes in the vegetation of wet dune slacks on Voorne. Phytocoenosis, 7, 105-117.

Leach, S., 1985. The problem of setting grazing levels on dune-heath Earlshall Muir - Fife. In: Sand dunes and their management. Focus on Nature Conservation No. 13. edited by P. Doody, 135-143. Peterborough: Nature Conservancy Council.

Londo, G., 1975. Nederlandse lijst van hydro- , phreato-, en afreatofyten. Leersum: Rijksinstituut voor Natuurbeheer.

Maarel, E. van der, 1979. Transformation of cover-abundance values in phytosociology and its effect on community similarity. Vegetatio, 39, 97-114.

Maarel, E. van der, 1981. Fluctuations in a coastal dune grassland due to fluctuation in rainfall: experimental evidence. Vegetatio, 47, 259-265.

Marrs, R.H., 1985. Scrub control. In: Sand dunes and their management. Focus on Nature Conservation No. 13. edited by P. Doody, 243-251. Peterborough: Nature Conservancy Council.

Oosterveld, P., 1981. Begrazing alsnatuurtechnische maatregel. Unpubl. ms.

Oosterveld, P., 1985. Grazing in dune areas: the objectives of nature conservation and the aims for research for nature conservation management. In: Sand dunes and their management. Focus on Nature Conservation No. 13. edited by P. Doody, 187-204. Peterborough: Nature Conservancy Council.

Ovington , J.D., 1971. The afforestation of Tentsmuir sands. Journal of Ecology, 39, 363-375.

Putman, R.J., 1986. Grazing in temperate ecosystems. Large herbivores and the ecology of the New Forest. London: Croome Helm.

Ranwell, D.S., 1960. Newborough Warren, Anglesey. III Changes in the vegetation on parts of the dune system after the loss of the rabbit by myxomatosis. Journal of Ecology, 48, 385-395.

Ranwell, D.S., 1972. Ecology of salt marshes and sand dunes. London: Chapman & Hall.

Ranwell, D.S., & Boar, R.R., 1986. Coast Dune Management Guide. Huntingdon: Institute of Terrestrial Ecology.

Rothwell, P., 1985. Management problems on Ainsdale Sand Dunes,National Nature Reserve. In: Sand dunes and their management. Focus on Nature Conservation No. 13. edited by P. Doody, 151-158. Peterborough: Nature Conservancy Council.

Shaw, M.W., 1985. Sand dunes in Scotland - the Scottish Coastal Survey. In: Sand dunes and their management. Focus on Nature Conservation No. 13. edited by P. Doody, 99-131. Peterborough: Nature Conservancy Council.

Sothern, E., Randerson, P. Williams, A., & Dixon, J., 1985. Ecological effects of recreation at Merthyr Mawr dunes, south Wales. In: Sand dunes and their management. Focus on Nature Conservation No. 13. edited by P. Doody, 151-158. Peterborough: Nature Conservancy Council.

Tansley, A.G., 1949. The British Isles and their vegetation. Cambridge University Press.

Wallage-Drees, J.M., 1987. Dag- en nacht-activiteit bij konijnen en de relevantie voor de telmethode. De Levende Natuur, 87(2), 40-46.

Watkins, E.E., 1973. A handbook for Ynyslas Nature Reserve in Cardiganshire. Aberystwyth: Nature Conservancy Council.

Webb, N., 1986. The New Naturalist - Heathlands. London: Collins

Wells, T.C.E., 1975. The floristic composition of chalk grassland in Wiltshire. In: Supplement to the Flora of Wiltshire, edited by Stearn, L.F., 99-125. Wiltshire Archaeological and Natural History Society.

Whittaker, R.H., 1975. Communities and Ecosystems. London: Macmillan.

Willis, A.J., Foulkes, B.F., Hope-Simpson, J.F., & Yemm, E.W., 1959. Braunton Burrows: the dune system and its vegetation - 2. Journal of Ecology, 47, 249-285.

Zeevalking, H.J., & Fresco, L.F.M., 1977. Rabbit grazing and species diversity in a dune area. Vegetatio, 35(3), 193-196.

10. Appendix tables

Introduction and notes

Appendix Tables 11.1 - 11.48 give a summary of the data from each quadrat recorded in the grazing survey.

The quadrat number consists of two components; the whole number is the site number (Table 3.2), the decimal part is the quadrat number for that site.

'Species' gives the number of species of vascular plants, bryophytes and lichens found in that quadrat.

'Height' refers to the height, in centimetres, of the vegetation and it is the mean of five values.

'Animal' is the species of grazing animal either visibly present or deduced to have been present by virtue of the occurance of droppings etc. The animals are coded 1 = horse, 2 = cattle, 3 = sheep, 6 = rabbit, 7 = hare, and are arranged in order of apparent significance of impact; brackets indicate that while there were no signs of that animal in the quadrat, there were signs within 50m.

'Signs' and 'impact' were both assessed on a scale 1-4 (Table 3.5)

'Habitat' indicates the habitat type of the quadrat concerned (yd = yellow dune, gr = dune grassland, ds = damp slack, ws = wet slack and dh = dune heath - see Table 3.6).

The date of the quadrat survey and other relevant information is given at the end of each table.

The tables are arranged in alphabetic order of the site name (Table 3.2).

Appendix Table 11.1

Aberffraw, Anglesey, Gwynedd

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
21.05	2	56.0	0	0	0	yd
21.10	3	62.0	6(6)	0	0	yd
21.15	8	33.4	6(2)	1	1	yd
21.01	20	2.2	6	1	2	gr
21.02	20	1.8	6	2	2	gr
21.03	23	5.8	6(2)	1	2	gr
21.06	23	2.6	6,7(2)	2	2	gr
21.07	17	1.2	6(2)	2	2	gr
21.08	16	26.0	6(2)	1	1	gr
21.09	23	3.6	6(2)	2	2	gr
21.11	29	4.2	6(2)	2	2	gr
21.12	22	4.0	6(2)	2	2	gr
21.17	23	3.0	2,6	2	2	gr
21.18	19	9.8	6,7,3	2	1	gr
21.19	23	7.8	6(7)	1	1	gr
21.13	10	14.6	6(2)	0	1	ds
21.16	23	5.2	6(2)	1	2	ds
21.14	20	4.6	6	2	2	ws

Quadrats recorded 20.05.85, 42 cows and their calves seen during visit, significant trampling erosion on dune tops.

Appendix Table 11.2

Aberlady Bay, East Lothian

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
7.01	8	39.6	(6)	0	0	yd
7.04	8	48.0	6	1	1	yd
7.08	7	40.2	6	2	0	yd
7.12	11	23.2	6	2	1	yd
7.21	7	49.6	(6)	0	0	yd
7.24	5	58.8	0	0	0	yd
7.28	6	47.4	6	1	1	yd
7.32	9	30.4	6	3	1	yd
7.02	13	2.4	6	2	2	gr
7.03	23	1.0	6	3	3	gr
7.05	15	1.2	6	1	3	gr
7.06	9	12.4	6	2	1	gr
7.07	22	1.8	6	3	3	gr
7.09	13	11.8	6	1	1	gr
7.10	28	2.0	6	3	3	gr
7.11	12	20.8	6	1	1	gr
7.13	10	6.8	6	2	2	gr
7.14	18	13.8	6	1	3	gr
7.15	11	7.2	6	1	2	gr
7.16	19	7.0	6	1	2	gr
7.22	13	1.2	6	2	2	gr
7.23	27	1.4	6	3	2	gr
7.25	21	1.6	6	2	2	gr
7.26	18	26.4	6	2	1	gr
7.27	21	2.2	6	1	2	gr
7.29	16	18.2	6	2	3	gr
7.30	17	12.4	6	2	1	gr
7.31	21	1.2	6	3	3	gr
7.33	20	3.8	6	2	2	gr
7.34	12	23.2	6	1	1	gr
7.35	13	10.6	6	2	2	gr
7.36	13	1.4	6	3	2	gr

Quadrats 7.1 - 7.16 recorded 16.05.85; quadrats 7.21 - 7.36 recorded 02.08.85. 12 rabbits seen during visit.

Appendix Table 11.3

Ainsdale, Lancashire

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
9.01	15	27.8	6	2	1	yd
9.06	8	23.6	6	3	1	yd
9.13	0	*	0	0	0	yd
9.04	23	3.8	6	2	3	gr
9.05	14	28.6	6	1	1	gr
9.07	18	9.8	6	2	2	gr
9.08	16	5.4	6	3	3	gr
9.09	19	4.4	6	2	2	gr
9.10	9	28.2	6	2	1	gr
9.14	17	3.6	6	4	3	gr
9.15	12	2.8	6	2	2	gr
9.03	14	31.4	(6)	0	0	ds
9.12	16	1.8	6	3	2	ds
9.02	14	13.2	(6)	0	0	ws
9.11	9	6.6	6	0	1	ws

Quadrats recorded 21.05.85

Appendix Table 11.4

Alnmouth, Northumberland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
39.04	5	53.8	0	0	0	yd
39.06	13	34.6	0	0	0	yd
39.09	11	58.4	0	0	0	yd
39.01	10	65.2	0	0	0	gr
39.02	7	86.2	0	0	0	gr
39.03	7	54.4	0	0	0	gr
39.05	9	53.2	0	0	0	gr
39.07	14	43.4	0	0	0	gr
39.08	15	29.8	0	0	0	gr

Quadrats recorded 01.8.85, site completely ungrazed.

Appendix Table 11.5

Bamburgh Links, Northumberland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
37.01	9	55.2	0	0	0	yd
37.03	10	47.8	0	0	0	yd
37.07	14	43.6	6	1	1	yd
37.02	15	34.4	0	0	0	gr
37.05	12	39.2	0	0	0	gr
37.06	11	54.0	0	0	0	gr
37.08	21	37.2	6	0	1	gr
37.04	8	63.8	0	0	0	ws

Quadrats recorded 31.07.85, no rabbits seen, vegetation all tall.

Appendix Table 11.6

Bar Point, St. Mary's, Isles of Scilly

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
1.01	10	50.0	6(1)	1	1	yd
1.02	7	57.0	(1)	0	0	yd
1.03	7	35.0	6	0	1	yd
1.04	13	14.8	6	1	1	yd
1.05	15	26.2	6	1	1	yd
1.06	4	57.4	0	0	0	yd
1.07	12	29.0	0	0	0	yd

Quadrats recorded 30.04.85, some damage from trampling and sand extraction.

Appendix Table 11.7

Braunton Burrows, Devon

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
12.01	13	17.4	(6)	0	0	yd
12.03	18	10.6	(6)	0	0	yd
12.08	6	*	(6)	0	0	yd
12.13	7	30.8	0	0	0	yd
12.18	8	28.8	(6)	0	0	yd
12.02	11	5.8	(6)	1	1	gr
12.04	18	13.2	(6)	0	0	gr
12.05	20	10.4	6	1	1	gr
12.06	15	3.2	6	1	1	gr
12.07	16	11.4	0	0	0	gr
12.09	8	28.0	(6)	0	0	gr
12.12	19	3.2	6	1	1	gr
12.14	21	17.0	6	1	1	gr
12.15	22	26.0	(6)	0	0	gr
12.16	26	13.0	(6)	0	0	gr
12.17	22	4.0	6	2	2	gr
12.19	21	8.6	6	2	2	gr
12.20	16	2.0	6	2	3	gr
12.21	16	13.4	(6)	0	0	gr
12.10	13	7.8	(6)	0	0	ds
12.11	18	11.8	6	1	1	ds
12.22	16	6.2	(6)	0	0	ws

Quadrats recorded 28.05.85, rabbit population less than formerly, site has signs of undergrazing.

Appendix Table 11.8

Breakon, Yell, Shetland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
27.01	6	30.0	6,3	3	1	yd
27.05	1	1.0	3,6	0	4	yd
27.07	6	30.0	6,3	2	1	yd
27.02	6	13.6	3,6	1	1	gr
27.03	10	5.8	3(6)	1	1	gr
27.04	6	1.0	6(3)	2	2	gr
27.06	14	1.0	6(3)	3	2	gr
27.08	11	1.2	3,6	1	2	gr
27.09	10	1.8	3,6	0	2	gr
27.10	10	1.0	3,6	1	2	gr
27.11	13	1.2	6,3	3	2	gr
27.12	9	1.0	6,3	3	2	gr

Quadrats recorded 10.07.85, quadrat 27.5 - Equisetum arvense dominant on area used as stamping ground by sheep.

Appendix Table 11.9

Brownslade Burrows, Dyfed

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
34.01	5	56.4	0	0	0	yd
34.05	10	44.8	0	0	0	yd
34.09	8	36.8	(6)	0	0	yd
34.13	17	37.2	6	2	2	yd
34.02	12	34.2	0	0	0	gr
34.03	11	42.6	(6)	0	0	gr
34.04	25	2.2	6	2	2	gr
34.06	18	3.6	6	1	2	gr
34.07	23	1.8	6	3	2	gr
34.08	21	2.6	6	3	2	gr
34.10	13	2.2	6	2	2	gr
34.12	18	1.4	6	2	2	gr
34.14	14	1.2	6	3	3	gr
34.15	10	1.8	6	3	2	gr
34.16	19	1.2	6	3	2	gr
34.11	15	60.6	0	0	0	ws

Quadrats recorded 24.07.85, 130 rabbits seen in area.

Appendix Table 11.10

Cabin Hill, Lancashire

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
10.03	13	6.4	2(6)	2	2	gr
10.04	16	7.4	2(6)	0	2	gr
10.06	18	4.4	2,6	1	2	gr
10.01	8	51.2	(6)	0	0	ds
10.05	10	41.2	(6)	0	0	ds
10.08	11	30.4	(6)	0	0	ds
10.09	13	29.2	2(6)	1	2	ds
10.02	14	26.6	2(6)	0	2	ws
10.07	13	6.0	2(6)	0	2	ws

Quadrats recorded 22.05.85, part of area winter grazed by 15 beasts.

Appendix Table 11.11

Conninghole, Sanday, Orkney

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
29.01	10	15.8	0	0	0	gr
29.02	12	5.0	2	0	1	gr
29.03	12	2.2	2	0	2	gr
29.04	14	1.8	2(6)	1	2	gr
29.05	12	2.0	2,6	1	2	gr
29.06	13	10.6	2,6	1	1	gr
29.07	10	8.6	2(6)	1	1	gr
29.08	16	9.6	6,2	3	2	gr
29.09	15	7.2	6(2)	1	2	gr
29.12	12	1.0	6	3	2	gr
29.13	14	2.8	6(2)	1	2	gr
29.14	20	1.4	6(2)	3	2	gr
29.15	17	1.2	6	3	2	gr
29.16	14	6.0	6	3	2	gr
29.10	11	6.0	2,6	1	2	ds
29.11	11	12.8	2,6	0	1	ds

Quadrats recorded 14.07.85, quadrats 29.8, 29.9, 29.10, 29.11 (14 Ha) winter grazed by 20 cattle (October - April). Formerly some sand extraction at this site but area recolonised.

Appendix Table 11.12

Druridge Bay, Northumberland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
38.07	3	78.6	0	0	0	yd
38.09	7	42.2	0	0	0	yd
38.01	12	31.2	2	1	3	gr
38.02	19	35.2	0	0	0	gr
38.03	13	41.6	(6)	0	0	gr
38.04	17	15.4	0	0	0	gr
38.05	11	40.0	0	0	0	gr
38.06	16	13.0	0	0	0	gr
38.08	16	28.6	0	0	0	gr
38.10	11	22.0	0	0	0	gr

Quadrats recorded 01.08.85. very little grazing, no animals seen. Area studied is the north end of the site (National Trust). south end not studied in detail but overgrazed and degraded.

Appendix Table 11.13

Earlshall Muir, Fife

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
8.04	7	54.8	0	0	0	yd
8.09	11	39.2	6	(6)	0	yd
8.01	13	23.2	6	2	1	gr
8.02	16	4.4	6	3	2	gr
8.03	14	5.8	6	3	1	gr
8.05	14	1.0	6	4	2	gr
8.10	15	2.2	6	2	2	gr
8.11	10	7.6	6	1	1	gr
8.12	13	14.2	6	0	1	gr
8.14	16	13.4	6	2	2	gr
8.18	16	11.4	6	1	1	gr
8.15	12	33.0	0	0	0	ws
8.06	11	5.4	6	3	2	dh
8.07	14	8.8	6	3	1	dh
8.08	12	5.6	6	2	2	dh
8.13	9	17.4	6	1	1	dh
8.16	15	31.2	0	0	0	dh
8.17	14	19.2	6	1	1	dh

Quadrats recorded 05.08.85. 11 rabbits seen during visit.

Appendix Table 11.14

Fidge, Sanday, Orkney

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
28.09	9	37.8	2,6	1	1	yd
28.01	13	3.6	3,6(2)	1	2	gr
28.02	13	4.2	3,6,2	0	2	gr
28.03	14	2.0	3,6(2)	1	2	gr
28.04	14	11.0	3(2,6)	1	2	gr
28.05	7	21.0	3,2,6	0	1	gr
28.06	14	2.6	3,6(2)	0	2	gr
28.07	18	2.0	3,6(2)	0	2	gr
28.08	17	3.4	3,6(2)	0	2	gr
28.10	15	2.2	6	2	2	gr
28.11	15	1.0	6	3	2	gr
28.12	19	1.8	6	1	2	gr
28.13	12	1.4	2,6	0	2	gr
28.14	8	40.0	2,6	2	1	gr
28.15	21	4.4	2,6	1	2	gr
28.16	13	10.4	6	1	2	gr
28.17	16	3.4	6	2	3	gr
28.18	14	2.8	6	2	2	gr
28.19	18	1.0	6	2	2	gr
28.20	18	2.8	6	1	2	gr

Quadrats recorded 13.07.85, quadrats 28.1 -28.8 in area used as golf course and grazed by 100+ sheep, 50+ rabbits seen in whole area during visit.

Appendix Table 11.15

Forvie, Aberdeenshire

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
48.01	7	48.0	6	1	1	yd
48.02	19	8.2	6	2	2	gr
48.04	9	18.4	6	0	0	gr
48.09	9	25.0	6	0	0	gr
48.10	17	2.8	6	0	2	gr
48.14	8	3.2	6	2	2	ds
48.03	13	3.4	6	1	2	dh
48.05	12	5.4	6	3	1	dh
48.06	4	33.6	0	0	0	dh
48.07	10	18.6	6	1	0	dh
48.08	11	24.0	6	1	1	dh
48.11	7	13.0	0	0	0	dh
48.12	6	10.6	0	0	0	dh
48.13	9	30.2	0	0	0	dh

Quadrats recorded 21.08.87, 15 rabbits seen during visit.

Appendix Table 11.16

Gibraltar Point, Lincolnshire

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
22.01	10	22.4	6	3	3	yd
22.02	14	4.2	6	2	3	gr
22.03	13	3.4	6	2	2	gr
22.04	11	40.4	(6)	0	0	gr
22.05	10	25.4	6	1	3	gr
22.06	16	3.2	6	2	3	gr
22.07	8	33.4	(6)	0	0	gr
22.08	8	4.4	6	2	2	gr
22.10	8	51.4	6	1	3	gr
22.16	15	15.6	6	2	1	gr
22.17	21	11.0	6	3	2	gr
22.19	13	24.8	6	2	1	gr
22.20	13	4.4	6	3	2	gr

Quadrats recorded 26.06.85. 200+ rabbits seen during visit.

Appendix Table 11.17

Great Bay, St. Martin's, Isles of Scilly

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
3.02	11	39.0	0	0	0	yd
3.06	3	52.0	0	0	0	yd
3.09	6	34.0	0	0	0	yd
3.10	11	24.0	6	1	1	yd
3.13	5	45.4	0	0	0	yd
3.14	17	24.4	6	1	1	yd
3.01	18	15.8	6	1	1	gr
3.03	21	2.2	6	3	3	gr
3.07	31	1.4	6	3	3	gr
3.11	14	1.0	6	3	3	gr
3.15	19	1.0	6	3	3	gr
3.16	16	1.0	6	3	3	gr
3.02	11	39.0	0	0	0	dh
3.06	3	52.0	0	0	0	dh
3.09	6	34.0	0	0	0	dh
3.10	11	26.0	6	1	1	dh
3.13	5	45.4	0	0	0	dh
3.14	17	24.4	6	1	1	dh

Quadrats recorded 02.05.85

Appendix Table 11.18

Herm, Channnel Islands

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
47.02	9	1.0	6	2	3	yd
47.01	11	4.8	6	2	2	gr
47.03	13	8.6	6	2	1	gr
47.04	13	1.0	6	3	2	gr
47.07	20	12.2	6	3	2	gr
47.08	4	12.2	6	0	1	gr
47.09	13	3.4	6	3	3	gr
47.10	13	1.0	6	2	3	gr
47.11	6	1.0	6	2	2	gr
47.13	10	1.0	6	2	2	gr
47.14	13	3.4	6	1	2	gr

Quadrats recorded 01.10.86. 4 rabbits seen during visit.

Appendix Table 11.19

Holkham, Norfolk

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
4.02	20	4.0	6	1	1	yd
4.09	2	34.6	0	0	0	yd
4.12	16	22.2	(6)	0	0	yd
4.13	9	6.4	2	1	4	yd
4.14	12	50.0	(6)	0	0	yd
4.25	19	8.8	2,6	1	3	yd
4.26	15	12.0	2,6	1	1	yd
4.01	17	28.4	(6)	0	0	gr
4.03	17	4.2	6	0	2	gr
4.04	12	30.2	0	0	0	gr
4.05	19	2.4	6	1	1	gr
4.06	14	16.2	6	1	1	gr
4.08	14	15.4	(6)	0	0	gr
4.10	16	1.2	6	2	3	gr
4.11	16	3.6	6	1	1	gr
4.15	19	19.6	(6)	0	0	gr
4.16	20	4.0	6	1	1	gr
4.17	20	5.4	6	1	1	gr
4.18	23	2.8	6	1	2	gr
4.20	23	7.4	2(6)	0	2	gr
4.21	17	20.8	6	3	2	gr
4.22	17	3.2	6	1	1	gr
4.24	15	3.4	6	2	2	gr
4.19	11	14.6	2(6)	1	1	ds

Quadrats recorded 07 & 10.06.85. rabbit population nas fallen compared with what it was ten years ago. Quadrats 13, 19, 20, 25 and 26 are inside cattle grazed area.

Appendix Table 11.20

Kenfig Burrows, Glamorgan

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
17.01	10	13.6	(3,)	0	0	yd
17.13	9	16.0	(6)	0	0	yd
17.02	30	7.8	(6)	2	1	gr
17.04	20	20.2	3,7(6)	1	0	gr
17.05	24	24.8	3	1	1	gr
17.06	12	8.8	3	0	1	gr
17.09	28	14.8	3	1	1	gr
17.10	13	15.8	(3)	0	0	gr
17.15	16	12.2	7(1)	1	0	gr
17.16	12	42.0	0	0	0	gr
17.03	31	25.4	6(3)	2	1	ds
17.08	16	22.6	0	0	0	ds
17.14	12	25.8	0	0	0	ds
17.07	13	14.0	(3)	0	0	ws
17.11	17	15.4	(3,6,7)	0	0	ws
17.12	15	43.2	0	0	0	ws

Quadrats recorded 13.06.85. quadrat 17.09 burnt previous year.

Appendix Table 11.21

Kilpaison Burrows, Dyfed

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
32.01	6	46.8	0	0	0	yd
32.06	3	60.6	0	0	0	yd
32.09	5	51.2	(6)	0	0	yd
32.12	7	49.4	0	0	0	yd
32.16	11	24.4	0	0	0	yd
32.17	13	39.0	(6)	0	0	yd
32.02	13	28.6	0	0	0	gr
32.03	16	2.0	6(2)	0	2	gr
32.04	15	8.6	6	1	2	gr
32.05	19	2.8	2,6	0	2	gr
32.07	11	19.0	0	0	0	gr
32.08	17	2.8	6(2)	2	2	gr
32.10	18	2.6	6(2)	1	2	gr
32.11	9	53.2	0	0	0	gr
32.13	16	2.8	2,6	0	2	gr
32.15	18	2.0	2	0	2	gr
32.18	12	4.6	2,6	0	2	gr
32.19	13	2.6	2,6	0	2	gr
32.20	16	2.6	2,6	0	2	gr

Quadrats recorded 23.07.85. Extensive sand extraction within these dunes. No rabbits seen on this site but at least 10 cows to east of fence

Appendix Table 11.22

Levenwick, Shetland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
43.01	10	50.4	0	0	0	yd
43.06	8	2.8	3	1	2	yd
43.07	11	54.2	0	0	0	yd
43.02	7	9.2	3	1	1	gr
43.03	10	39.0	0	0	0	gr
43.04	8	1.6	3	1	2	gr
43.05	9	30.0	0	0	0	gr
43.08	12	5.0	3	1	1	gr

Quadrats recorded 21.07.86. 3 rabbits seen on this site, narrow strip of dune with improved machair behind.

Appendix Table 11.23

Lindesfarne, Northumberland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
35.01	10	22.0	(6)	0	0	yd
35.03	19	21.8	6	2	1	yd
35.11	19	23.6	6	1	1	yd
35.05	19	1.8	6	3	2	gr
35.06	14	4.4	6	3	2	gr
35.07	14	11.8	6	1	1	gr
35.08	13	29.6	(6)	0	0	gr
35.09	11	32.8	(6)	0	0	gr
35.12	7	27.8	0	0	0	gr
35.13	18	7.0	6	2	2	gr
35.15	18	11.4	6	3	2	gr
35.02	10	14.2	(6)	1	0	ds
35.04	12	7.4	(6)	0	0	ws
35.10	18	11.8	6	1	1	ws
35.14	20	12.0	6	0	1	ws

Quadrats recorded 30.07.85, 12 rabbits seen during visit.

Appendix Table 11.24

Llangennith Burrows, Glamorgan

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
19.02	2	*	0	0	0	yd
19.06	9	41.0	0	0	0	yd
19.10	3	50.4	0	0	0	yd
19.11	11	11.0	0	0	0	yd
19.01	8	38.6	0	0	0	gr
19.03	21	5.4	0	0	0	gr
19.04	18	3.0	3	1	1	gr
19.05	15	50.0	(7)	0	0	gr
19.08	22	6.6	0	0	0	gr
19.09	20	3.2	(6)	0	0	gr
19.12	16	7.4	0	0	0	gr
19.14	18	9.0	(6)	0	0	gr
19.15	7	31.4	0	0	0	gr
19.16	14	26.8	0	0	0	gr
19.17	17	1.6	6	1	2	gr
19.07	14	6.0	0	0	0	ds
19.18	19	18.6	(6)	0	0	ds

Quadrats recorded 14.06.85, site appears to have a higher grazing intensity than formerly, scattered rabbit 'lawns' with taller vegetation.

Appendix Table 11.25

Morfa Dyffryn, Gwynedd

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
14.01	7	26.0	6	2	3	yd
14.08	6	10.8	6	2	3	yd
14.09	13	1.6	6	3	3	yd
14.10	3	35.6	6	1	0	yd
14.14	11	2.0	6	2	1	yd
14.15	1	52.8	6	1	0	yd
14.16	7	44.6	6	1	1	yd
14.17	3	47.6	6	1	1	yd
14.03	11	3.0	6	3	3	gr
14.04	15	4.0	6	3	2	gr
14.06	18	2.6	6	3	3	gr
14.12	20	1.2	2,6	1	2	gr
14.18	19	4.8	2,6	1	2	gr
14.02	6	2.0	6	2	2	ds
14.05	11	10.2	6	1	1	ds
14.07	12	9.4	6	1	1	ds
14.11	12	36.2	6	1	1	ds

Quadrats recorded 04.06.85

Appendix Table 11.26

Morfa Harlech, Gwynedd

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
15.01	21	25.0	6	2	3	yd
15.14	8	28.0	6	1	3	yd
15.02	21	4.0	2,6	1	2	gr
15.04	19	5.8	2,6	1	2	gr
15.05	15	4.0	(6)2	0	2	gr
15.07	16	18.0	6	3	3	gr
15.08	18	4.4	2,6	0	2	gr
15.09	21	3.2	2,6	0	2	gr
15.11	12	29.2	6(2)	1	1	gr
15.12	15	9.6	6	3	2	gr
15.15	19	8.0	6,2	2	2	gr
15.03	17	14.6	2	1	2	ds
15.06	9	4.2	(6)	0	2	ds
15.10	6	34.4	6	1	1	ws
15.13	13	7.2	6	2	1	ws

Quadrats recorded 05.06.85

Appendix Table 11.27

Newborough Warren, Anglesey, Gwynedd

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
20.01	8	24.6	(6)	0	0	yd
20.06	8	35.2	0	0	0	yd
20.11	6	41.0	0	0	0	yd
20.16	9	51.0	0	0	0	yd
20.02	22	8.6	(6)	0	0	gr
20.03	14	22.2	0	0	0	gr
20.04	15	5.6	6	1	1	gr
20.08	16	9.8	(6)	0	0	gr
20.10	19	3.0	6	2	2	gr
20.12	18	16.2	0	0	0	gr
20.14	8	17.0	(6)	0	0	gr
20.17	21	69.4	0	0	0	gr
20.18	9	21.4	0	0	0	gr
20.20	9	27.8	0	0	0	gr
20.05	17	17.4	(6)	0	0	ds
20.07	21	3.8	6	1	1	ds
20.09	9	7.8	6	0	1	ds
20.13	14	17.6	(6)	0	0	ds
20.15	10	34.4	0	0	0	ds
20.19	12	3.8	0	0	0	ws
20.21	23	4.6	3	2	2	ws

Quadrats recorded 18.06.85, quadrat 20.21 within experimental sheep grazing enclosure.

Appendix Table 11.28

Newton Links, Northumberland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
40.01	7	52.8	0	0	0	yd
40.04	8	45.0	0	0	0	yd
40.06	8	54.4	0	0	0	yd
40.08	7	41.2	0	0	0	yd
40.02	17	22.8	6	0	1	gr
40.03	12	32.8	0	0	0	gr
40.05	14	29.0	6	2	1	gr
40.07	12	37.4	0	0	0	gr

Quadrats recorded 01.08.85, some signs of former cattle grazing.

Appendix Table 11.29

North Walney, Cumbria

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
23.01	8	7.8	6	1	1	yd
23.02	14	26.2	6	1	1	yd
23.08	8	30.6	(6)	0	0	yd
23.03	23	10.2	6	1	1	gr
23.04	11	18.0	6	1	1	gr
23.05	16	11.0	6	2	1	gr
23.06	22	6.2	6	1	1	gr
23.07	7	26.6	(6)	0	0	gr
23.09	13	26.2	0	0	0	gr
23.10	19	3.6	6	2	1	gr
23.11	7	60.0	0	0	0	gr
23.12	11	15.6	0	0	0	gr
23.13	8	33.0	0	0	0	gr
23.17	6	32.0	0	0	0	ds
23.15	6	16.8	(6)	0	0	dh
23.16	7	15.6	(6)	0	0	dh

Quadrats recorded 02.07.85, area very lightly grazed by rabbits.

Appendix Table 11.30

Oxwich, Glamorgan

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
18.01	7	18.8	0	0	0	yd
18.05	6	32.0	0	0	0	yd
18.07	4	26.6	0	0	0	yd
18.02	14	21.2	0	0	0	gr
18.03	5	26.6	0	0	0	gr
18.06	16	5.6	0	0	0	gr
18.08	15	34.2	0	0	0	gr
18.09	12	16.2	0	0	0	gr
18.10	12	19.2	0	0	0	gr
18.11	20	5.6	0	0	0	gr
18.12	21	20.6	0	0	0	gr
18.13	12	11.2	0	0	0	gr
18.14	11	12.0	0	0	0	gr
18.15	14	18.4	0	0	0	gr
18.16	11	26.8	0	0	0	gr
18.17	8	23.6	0	0	0	gr
18.04	8	33.4	0	0	0	ws

Quadrats recorded 14.06.85, whole area under heavy public pressure except enclosed area (quadrats 18.10 and 18.14). Some rabbit grazing to the south of areas recorded.

Appendix Table 11.31

Pentle Bay, Tresco, Isles of Scilly

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
2.01	5	17.2	0	0	0	yd
2.02	19	8.6	6	1	1	yd
2.04	13	38.6	6	2	3	yd
2.05	10	32.0	6	1	1	yd
2.09	4	56.6	0	0	0	yd
2.10	14	51.0	6	0	0	yd
2.13	7	79.0	0	0	0	yd
2.15	9	65.0	0	0	0	yd
2.03	20	7.0	6	4	4	gr
2.06	9	*	6	1	1	gr
2.16	10	10.0	0	0	0	gr
2.07	15	2.0	6	4	3	dh
2.08	12	6.4	6	1	2	dh
2.11	17	1.8	6	2	3	dh
2.12	10	7.0	6	1	1	dh
2.14	11	7.2	6	0	0	dh

Quadrats recorded 01.05.85

Appendix Table 11.32

Quendale, Shetland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
26.01	5	36.0	0	0	0	yd
26.06	4	48.6	0	0	0	yd
26.11	9	41.0	0	0	0	yd
26.16	6	45.2	0	0	0	yd
26.02	12	4.6	3(6)	2	2	gr
26.03	12	8.4	3,6	1	2	gr
26.04	15	6.0	3	0	2	gr
26.05	12	14.4	3(6)	1	1	gr
26.07	17	2.8	3(6)	1	2	gr
26.08	21	2.0	3(6)	0	2	gr
26.09	15	3.6	3(6)	1	2	gr
26.10	15	1.8	6,3	2	2	gr
26.12	16	2.4	6(3)	2	2	gr
26.13	16	2.8	3(6)	1	2	gr
26.14	13	2.2	3(6)	2	2	gr
26.15	12	1.0	3,6	2	2	gr
26.17	18	4.4	3(6)	1	2	gr

Quadrats recorded 09.07.85, rabbits very abundant, forty seen during visit including some brown and white ones; area to west is semi-improved and grazed by sheep and ponies; seaward quadrats less heavily grazed by both sheep and rabbits (quadrats 26.1 - 26.3, 26.6, 26.7, 26.11, 26.12, 26.16 and 26.17).

Appendix Table 11.33

Quennevais, Jersey, Channel Islands

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
46.04	11	1.6	6	2	3	yd
46.06	8	1.4	6	3	3	yd
46.07	12	28.8	6	1	1	yd
46.08	7	42.0	6	0	0	yd
46.09	12	46.8	6	2	1	yd
46.11	11	5.6	6	3	1	yd
46.12	9	2.2	6	2	3	yd
46.01	18	1.2	6	3	2	gr
46.02	15	1.6	6	3	3	gr
46.03	18	1.0	6	3	3	gr
46.05	12	8.6	6	1	1	gr
46.10	10	2.0	6	4	3	gr
46.13	12	5.6	6	2	2	gr
46.14	10	3.8	6	2	3	gr
46.20	15	1.0	6	1	3	gr

Quadrats recorded 30.09.86

Appendix Table 11.34

Ross Links, Northumberland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
36.05	13	57.4	(6)	0	0	yd
36.06	15	41.8	(6)	0	0	yd
36.09	6	70.6	(6)	0	0	yd
36.15	9	38.4	(2)	0	0	yd
36.01	6	68.2	0	0	0	gr
36.02	19	24.8	(2)3	1	1	gr
36.03	18	4.0	3,6	1	2	gr
36.04	16	11.4	2	1	1	gr
36.08	8	9.8	3	1	2	gr
36.10	18	16.2	0	0	0	gr
36.12	11	16.2	2	0	1	gr
36.14	14	13.6	6,2	3	2	gr
36.16	14	17.6	2	0	1	gr
36.07	16	18.0	(2)	0	0	ds
36.11	6	30.2	0	0	0	ds

Quadrats recorded 31.07.85. 250 Ha winter grazed by 400 cattle and 300 sheep with supplimentary feeding, lightly cattle grazed in the summer.

Appendix Table 11.35

St. Cyrus, Aberdeenshire

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
41.01	7	53.6	6	1	0	yd
41.04	7	53.6	6	2	1	yd
41.07	5	58.8	6	3	1	yd
41.08	11	15.8	6	3	3	yd
41.10	4	86.0	6	2	0	yd
41.12	11	31.2	6	3	1	yd
41.02	15	18.0	6	3	3	gr
41.03	17	50.6	0	0	0	gr
41.05	17	20.8	6	3	1	gr
41.09	6	19.0	6	3	2	gr
41.11	20	32.0	6	2	1	gr
41.13	12	35.6	0	0	0	gr

Quadrats recorded 03.08.85

Appendix Table 11.36

St. Ninian's, Shetland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
45.04	8	49.4	0	0	0	yd
45.07	4	18.2	0	0	0	yd
45.01	9	30.8	0	0	0	gr
45.02	11	47.6	0	0	0	gr
45.05	11	24.2	0	0	0	gr
45.08	8	4.8	0	0	0	gr

Quadrats recorded 21.07.86, foredune communities damaged by beach vehicles.

Appendix Table 11.37

Saltfleetby, Lincolnshire

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
13.01	14	20.0	(3)	0	1	gr
13.02	13	20.2	(3)	0	1	gr
13.03	22	14.4	(3)	0	2	gr
13.07	16	19.4	(3,6)	0	1	gr
13.08	14	3.0	(3)6	2	2	gr
13.09	14	11.8	(3)6	2	1	gr
13.10	9	19.2	(3)6	2	1	gr
13.11	18	2.6	(3)6	2	2	gr
13.04	7	21.2	(2,3)	0	1	gr
13.05	11	22.0	(2,3)	0	1	gr
13.06	13	22.2	(2,3)	0	1	gr
13.12	14	10.0	(2,3)6	1	1	gr
13.13	17	19.6	(2,3,6)	0	1	gr
13.15	19	9.8	(2)6	1	1	gr
13.16	22	18.6	(2)6	1	1	gr
13.18	18	17.8	(2)6	1	1	gr
13.19	18	9.4	(2)6	1	1	gr
13.21	11	31.6	0	0	0	gr
13.22	6	43.6	0	0	0	gr
13.24	13	35.6	0	0	0	gr
13.25	5	62.6	(6)	0	0	gr
13.26	7	31.4	0	0	0	gr
13.27	7	33.6	(6)	0	0	gr
13.14	5	52.4	(2,3)	0	1	ws
13.17	3	61.4	(3)	0	1	ws
13.20	5	45.4	(3)	0	1	ws
13.23	3	62.6	0	0	0	ws

Quadrats recorded 31.05.85, quadrats 13.1 - 13.3 & 13.7 - 13.11 sheep grazed, quadrats 11.4 - 11.6, 11.12 & 11.13 sheep and cattle grazed, quadrats 11.15, 11.16, 11.18 & 11.19 cattle grazed and quadrats 11.21, 11.22, 11.24 - 11.27 ungrazed.

Appendix Table 11.38

Sandscale, Cumbria

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
24.06	7	2.2	0	0	0	yd
24.10	4	41.2	(2)	0	0	yd
24.01	10	8.0	(6,2)	0	0	gr
24.02	8	9.0	3(6)	1	0	gr
24.03	16	18.2	(6,2)	0	0	gr
24.07	20	26.0	6,2	2	1	gr
24.11	17	*	2,3,6	0	2	gr
24.13	16	3.0	2(3)	1	2	gr
24.14	18	3.2	2(3,4)	1	2	gr
24.15	10	3.0	2,3,6	1	3	gr
24.16	22	1.6	6,3(2)	2	2	gr
24.17	9	7.2	0	0	0	gr
24.18	16	2.2	6	3	3	gr
24.19	15	2.2	6,3	1	3	gr
24.20	25	3.0	2	1	2	gr
24.04	15	29.6	(2,3)	0	0	ds
24.05	16	6.4	6(3)	0	1	ds
24.08	17	10.6	3(6)	1	1	ds
24.09	19	5.6	6(3)	1	2	ds
24.12	14	5.0	2(3,6)	0	2	ws

Quadrats recorded 03.07.85, area winter grazed by 30 - 40 cattle, at time of visit (July) 70 cattle and 32 sheep seen, cattle normally kept off the higher outer dunes by ring fence.

Appendix Table 11.39

Scolt Head, Norfolk

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
42.01	3	33.8	0	0	0	yd
42.03	11	10.0	0	0	0	yd
42.04	16	19.6	6	0	0	yd
42.11	10	18.6	6	0	0	yd
42.13	4	46.6	6	1	1	yd
42.14	3	19.4	6	1	1	yd
42.15	4	21.6	0	0	0	
42.02	13	12.0	6	2	1	gr
42.05	9	21.0	6	0	0	gr
42.06	10	33.0	0	0	0	gr
42.07	4	18.0	6	1	1	gr
42.08	19	3.2	6	1	1	gr
42.09	20	15.8	6	1	1	gr
42.10	14	13.4	0	0	0	gr
42.12	8	22.8	0	0	0	gr
42.16	11	27.4	6	0	0	gr

Quadrats recorded 27.05.86.

Appendix Table 11.40

Scousburgh, Shetland

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
44.01	7	61.2	0	0	0	yd
44.04	7	74.2	0	0	0	yd
44.07	7	43.6	0	0	0	yd
44.10	11	45.8	3	0	1	yd
44.02	16	3.4	6	1	2	gr
44.03	11	3.4	6	1	2	gr
44.05	10	8.4	3(6)	0	0	gr
44.06	14	4.0	3(6)	6	1	gr
44.08	13	2.4	3(6)	2	2	gr
44.11	11	8.6	3	2	1	gr

Quadrats recorded 21.07.86. 7 rabbits and one hare seen on this site.

Appendix Table 11.41

South Walney, Cumbria

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
25.01	9	7.2	6(2)	3	2	gr
25.02	6	7.2	6,2	3	3	gr
25.03	10	5.4	3	0	2	gr
25.04	16	2.2	3(2)	1	2	gr
25.05	5	17.6	2,6	0	2	gr
25.06	7	39.6	6(3)	1	1	gr
25.07	11	6.0	6,2(3)	2	1	gr
25.08	7	20.0	6(2,3)	1	1	gr
25.09	15	18.4	(3,6)	0	0	gr
25.10	8	26.4	6(2)	3	3	gr
25.11	8	30.6	6	3	3	gr
25.12	10	23.8	6	2	2	gr
25.14	6	34.2	6(2)	3	1	gr
25.15	13	9.8	6(2)	2	2	gr
25.16	17	6.2	6,3(2)	2	3	gr
25.17	11	1.4	6	3	2	gr

Quadrats recorded 04.07.85, area grazed by 70 cows and followers and 200 sheep May - July. Vegetation strongly affected by the very high numbers of nesting gulls present.

Appendix Table 11.42

Stackpole, Dyfed

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
33.07	8	38.6	6	2	2	yd
33.01	23	1.6	6(3)	3	2	gr
33.02	25	1.0	6	3	3	gr
33.03	22	1.0	6	3	2	gr
33.04	15	39.4	6	4	2	gr
33.05	13	51.2	6	2	1	gr
33.06	12	90.4	6	1	0	gr
33.08	16	1.4	6	3	2	gr
33.09	11	6.2	6	2	3	gr
33.10	20	3.8	6	3	2	gr
33.11	10	25.6	6	2	3	gr
33.12	6	45.6	6	2	1	gr
33.13	14	15.4	6	2	2	gr
33.14	17	4.6	6	2	2	gr
33.15	16	1.0	6	3	3	gr
33.16	20	10.6	6	3	2	gr

Quadrats recorded 24.07.85. 40 rabbits seen during visit, marked contrast between areas with tall bracken and areas with closely grazed grassland and no bracken.

Appendix Table 11.43

Strathbeg, Aberdeenshire

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
31.01	2	49.6	6	1	0	yd
31.05	3	44.0	(6)	0	0	yd
31.09	2	70.0	6	1	0	yd
31.13	2	56.8	6	2	1	yd
31.21	4	31.0	6	3	1	yd
31.24	3	59.0	6	1	0	yd
31.02	16	2.0	6(3)	2	2	gr
31.03	16	9.6	6,3	1	2	gr
31.04	17	2.2	6(3)	1	2	gr
31.06	18	17.4	6	2	1	gr
31.07	16	2.6	6(3)	3	2	gr
31.08	13	3.4	6(3)	2	2	gr
31.10	13	1.8	6(3)	3	2	gr
31.11	17	2.6	6(3)	2	2	gr
31.14	9	2.0	6	2	2	gr
31.15	15	1.0	6(3,2)	2	2	gr
31.22	15	8.6	6	2	2	gr
31.23	21	1.8	6	1	2	gr
31.24	14	8.8	6	1	1	gr
31.25	16	3.6	6	2	2	gr
31.26	15	2.4	6(2)	1	2	gr
31.28	10	7.2	6	2	1	gr
31.29	11	3.4	6	1	2	gr
31.30	12	5.4	6(3)	1	2	gr
31.31	14	2.0	6(3)	3	2	gr
31.12	26	3.2	3,6	0	2	ds
31.16	21	5.4	6(3,2)	1	2	ds
31.17	19	7.4	3(6,2)	1	1	ds

Quadrats 31.1 - 31.17 recorded 18.07.85, 150 rabbits and 50+ sheep seen during visit, quadrats 31.21 - 31.31 recorded 20.8.87,15 rabbits seen in half of area.

Appendix Table 11.44

Studland, Dorset

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
5.01	10	33.8	6	1	1	yd
5.06	7	41.0	6	2	1	yd
5.09	6	45.4	6	1	1	yd
5.12	9	2.0	6	0	2	yd
5.15	4	6.4	6	1	1	yd
5.02	4	73.0	0	0	0	dh
5.04	3	27.6	(6)	0	0	dh
5.05	6	33.4	0	0	0	dh
5.07	6	22.0	6	1	1	dh
5.10	9	46.4	(6)	0	0	dh
5.13	9	35.2	(6)	0	0	dh
5.14	5	43.0	0	0	0	dh
5.16	4	39.4	(6)	0	0	dh
5.17	4	49.0	0	0	0	dh

Quadrats recorded 09.05.85. heavy public pressure affects many parts of this site especially to north and east.

Appendix Table 11.45

Tentsmuir, Fife

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
6.01	7	16.4	6	2	1	yd
6.02	9	8.8	6	3	1	yd
6.07	10	21.6	6	1	1	yd
6.10	17	20.8	(6)	0	0	yd
6.13	11	32.6	(6)	0	0	yd
6.15	10	41.0	(6)	0	0	yd
6.03	17	10.4	6	2	1	gr
6.04	16	1.4	6	4	2	gr
6.11	17	1.6	6	2	1	gr
6.16	17	14.8	6	2	1	gr
6.05	11	5.4	6	2	2	ds
6.06	12	11.4	(6)	0	0	ds
6.08	10	12.0	6	3	3	ds
6.09	17	7.4	6	2	2	ds
6.14	7	9.6	6	1	1	ds

Quadrats recorded 14.05.85, sometimes difficult to assess impact of rabbits because of extensive moss and lichen communities, experimental grazing with goats at this site.

Appendix Table 11.46

Whiteford Burrows, Glamorgan

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
16.12	13	21.6	1(2,6)	0	1	yd
16.01	16	12.2	6(1)	1	1	gr
16.03	17	12.2	6,1	3	1	gr
16.04	16	29.2	6,3(1)	2	2	gr
16.06	12	16.6	1,6(3)	1	0	gr
16.07	12	26.2	6(1)	1	1	gr
16.10	20	8.0	3,1,6,2	1	2	gr
16.14	18	11.2	1(6)	0	1	gr
16.15	12	7.6	1(2,6)	1	2	gr
16.16	17	8.0	3,6(1)	0	1	gr
16.17	9	11.0	(1)	0	0	gr
16.02	15	13.4	6(1)	2	1	ds
16.05	15	9.6	1(6)	1	1	ds
16.09	22	8.6	6(1)	1	1	ds
16.11	12	1.2	6(3,1)	4	2	ds
16.13	15	29.4	1(6)	1	1	ds
16.18	18	7.8	1	0	1	ds
16.08	7	5.2	6,1	1	2	ws

Quadrats recorded 12.06.85. difficult to assess relative importance of the different grazing animals but in 1983 there were 64 ponies, 33 sheep and no cattle; at time of this survey rabbits and ponies were dominant in different areas.

Appendix Table 11.47

Whitemills, Sanday, Orkney

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
30.13	7	*	6	2	2	yd
30.01	7	45.2	6	2	1	gr
30.03	18	2.6	6	1	2	gr
30.04	12	6.6	6(2)	0	1	gr
30.05	10	1.4	6(2)	3	2	gr
30.06	11	2.4	6,2	3	2	gr
30.07	10	5.2	6(2)	3	2	gr
30.08	11	1.0	6	3	2	gr
30.09	15	9.0	6	3	1	gr
30.10	16	11.0	6	2	1	gr
30.11	12	2.6	6	3	2	gr
30.14	13	1.0	6	3	3	gr
30.15	14	10.2	6	1	1	gr
30.16	10	2.2	6	3	2	gr
30.17	10	2.6	6	1	2	gr
30.02	16	3.2	6	2	2	ds
30.12	12	15.8	0	0	0	ds

Quadrats recorded 15.07.85

Appendix Table 11.48

Winterton, Norfolk

Quadrat No.	Species	Height	Animal	Signs	Impact	Habitat
11.01	7	20.6	6	2	1	yd
11.04	5	33.0	(6)	0	0	yd
11.07	3	3.0	6	1	3	yd
11.10	6	11.2	6	2	1	yd
11.11	6	22.4	6	1	1	yd
11.13	8	12.8	6	1	1	yd
11.15	10	5.2	6	2	1	yd
11.16	5	8.8	6	1	1	yd
11.17	3	4.8	6	1	0	yd
11.21	7	42.2	6	1	1	yd
11.25	2	31.6	(6)	0	0	yd
11.29	3	44.4	6	1	1	yd
11.30	4	25.0	(6)	0	0	yd
11.32	4	4.2	6	1	1	yd
11.34	4	42.8	6	1	0	yd
11.37	3	2.6	6	0	1	yd
11.38	5	28.8	(6)	0	0	yd
11.03	8	3.8	6	4	2	gr
11.05	9	8.0	6	3	3	gr
11.08	7	10.4	6	2	1	gr
11.12	4	16.0	(6)	0	0	gr
11.14	8	4.0	6	1	1	gr
11.23	5	3.6	6	2	2	gr
11.26	6	20.8	(6)	0	0	gr
11.28	5	2.8	6	2	1	gr
11.33	7	19.0	6	1	0	gr
11.35	8	4.4	(6)	0	0	gr
11.36	7	11.0	(6)	0	0	gr
11.02	7	28.0	6	0	0	dh
11.06	6	8.0	6	1	1	dh
11.09	5	12.2	6	1	1	dh
11.18	5	20.2	6	0	0	dh
11.19	11	15.4	6	1	1	dh
11.22	7	7.2	6	1	2	dh
11.24	7	12.2	6	1	2	dh
11.27	6	26.0	6	1	1	dh
11.31	5	12.4	6	0	1	dh

Quadrats 11.1 - 11.19 recorded 23.05.85. quadrats 11.21 - 11.38 recorded 08.08.85