The Effect of Herbivore Grazing on Grassland Diversity in Longis Common, Alderney

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ABSTRACT

The Channel Island of Alderney is known for its diverse grassland plant species. However, in recent years, reduced land management of the farm-cultivated landscape of Alderney has lead to a reversion to a more natural state. Longis Common is a species-rich calcareous grassland in the process of being gradually degenerated into scrubland of bracken and bramble. The long-term management priorities of the Island by the Alderney Wildlife Trust are to keep the Common open for walkers and to encourage the diversity of wild grassland flora. A botanical survey of Longis Common was undertaken to investigate the effect that a cattle and pony grazing scheme has had on the plant diversity. Flora was surveyed within ten randomly assigned metre squared quadrats in five stocked and five corresponding un-stocked plots over Longis common. Plant species type and Domin percentage cover were recorded. Statistical analysis showed that grazing had a significant effect on diversity by increasing both species richness and eveness ($P<0.001$) between un-stocked and grazed plots. Grazing significantly increased species diversity in three out of the total five grazed plots. The species diversity was not significantly affected by grazing in the other 2 plots. Herbivore type (cattle, pony or cattle and pony) did not significantly effect plant species richness ($P<0.181$) or plant species diversity ($P<0.106$). Number of days grazing ($P<0.001$) and intensity ($P<0.001$) had a significant effect on species diversity. Sward height was found to be significantly different between grazed and un-grazed plots ($P<0.02$), significantly affected by richness ($P<0.001$) rather than grazing ($P<0.594$). The finding supported the continuation of this conservation grazing management scheme. It was recommended that grazing could be kept for longer periods of time in larger plots to encourage grazing pressure on dominant species such as Sea Couch and scrub, thereby opening up Longis Common.

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1. INTRODUCTION

1.1 What are grasslands?

Grassland habitats appeared on Earth about 70 or 80 million years ago. Grassland is land colonised with plant communities dominated by Poaceae (grasses) and herbaceous non-woody plants, rather than shrubs and trees. Globally, natural and semi-natural grasslands cover approximately 20% of the terrestrial land area at a range of latitudes (Swift *et al*., 1979). They dominate many parts of Northern Europe and cover 45% of the UK land area (DEFRA, 2005a). Grasslands are the main habitat for the majority of grazing animals and their predators.

Through natural succession, grasslands develop into tall rank grassland, scrub is colonised and eventually woodland develops. The removal of vegetation biomass by grazing and browsing prevent this process. Grazing creates a stable mix of vegetation, with nutrients being naturally re-cycled by fungi and soil organisms to maintain soil fertility (Cox, 2002; Griffith and Roderick, 2007). Succession is also prevented by low rainfall (250–1,500mm year) and fire (Ford *et al*., 2004). Palynological (pollen) evidence indicates that most of Northern Europe was under continuous forest cover until approximately 4,000 Before Present and that there has since been progressive deforestation to grasslands. Controversially, Vera (2000) and Bakker *et al*., (2004) suggested that in pre-human quaternary times, considerable areas of Northern Europe were in fact maintained as open grassland and heathland by wild grazing animals maintaining habitat heterogeneity. Kirby (2003) however, suggested that little grass pollen had been detected in cores dating from these quaternary times.

The colonisation of Britain by Mesolithic farmers consolidated the pattern of natural clearings and glades within primeval forests. It is likely that shifting areas of cultivation would have followed the clearings and glades originally created by wild herbivore grazing (Vera *et al*., 2000). In the past two centuries anthropogenic factors such as the migration of Europeans and their agricultural practices have altered grasslands. For example, anthropogenic deforestation has occurred through domesticated livestock farming, controlled fires and logging for fuel. Grasslands in areas of high human population are among the most disturbed habitats as they are susceptible to political, social or economic change which can cause destruction by ploughing up of grasslands, or conversely the abandonment of arable farming and grazing. It is likely that most North European grasslands have been cultivated at some point in the past.

1.2 Grassland biodiversity and conservation

Semi-natural grasslands are those where wild-plant communities occur naturally, undisturbed by agricultural improvement such as fertilisers, weed killers, ploughing or re-seeding. These often contain a high diversity of wild plant species - grasses, sedges, rushes and herbaceous species with associated invertebrates, fauna and birds. Natural grasslands are now rare, as grasslands are of vital human and economic importance, such as for raising livestock for human consumption and dairy products (DEFRA, 2005a). UK grassland is seen as a plagioclimax community where the species that exist in the ecosystem are as a result of the influence of human activity. In the last 50 years agricultural intensification has put semi-natural grasslands at a risk of destruction (Griffith and Roderick, 2007). This includes cultivation, ploughing, extensive modification by over-grazing from domesticated livestock, modern forms of mechanised agriculture and use of synthetic fertilisers (Watkinson and Ormerod, 2001). Cultivated agricultural grasslands are usually poor in wild plant species due to the original wild-plant communities having been replaced by sown monocultures of cultivated varieties of grasses and clovers, such as *Lolium perenne* (Perennial Ryegrass) *and Trifolium repens* (White Clover).

Declining grassland diversity throughout Europe within the last decade threatens biological diversity conservation (Klimek *et al*., 2007). There is a genuine wish in the conservation movement to return to more natural systems that aim to be economically, environmentally and culturally sustainable. Semi-natural lowland grasslands declined in extent and condition during the late 20th century, with only 1-2% of the remaining permanent lowland grassland estimated to be of high nature conservation value (Blackstock *et al*., 1997). Species-rich agriculturally unimproved lowland grassland is therefore a scarce resource in the UK and thus a high priority for nature conservation and biodiversity of the wild flora and its associations (Robertson and Jefferson, 2000). Lowland calcareous grassland are priority habitats within the UK Biodiversity Action plan (Cox, 2002). It has been shown that 38% of

179 native UK plant species in decline in the last 40 years were species of calcareous, unimproved or acidic grassland/ heathland. Changes in the European Union Common Agricultural Policy (CAP) have placed increased emphasis on multi-functional use of grasslands and in particular management to enhance or maintain biodiversity (Oglethorpe, 2005). If semi-improved grasslands remain un-ploughed and un-treated with herbicide or fertiliser for many years, there is a slow transition back to a semi-natural state, becoming species-rich (Cox, 2002). This study focuses on the effect of large herbivore grazing on the preservation of diverse semi-natural grasslands in Longis Common, Alderney.

1.3 The ecology of grazed habitats

There is a growing appreciation of the key role that large herbivores species have in controlling plant species richness, a critical issue in the conservation and management of grassland biodiversity (Olff and Ritchie, 1998). Grazers can drive the ecology of many habitats and maintain structural diversity in the vegetation and biological diversity (Van Wieren, 1995). Management of herbivores has therefore become a crucial component in efforts to restore or maintain grassland biodiversity (Olff and Ritchie, 1998). Grazing is a natural process affecting the composition and structure of plant communities, a generally accepted tool to achieve grassland nature conservation objectives. These objectives are generally the control of successional change towards scrub and woodland encroachment, and the creation of structural heterogeneity in the vegetation to enhance or maintain overall biodiversity value (Tallowin *et al.*, 2005). Field experiments of grazed grassland plant communities however have shown conflicting results. The level of grazing, the timing and the animals species involved is important, as too much grazing may often lead to land degradation and the loss of biodiversity, while too little grazing may lead to succession from grassland to woodland and the loss of the grassland habitat (Watkinson and Ormerod, 2001).

Semi-natural grassland systems are maintained by grazing, and removal of herbivores usually leads to gradual afforestation. Sir Arthur Tansley (1911), pioneer of plant ecology recognised the significance of grazing in determining the structure and composition of grassland when he published his first survey of British vegetation types. He showed that grazers such as sheep and rabbits reduced productivity of grasslands by around 25%, grazing selectively on preferred species, which held back development of dominance by more aggressive species and allowed the establishment of less competitive and annual plants, so encouraging the redevelopment of biodiversity. Grazing is therefore one of the central issues affecting grasslands, linking their maintenance, productivity, economic use and management for biodiversity. However, plant responses to grazing are difficult to predict. Grasslands depend critically on the activity of grazing animals, and to understand plant responses to grazing it is therefore imperative to explore the impacts of variation in grazing on community structure (Watkinson and Ormerod, 2001). A recent English nature report revealed that in 1999 Exmoor ponies, adapted to digest low-quality forage were introduced on the South Downs near Lewes, to aim to take out *Brachypodium pinnatum* (Tor grass) and the dead thatch from the grassland. This resulted in the sward opening up which gave room for less dominant species. By doing so, the re-growth of wild flowers, grasses and herbs was encouraged. Stark and Grellmann (2002) found that herbivore activity increases NPP. Klimek *et al*., (2007) concluded that as well as reduced nitrogen fertilisation, grazing at low stocking levels was seen to help to conserve biodiversity. Rough grazing on uncultivated grassland covers approximately 23% of the UK land area at about 5.6 million hectares (DEFRA, 2005a)

Breed selection is as important as the regime they are managed in and they can have different feeding behaviour. For example, goats habitually browse, sheep preferentially graze, ponies graze, browse and strip bark, cattle graze but readily browse growth of the current year, whereas pigs root in the soil as opposed to grazing or browsing (FACT, 2003). The effect of cattle and pony on plant species diversity is compared.

1.4 Alderney history

The Island of Alderney is the third largest of the Channel Islands of the United Kingdom, situated 13km West of Cap de la Hage of France, and 80 km South of Portland Bill, UK at Latitude 49° 43’N and Longitude 2° 12’ W (Figure 1). Alderney is 5km (3 miles) in length and 2.5km (1.5 miles) width, with an area of circa 8 km^2 (3 square miles, 4942 acres) and total human population of 2,400. It is important to know about the history of Alderney that has led to its conservation grazing scheme. Alderney was separated from mainland Europe land mass about 6-7,000 BC by rising sea levels after the end of the last Ice Age. During the time between the last ice age and the present day, vast forests, including *Alnus glutinosa* (Alder), *Corylus avellana* (Hazel), *Tilia spp.* (Lime) and *Ulmus spp.* (Elm), with *some Pinus* *spp*. (Pine), but predominately *Quercus spp*. (Oak) covered the Channel Islands and much of present day France. Evidence of this lies in several peat beds.

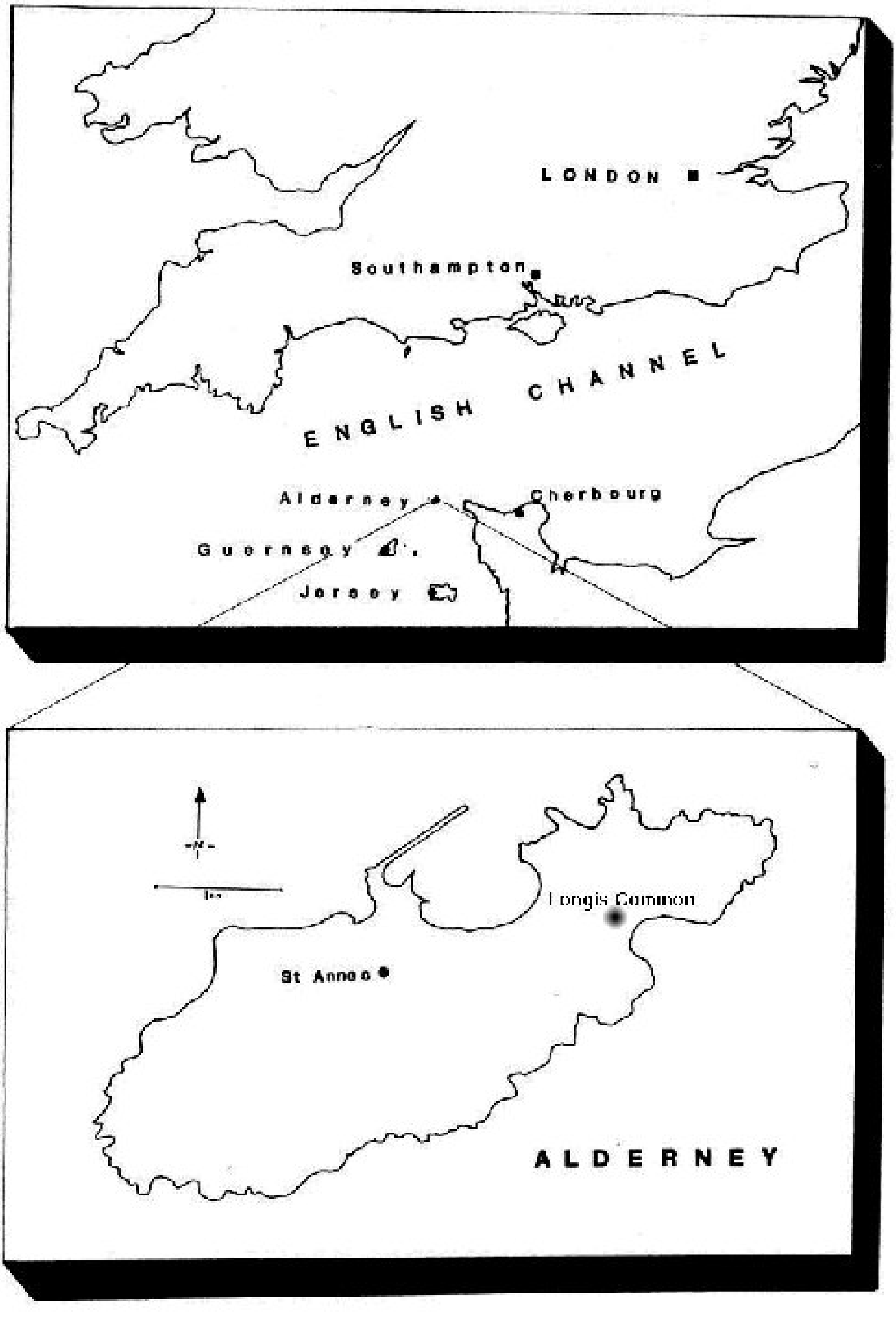


Figure 1. Map showing position of Alderney in the Channel Islands, in relation to United Kingdom and France. Town of St. Anne is shown in the centre of Alderney, with Longis Common shown to the East.

Alderney is the only Channel Island with an appreciable amount of sandstone, which covers the underlying rocks over the majority of the East and Southeast side of the island. Longis Common is a calcareous grassland with “Sandwich Series” soil (Figure 1a: Appendix 1). Sandwich soil is poorly developed loamy sand overlying horizons of deep dune sand, which is calcareous throughout but with no chalk deposits or limestone rock. It occurs where there layer of shell-rich windblown sand-dunes, which makes the soil in Alderney mostly alkaline. The typical pH value for calcareous grasslands soils is between 6.5 and 8.5 (DEFRA, 2005b). Borehole logs have revealed the presence of an organic rich peat bed of 100-120cm sandwiched between 3-4 metres of dune sand across the extent of Longis Common (Campbell, 1994; James and Renouf, 1998). Sandwich soils therefore only have small reserves of water available for plant growth and so are droughty (Hazelden, 1990).

Longis Bay (Figure 2) was most probably the island's earliest harbour, which led the Romans to use it as their base, with the earliest island settlement at Longis Common, later buried under drifting sand. Neolithic Dolmens (burial chambers) and an Iron Age pottery, dated around 490BC, excavated on Longis Common in the 1960s showed permanent occupation for at least the last 5-6,000 years, through the late Stone Age, Bronze and Early Iron Ages (Alderney Government, 2007). It is likely that much of the woodland gradually declined due to high stocking levels preventing seedling establishment. Bukach (2004) suggested that the Neolithic farmers relied on domestic cattle, supplemented by wild resources. Gregg (1988) suggested that early agriculturalists were often mobile, clearing intermittent patches of forest in order to plant domestic crops and raise livestock.

Alderney continued a strip agriculture and communal rough grazing system into the 20th century. The Commoner’s cattle, ponies and other livestock would have followed the effects of any primeval wild herbivores they replaced. At the beginning of the 20th century there was a pure-breed of Alderney cattle, born and bred on the island and distinctly different from the Guernsey or Jersey cows. They were famous for the richness and quantity of the milk they produced from scanty food, their easy temperament and especially for their capacious milk bags (Alderney Society, 2007). Most of these pure-bred cattle were removed from Alderney to Guernsey during the German occupation, but none were returned, ending the native line. The few remaining were killed and eaten in 1944 and the pure Alderney breed is now extinct, although hybrids still exist (Alderney Government, 2007).

Fertility of the soil was maintained by vraic seaweed (*Fucaceae spp*.) to help retain soil moisture. Corn crops were grown continuously, with little fallowing, and potato growing was introduced in the late 18th century. Most of the island, right up to the coastline was managed for agricultural practice (Bukach, 2004). The few valleys that supported woodlands were used for horticulture and grazing. These laws and customs were kept until the island was evacuated in 1940 when a considerable proportion of the islanders were still engaged in agricultural activity and small holdings. Alderney was then run as a communal farm with flower and potato harvests, declining until it virtually ceased in 1999 (Alderney Government, 2007).

Traditional hay-making, both preceded and followed by grazing, and other traditional farming techniques, have now been dropped (Bonnard, 2001). *Pteridium aquilinum* (Bracken) from the common lands used to be cut for bedding and *Ulex europaeus* (Gorse) cut and dried regularly to fuel bread ovens. However, with not enough agricultural team workers to keep the land clean over the last 30-40 years, U. europaeus, *P. aquilinum* and *R. fructicosus* (Bramble) scrub had gradually encroached on much of cliff areas and some of the agricultural land (Alderney Government, 2007). All these factors have had a considerable effect on the landscape and ecology of the island.

1.5 Longis Common historical land use

Longis Common, found in the East of the island of Alderney (Figures 1 and 2), is an important example of species rich calcareous coastal grassland (Figure 3). The land of Longis Common, jointly owned by States of Alderney and Drifield States Limited, experienced dramatic changes in the land use since the Second World War, when it was disturbed by a WWII burial ground (Figure 2). The 80 hectares of land contained within Longis Common was once used for the grazing of livestock, and the growing of crops. However since the early 1950’s most of the land has seen no such management, with grazing only by rabbits in recent decades. Anecdotal evidence from the AWT Manager, Roland Gauvain suggested the last known stocked herbivore was in the late 1950’s by a local resident. The reversion to pasture would probably have allowed rapid re-colonisation of wild grassland species from both the soil seed bank and adjacent fields and a diverse flora established itself.

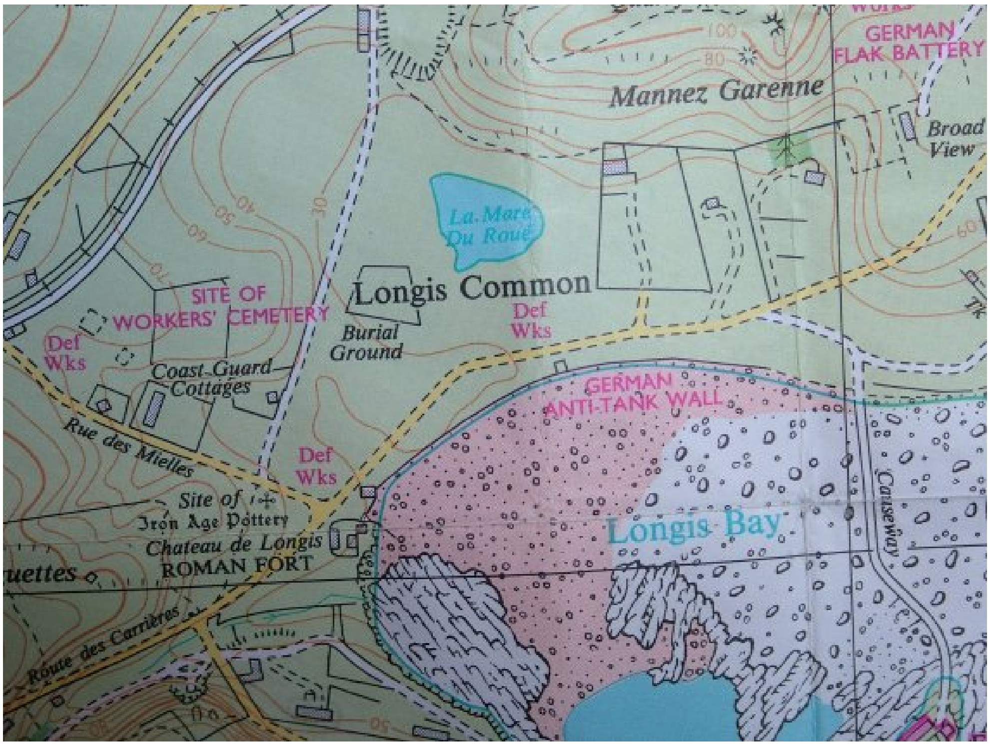


Figure 2. Ordnance Survey Map (2001) showing Longis Common and Longis Bay in East of Alderney. Scale: 6cm = 0. 25 mile.

Figure 3. Photograph looking East towards Longis Common, with Longis Bay to the right. Scrub is seen in the foreground by the road surrounding cattle-grazed Plot A1. Photo taken from Barrack Master’s Lane, July 2007.

Results from palynological analyses of organic sediments in Longis Common by James and Renouf (1998) dated indicated an 'open vegetation characterised by a rich assemblage of herbaceous and aquatic taxa and correspondingly low arboreal values' (Campbell, 1994). Initially 3,780 ± 45 years BP Longis Common was an area of mainly damp, open grass (with *Urtica* and *Hydrocotyl*), fern and sedge vegetation with some salt marsh plants. The low values of tree and shrub pollen are of interest and were suggested by Keen (1981) to be as a result of local oceanic conditions and strong winds which inhibited tree growth. This was followed by an increase in open herbaceous vegetation dominated by *Poaceae* (grass) (40%) and *Cyperaceae* (sedge) (40%). In the next band over 1,100 years ago, there was a rise in the values of aquatic taxa, such as *Myriophyllum*, *Potmogeton*, *Nymphoea* and *Hydrocotly*, which indicated areas of open fresh water in the area which included the presence of Longis pond (Bonnard, 2007). The herb flora in this zone including *Plantago lanceolata* (Ribwort Plantain), *Ranunculaceae* and maritime communities represented such as *Plantago coronopus* (Buck's-Horn Plantain) and a number of cereal seeds which suggested agricultural cultivation, and the addition of Rubiacae, Brassicaceae and Asteraceae (Campbell, 1994).

1.6 Present Day Longis Common

The 80 hectare Longis Nature Reserve, including Longis pond was formally opened in June 2003 as the first Wildlife Trust Reserve in the Channel Islands (Alderney Wildlife Trust, 2007). The reserve operates under a Management agreement between Local Government, landowners and the Alderney Wildlife Trust. Longis Common has a mixture of longer tufted grasses providing cover for small mammals, including *Crocidura russula* (greater white-toothed shrew) and areas of tightly packed turf, supporting a rich diversity of flora including *Anacamptis pyramidalis* (Pyramidal orchid) and *Thymus polytrichus* (Wild thyme). Alderney is at the northern limit of the range of a number of Mediterranean or Southern European species, which are rarely found in Britain, or mainly in the Southwest (Bonnard, 2007). Longis Common is part of Alderney's largest natural soil aquifer, with the pond's water level playing an important part in the life cycle of the local flora. In the winter parts of the Common can become flooded, whilst in summer the area often suffers from drought (Pers. comm. Roland Gauvain).

Cessation of stocking by domesticated animals, and lack of any mowing regimes meant the species-rich grasslands of Longis Common had become increasingly scrubby with invasive species such as *R. fructicosus*, *P. aquilinum* and coarse grasses. Changes in farming practices had caused a gradual but steady loss of open habitats. R. fructicosus and P. aquilinum had become dominant and footpaths, archaelogy and landscape features had become overgrown and hidden from sight. Ongoing work by the AWT since 2004 focussed on the reclamation of the species-rich calcareous grassland from the invasion of *R. fructicosus and P. aquilinum*, to promote the increase in floral biodiversity, whilst also improving public access to the area. The aim was that grazing would help to restore and maintain the richness and diversity of this wildlife site and control the invasive species. The theory of island biogeography introduced by MacArthur and Wilson (1967) suggested that a small island far from the mainland would have fewer indigenous species and is sensitive to any loss of biodiversity. This has important implications for Alderney, as the loss of species would have lasting consequences.

Rabbits (*oryctolagus cuniculus*) were possibly introduced by the Romans or the Monks of the 8-9th centuries and are now the most Common wild mammal on Alderney and many burrows are found on Longis Common. In mid-1952 myxomatosis was deliberately introduced into France by a retired physician who occupied a rabbit-infested estate near Paris. The introduction of myxomatosis in the UK in 1953 destroyed 99% of the rabbit population (Thompson, 1956). Rabbit numbers in Alderney have fluctuated from year to year with myxomatosis since the mid 1950’s. They are often severely controlled by poisoning or gassing (Alderney Government, 2007). The low number of natural predators apart from buzzards and foxes ensures their survival. Rabbits have influenced the vegetation of Alderney by the grazing of seedlings and prevention of regeneration of trees from seed by succession. There has never been a rabbit census on Alderney so it is difficult to know the population size and its fluctuations as a result of myxomatosis.

1.7 The Alderney Grazing Animals Project (AGAP)

The use of traditional farming methods to aid modern conservation strategy is becoming an increasingly popular practice in the UK (Van Wieren, 1995). Grazing is the major management activity for economic and conservation objectives in the UK (Bullock *et al.*, 2001). The national Grazing Animal project (GAP) was started in 1997 to promote and facilitate the use of livestock for the management of conservation sites. The Alderney Wildlife Trust introduced The Alderney Grazing Animals Project (AGAP) in 2003, supported by the States of Alderney and local Kiln Farm Dairy to counteract scrub invasion on Longis Common as an experimental method of scrub management. The Trust therefore introduced its own grazing herd of Guernsey cattle as first grazers to open up areas that had become overgrown and inaccessible to walkers and less biologically diverse, with the aim to continue to support a varied range of habitats and diversity of species. The option to follow on with pony gazing was carried out on some sites.

Young cattle were provided for AGAP by the local farmer of Kiln Dairy, Mike Cox. The number of cattle varied, starting with two steers and seven heifers, with the maximum carrying capacity for the management areas being nine cattle. The numbers of cattle were regulated by the availability of forage and financial retractions relating to the amount of time involved in handling and additional costs such as supplement feed. Guernsey cattle are well suited to conservation grazing as they are hardy, sure-footed and relatively small, so less likely to damage fragile soils than larger animals. They are good forage converters, able to break down woody or herbaceous growth which other cattle would avoid, and can therefore survive on a relatively poor diet (FACT, 2003). However after a lengthy period on poor grazing the cattle requires a feed supplement or grazing on improved grasslands for a few weeks. The pony that has grazed Longis Common from 2004 was a Welsh Cob owned by Longis Common neighbours, Mr and Mrs. Tate. Grazing occurs on the conservation sites on Longis Common throughout the winter and summer, with the cattle moved to fields elsewhere on the island in the spring and autumn. Animal welfare is paramount to the Wildlife Trust, who follow the nationally recognised codes of best practice and animal welfare (GAP, 2001). Cattle and horses are better at keeping scrub back than removing (Crofts and Jefferson, 1999), so some direct clearance has occurred on Longis Common by the AWT to help remove invasive species that are not removed by cattle. The reedbank to the West and South of Longis pond was cut back in February 2007. P. aquilinum was cut back on the Western and Southern edges of Coastguards hillside in 2005 with 2 further cuts in 2006 and 2007.

Care was taken by the Alderney Wildlife Trust during the grazing scheme design to ensure that all permissive footpaths, tracks and paths on Longis Common remained open and accessible during grazing periods. To make such selective grazing possible and to prevent conflict with public footpaths and access, the grazing plots were selected around the Longis Common Reserve based on footpath layouts, and so were not even in size or shape. Wooden corner posts and plastic fence posts were erected around the boundary of each plot, with no permanent fencing. A dog-proof electric wire was attached around the fence posts to enclose the areas and prevent the cattle from leaving the plot. The grazing animals were free to roam and graze at will within the fenced areas. Due to the nature of the wire fencing, rabbits which inhabit the Common, were also able to graze the plots.

A herd of 9 Guernsey cattle were rotated through each of these plots twice a year, being the maximum carrying capacity for each plot. The plots were initially grazed from November 2004 onwards for three to six weeks, depending on plot size. This was followed by pony grazing in some sites. The cows were then moved onto another plot on Longis Common, or elsewhere on other plots on the island. Livestock movements were based on plant growth and utilisation and not calendar dates as suggested by Natural Resources Conservation Service (1997) for prescribed grazing (See Table 1 for complete dates of grazing). Fencing was temporary in nature as a single set of fencing was used, and moved on with the cattle so that visitors and residents were not affected by unsightly enclosures left on the Longis Common Reserve. The fencing was then removed, leaving only corner posts remaining for future reference points.

The grazing herd costs the AWT approximately £600 a year (Figure 3c; Appendix 3). Constant maintenance costs are also required, for example wire must be purchased every year, and batteries for fencing charged. A large number of hours are dedicated to the upkeep and relocation of the cattle. 15 minutes is spent every day to check the herd is safe, and the water tank is working. Every four to five days the boundary line must be walked to check the electric fence is in working order. Every month the cattle must be moved to a new site within the islands plots set aside for grazing. Relocation of the cattle herd takes up to 5 hours, with two people, at 300 hours a year. It is therefore important that the effects of grazing on grassland diversity are known, as conservation must come at a price. David and Ozanne (2004) carried out an initial survey of transects in 2004 to provide a baseline of the state of the vegetation at the start of the grazing scheme. Transects of 0.5m quadrats ($0.25m^2$) were taken across the width of the grazed plots with few quadrats outside the grazed areas. This data enabled a comparison to be made after 4 years of grazing.

1.8 Aims

This project aims to provide insight into the effect the AGAP grazing scheme since 2004 on plant species diversity in Longis Common. It therefore provides recommendations and a management plan to the Alderney Wildlife Trust for the continued use of grazing as a conservation management strategy. It aims:

1. To test the hypothesis that grazing by larger herbivores (cattle and pony) affects the species diversity and species richness of higher plant species.

2. To test the hypothesis that grazing by different large herbivores (cattle or ponies; both separately and alone) has different effects on species plant richness.

3. To test the hypothesis that grazing intensity (number of days grazing) affects plant species richness.

4. To produce a management plan for Longis Common, making recommendations for future management practices in order to obtain a range of habitats within the site.

2. METHODS AND MATERIALS

Throughout this report plots are referred to as ‘grazed’ where they have been grazed by stocked cattle and/or pony and referred to as ‘un-stocked’ where no cattle or pony has grazed. All areas were accessible by rabbit grazing.

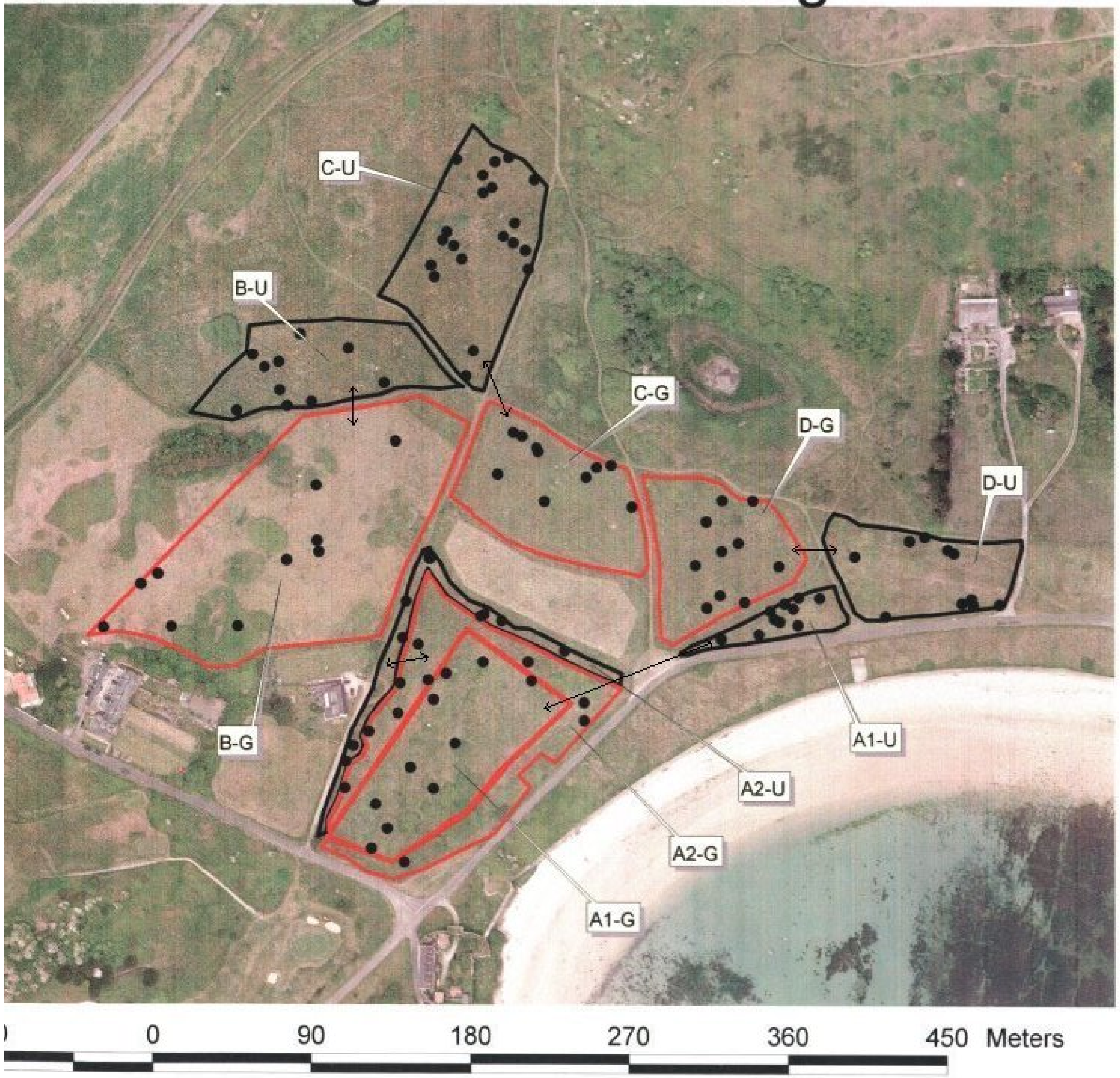
2.1 Experimental design

4 plots previously grazed by large stocked herbivores were chosen as grazed areas to survey, A, B, C and D. Grazed plot A had its boundary increased in September 2006 and the area outside was named as A2. 5 corresponding un-stocked areas found as close to the grazed plots as possible were surveyed as un-stocked replicates, with similar ground make-up of location, aspect and soil properties. All of the cattle and/or pony grazed and the assigned un-stocked plots surveyed are shown in Figure 4 and described in Table 1. Confounding effects to the land that may have affected results were minimal as examination of historical evidence had shown previous grazing, ploughing or application of fertilisers has not occurred since 1950’s. A previously cattle grazed plot as part of the AGAP scheme found closely associated with flushes from the Longis Pond to the East of the Common at the lowest point was not included in the survey. This area supported plants suited to a damp habitat such as the rush *Phragmites,* which was seen as a confounding factor to the plant diversity in that area. Plot B-grazed was the largest plot area, but the West side had had p. aquilinum cutting management over 3 years, which was seen as a confounding factor, so only the East side of the plot was included in the survey. The total plot area for the 10 grazed and non-stocked sites was 70,168 m^2 (7 ha or 17.3 acres). The grazing intensity assumes that 1 cow and 1 pony have the same grazing effect. It was decided not to do transects, as had been done in a previous survey (David and Ozanne, 2004) as it was thought that transects would not give a fair representation of the vegetation across the whole of the plots and cover rather than presence/absence to show dominating vegetation and rarer species.

Table 1. Dates of cattle and Pony grazing in plots.

Plot Name	Area (m^2)	Grazed (Cattle +/or Pony) or un-stocked (-)	Grazing dates (no. days and start month)	Total no. days grazed	Livestock Unit intensity LU/ ha	$\frac{\text{LU x days}}{\text{ha}}$
A1-G	7,456	Cattle	25 days: Nov'04 30 days: Mar '06 23 days: Sep '06	78	12	936
A1-U	1,329	-	-	0	-	
A2-G	5,930	Cattle	23 days: Sep '06	23	6.7	154
A2-U	1,953	-	-	0	-	
B-G	(7,202 surveyed) Total =14,404	Cattle	55 days: Apr '05 43 days: Apr '06 18 days: May '06 44 days: Oct '06	160	6.25	694
B-U	5,175	-	-	0	-	
C-G	6,402	Cattle followed by pony (separately)	Cattle: 17 days Dec '04 Pony: 46 days Feb '05 & 94 days May '06	157	14 (cattle) 1.6 (pony)	311.6
C-U	7,407	-	-	0	-	
D-G	5,422	Pony	58 days: Dec '04 28 days: Mar '06 126 days: Aug '06	212	1.4	296.8
D-U	4,444	-	-	0	-	

Grazing Areas of Longis Common



Plots A,B,C,D (All plots accessible by rabbit grazing)

Grazed: (RED):
A1-G = Cattle grazed 78 days (Nov '04 - Sep '06)
A2-G = Cattle grazed 23 days (A1 Boundary increased Sep '06)
B-G = Cattle grazed 160 days (Apr '05 - May '06)
C-G = Cattle 17 days (Dec'04) then Pony 140 days (Feb'05-May'06)
D-G = Pony grazed 212 days (Dec'04 - Aug '06)

Un-stocked control since 1960 (BLACK):
A1-U, A2-U, B-U, C-U, D-U

Dots = Location of Random Quadrats

Arrows show compared grazed and un-stocked plots

Figure 4. Grazing areas of Longis Common showing location of grazed and un-stocked plots with location of random quadrats.

2.2 Surveying Methods

A week was spent identifying all of the species in Longis Common using flora identification keys, Rose (1991) and Rose (1989) to compile a complete species identification book and list. A nested quadrat design was then carried out, whereby increasingly large square quadrat sizes consisting of side lengths of 0.25m, 0.5m, 1m, 1.5m, 2m and 2.5m were surveyed for the number of different plant species to give the maximum number of species (Figures 5 and 8). A 1-metre^2 quadrat area was chosen for surveying, as the number of species found in quadrat areas larger then this did not have a significantly larger number of species (Figure 8). It is recommended by Joint Nature Conservation Committee Common standards monitoring guidance for lowland grasslands (JNCC, 2004) that 2m^2 quadrats are often used for grassland surveying, however this area was seen as too large an area to survey for 100 quadrats required in the time given.

Plots were surveyed between June and August 2007. Aerial photographs of Longis Common which showed past grazing plot boundaries were used to re-create the plot boundaries (Figures 1c and 1d; Appendix 1). Plastic fence posts were placed at 2m intervals around the edges of each plot to be surveyed. Ten 1-metre quadrats were surveyed for each of the 10 plots. In order to find random points at which to carry out the quadrat surveys in each of the ten plots, ten randomly chosen co-ordinates were generated for each plot area using a random point generator from a computer ArcView package. It was decided to use a computer generated random number rather than throwing the quadrat randomly as this could have introduced a degree of error by an area unknowingly being chosen. The generated points were completely randomised, apart from a minimum distance of one metre from the fence plot boundary. This was to avoid the effect of cattle trampling at the fence boundary and dog fouling, which may have enriched the soil, and affected the vegetation. A list of grid references for all the quadrats was thus created, based on a Universal Transverse Locator Co-ordinate system (UTL). The location was found using a GPS locator. A wooden peg was used to mark the spot, and a metre ruler placed towards due North from the point to create a corner. Two more corners were created at right angles with a metre ruler to create a 1-metre squared quadrat area. String was wrapped around the four corner posts to give an outer boundary line and contain tall plant species (Figure 6).

Figure 5. Photograph of nested quadrat design. Metre rule, string and wooden posts used to create square quadrats of side lengths 0.25m, 0.5m, 1m, 1.5m, 2m and 2.5m to find maximum number of plant species. 1 metre ruler shown for scale in foreground.

Figure 6. Photograph showing method used to create a 1-metre squared quadrat area in grassland using a metre rule, four wooden posts and string.

Each quadrat was viewed from the South side, before being viewed from the West, North and East sides in a clockwise manner to ensure that all species were identified. The quadrat was surveyed from each side for approximately eight minutes to identify species present. Different types of species were identified within the metre quadrat area and marked onto a prepared species list results sheet. The percentage covers of the species were then marked onto the sheet using a Domin scale (Table 2 and Figure 7). Approximately eight minutes were spent on determining species cover values. Each quadrat was thus surveyed for a total of 40 minutes, to ensure survey methods were equally rigorous for each quadrat. A total of 100 quadrats were surveyed between June and August 2007.

Table 2. Domin Scale used to present scale of plant species cover in a metre quadrat related as a number between 1 and 10.

10	91 – 100%
9	76 – 90%
8	51 – 75%
7	34 – 50%
6	26 – 33%
5	11 – 25%
4	4 – 10%
3	many individuals
2	several individuals
1	1 – 2 individuals

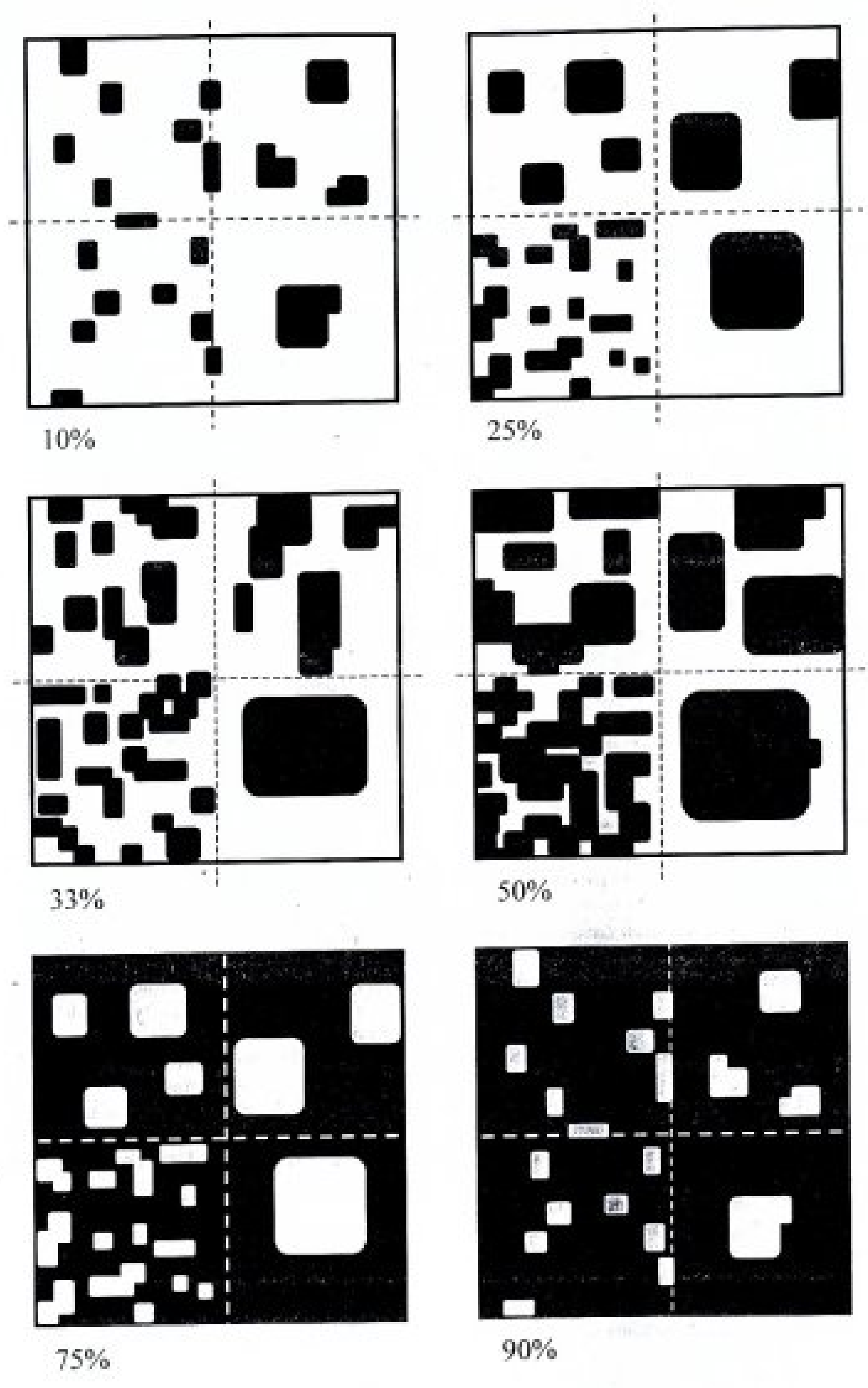


Figure 7. A visual interpretation of Domin cover/abundance thresholds. In the diagrams, each sub-square has the same total area of black. After JNCC National Vegetation Classification User's Handbook (2006), page 39, by Rodwell, S.

3.RESULTS

For full set of botanical survey data and statistics see Appendix 2.

Throughout this report plots are referred to as ‘grazed’ where they have been grazed by stocked cattle and/or pony and referred to as ‘un-stocked’ where no cattle or pony had grazed. All areas were accessible by rabbit grazing.

3.1 Phase 1 Survey

Figure 1e; Appendix 1 showed that in 2000 Longis Common consisted of B1 semi-improved grassland, B1/2 semi-improved/improved grassland and B1/6 semi-improved/dune grassland and small areas of B1/C3(iv) semi-improved grass with R. fructicosus / and grass mix. This suggested that since 2004 there were more parcels of scrubland with P. aquilinum. Initial observations of the Longis Common showed that there was no obvious difference in the grassland vegetation found between the grazed and un-stocked plots, as shown by photograph Figure 3b; Appendix 3. A Phase 1 habitat survey was undertaken on the 28th May 2007 between 10:00 and 13:15. Weather conditions were warm, dry, with scattered cloud cover. The methodology was based on that of a standard Phase 1 Habitat Survey, as described in the Joint Nature Conservation Committee ‘Handbook for Phase 1 Habitat Survey - A Technique for Environmental Audit’ (JNCC, 1993). Where possible, the area was walked, the vegetation examined and dominant species, or species of conservation interest recorded. Photographs were taken in the field to assist with later preparation of the project. It should be noted that species identification was difficult due to the relatively early time of year and the particularly slow development of vegetation. Habitat types were nonetheless readily identifiable in spite of these limitations.

The Phase 1 survey identified that Longis Common comprised a semi-natural calcareous grassland reserve, with vegetation dominanted by *F. rubra.* The interior of the surveyed area was predominantly improved/semi-improved grassland. There were small areas of coastal grassland towards the roadside, with grassland species such as *F. rubra* present in amongst a predominantly *E. atherica* dominated sward. An area of acidic dune grassland was present nearer the shore. There appeared to be mosaic habitats of shorter grassland areas, tall grass areas and some scrub in patches around the South of the Common by Longis Road and to the

East. A single clump of trees occurred on the hillside near to plot B-grazed. David and Ozanne (2004) noted that there was a presence of *Elymus farctus* in the area of grassland near the roadside transition, however this was not identified.

3.2 Phase 2 Survey, National Vegetation Classification (NVC)

Longis Common consisted of CG2 – species rich grassland widely distributed principally over southern lowland calcareous formations, with regional differences showing up as sub-communities, as defined by the National Vegetation Classification (JNCC, 2006). Longis Common was a mosaic of coastal grassland habitats dominated by *F. rubra*, *D. glomerata*, *E. atherica* and *Raphanus raphanistrum* (Wild Radish). There were areas of poor semi-improved grassland (B6) left to grow long, which was rank with many weed species such as *Cirsium* arvense (Creeping Thistle), *R. raphanistrum* and *Holcus lanatus* (Yorkshire Fog). There were areas of tall ruderal vegetation (C3.1) in clumps surrounding the encroaching scrubland. Species here included *Heracleum sphondylium* (Hogweed), and *Cirsium vulgare* (Spear thistle). Also present were areas of scattered scrub (A2.2) of *R. fructicosus*, *Urtica. Dioica* (Nettle), and *H. sphondylium,* which encroached on the site mainly by Longis road, Barrack Master’s Lane and in the East of the Common. The site provided scrub suitable for breeding birds. Birds noted to have nested in Longis Common in the past include Anthus pratensis (Meadow Pipit) in the grassland, and *Troglodytes troglodytes* (Wren) and *Prunella modularis* (Dunnock) amongst *R. fructicosus*. *Falco tinnunculus* (Kestrel), *Accipiter nisus* (Sparrow hawk) and *Buteo buteo* (Buzzard) were also regularly seen hunting above the Common. *Acrocephalus spp.* (Warbler) have also been noted to nest near Longis pond (Pers. Comm. Atkinson, 2007). Disturbances by dogs however mean that bird numbers might not be as prolific as they could be.

Grazing pressure by rabbits was heavy due to rabbits living on the Common, right up to the dune region across the road. There was evidence of significant number of rabbit burrrows. In some areas there were patches of *T. polytrichus* grassland more associated with upland areas, possibly as a result of extended grazing or walking. Other typical limestone grassland species included *Bromus spp*., *Trisetum* flavescens (Yellow oatgrass) and *Carex flacca* (Glaucous Sedge). There were developments of distinct tussock, hummock and sward components, which have a consequence for the distribution of small arthropods, leafhoppers and spiders (Dennis, 2003). Further Northeast were habitats characteristic of marshy grassland M23a/b: *Phragmites australis*, *Carex spp.*

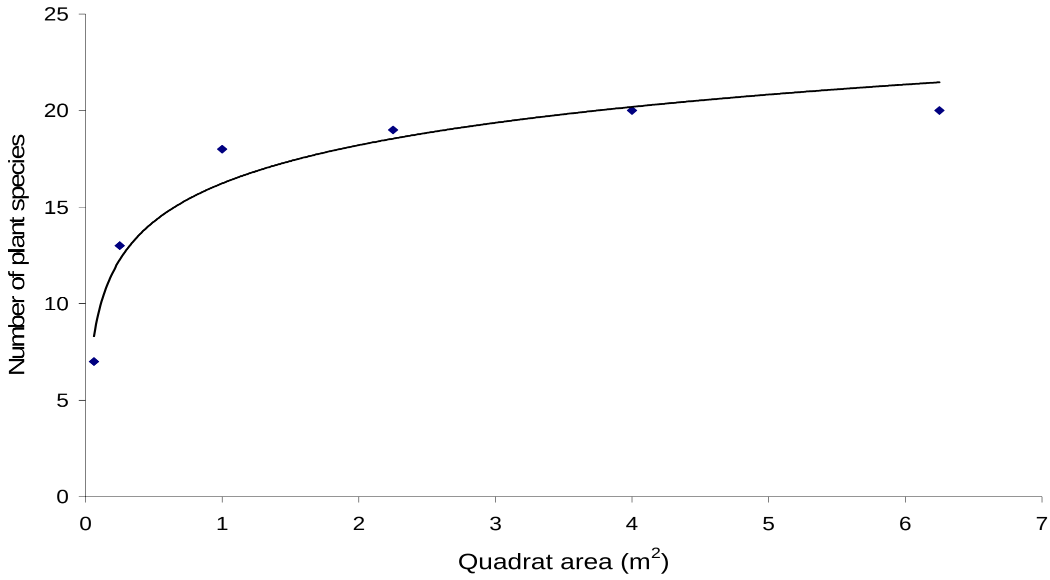


Figure 8. Scatter graph showing number of plant species found in different sized quadrats in a nested quadrat design of quadrat side lengths of 0.25m ($0.06m^2$) , 0.5m ($0.25m^2$), 1m ($1m^2$), 1.5m ($2.25m^2$), 2m ($4m^2$) and 2.5m ($6.25m^2$) in Longis Common, June 2007.

3.3 Statistics

Statistical analysis was carried out on all of the raw data using Microsoft Excel, Minitab (V12.23) and MVSP (V3.1). The data were found to be normally distributed with a homogeneity of variance. The data were then analysed using one-way and two-way ANOVAs and Tukey's tests to assess differences between means to determine any significant differences in the data. Simpson's diversity index (Simpson, 1949) was used as a measure of diversity as well as species richness (number) and evenness. Species evenness, *E* is a diversity index which quantifies how equal the populations are numerically. *E* is constrained between 0 and 1 where the less variation in populations between the species, the higher the E value. Correspondence Analysis (CA) was used to compare similarities between plots and species distributions.

3.4 Species Diversity

The number of different plant species in each quadrat was found to be an overall average of 13.6 over the total 100 quadrats. The average number of species in grazed quadrats by cattle or pony was 14.8 compared to an average of 12.3 in un-stocked quadrats, an increase of 20% (Table 3). Taking averages can introduce statistical hazards although it is useful for illustrating key patterns.

Table 3. Average number of species per quadrat in grazed and un-stocked areas.

Type of grazing animal(s)	Plot name	Total no days grazed	Av. no. spp in $1m^2$ Grazed quadrats	SD of mean	Av. no spp. In un-stocked quadrats	SD of mean
Cattle	A1	78	17.2	3.61	9.9	3.84
Cattle	A2	23	13.7	3.13	9.5	1.51
Cattle	B	160	14.2	1.69	15.6	2.72
Cattle and pony alternately	C	17 & 140	13.1	2.88	15	3.27
1 Pony	D	212	15.7	3.86	11.4	4.99
Average		126	14.8	3.03	12.3	3.27
Total Average	13.6					

Analysis of variances (ANOVA) showed grazing significantly effected species richness (P<0.001) (See Figure 10), therefore the null Hypothesis 1 is rejected as there is a significant difference in plant species richness between un-stocked and grazed plots. Grazed plots were significantly different, un-stocked plots were significantly different, but all plots were not significantly different (Figure 14). The results showed that P< 0.036 for plot and P< 0.001 for interaction (Figure 10) which meant that grazing significantly affected some plots but not the others. Species richness appeared to increase in plots A1, A2 and D as expected, but species richness appeared to decrease in plots B and C (Figure 9). To test the significance of this, 5 one-way ANOVAs of each of the individual plots showed that grazing in plot A1 (P<0.001, F=19.15), plot A2 (P<0.001, F=14.62) and plot D (P<0.045, F=4.64) significantly increased plant species richness as would be expected (Figure 11). However, grazing in plots B (P<0.183, F=1.92) and C (P<0.185, F=1.90) did not significantly effect plant species richness in these plots.

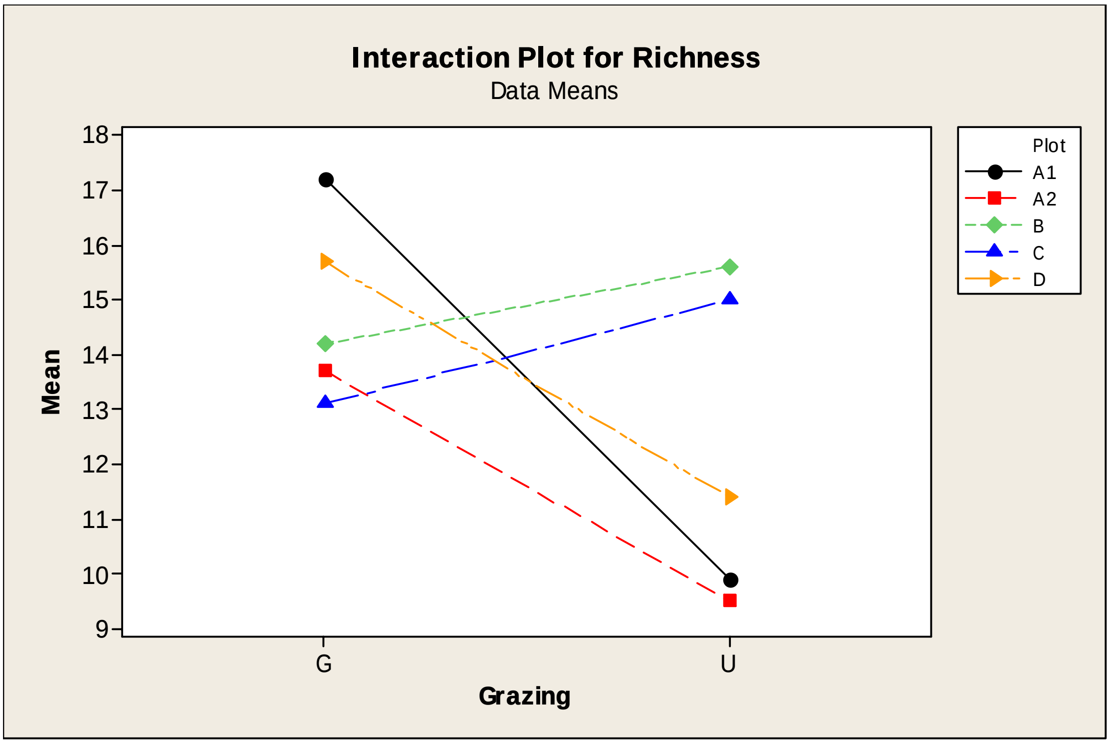


Figure 9. An interaction plot of plant species richness in each of the grazed and un-stocked plots on Longis Common.

```
Source       DF       SS       MS      F      P
Plot          4   117.46   29.365   2.70  0.036
Grazing       1   156.25  156.250  14.34  0.000
Interaction   4   318.70   79.675   7.31  0.000
Error        90   980.50   10.894
Total        99  1572.91

S = 3.301   R-Sq = 37.66%   R-Sq(adj) = 31.43%


             Individual 95% CIs For Mean Based on
             Pooled StDev
Plot   Mean  -------+---------+---------+---------+--
A1    13.55               (--------*--------)
A2    11.60  (--------*---------)
B     14.90                      (--------*--------)
C     14.05                 (--------*--------)
D     13.55               (--------*--------)
             -------+---------+---------+---------+--
                 11.2      12.8      14.4      16.0


                Individual 95% CIs For Mean Based on
                Pooled StDev
Grazing   Mean  -----+---------+---------+---------+----
G        14.78                      (-------*-------)
U        12.28  (------*-------)
                -----+---------+---------+---------+----
                   12.0      13.2      14.4      15.6
```

Figure 10. Two-way ANOVA: Richness versus Plot, Grazing

Table 4. 5 one-way ANOVA's of grazing on species richness in plots A1, A2, B, C, and D.

Plot	F value	P value
A1	19.15	**<.0001**
A2	14.62	**<0.001**
B	1.92	<0.183
C	1.90	<0.185
D	4.64	**<0.0454**

Grazing significantly affected species diversity index with P<0.001 (figure 11), therefore Null hypothesis 1 can be rejected as species diversity was significantly effected by grazing. Grazed plots had an average diversity index of 0.904, compared to un-stocked plots with an average of 0.933, where 0 is most diverse and 1 is least diverse (Figure 12). Species diversity significantly increased in grazed plots A1, A2, and D, with no effect in B or C (as seen in Figure 12). It was found that grazing significantly affected species eveness (P<0.001, F=14.22) and grazed plots were on average more even (0.961) compared to less varied un-stocked plots (0.984) A tukey's test showed that grazed plots A2, B, C and D were significantly more even than plot A1 (Figure 2l; Appendix 2).

```
Source   DF       SS       MS      F      P
Grazing   1  0.02179  0.02179  17.93  0.000
Error    98  0.11907  0.00122
Total    99  0.14086

S = 0.03486   R-Sq = 15.47%   R-Sq(adj) = 14.60%


                             Individual 95% CIs For Mean Based on
                             Pooled StDev
Level   N     Mean    StDev  ----+---------+---------+---------+-----
G      50  0.90370  0.04514  (-----*------)
U      50  0.93322  0.01981                     (-----*------)
                             ----+---------+---------+---------+-----
                               0.900     0.915     0.930     0.945
```

Figure 11 One-way ANOVA of diversity index versus grazing.

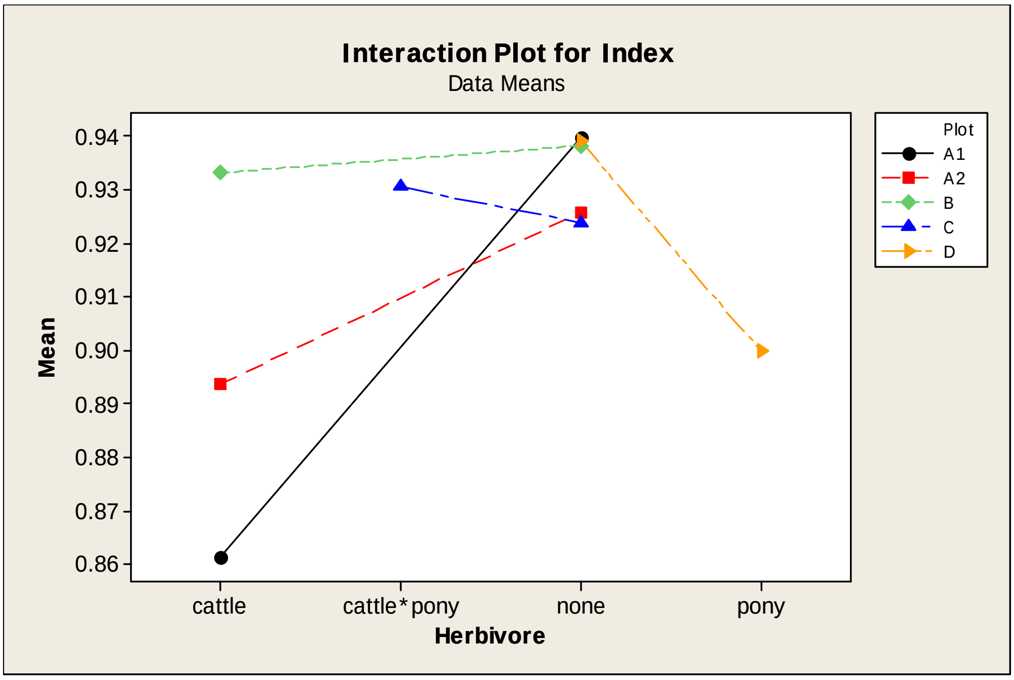


Figure 12 Interaction plot for plot and type of herbivore grazer against species diversity.

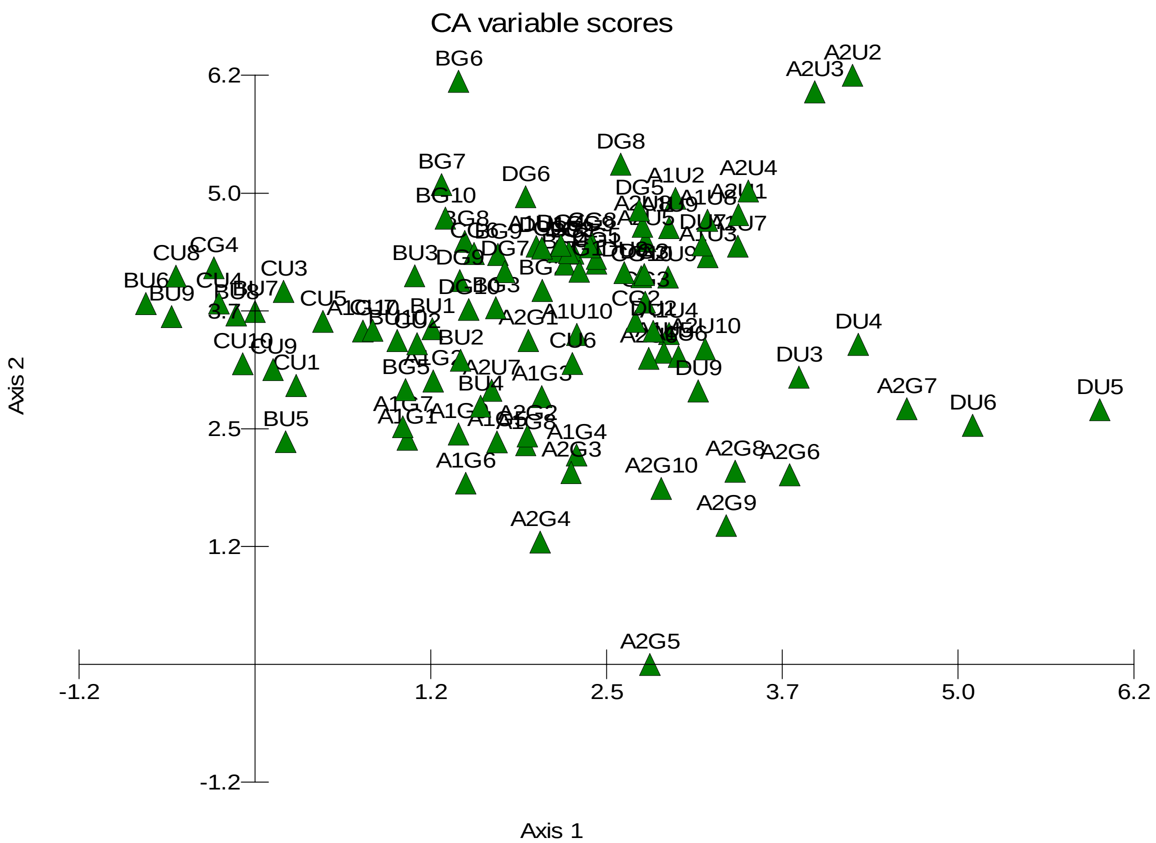


Figure 13.2D Detrended Correspondence Analysis (CA) Plot of plant species found in all grazed and un-stocked quadrats, with no clusters shown.

3.5 Species compostion and sward height

Many plant species were Common to both grazed and un-stocked quadrats (Figure 14). Species found in every grazed and un-stocked quadrat were *R. raphanistrum, Lotus corniculatus* (Bird's foot trefoil), *Vicia sativa* (Common Vetch), *Achillea millefolium (* Yarrow), *Lazula campestris* (Field wood rush), *Carex arenaria* (Sand Sedge), *F. rubra, D. glomerata* and *E. atherica.* These were seen as dominant species in Longis Common, which may out-compete other plants.

Some species were found only in large herbivore grazed-only plots, which included A*nagallis arvensis* (Scarlet pimpernel) found in A1-cattle grazed, C-cattle and D-pony grazed plots, Vi*cia hirsuta* (Hairy Tare) found in A2-cattle grazed and D-pony grazed plots, *Medicago lupulina* (Black Medick) found in plot D-pony grazed, T. repens found in plot A2-cattle grazed, *Euphrasia tetraquetra* (Maritime eyebright) found in plot A1-cattle grazed and *Carex paniculata* (Greater Tussock Sedge) found in cattle-grazed A2. All of these species found in grazed areas had a quadrat cover of ‘1 or more individuals’ or ‘several individuals’.

Average sward height in grazed un-stocked quadrats was 35.12 cm compared to 27.76 in grazed quadrats (Figure 2j; appendix 2), which was significantly different ($P<0.02$). However it was seen that sward height was significantly affected by richness ($P<0.001$) but not significantly affected by grazing ($P<0.594$). This meant that where areas were low in sward height, they were high in species richness in both the grazed and un-grazed plots. Sward height did not significantly affect species diversity index ($P<0.744$, $F=0.8$).

Plant species found only in un-stocked plots over Longis Common were *Cerastium glomeratum* (Sticky Mouse-ear) in plot D, *Foeniculum vulgare* (Fennel), in plot A2 and *Arrhenatherum elatus* (False Oats Grass) in plot A2 all as ‘1 or more individuals’. *Bromus sp* was found in un-stocked plots A2, B and C as ‘many individuals’. This may suggest that *Bromus sp*. tends to be found in un-stocked areas. *U. dioica* and *R. fructicosus* tended to be found together in areas of scrub in both grazed and un-grazed plots (Figure 15).

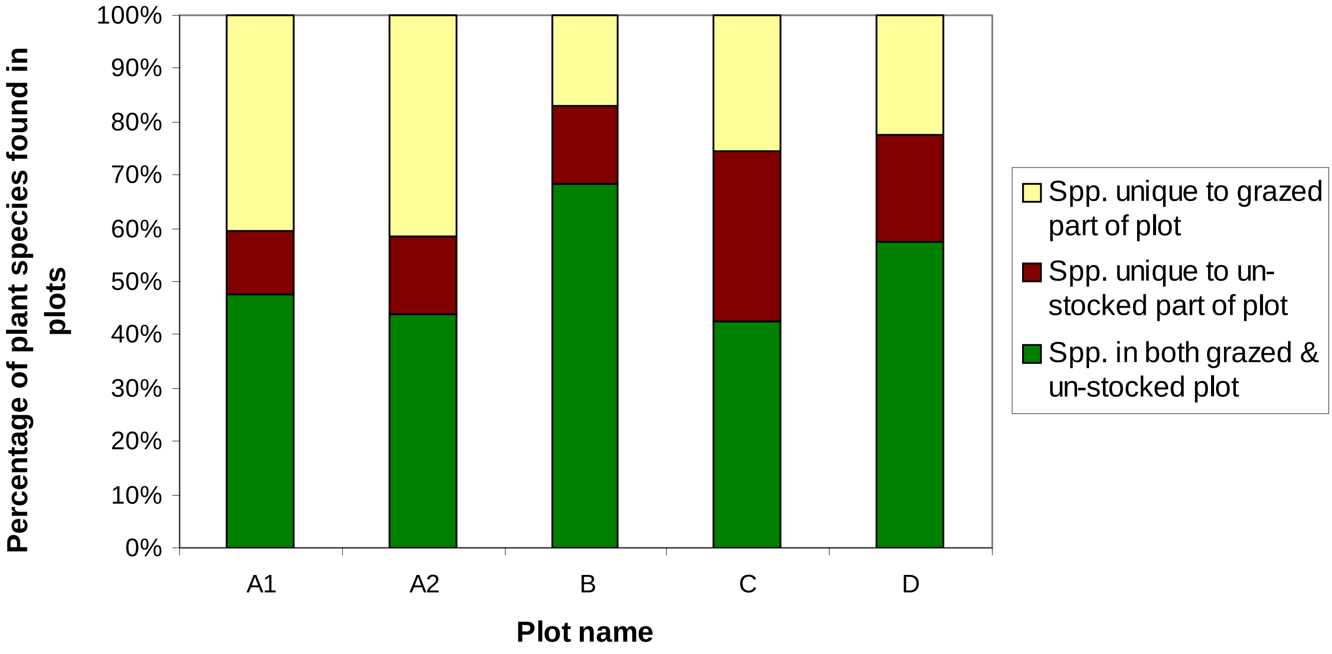


Figure 14. Stacked column showing percentage of plant species found in the grazed, un-stocked and in both parts of each plot in Longis Common. N.B Some species unique to grazed or un-stocked part of a plot were found in other plots.

3.6 Herbivore type and grazing intensity

However Null hypothesis 2 can be accepted as herbivore type (cattle, pony or cattle and pony) did not significantly effect plant species richness ($P<0.181$, $F=1.77$) (Figure 2h; Appendix 2) or plant species diversity index ($P<0.106$, $F=2.35$) (Figure 2k; Appendix 2). Null hypothesis 3 can be rejected as number of days grazing ($P<0.001$, $F=12.65$) and grazing intensity ($P<0.001$, $F=12.65$) significantly affected plant diversity index between grazed and un-stocked plots. Different number of days grazing ($P<0.001$, $F=6.04$) and different grazing intensities ($P<0.001$, $F=12.65$) also significantly affected diversity index between the grazed plots (Figures 2i, 2m and 2n; Appendix 2).

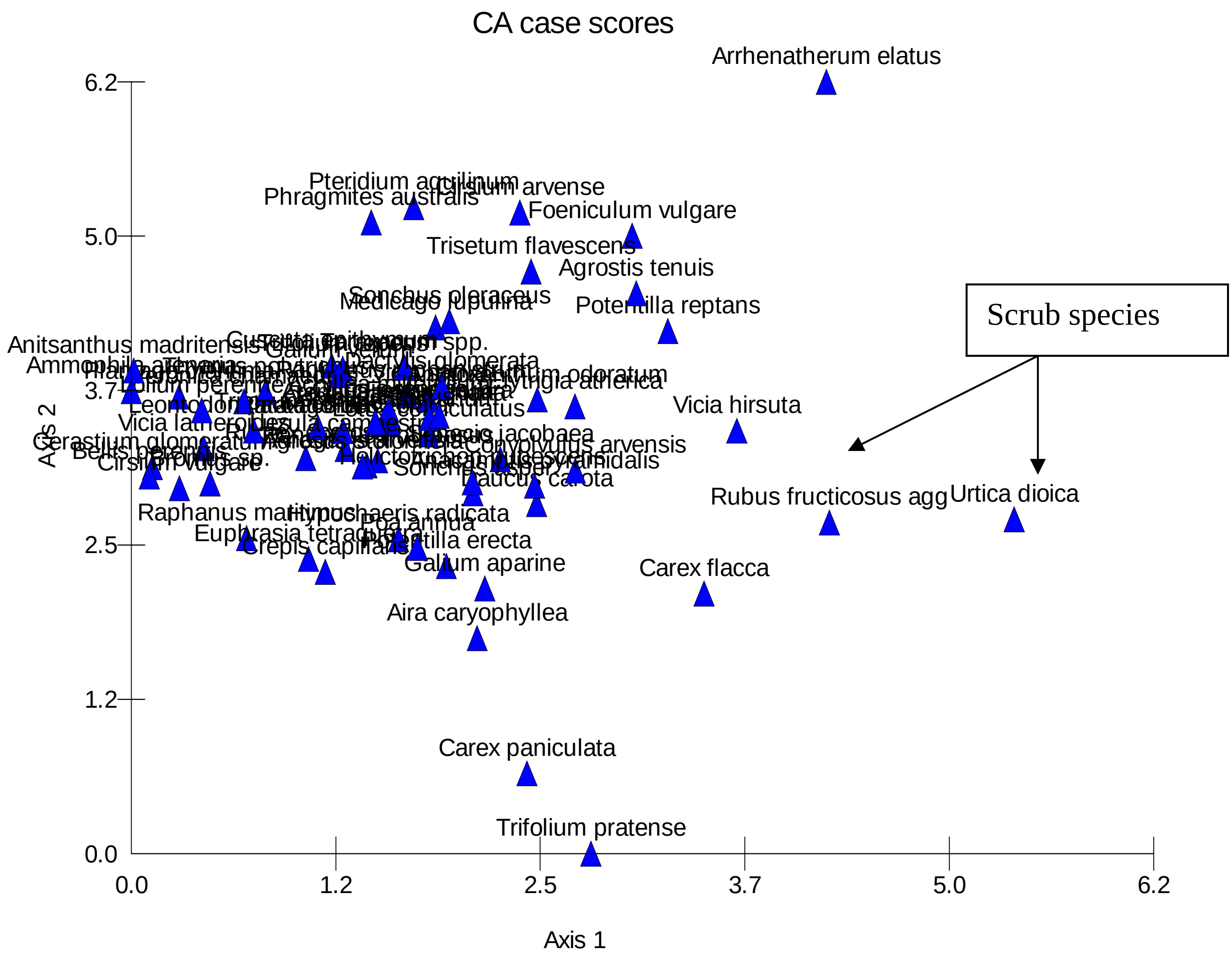


Figure 15. Detrended Correspondence Analysis (CA) Plot of plant species found in all grazed and un-stocked quadrats.

4. DISCUSSION

4.1 General effect of grazing on grassland community

Many studies have looked at the effect of grazing on grassland communities, which have produced mixed results. Some studies have shown that grazing increases plant richness and diversity, others have shown grazing to have a negative impact, whilst others have shown no impact by grazing. Data from 10 published experiments on semi-natural and agricultural grasslands in Scotland determined 9 out of 22 species showed a consistent response to grazing, controlled by the productivity of the vegetation (Pakeman, 2004). In this study the results suggested that grazing has followed that seen in previous studies whereby grazing significantly increased plant richness, diversity and evenness between un-stocked and grazed plots, by an average increase in 20% of species. 3 out of the 5 grazed plots (A1, A2 and D) showed a significant increase in species richness, which suggested that livestock grazing has the potential to affect habitat diversity. An explanation for the lack of response in the other two grazed plots B and C to grazing could be attributed to the high degree of spatial heterogeneity present in Longis Common. The many types of vegetation patches found in Longis Common meant that the quadrats surveyed may not have been representative of the community and therefore masked a grazing treatment response. In the introduction it was shown that previous land management on Longis Common would not have affected the results of this survey, as the last recorded management was a few cattle in 1950's. Furthermore, the geology if the common was seen to be same over the whole reserve, so would not affect individual plot vegetation.

The temporal and spatial heterogeneous nature of grassland communities makes interpretation of comparative community studies difficult (Thorshallsdottir, 1990). This may explain the mixed results in this experiment. For example, Klimek, *et al.* (2007) found that in 117 grasslands studied, the largest fraction of explained variation in plant species richness and species composition was accounted for by the pure effects of environmental and local field management variables. Similarly Vesk and Westoby (2001) found that in 35 published studies from Australian rangelands, 41% responded inconsistently to livestock grazing, increasing at least once and decreasing at least once and particular species were also not inherently more or less consistent. A binomial model indicated that the probability of an opposite response, across all species, was 0·275. This suggested that the ability to predict vegetation change under grazing is limited, predicted to an upper limit of about three-quarters of the time, based on species' traits alone. The plots in this study were shown not to be significantly different which ruled out plot anomalies such as varying ground structure, slope and altitude.

4.2 Comparison to baseline report

It was difficult to compare the data between the baseline study by Ozanne and David (2004) and this study as the 2004 baseline study used different methodologies. This included use of smaller sized ($0.25m^2$) quadrats rather than $1m^2$ quadrats, a transect method rather than random sampling, different plots surveyed and different skill of plant identification used. The 2004 survey showed that the corresponding mean number of species found in a 0.5m quadrat ($0.25m^2$) in grazed plot A1 to be 9.75. Three years later this study found the mean number of species in a larger, $1m^2$ quadrat in grazed plot A1 to be 17.2. Their use of smaller sized $0.25m^2$ quadrats in 2004 meant that a direct comparison could not be made with the $1m^2$ quadrats used in this report. Nevertheless, the nested plot design that was carried out in grazed plot A1 would suggest that a $0.25m^2$ area gave a species number of 13 (Figure 8). This suggested an increase from 9.75 to 13 species (33%) over three years in grazed plot A1. The mean number of species found in the un-stocked section of plot A1 in 2004 was 8 species in $0.25m^2$, compared to 9.5 species found in a $1m^2$ in 2007. This suggests that the number of species in the un-stocked areas has increased by 18.75 % in the last three years. This may be because this survey found more species in general due to different survey techniques or expertise used in the two surveys. It is suggested that future surveys of Longis Common should carry out similar methods to those used in this project to allow a more robust comparison over time.

4.3 Plant Diversity

Diversity has two components: species richness, or the number of plant species in a given area, and species evenness, or how well distributed abundance or biomass is among species within a community (Olff and Ritchie, 1998). Biodiversity in plant communities is important to the health of a habitat. In this study the average diversity index over the whole common was 0.918 where 0 represents infinite diversity and 1, no diversity. Therefore it is shown to be on the low side of diversity. However, grazing significantly increased species richness in three (A1, A2 and D) out of five grazed plots. Grazing did not significantly affect species richness in the other two grazed plots (B and C). Furthermore, plots A2, B, C and D were more significantly even than plot A1. Grazed plots B and C may have differed from the other plots as they tended to be grazed earlier on in the year during the spring compared to the other plots grazed after the summer. This could have meant that species in plots B and C did not take hold during the reproductive period, but were removed by grazing.

Grazing has been shown to enhance diversity by increasing both richness in terms of species number and evenness, by evening out the production of individual plant species, preventing any one species from dominating a landscape. By inhibiting the dominant species in a system, grazing promotes the establishment of secondary species. Plant biodiversity is highest when plant species are more evenly distributed within the community. Research has suggested that local species richness is determined by a dynamic interaction between local colonisation via dispersal and establishment, and regeneration processes contributing to reduced local extinction by the number of species available to colonise the area from a species pool at larger spatial scales (Olff and Ritchie, 1998). The ultimate effect of herbivores on plant diversity may depend on their relative impact on the biomass and reproduction of dominant plant species, the density and type of regeneration sites and the supply of propagules from rare plants (Olff and Ritchie, 1998).

4.4 Effect of grazing on species composition and sward height

The phase 1 and 2 surveys of Longis Common appeared to show a varied vegetation structure of tall and short grassland that is of vital importance for many invertebrates, ground nesting birds and small mammals. However species composition was not significantly affected by grazing. The plant species results suggest that the plant species type found on Longis Common today are of very similar type to those found in its paleoenvironmental history, and the persistence of the dominant species and the relatively small amplitude of change in functional plant groups suggest that the community was stable in spite of the varied grazing regimes and coastal conditions (Sternberg *et al*., 2000). The CA plot (Figure 15) suggested that the lack of groupings meant that species tended to occur all over the common, regardless of grazing.

Plants indicative of nutrient enrichment, such as *T. repens* and *D. glomeratus* were Common in the reserve. Whilst examination of Longis Common history has shown that there has been no fertiliser application since seaweed in World War Two, the presence of these grassland species suggest that cattle faeces have contributed to nutritionally enriched soil. An example of over richment was seen on the verges around Longis Common. These were frequently mown, with cuttings left on the surface (Bonnard, 2001). The subsequent nutrient enrichment of the soil is not suitable for poor soil species and suppressed smaller wildflowers. For example, Mountford *et al*., (1993) found that the effect of addition > 50kg ha-1 yr-1 after four years, despite grazing regimes, showed a significant reduction in species richness that outweighed the effect of grazing in the long term.

The spatial structure of grassland community is often based on a matrix of a few dominant species with other generalistic species (Rusch and Fernandez-Palacios, 1995). In Longis Common it was seen that the core species included dominant grass species, such as *F. rubra, D. glomerata* and *E. atherica,* and spreading flowering plants such as *R. raphanistrum* as these were present in all of the quadrats surveyed and observed across the entire Common.

A. arvensis and *E. tetraqueta* were only found in grazed quadrats. This was expected as small plants such as these require short sward height to grow, as this allows sunlight to intercept to allow these small plants to grow and compete with other neighbouring plants for surrounding nutrients.

The species that were found only in un-stocked quadrats, are as important as those species found only in grazed quadrats, as the number of species present in a habitat at a given time can be determined by a balance of extinction and colonization (MacArthur and Wilson, 1969). The extinction of plants is of more consequence on a small island such as Alderney as once the species has gone from an area, it would have to be artificially introduced to re-colonise the area. However in this survey the few species found only in un-stocked plots were given a cover of ‘1 or more individuals’, which may suggest an insignificant finding, or the low presence of such species. Therefore it does not seem that grazing has caused a loss of plant species.

A study by Smith and Rushton (1991) found that in a grazed system, *A. odoratum* and *Agrostis capillaris* (Common Bent) were dominant in the sward, while in un-grazed sites only *F. rubra, D. glomerata* and *H. lanatus* became dominant. These shifts were found to be primarily due to the selective nature of grazers as they preferentially grazed species that were more palatable or lacked secondary defence compounds. Such preferred species will therefore increase under grazing, whilst the less preferentially grazed species will decrease (Bullock *et al.*, 2001). In dry environments on fertile soils, such as in Longis Common, competitively dominant plant species such as *E. atherica* tend to be palatable and are likely to tolerate herbivory because of the regrowth opportunities owing to the high nutrient availability in fertile soils (Olff and Ritchie, 1998). Rare species found previously in Longis Common such as *Thesium humifusum* (Bastard Toadflax) and *Bupleurum falcatum* (Small hare's-ear) were not found in the quadrats surveyed, which may suggest a loss in these species, or a very low abundance. It is interesting to note that cattle tended only to eat *E. atherica* under high intensity grazing, therefore unless the grazing is continued to be intensive enough, it is predicted that it would continue to dominate and cover Longis Common, reducing species diversity as a result.

Species composition did not appear to change significantly since 2004. Similarly, Hulme *et al.*, (1999) showed that changes in species composition were small over a 7 years grazing experiment. Few species invaded or were lost during the course of the study, largely as a result of shifts in abundance of the dominant species. It was suggested that plant community responses to grazing management are likely to be slow to develop, as indicated by other long-term studies. A sustainable lowland grazing project (SUSGRAZ) by The Institute of Grassland and Environmental Research (IGER) showed that after four years there was no significant change in botanical diversity between the grazing severity treatments. Similarly, Pywell *et al.*, (2007) found that in two productive grasslands over four years of restoration treatments, low-level disturbance by grazing was ineffective in increasing diversity.

Average sward height was significantly different between grazed and un-stocked plots ($P<0.02$), but this was significantly affected by richness ($P<0.001$) rather than grazing ($P<0.594$). Therefore, areas of lower sward height tended to have a higher diversity. This may be because a short turf is open to sunlight, and allows many small species to grow. Average sward heights of 31.44cm in July across Longis Common were higher compared to existing guidelines of 15cm by Development of sward-based Guidelines for Grassland management in ESA's and Countryside Stewardship (DEFRA, 1997). The model developed for sward height in July suggests that, in order to produce a height of 15cm in July, stocking levels in the preceding months would have to total about 180 LU/ha, whereas stocking rate was at a maximum of 14 LU/ha (Table 1).

4.5 Scrub

The phase 1 survey in 2000 (Figure 1e; Appendix 1) showed general coverage of mostly B1 semi-improved grassland, but the current phase 1 survey in 2007 showed larger areas of B1/C3(iv) semi-improved grass with R. fructicosus /and grass mix, of low conservation value. This suggests that there were more parcels of scrub land compared to 2000 despite the grazing scheme. As Tallowin *et al*., (2005) suggested, additional management may be required to deliver all the biodiversity goals for Longis grasslands.

It is important to note that the scrub/grassland ecotone is a particularly important habitat of the species-rich semi-natural calcareous grasslands, in which specialist plants and animals, including the orchid *A. pyramidalis* occurred. Therefore for nature conservation purposes there is a need to strike a balance in controlling succession (Crofts and Jefferson, 1999. For example, *R. fruticosus* is an important shelter and food supply for birds and mammals (Mortimer *et al*., 2000). The difficulties for nature conservationists is that the problematic elements of the vegetation, such as scrub, coarse grasses *(E. atherica)* and ruderal herbs which conservationists seek to control, are selectively avoided by many grazing animals. Grazing animals feed highly selectively, favouring certain elements of the vegetation and avoiding others. In the absence of control and where more palatable herbs and grasses are heavily grazed, many of the less desirable vegetation elements will readily increase. For example, Bobbink and Willems (1987) found that in sheep grazed *B. pinnatum* swards, the sheep heavily grazed the finer grasses but avoided the Tor-grass, which provided ideal conditions for its expansion. One of the main challenges for nature conservation grazing is how to overcome selective feeding. Factors such as the timing and intensity of stock grazing are vital, as well as type of stock used (GAP, 2001). Exclusion of preferred habitat patches could also disproportionately concentrate pressure on less preferred patches. Scrub invasion on these habitats can cause conservation problems and the maintenance of a mosaic is a significant challenge (Mortimer *et al.*, 2000). Livestock can browse accessible and palatable scrub to maintain stand structure at a finer level and can limit scrub encroachment by browsing seedlings and re-growth. Grazing can therefore manipulate scrub and its relationship with other habitats in a way that is much closer to natural processes than can be achieved otherwise (FACT, 2003).

P. aquilinum is another species that requires management as once established it heavily shades and discourages other plant species from germinating. It is quickly able to replace destroyed fronds, which means that even if grazed, patches persist from active food reserves. *P. aquilinum* also produces allelopathic chemicals from its rhizomes which prevent colonisation, germination and growth of other plant species and is also toxic and carcinogenic at various stages of growth, causing problems for grazers (GAP, 2001). Grazing and browsing are one of the most sustainable methods of management, but other management options might need to be included. Removal of invasive scrub is most efficient if done at an early stage of encroachment as it is much harder to restore invaded habitats or scrub after years of neglect.

4.6 Herbivore grazing type

It was seen that herbivore type (cattle, pony or cattle and pony) did not significantly effect plant species richness ($P<0.181$) or plant species diversity ($P<0.106$). Until recently, equivalent stocking rates or densities had been given more emphasis in determining the outcome of grazing, than consideration of the impact of species or breed of grazing animal used (FACT, 2003). Controversial to this, as stated in the introduction, literature has suggested that choice of stock can influence vegetation structure, plant composition, impact on rare species, and tree or scrub cover. Studies have shown cattle to be less selective grazers than horses, grazing at 6/9 cm, with more balanced cropping. Ponies have been found to graze much closer to the ground at 2-4cm, as primarily grass feeders, but will browse evergreen shrubs and buds of deciduous species in winter and spring, helping to reduce the rate of scrub colonisation into open habitats. In this experiment the herbivore type may not have affected species diversity as the grazing regimes had not been in place long enough or at a high enough intensity to show a change in vegetation. Mixed cattle and horse grazing did not significantly affect plant species diversity, and produced the least number of species over the surveyed area. This was not as expected as the both addictive (i.e. the impact of one species reinforcing that of the other) and complementary (i.e each species' behaviour resulting in different impacts) mechanisms were expected to enhance the development of plant species. For example, Loucougary *et al.*, (2004) found that mixed grazing best limited competitive grasses and opened gaps within the sward, maximizing biodiversity. Mixed grazing may not have significantly affected diversity, as the cattle only grazed for 17 days, so cannot be attributed to ‘mixed grazing’. Nevertheless there are differences in the practicalities of keeping cattle or pony, such as method of enclosure and staff involvement.

4.7 How grazing affects grasslands

The reasons behind the affects of grazing on diversity seen in this study have been well documented. In grazed systems tall species are suppressed which opens up the sward to colonisation from other species which therefore increases species richness of the grassland. The species competitive ability, life history, and morphology along with grazer selectivity will affect the species present in the sward (Bullock *et al*., 2001). For example, herbivores are thought to enhance plant richness by their direct consumption of competitively dominant plant species and indirect effects on plant competition (Olff and Ritchie, 1998). Livestock can disperse seeds via their coat, hooves and the gut. Grazing animals also promote the cycling of nutrients in the grassland ecosystem as nutrients are added in the form of dung and urine and removed by grazing (Tallowin *et al*., 2005). Animal dung is also an important feeding habitat for many insect species and habitat for many fungi (Dennis *et al*., 1998). Grazing helps to keep the nutrient levels low thus limiting the competitive species ability to achieve dominance. Livestock has been seen to increase the habitat diversity by trampling, which produces localised micro-habitats where specialised plants and insects occur (Loucougary *et al*., 2004). Furthermore patches of bare earth from hoof prints are good for the life cycle of many invertebrates, which in turn feed birds, shrews and bats (Dennis, 1998). Moderate trampling can be beneficial in neglected grasslands as the hoof action breaks up the litter layer and tramples and crushes the coarse vegetation. It also creates bare ground, which enables short-lived species to establish.

Frank (2005) suggested that the size of the pool of species available to colonise grassland is an important factor controlling the response of grassland species richness to herbivory, particularly from low- to intermediate-productive grassland. Reedera and Schumanba (2001) also suggested that significantly higher soil C was measured in grazed pastures compared to non-grazed, due to more rapid annual shoot turnover, and redistribution of C within the plant–soil system as a result of changes in plant species composition.

4.8 Heterogeneity

Rotational grazing as seen in Alderney provided habitats for those species requiring short swards and also taller older swards. A mosaic which includes such patches of grassland that have been grazed and un-stocked, such as that found in Longis Common may prove to be optimal for conservation of grassland invertebrates. This short term study with single quadrat survey points located at a variety of plot locations in the grassland community meant that the values obtained were representative of the local assemblage, but given the considerable local heterogeneity that occurs in grassland communities this is by no means certain (Wiens, 1981). The overall treatment effect may have been confounded by the heterogeneity in the system (Dutilleul, 1993). Grassland communities are inherently spatially and temporally heterogenic; communities arise from the repeated occurrence of particular combination of species (Thorhallsdottir, 1990). This experiment was not set out in a randomised block design so statistical analysis may have been confounded by the spatial heterogeneity in the field, not allowing for variables to be independently and identically randomly distributed. The heterogeneity has been seen to be further enhanced by livestock grazing by selective grazing and urine deposition creating micro patches in the vegetation (Jaramillo and Detling, 1992). It has been shown that areas of a variety of grazing intensities of heavily, moderately, lightly and un-stocked could create a wide range of homes for a great variety of species across the landscape, being a beneficial way to conserve regional biodiversity (Thorshallsdottir, 1990).

4.9 Grazing intensity

It was seen that number of days grazing and grazing intensity (LUxdays/ ha) had a significant effect on species diversity ($P<0.001$). As a general rule, grazing pressure has an effect on biodiversity. Grazed Plot B had the lowest grazing intensity for cattle at 6.5 LU/ha, which may have caused the lack of significant change in species diversity, as the grazing was not intense enough. This study concluded that the highest stocking density of 14 Lu/ha in plot A1 provided the highest increase in plant diversity, but this was seen as low compared to many studies. However it should be noted that the higher the grazing pressure the more detrimental the overall effects. The “grazing optimization hypothesis” states that plant productivity increases with grazing and reaches a maximum at a moderate rate of herbivory by nutrient cycling (Watkinson and Ormerod, 2001; Olff and Ritchie, 1998). Weber *et al.,* (1998) compared grasslands grazed at low and high stocking rates, and showed that plant diversity and profitability were highest on lands grazed moderately. Similarly, research carried out by the Institute of Grassland and Environmental Research (IGER) indicated that lenient grazing pressure for species-rich grassland over a five-year period maintained biological diversity and abundance of positive indicator species of nature conservation value. At moderate levels, trampling creates small basins for water and grass seedlings to catch, but when too excessive, trampling compacts soils and may contribute to wind and water erosion. Lenient grazing pressure may allow herbaceous species that are well protected against grazing, such as *C. vulgare* and *C. arvense* to become abundant and form dense patches which may facilitate succession by denying grazing access to these patches (Tallowin *et al*., 2005). Sternberg *et al*., (2000) found that paddocks under continuous grazing were higher in number of species compared with paddocks subjected to seasonal grazing, independently of grazing intensity. There are few long-term experimental studies of plant community responses to changes in grazing intensity. After a 12 years grazing experiment, Bullock et al., (2001) showed that 17 of the 22 most Common species showed responses to grazing treatments where more species responded to the grazing treatments after 12 years compared to after 4 years.

It seems that setting stocking rates at any site requires careful consideration of the productivity and composition of the vegetation present, and regular monitoring is desirable to ensure that the biodiversity objectives are being achieved (Kirkham *et al*., 2005).it seems that grazing schemes with low densities such as in Longis Common can be increased until the desired effect is achieved, as it avoids irreversible damage to the vegetation and plant diversity. By allowing enough time to evaluate results before changing regime as effects can be slow to materialise. On the other hand, high densities well in excess of normal carrying capacity of land used for short periods will effect rapid change by opening rank stands or browsing off unwanted scrub.

Over-grazing however has been shown by studies to cause a decline in the productivity and diversity of the vegetation. High grazing pressure of large herbivores may result in dominance of only a few tolerant species and thus reduce plant diversity by unselective grazing and widespread erosive, detrimental soil disturbances (Olff and Ritchie, 1998). Over-grazing can also cause soil degradation and if grasses and wildflowers are grazed very hard sensitive plant species are lost from the sward. For example, English Nature (1997) stated that sward height should be kept at least five centimetres (two inches) through most of the grazing period and not less than two to five centimetres (one to two inches) at the end of the grazing period. Rotating grazing around different fields as seen in this study is therefore a good way of preventing over-grazing.

4.10 Rabbit grazing

The reason the whole area has not changed by succession to continuous scrubland appears to be partly due to the intense grazing pressure from the rabbit population. Browsing by rabbits at high densities can dramatically affect the composition and structure of scrub stands (FACT, 2003). Olff and Ritchie (1998) suggested that periodic outbreaks of smaller herbivores such as rabbits at intervals not detectable in short experiments, could maintain high plant diversity. This suggests that the spatial and temporal scale of herbivore effects must be explicitly considered to explain the impact of herbivores on plant species richness. There is a lack of predatory species on the island, so the rabbit population is not regulated by predation and has naturally been allowed to grow to saturation levels. Mixomitosis appears to be its main threat. Rabbits do not generally range far from their burrows, avoiding predation by not going farther than the food they need (Thompson, 1956). This was noted in well defined concentric zonations of vegetation concentrically around the warren, surrounding a bare patch of sandy soil. The vegetation appeared to be grazed to approximately 1cm over a considerable zone, with a higher sward high further from the burrow. Some of the rabbit warrens were found close together, so the grazed areas overlapped. As the environment of Longis Common is relatively non-threatening, apart for dogs and walkers and local buzzards, rabbits can remain outside the burren for many hours, grazing at intervals. It is estimated that if the rabbit population rapidly declined on Longis Common, the height of grassland would increase and natural succession to scrubland and then woodland would occur more rapidly, despite its exposure to sea winds. Where scrub is controlled or eradicated, rabbits can totally prevent re-growth negating the need for herbicide, so they can contribute to the maintenance of low scrub stands. Stocking levels of herbivores therefore may need to be lower than anticipated if rabbits continue to contribute to the overall impact (FACT, 2003).

4.11 AGAP future?

Whilst AGAP is used purely for conservational purposes, there is still a need to keep an economic balance. Grazing and browsing has been seen to contribute to achieving a range of management objectives. As well as reducing reliance on labour and herbicides, livestock manipulate scrub and its relationship with other habitats in a way that is much closer to natural processes than can be achieved otherwise with machinery (FACT, 2003). Browsing pressure contributes to prevent spread of scrub and maintaining structure of low growing species and so can help to develop a dynamic between scrub and open habitat that could be an important feature, replicating natural processes. However, there are limitations to using livestock as a management tool. Grazing is not a long term solution for reducing scrub as whilst grazing, browsing and barking may reduce or kill stems most scrub species will produce new growth from remaining stems/stumps once animals are removed. Rare species may be vulnerable to grazing and certain shrubs that are not palatable to livestock may gain a competitive edge. Sankaran and Augustine (2004) also suggested that mineralisation of vegetation in the digestive tracts of grazers and in dung, reduced microbial biomass in grassland soil by up to 30%.

However, when grazing animals do not consume plant biomass, above ground biomass accumulates and blocks out the emergence of new plants. Therefore, un-stocked grasslands can cause a decrease in biodiversity. Grasslands that are left un-stocked and unburned may become dominated by dominant species such as rough fescue. Grazing reduces this dominance and increases the diversity of other species. Un-stocked grasslands have been shown to develop heavy amounts of litter which tends to smother healthy plant growth. In light of this, the results have suggested a significant increase in species diversity (both richness and evenness) in three of the five plots which may negate the cost (Figure 3c; Appendix 3) and time involved in the AGAP scheme.

4.12 Timing of Grazing

Timing of the grazing is vital, if grasslands are cut too early and species have not yet set in seed, this prevents seedling establishment and later seed dispersal. In this study it could be suggested that Plots A1, A2 and D resulted in significant increase in species diversity due to not grazing during April and May period. It may be because flowers set seed at this time, being earlier in the year than the rest of the UK as a result of Alderney's Southern position and higher temperatures. It is suggested that if grazing occured during the flowering and seeding stages, reproductive capabilities would be lost and there is little time and energy left for the plant to re-grow and set seed. Dormancy in winter on the other hand is the least critical time of the year to graze because little harm is done to the plant. If the grass is grazed after the seed dispersal is allowed to occur, the seed bank is maintained. Therefore it is recommended that grazing does not occur from April over the summer months but rather in autumn and early spring. In agreement with this, Bullock *et al*., (2001) found that after 12 years of grazing, species richness was increased by spring grazing, decreased by heavier summer grazing and unaffected by winter grazing.

4.13 Limitations and further work

This study had limitations which can be used to help extend and improve future work regarding grazing in Longis Common in the future. It is seen that this study can form part of a continued assessment of vegetation in Longis Common over time, with regard to the effect of grazing. In practice, site surveys only provide a snapshot view of the vegetation at the particular time of survey. This study was carried out between June and August, therefore future surveys should be carried out at similar time to avoid the dominance of other species at different times in the season. However surveys could also be done at different seasons to investigate diversity throughout the year, and the effect of grazing on it. The use of a Domin scale brought about error as this method depends on the surveyor's eye to judge cover values. A point cover quadrat could be used to assess vegetation composition in future.

There was no vegetative data of the plots before the grazing started to take place in 2003, so comparisons could not be made with the change in species due to grazing from the same plot. It would have been better to have had a control survey before grazing and after grazing to compare the effect of grazing. A limitation to this study is that the un-stocked areas chosen as control replicates were not always immediately next to the grazed plots, so did not act as exact comparisons. Other factors may have influenced species composition in those areas, such as altitude, slope or soil quality. It would be useful o compare average species diversity in Longis Common in the future with the diversity value of 0.918 found in this study.

It appeared that random sampling may not have provided a good representation of each plot, as the vegetation varied widely between quadrats. In future the plots could be set out in a completely randomised block design whereby the blocks are defined as groups of similar experimental unit and each block is subdivided into many treatment levels as necessary. When statistical analysis is then applied to the results, it would allow the effect of spatial heterogeneity to be taken into account, as it allows to see if there is a block effect as well as a treatment effect. This method of setting out plots is commonly used in grassland experiments (Mountford *et al*., 1993). Stratified random sampling could also be carried out in future to take into account the different types of vegetation patches that occur, so the quadrats are representative of the community and do not mask a grazing response.

The complete vegetation in grazed plot B could be surveyed in future in spite of any cutting management. Where some grasses were very short and only young seedlings, it was difficult to identify and generally regarded as *F. rubra.* However this may have affected the interpretation of the amount of this grass within the results. In future a name of "unidentifiable young grass species" could be used to avoid miss-identification. Some species, especially grasses were hard to identify before flowering which may have affected the results. In future surveys could be done in teams to prevent miss-identification.

Previous grazing studies on grasslands have been carried out over longer periods of time with longer grazing periods, whereas this study had a maximum of 212 days pony grazing in one plot over two years. If the grazing scheme had been left to graze a year or longer before having a survey, more significant results might have been shown.

Soil could be analysed to look for pH in different plots, to see whether grazing affects the soil nutrient quality. In future animal diversity could be studied at the species level for birds, hares, butterflies and grasshoppers, and at higher taxonomic level for ground-dwelling arthropods, which may provide further evidence for biological diversity.

5. RECOMMENDATIONS

5.1 Management recommendations for Longis Common

Current status

In August 2007 Longis Common appeared to have favourable number and diversity of grassland species.

Rationale and Prescription:

1 – Continue to manage habitat by suitable grazing regime with cattle and/or ponies

It is recommended that grazing is continued by the Alderney Wildlife Trust in order to maintain the area and quality of this habitat type, and monitor the effects of grazing in the future. The grazing regime should be continued to achieve the recommendations as set by JNCC (2004), with sward height being 4 - 30cm overall, 10 - 15cm in late summer, no shorter than 4 - 7cm overall. It is suggested to have cattle grazing for longer periods of time before being moved on, so that an increased grazing pressure forces cattle to feed on scrub. At higher stocking rates animals are generally forced to be less selective and eat both the older, tougher plant material and the coarser plant species, which is a useful way of restoring neglected grasslands. Nutrient enrichment is an important issue so less supplementary feed should be provided, whilst allowing cattle to be kept longer on plots so sward is grazed lower, and scrub is grazed.

It is recommended to graze fewer places for longer by increasing the areas of the plots. Enlarging and linking the plots within the nature reserve to manage at a landscape scale may have numerous advantages over conservation in small fragmented sites. For example, Plots A1 and A2 could be merged with its neighbouring plot to create a larger area that can be grazed for longer. This would mean the loss of a public footpath between the sites, but this would fit in with the AWT current policy of phasing out minor footpaths in favour of enlarging more major footpaths across the Common (pers. comm. Roland Gauvain). Furthermore, increased grazing pressure in this enlarged plot would result in increased scrub browsing as preferential grass is grazed, removing encroaching R. fructicosus in the Southern corner of plot A1 along Longis Road. Whilst neither Pony nor cattle had a more significant difference, it is recommended to continue with both types of grazing animal to look for further changes in species composition in the future. Sheep would not be suggested as they would require a larger plot area, which would not be available with the rights of way across Longis Common. The current management of using electric fencing is also more difficult and expensive when used with sheep as net or three-strand fencing is required, against the cost of single strand fencing for cattle. Furthermore moving stock on and off is difficult on an island. It is suggested not to graze during the early months of April through the summer to encourage optimum new shoot growth of flowering plants during the reproductive season. Autumn, winter and early spring grazing is recommended. Winter grazing is useful in removing a build up of litter associated with an excessively rank sward. The current stocking levels have been found to achieve the desired average sward height on this site, but these levels may need to be exceeded when vegetation growth rates are unusually high or low due to variability in climate. The other benefits of the grazing herd include personal relations with visitors, and children, with the cows being seen as an attraction, and used in educational visits.

2 – Manage habitat by other artificial activities

Some scrub should be left to ensure habitats for wildlife such as nesting birds and small mammals. It may be best to sacrifice a section to scrub to allow natural restoration of vegetation in an area for continued wildlife protection. However the extent of scrub should be manually controlled to ensure it does not become unmanageable by grazing cattle. The most efficient management is to intervene at as early a stage as possible when small hand tools may be used effectively. If management is left until a later stage in the development of scrub then larger machinery may be the only management option. A topper could be used to remove the tops of the plants, with a flail collector to break the plant material into tiny cuttings. However on the uneven ground on Longis Common, this would prove time consuming. The disadvantages of mechanical techniques are that on large areas and in the long term they are more expensive, produce a uniform result, do not remove nutrients, look artificial, and are less environmentally friendly. U. europaeus should be uprooted if possible as cattle will not selectively graze on it once it becomes spiny. A complementary range of management activities could help to reduce the abundance of invaders (Watkinson and

Ormerod, 2001). P. aquilinum should be continually chopped, and ragwort removed, to prevent further dominance of these species. If scrub becomes a significant problem, controlled burning could be a possible solution, but this recommendation comes with warnings, as uncontrolled fire may result in an irreversible loss of species. By preventing the invasion of R. fructicosus and P. aquilinum, Alderney can continue to support a varied range of habitats and diversity of species. If grasslands are mowed to prevent dominant tall grass swards developing, grass clippings should be removed to prevent nutrient enrichment of the soils. Herbicide spraying would bring the management technique of last choice due to the potential impacts of the wider environment, including toxic chemicals getting into the water table and local drinking water.

3 - Maintain and record other features associated with Longis Common grasslands

Data could be collected to monitor dominance of grasses with a full vegetation surveys carried out every three years to look for changes in species composition. Similar methodologies to this study can be used as a comparison. The same quadrat sites could be surveyed. Records of rare plant species should be maintained in the Alderney reserve database. Further aerial photographic images could be obtained in the future to compare habitat changes and map in relation to 2006 or earlier versions. General photographs and ground photographs should be collected and stored in reserves file. The secondary features considered important to the diversification of the reserve could be mapped and photographed to form a base, from which the scrub should not be allowed to increase beyond this extent. A rabbit survey could be undertaken to monitor the population levels of this important grazing herbivore. Data could be collected concerning the distribution of small mammals and invertebrates, which appear under-recorded on this reserve.

4. Conservation - Access and interpretation

At present, there are few conflicts of interest between conservation strategies and user groups. However, the site is used by dog walkers and dog fouling is a problem that should ideally be addressed by providing dog litter bins at main entrances and by ensuring that dog owners are aware that dog fouling is distasteful to other visitors to the site. Education and understanding of the site and its wildlife by visitors to the reserves should be a priority to avoid unnecessary trampling by walkers on unmarked footpaths. Signs or leaflets should be provided to identify the reserve and its ownership and to assist visitors in navigation. It is suggested that an information board could be located at the main access gravel section by Longis Road. This could tell visitors about the species rich grassland with the reserve name and Alderney Wildlife Trust contact details. However it is not encouraged to specific rare species such as Bee orchids, to prevent species from being removed from the site. Encouraging visitors to the site will improve the profile of the Trust and increase the publics understanding of the importance of this kind of habitat in Alderney, and indeed internationally. It will also improve the ability of the Wildlife Trust to compile species records from Longis and gain volunteers to assist with practical and monitoring grazing or surveying projects.

6. CONCLUSION

The Alderney grazing animal scheme (AGAP) was introduced in 2003 to gauge the introduction of grazing to Longis Common, and also open up scrubland for walkers to use in the future. This study aimed to investigate the effect of herbivore grazing in Longis Common through a thorough botanical survey of the plots. It has been shown that in two years of rotational grazing, there has been a significant increase of species diversity by the stocking of grazing herbivores. Plant richness significantly increased in 3 out of the 5 grazed plots, with no significant effect in the other 2 grazed plots. The results seemed to suggest a trend towards an increase in number of plant species with increased grazing time and intensity. The use of grazing systems has been seen to maintain plant diversity, and thereby provide wildlife habitat. As Crofts and Jefferson (1999) recognised, there is a need for more specific and detailed guidance aimed at wildlife managers relating to the planning and preparation of grazing schemes. It is noted that this project appears to be an early pilot study of the Alderney grazing scheme since the longest the animals had grazed a plot was 212 days over 2 years. It has been seen that there are a number of complex factors which determine the effect of grazing on grassland. This study has shown the need for long-term experimental analyses of community responses to grazing as vegetation responses may develop over a long time, as shown by a 12 year experiment by Bullock *et al*., (2001). By analysing the traits it may be possible to predict changes in species composition under grazing through an understanding of the mechanisms of plant responses.

This investigation has shown that each conservation site is unique and the development of good grazing practice that suits both wildlife and stock is far from straightforward. It has been shown that if properly managed, grazing can be a beneficial asset to plant production and wildlife habitat biodiversity. By increasing plant productivity and biodiversity through moderate grazing, a healthier grassland ecosystem could be obtained in Longis Common to support diverse floral species and native wildlife. The natural grassland system of Longis Common is currently maintained by grazing cattle and pony, so removal of these herbivores would lead to further scrub encroachment and gradual afforestation in a place of public interest. Therefore the continued open existence of Longis Common is dependent on appropriate low-intensity management, largely by grazing. Close monitoring is a necessity to evaluate the effects of grazing systems. Evaluations would allow AWT members to adapt livestock stocking rates and grazing seasons to perpetuate plant production and diversity.

There is also need to understand how other management practices, mowing or specific control methods could be used periodically and be effectively integrated in conjunction with grazing to prevent scrub from forming, and remove persistent vegetation, such as *P. aquilinum*. As suggested by Ozanne and David (2004) a longer term study should be carried out in three years time (2010), after significant seasons of continuous grazing have been in place on Longis Common to investigate any change in biological diversity and levels of scrub encroachment. It is predicted that a similar increase in species would be apparent by 2010 if sufficient grazing has occurred.

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Appendix 1:

Maps

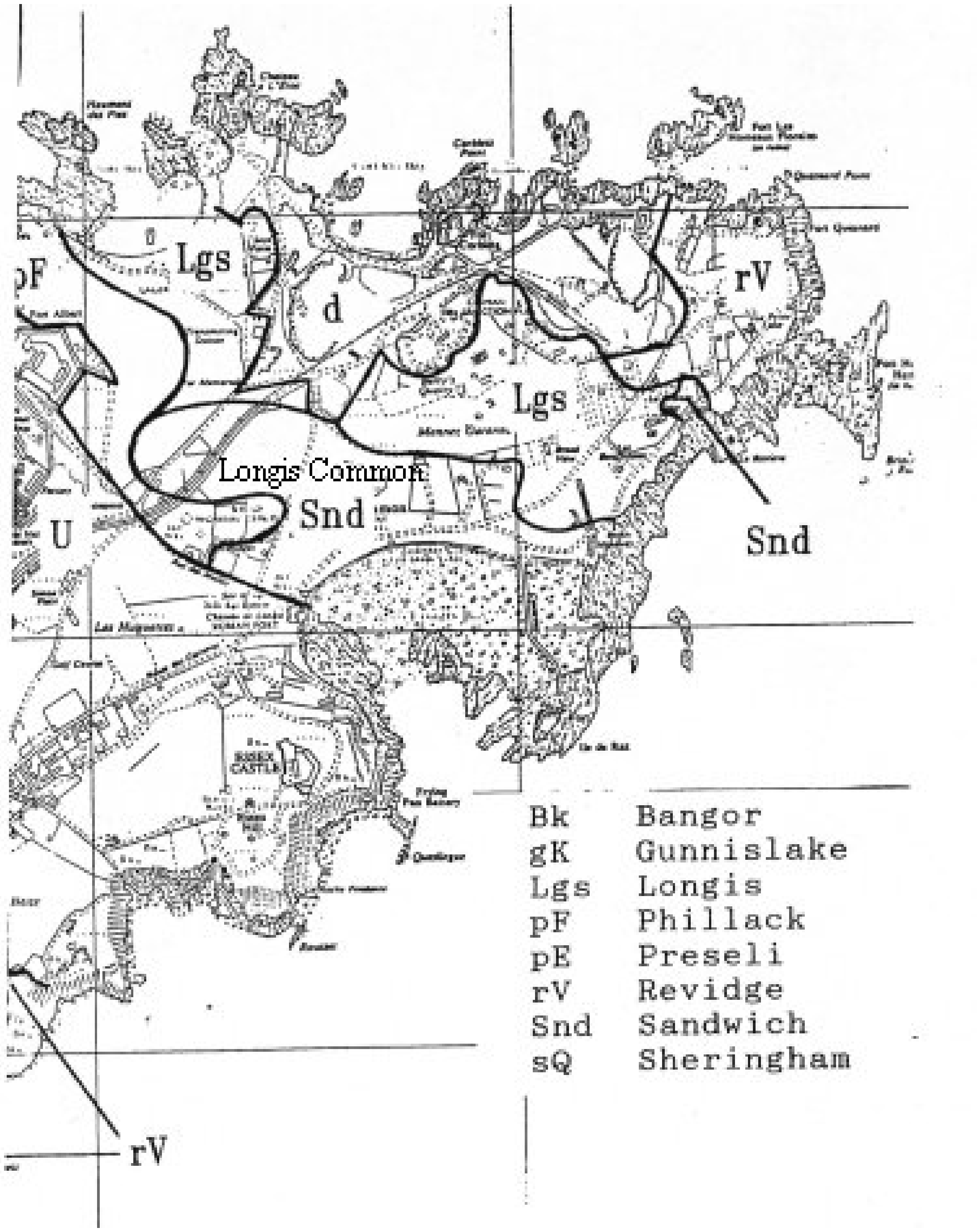

Figure 1a. Geology map of Longis Common and surrounding areas in Alderney. After J Hazelden. Soil Survey and Land Research Centre. Cranfield Institute of Technology.

Figure 1b. Satellite Map of Alderney, showing Longis Common to the East

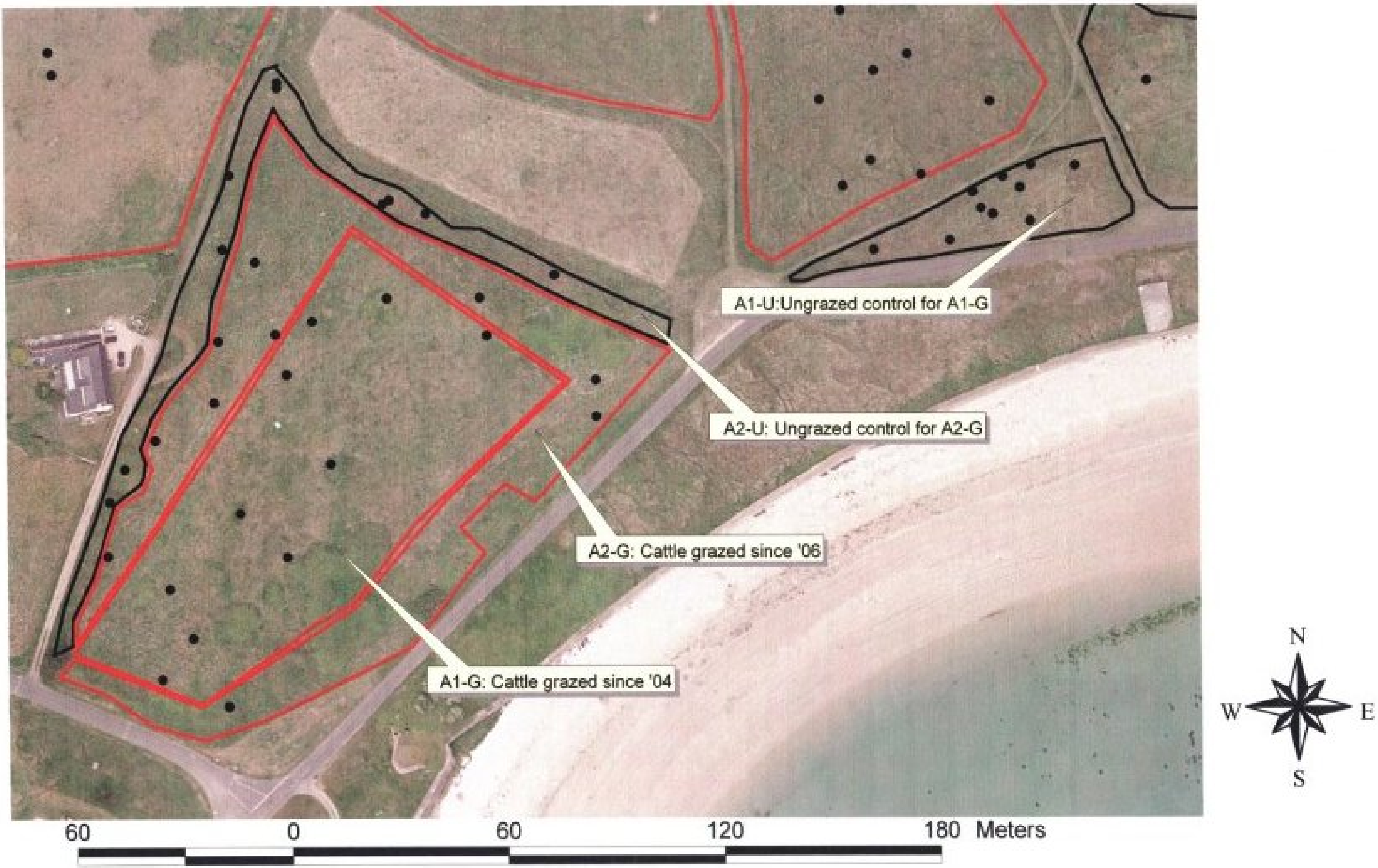

Figure 1c. Cattle grazed and ungrazed areas on Longis Common, Alderney with random quadrat survey points.

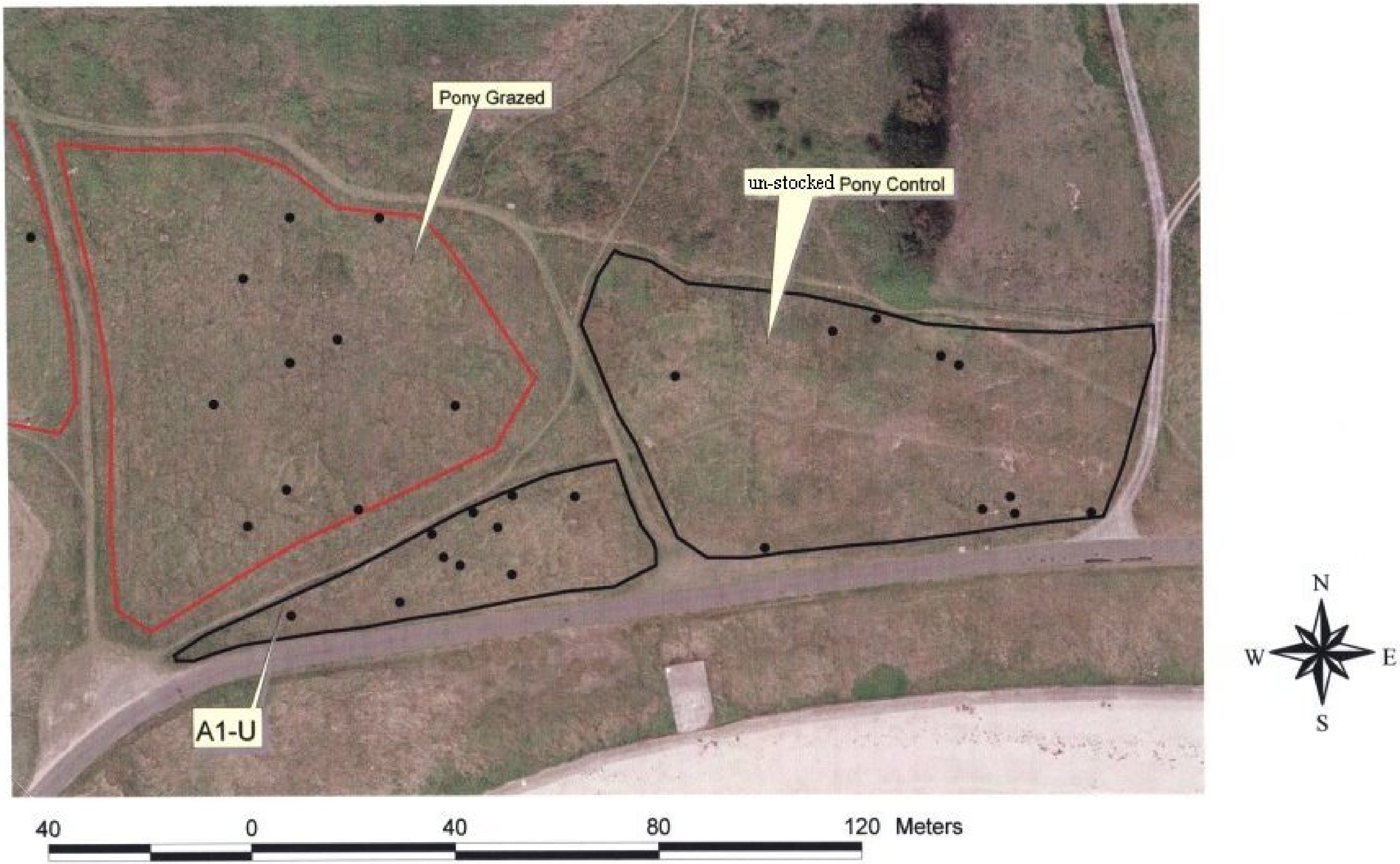

Figure 1d. Aerial Map of Longis Common, showing Pony-grazed (D-G) and un-stocked (D-U) plots with random quadrat points.

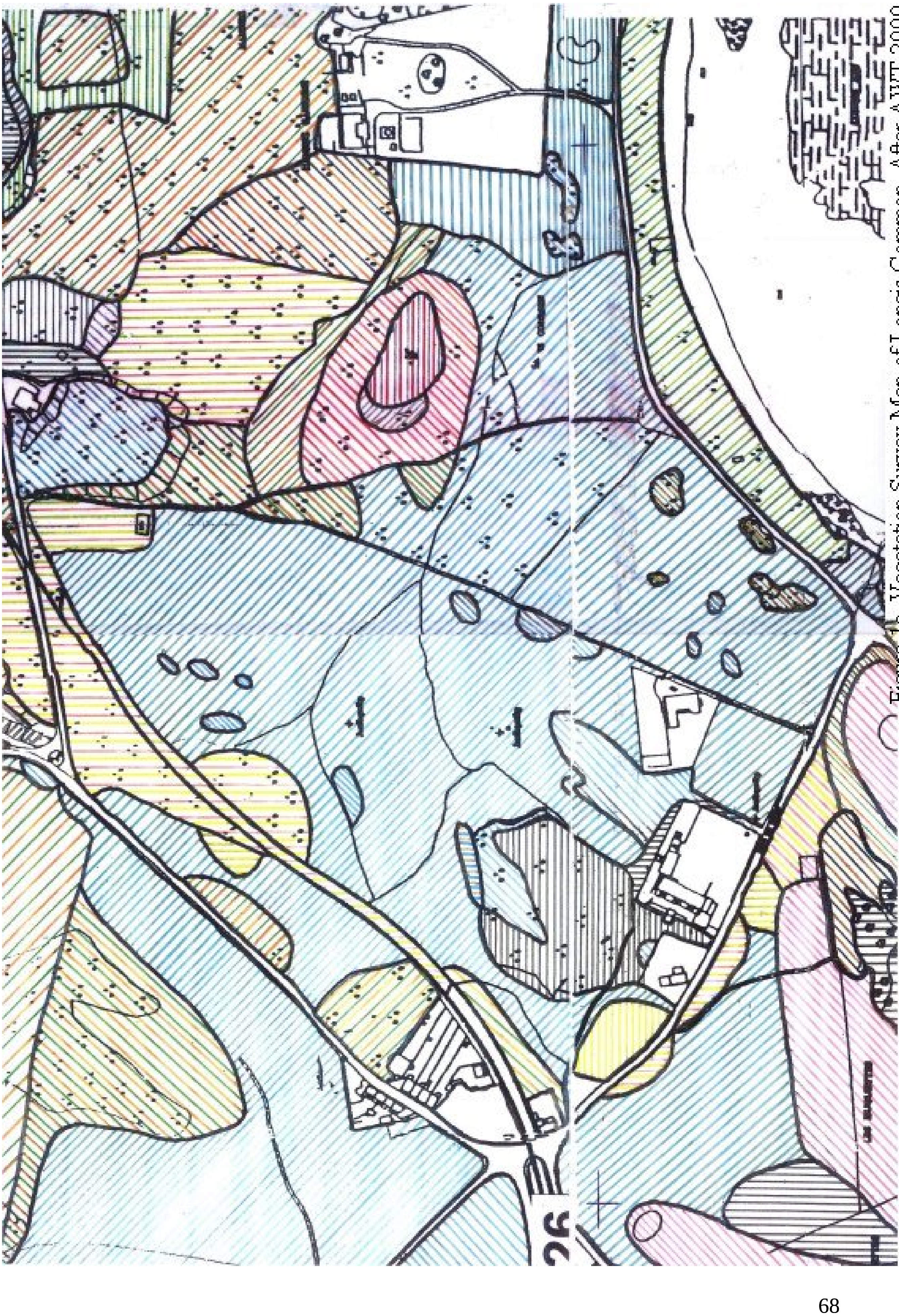

Figure 1e. Vegetation Survey Map of Longis Common. After AWT 2000

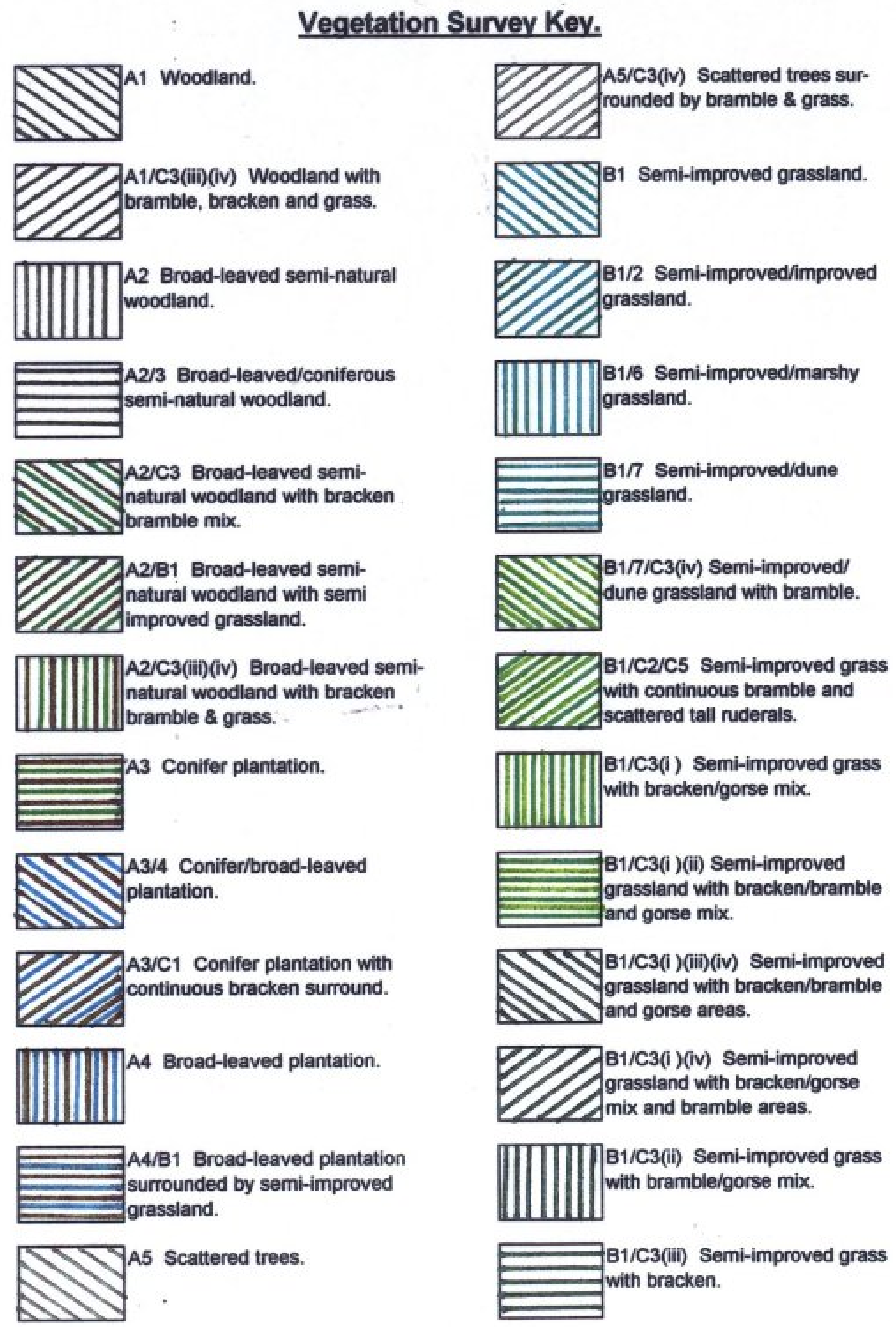

Figure 1f. Vegetation Survey Key. After AWT 2000

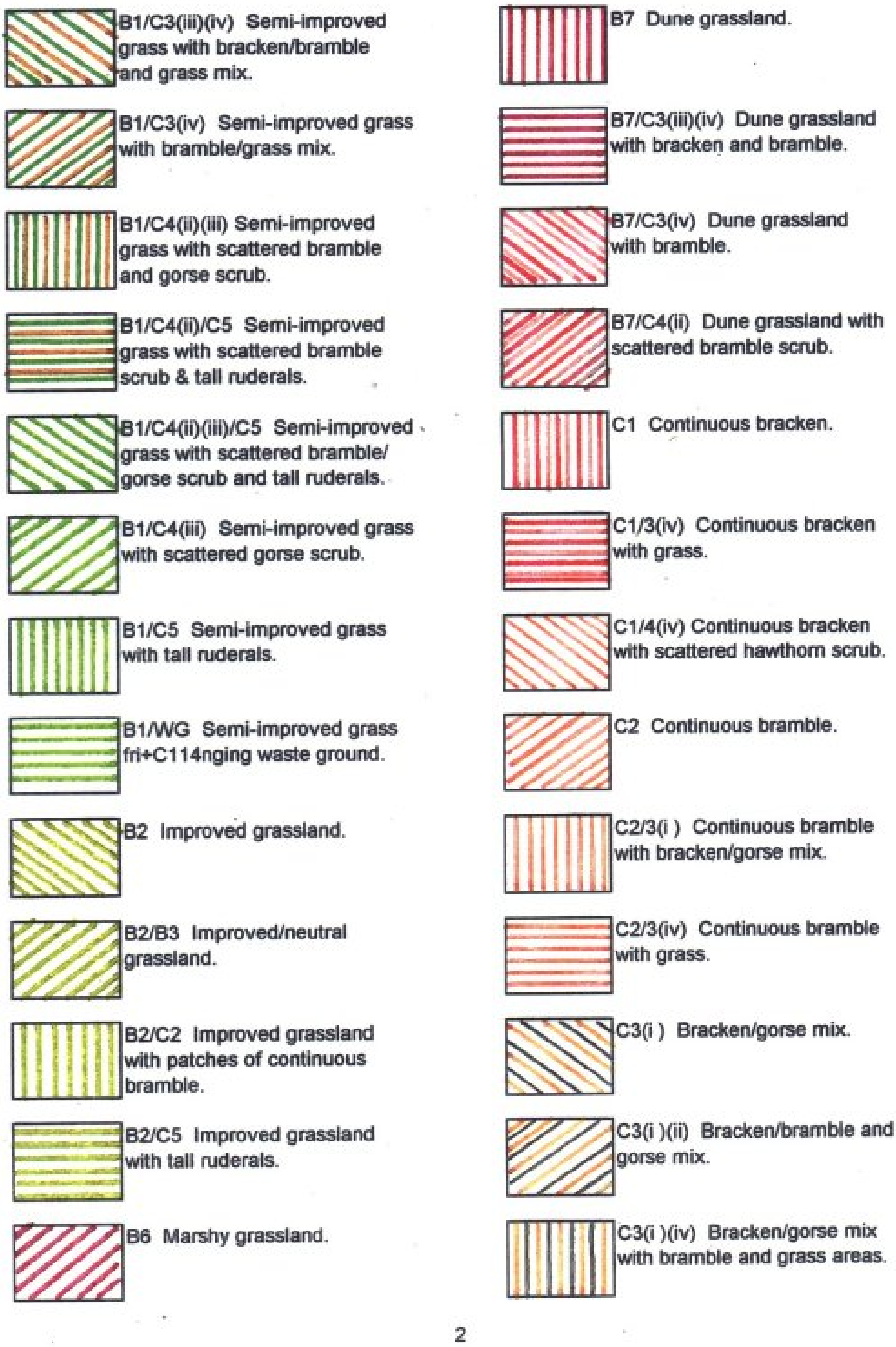

Figure. 1f. - Part 2

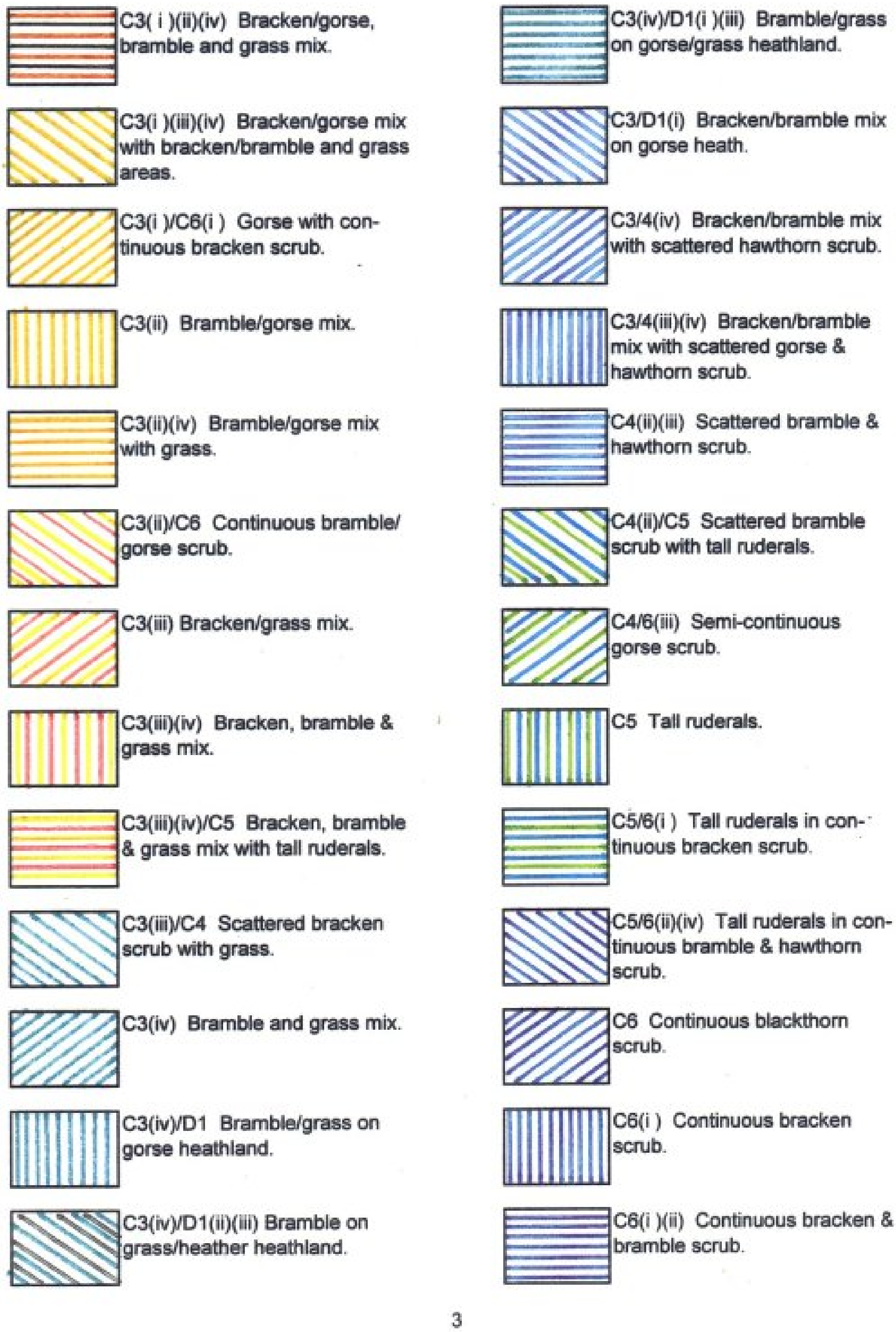

Figure. 1f. - Part 3

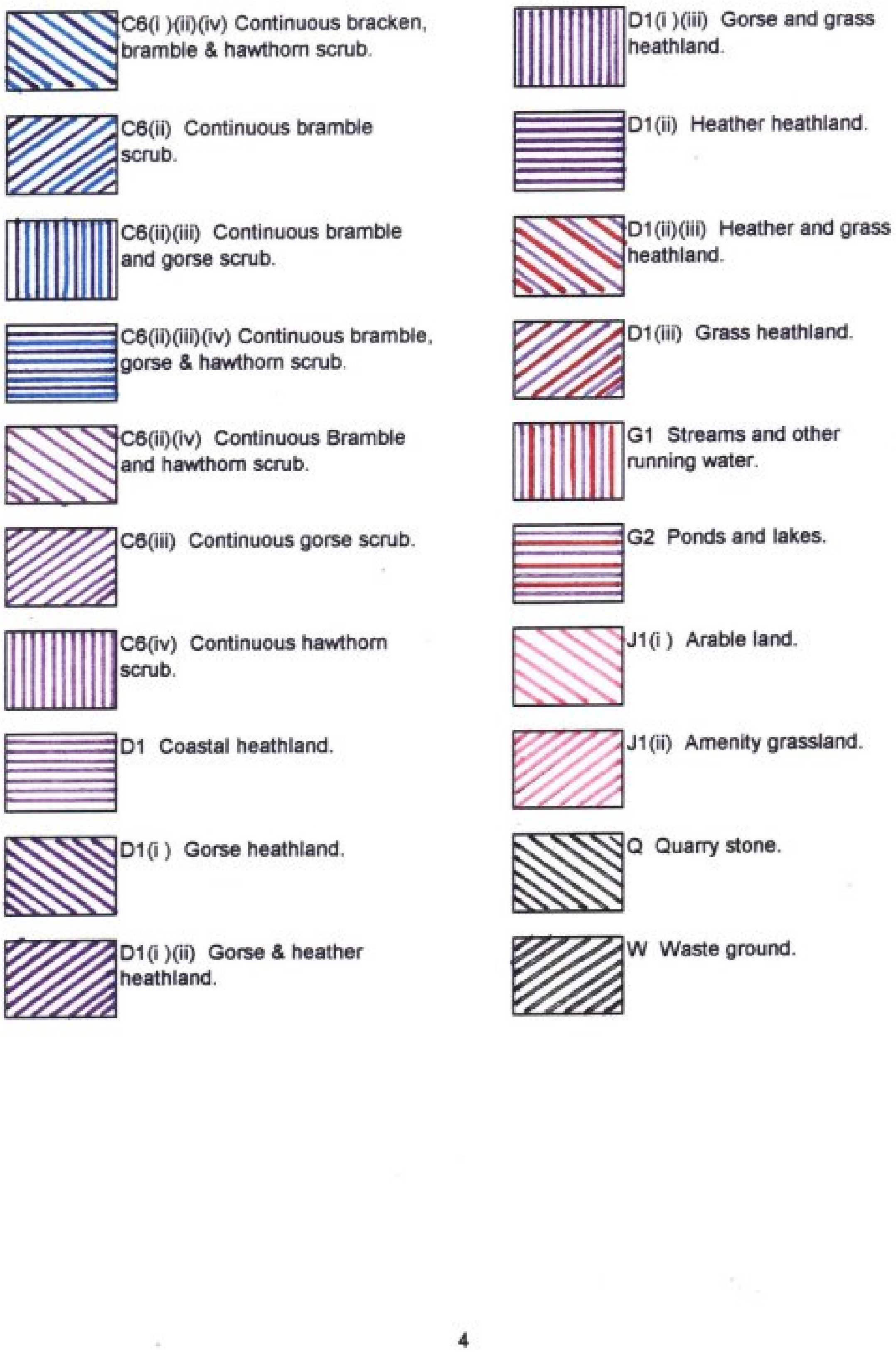

Figure 1f. - Part 4

Appendix 2:

Botanical survey results

On file

Figure 2g. Raw data and statistics for all quadrats

Plot	Quadrat no.	Herbivore	Grazing	Days	Intensity	Richness	Index	Evenness	No.Spp	Sward height
A1	1	none	U	0	0	18	0.937:	0.98	17	23
A1	2	none	U	0	0	14	0.928	0.983	14	33
A1	3	none	U	0	0	7	0.91	0.973	12	60
A1	4	none	U	0	0	9	0.927	0.985	13	56
A1	5	none	U	0	0	9	0.96	0.992	23	54
A1	6	none	U	0	0	6	0.957	0.991	22	62
A1	7	none	U	0	0	8	0.948	0.991	18	55
A1	8	none	U	0	0	7	0.949	0.989	19	61
A1	9	none	U	0	0	8	0.938	0.978	18	60
A1	10	none	U	0	0	13	0.942	0.992	16	28
A1	1	cattle	G	78	936	17	0.952	0.989	18	12
A1	2	cattle	G	78	936	14	0.921	0.968	14	9
A1	3	cattle	G	78	936	12	0.83	0.933	7	13
A1	4	cattle	G	78	936	13	0.862	0.94	9	24
A1	5	cattle	G	78	936	23	0.871	0.936	10	8
A1	6	cattle	G	78	936	22	0.774	0.886	6	14
A1	7	cattle	G	78	936	18	0.822	0.9	8	13
A1	8	cattle	G	78	936	19	0.795	0.884	7	24
A1	9	cattle	G	78	936	18	0.849	0.936	8	17
A1	10	cattle	G	78	936	16	0.938	0.988	13	28
A2	1	none	U	0	0	11	0.941	0.991	15	48
A2	2	none	U	0	0	8	0.945	0.989	16	64
A2	3	none	U	0	0	9	0.942	0.988	16	42
A2	4	none	U	0	0	11	0.946	0.986	18	52
A2	5	none	U	0	0	10	0.94	0.983	16	64
A2	6	none	U	0	0	8	0.917	0.972	13	24
A2	7	none	U	0	0	10	0.938	0.995	12	29
A2	8	none	U	0	0	12	0.897	0.982	9	32
A2	9	none	U	0	0	8	0.874	0.952	9	27
A2	10	none	U	0	0	8	0.917	0.985	11	45
A2	1	cattle	G	23	154	15	0.914	0.975	11	30
A2	2	cattle	G	23	154	16	0.881	0.974	8	25
A2	3	cattle	G	23	154	16	0.905	0.977	9	31
A2	4	cattle	G	23	154	18	0.921	0.983	11	37
A2	5	cattle	G	23	154	16	0.924	0.992	10	37
A2	6	cattle	G	23	154	13	0.862	0.949	8	95
A2	7	cattle	G	23	154	14	0.905	0.976	10	49
A2	8	cattle	G	23	154	9	0.936	0.992	12	57
A2	9	cattle	G	23	154	9	0.849	0.936	8	48
A2	10	cattle	G	23	154	11	0.84	0.925	8	39
B	1	none	U	0	0	15	0.947	0.993	16	23
B	2	none	U	0	0	17	0.935	0.981	15	25
B	3	none	U	0	0	19	0.933	0.978	15	24
B	4	none	U	0	0	14	0.935	0.983	14	26
B	5	none	U	0	0	21	0.954	0.996	16	23
B	6	none	U	0	0	15	0.945	0.99	16	25
B	7	none	U	0	0	15	0.938	0.994	13	28
B	8	none	U	0	0	13	0.93	0.985	13	23
B	9	none	U	0	0	15	0.923	0.987	11	16

B	10	none	U	0	0	12	0.942	0.994	13	30
B	1	cattle	G	160	694	16	0.922	0.971	15	33
B	2	cattle	G	160	694	15	0.942	0.986	17	17
B	3	cattle	G	160	694	15	0.946	0.986	19	22
B	4	cattle	G	160	694	14	0.925	0.979	14	23
B	5	cattle	G	160	694	16	0.954	0.987	21	11
B	6	cattle	G	160	694	16	0.93	0.98	15	21
B	7	cattle	G	160	694	13	0.933	0.982	15	12
B	8	cattle	G	160	694	13	0.929	0.988	13	17
B	9	cattle	G	160	694	11	0.934	0.984	15	15
B	10	cattle	G	160	694	13	0.916	0.978	12	15
C	1	none	U	0	0	19	0.908	0.973	11	15
C	2	none	U	0	0	11	0.89	0.97	9	27
C	3	none	U	0	0	16	0.884	0.955	10	20
C	4	none	U	0	0	17	0.95	0.987	18	19
C	5	none	U	0	0	11	0.919	0.975	12	24
C	6	none	U	0	0	12	0.933	0.98	14	35
C	7	none	U	0	0	13	0.951	0.989	17	24
C	8	none	U	0	0	17	0.913	0.978	11	20
C	9	none	U	0	0	14	0.94	0.992	13	34
C	10	none	U	0	0	20	0.949	0.994	15	26
C	1	cattle*pony	G	157	311.6	11	0.951	0.99	19	29
C	2	cattle*pony	G	157	311.6	9	0.904	0.971	11	24
C	3	cattle*pony	G	157	311.6	11	0.938	0.986	16	35
C	4	cattle*pony	G	157	311.6	18	0.94	0.984	17	45
C	5	cattle*pony	G	157	311.6	12	0.92	0.991	11	19
C	6	cattle*pony	G	157	311.6	14	0.91	0.972	12	14
C	7	cattle*pony	G	157	311.6	17	0.922	0.979	13	17
C	8	cattle*pony	G	157	311.6	11	0.934	0.977	17	11
C	9	cattle*pony	G	157	311.6	13	0.931	0.985	14	13
C	10	cattle*pony	G	157	311.6	15	0.955	0.991	20	15
D	1	none	U	0	0	18	0.906	0.98	9	19
D	2	none	U	0	0	13	0.951	0.989	19	25
D	3	none	U	0	0	7	0.949	0.986	18	53
D	4	none	U	0	0	8	0.939	0.985	15	52
D	5	none	U	0	0	6	0.913	0.988	10	54
D	6	none	U	0	0	7	0.956	0.989	19	44
D	7	none	U	0	0	8	0.954	0.989	19	35
D	8	none	U	0	0	12	0.923	0.979	13	39
D	9	none	U	0	0	15	0.959	0.995	19	16
D	10	none	U	0	0	20	0.939	0.981	16	13
D	1	pony	G	212	296.8	9	0.955	0.99	18	44
D	2	pony	G	212	296.8	19	0.929	0.983	13	36
D	3	pony	G	212	296.8	18	0.846	0.952	7	33
D	4	pony	G	212	296.8	15	0.879	0.975	8	40
D	5	pony	G	212	296.8	10	0.831	0.963	6	44
D	6	pony	G	212	296.8	19	0.865	0.972	7	35
D	7	pony	G	212	296.8	19	0.878	0.971	8	34
D	8	pony	G	212	296.8	13	0.919	0.975	12	27
D	9	pony	G	212	296.8	19	0.948	0.994	15	32
D	10	pony	G	212	296.8	16	0.948	0.994	15	45
Average						13.53	0.91827	0.97667	13.46	31.44

STATISTICS

```
Factor     Type   Levels  Values
Herbivore  fixed       3  cattle, cattle*pony, pony

Analysis of Variance for Richness, using Adjusted SS for Tests

Source     DF  Seq SS  Adj SS  Adj MS     F      P
Herbivore   2   38.61   38.61   19.31  1.77  0.181
Error      47  511.97  511.97   10.89
Total      49  550.58
```

Figure 2h. GLM ANOVA of type of herbivore (cattle, pony or both) effect on species richness

```
Source        DF        SS        MS      F      P
Grazing days   5  0.056657  0.011331  12.65  0.000
Error         94  0.084202  0.000896
Total         99  0.140859
S = 0.02993   R-Sq = 40.22%   R-Sq(adj) = 37.04%
                             Individual 95% CIs For Mean Based on Pooled StDev
Level   N     Mean    StDev  ---------+---------+---------+---------+
  0    50  0.93322  0.01981                             (--*--)
 23    10  0.89370  0.03361             (-----*-----)
 78    10  0.86140  0.06006  (-----*-----)
157    10  0.93050  0.01661                         (-----*-----)
160    10  0.93310  0.01150                          (-----*-----)
212    10  0.89980  0.04554               (-----*-----)
                             ---------+---------+---------+---------+
                                    0.870     0.900     0.930     0.960
```

Figure. 2i. One-way ANOVA: Index versus Grazing days

```
Source   DF     SS    MS     F      P
Grazing   1   1354  1354  5.59  0.020
Error    98  23728   242
Total    99  25083
S = 15.56   R-Sq = 5.40%   R-Sq(adj) = 4.43%
                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level   N   Mean  StDev  ---+---------+---------+---------+------
G      50  27.76  15.73  (--------*-------)
U      50  35.12  15.39                (-------*--------)
                         ---+---------+---------+---------+------
                         25.0      30.0      35.0      40.0

Analysis of Variance for Sward height, using Adjusted SS for Tests

Source     DF   Seq SS   Adj SS  Adj MS     F      P
Richness   17  10670.0   9366.5   551.0  3.11  0.000
Grazing     1     50.8     50.8    50.8  0.29  0.594
Error      81  14361.9  14361.9   177.3
Total      99  25082.6
```

Figure 2j. General Linear Model: Sward height versus Richness, Grazing

```
Source     DF       SS       MS     F      P
Herbivore   2  0.00908  0.00454  2.35  0.106
Error      47  0.09075  0.00193
Total      49  0.09984

S = 0.04394   R-Sq = 9.10%   R-Sq(adj) = 5.23%
```

Figure 2k. One-way ANOVA: Index versus Herbivore

```
Source  DF        SS        MS     F      P
Plot     4  0.015091  0.003773  8.35  0.000
Error   45  0.020329  0.000452
Total   49  0.035421

S = 0.02125   R-Sq = 42.61%   R-Sq(adj) = 37.50%


                             Individual 95% CIs For Mean Based on Pooled StDev
Level   N     Mean    StDev  ---------+---------+---------+---------+
A1     10  0.93600  0.03810  (------*------)
A2     10  0.96790  0.02319                 (------*------)
B      10  0.98210  0.00524                        (------*------)
C      10  0.98260  0.00750                         (-----*------)
D      10  0.97690  0.01363                     (-----*------)
                             ---------+---------+---------+---------+
                                  0.940     0.960     0.980     1.000

Pooled StDev = 0.02125


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Plot

Individual confidence level = 99.33%


Plot = A1 subtracted from:

Plot    Lower   Center    Upper  ----+---------+---------+---------+-----
A2    0.00488  0.03190  0.05892                 (--------*--------)
B     0.01908  0.04610  0.07312                     (--------*--------)
C     0.01958  0.04660  0.07362                      (--------*--------)
D     0.01388  0.04090  0.06792                    (--------*--------)
                                 ----+---------+---------+---------+-----
                                   -0.030     0.000     0.030     0.060
```

Figure 2l. One-way ANOVA: Evenness versus Plot

```
Source  DF       SS       MS     F      P
Days     4  0.03487  0.00872  6.04  0.001
Error   45  0.06497  0.00144
Total   49  0.09984

S = 0.03800   R-Sq = 34.93%   R-Sq(adj) = 29.14%

                             Individual 95% CIs For Mean Based on
                             Pooled StDev
Level   N     Mean    StDev   -+---------+---------+---------+--------
 23    10  0.89370  0.03361           (------*------)
 78    10  0.86140  0.06006   (------*------)
157    10  0.93050  0.01661                      (------*------)
160    10  0.93310  0.01150                       (------*------)
212    10  0.89980  0.04554             (------*------)
                              -+---------+---------+---------+--------
                             0.840     0.875     0.910     0.945

Pooled StDev = 0.03800


Tukey 95% Simultaneous Confidence Intervals

All Pairwise Comparisons among Levels of Days

Individual confidence level = 99.33%


Days =  23 subtracted from:

Days     Lower    Center    Upper     +---------+---------+---------+---------
 78   -0.08060  -0.03230  0.01600            (-------*-------)
157   -0.01150   0.03680  0.08510                       (-------*-------)
160   -0.00890   0.03940  0.08770                        (-------*-------)
212   -0.04220   0.00610  0.05440                  (-------*-------)
                                          +---------+---------+---------+---------
                                       -0.120    -0.060     0.000     0.060
```

Figure 2m. One-way ANOVA: Index versus Days

```
Source     DF       SS       MS     F      P
Intensity   4  0.03487  0.00872  6.04  0.001
Error      45  0.06497  0.00144
Total      49  0.09984

S = 0.03800   R-Sq = 34.93%   R-Sq(adj) = 29.14%


                             Individual 95% CIs For Mean Based on
                             Pooled StDev
Level   N     Mean    StDev   -+---------+---------+---------+--------
154.0  10  0.89370  0.03361            (------*------)
296.8  10  0.89980  0.04554              (------*------)
311.6  10  0.93050  0.01661                       (------*------)
694.0  10  0.93310  0.01150                        (------*------)
936.0  10  0.86140  0.06006   (------*------)
                              -+---------+---------+---------+--------
                             0.840     0.875     0.910     0.945


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Intensity

Individual confidence level = 99.33%


Intensity = 154.0 subtracted from:

Intensity     Lower    Center    Upper
296.8      -0.04220   0.00610  0.05440
311.6      -0.01150   0.03680  0.08510
694.0      -0.00890   0.03940  0.08770
936.0      -0.08060  -0.03230  0.01600

Intensity     +---------+---------+---------+---------
296.8                      (-------*-------)
311.6                           (-------*-------)
694.0                            (-------*-------)
936.0                (-------*-------)
              +---------+---------+---------+---------
           -0.120    -0.060     0.000     0.060
```

Figure 2n. One-way ANOVA: Index versus Intensity

Appendix 3:

Miscallaneous

Figure 3a. Photograph looking Southwest towards trees on Longis hillside. Path divides cattle grazed plot B to the left and un-stocked plot B to the right.

Figure 3b. Photograph showing typical Longis Common grassland, with *Raphanus raphanistrum.* Cow pat seen in foreground.

Alderney Wildlife Trust
Account QuickReport
January through December 2006

Type	Date	Num	Name	Memo	Split	Amount
Conservation & Ecology						
AGAP						
Cheque	22/05/2006	825	Farm Supplies	Electric fencing	Natwest Curre...	147.57
Cheque	09/06/2006	841	Kiln Farm Dairy	Calf nu.ts	Natwest Curre...	24.00
Cheque	09/06/2006	841	Kiln Farm Dairy	Diesel for tra...	Natwest Curre...	84.50
Cheque	24/08/2006	904	Kiln Farm Dairy	3 x Batteries ...	Natwest Curre...	126.97
Cheque	27/10/2006	949	States of Alderney	Grazing trans...	Natwest Curre...	158.65
Cheque	06/11/2006	954	Kiln Farm Dairy	calf nuts	Natwest Curre...	36.00
Cheque	24/11/2006	973	The D.I.Y. Shop	hose connect...	Natwest Curre...	4.64
Deposit	27/12/2006	100306	Cloete, R.	Donation for f...	Natwest Curre...	-100.00
Cheque	31/12/2006	1011	Kiln Farm Dairy	cattle feed an...	Natwest Curre...	117.18
Total AGAP						599.51
Total Conservation & Ecology						599.51
TOTAL						**599.51**

Alderney Wildlife Trust
Class QuickReport
January 1 through June 26, 2007

Type	Date	Num	Name	Memo	Amount
Conservatinon & Ecology					
AGAP					
Cheque	31/01/2007	1023	Farm Supplies	fencer	-312.52
Deposit	02/02/2007	100314		Tate - Fencer	312.52
Cheque	06/03/2007	1050	Alderney Fuel Servi...	Battery Char...	-65.00
Deposit	03/04/2007	100323		Meat	110.00
Deposit	05/04/2007	100325		Deposit	380.00
Cheque	10/04/2007	1071	D.I.Y. Shop	freezer bags ...	-8.28
Deposit	11/04/2007	100326		Deposit	125.00
Deposit	16/04/2007	100327		Deposit	120.00
Cheque	16/04/2007	1081	Kiln Farm	cut up beef a...	-140.00
Deposit	23/04/2007	100328		Deposit	105.00
Total AGAP					626.72
Total Conservatinon & Ecology					626.72
TOTAL					**626.72**

Figure 3c. Accounts of costs of Alderney grazing scheme for 2006 and 2007.