A STUDY OF THE IMPACTS OF FRAGMENTATION ON THE NORTH KENT GRAZING MARSHES LANDSCAPE CHARACTERISTICS, FEATURES AND VEGETATION COMMUNITIES.

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I certify that this work has not been accepted in substance for any degree, and is not concurrently submitted for any degree other than that of Doctor of Philosophy (PhD) of the University of Greenwich. I also declare that this dissertation is the result of the independent work by R. Gray. All other work reported in the text has been attributed to the original authors and is fully referenced in the text and listed in the reference section.

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Abstract

Coastal grazing marshes are low lying wet grasslands, which have been reclaimed from tidal saltmarsh. They are drained by a series of ditches and dykes, which together with the grasslands provide a range of fresh and brackish wetland habitats favourable to a wide range of plant, invertebrate, bird and mammal species. As a result of this range, coastal grazing marshes have been recognised as a habitat of major importance within the UK Biodiversity Action Plan.

The North Kent Grazing Marshes contain some of the largest remaining areas of coastal grazing marsh in the UK, but in recent years, the North Kent Grazing Marshes have become increasingly fragmented due to the pressure for land for arable production and development. The impacts of fragmentation on the North Kent Marshes have been described as 'death by a thousand cuts', but the impacts of fragmentation processes on coastal grazing marshes have not been previously studied.

Despite being highly valued in conservation terms, their importance having been recognised through conservation designations at local, regional, national and international levels; coastal grazing marshes have never been fully defined, either in terms of their vegetation communities or their landscape characteristics. This study sought to define coastal grazing marshes in terms of the landscape characteristics and features, and to identify the range of vegetation communities, which are typical of the North Kent Marshes. The methodology used both quantitative and qualitative field studies, and was aimed at associating changes to the landscape characteristics and features and the vegetation communities to different fragmentation processes.

Historical data (Ordnance Survey and historical maps) were used to determine the pattern of fragmentation of the North Kent Marshes from the end of the nineteenth century to the present day and to identify the fragmentation processes, which were responsible for the breaking up of the marshes.

The findings indicate that in most cases grazing marsh fragmentation was initially caused by division by roads or railways, which led to development pressures and fragmentation by intrusion, envelopment or encroachment. Changes to the landscape characteristics and features bought about by fragmentation were shown to be associated to changes in the vegetation communities. Significant correlations were found to exist between the area of a fragment and the status of the landscape characteristics and features and with the type of vegetation community present.

The results were discussed in terms of how the fragmentation processes have influenced changes to the landscape characteristics, features and the vegetation communities, and the possible implications of future fragmentation. The ideal grazing marsh was defined in terms of landscape characteristics; features and vegetation communities and monitoring procedures are also proposed.

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Chapter 1 Introduction

1.1 The North Kent Marshes.

The low-lying grasslands of the North Kent Marshes extend from Whitstable in the east, to the Inner Thames Marshes of Erith and Crayford in the west, Figure 1.1. Historical sources e.g. Hasted (1797), suggest that in all probability the marshes would have extended right into the heart of London, extending up stream as far as the London Bridge. Harris (1914) refers to marshy grassland extending as far west as Lambeth. Together with the marshlands of Essex, the North Kent Marshes form part of a much greater expanse of coastal habitat known as the Greater Thames Marshes, figure 1.2.

Fig 1.1 North Kent Marshes included in this study, (GIS, scale 1:25000).

The marshlands of North Kent have traditionally been regarded as 'wild, remote landscapes of grazing marsh, dykes and mudflats, with huge skies, bracing air, a sense of freedom and solitude,' (Cobham 1995). Today the North Kent Marshes comprise a series of discontinuous areas of marshy, lowland wet grassland extending from the banks of the Thames inland to the 10-metre contour line, that are the remnants of this once more extensive habitat. Figs 1.3a and b show the extent of fragmentation of the North Kent Marshes between 1935 and 1990.

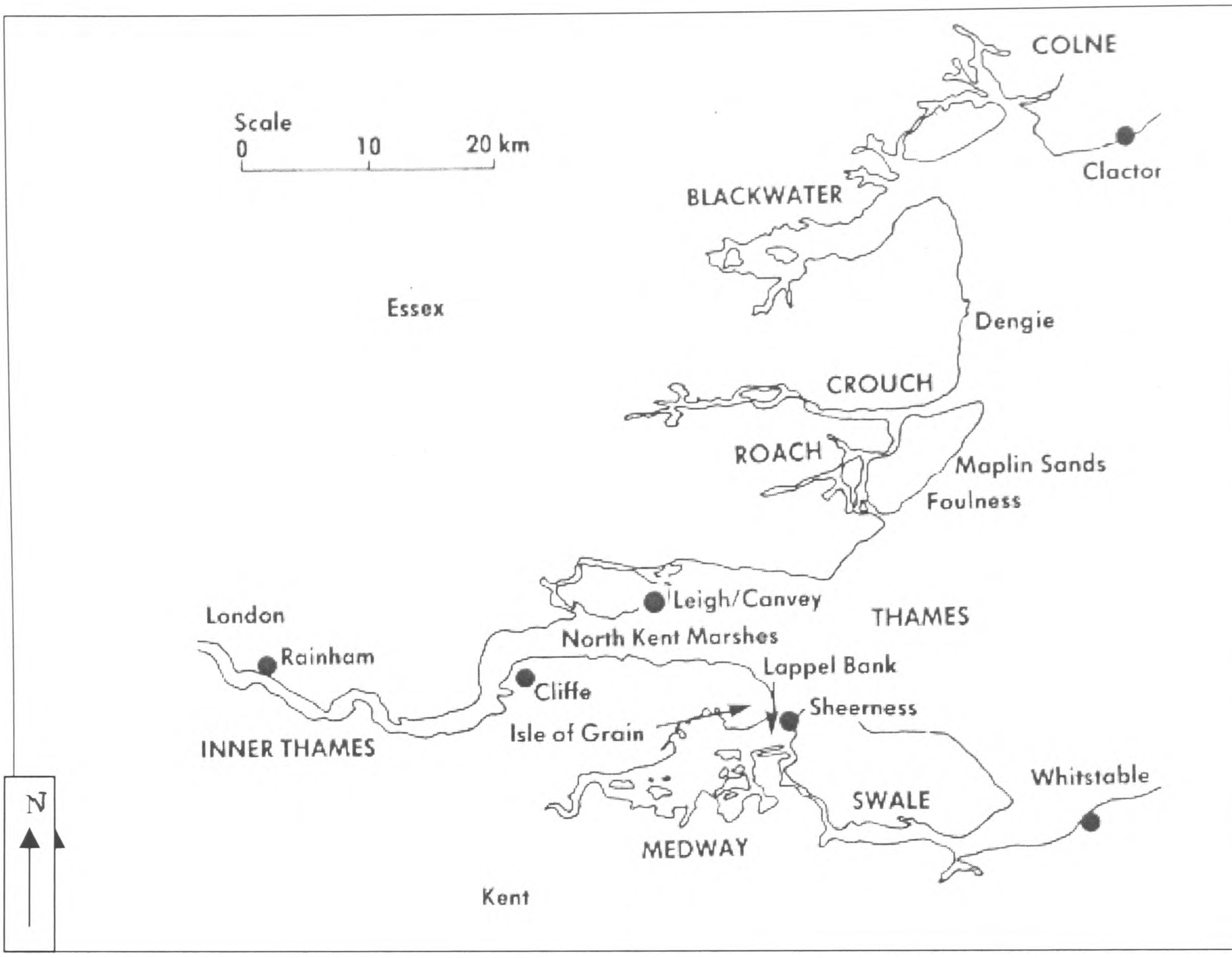

Fig 1.2 Map of the Greater Thames Estuary (from Clarke et al 1991).

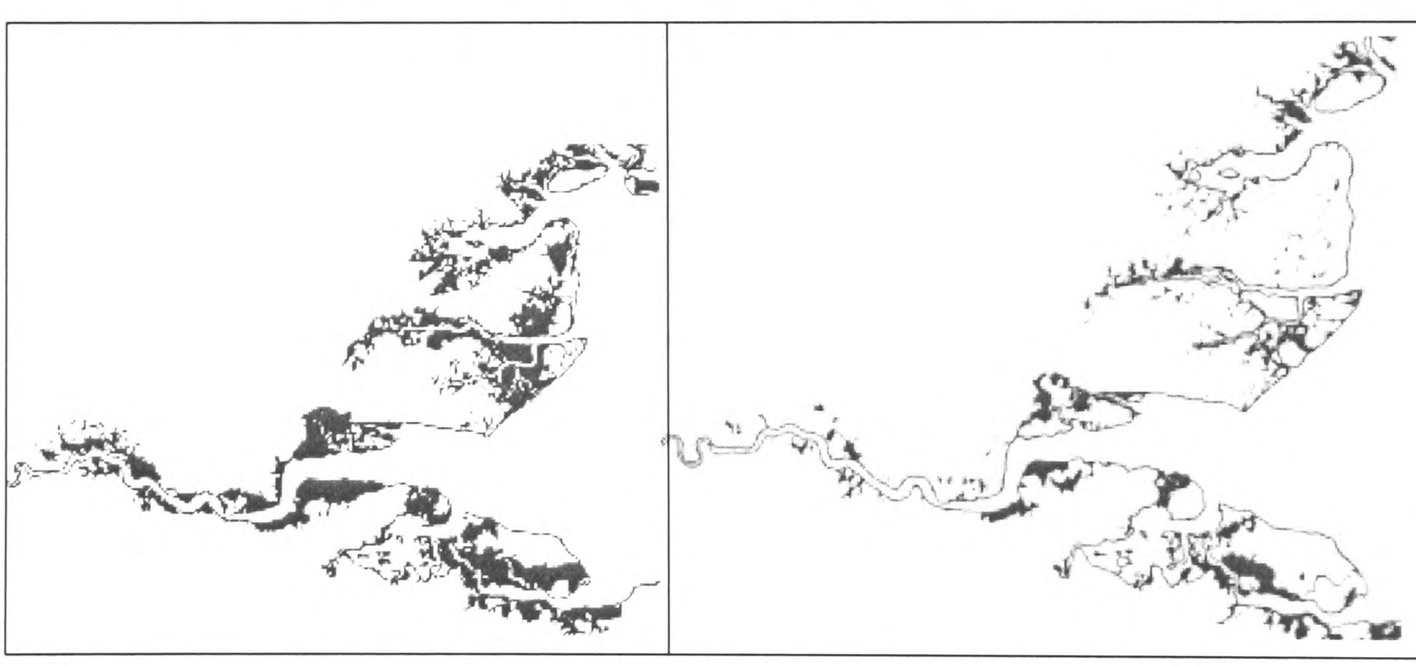

Fig 1.3a and b Changes in extent Greater Thames Marshes between 1930's and 1990. (from Clarke et al 1991), [not to scale].

The remaining open grasslands of the North Kent Marshes have been recognised for their important landscape significance, comprising 'the geographical position, between town and country, coast and hinterland, creating a landscape of great contrast and variety within a relatively limited area' (Cobham 1995). Cobham goes on to refer to the North Kent Marshes as one of the two enduring aspects of the region's 'natural identity', and English Nature (1999) has recognised the North Kent Marshes as a Natural Area. The landscape however, may not always fit everybody's description of classical beauty but in landscape terms, the North Kent Marshes represent 'a sense of place'.

The North Kent Marshes also provide a wildlife habitat of local, regional, national and international importance (Charman et al 1985, Clarke et al 1991, Cobham 1995, Kent BAP 1997, Bexley Biodiversity Action Plan 1998); they are therefore, of considerable nature conservation interest. In recognition of these important features together with their landscape significance, areas of the North Kent Marshes have received protection under various national and international designations, including Local Nature Reserves (LNR), Site of Special Scientific Interest (SSSI), National Nature Reserves (NNR), Special Protection Area (SPA), Natural Area, Special Landscape Area, Environmentally Sensitive Area (ESA) and Ramsar. Table 1.1 details the designations for the individual marshes in this study. The North Kent Marshes around the Medway Estuary and along the Hoo Peninsula has been designated as a potential Special Area of Conservation (SAC) under the 1992 Habitats Directive (92/43/EEC). Recent reports now suggest that Crayford and Dartford Marshes will receive SSSI designation in the near future; the first urban SSSI's to be created for many years (EN per comm.). In addition, both Erith and Crayford Marshes are recognised as Sites of Metropolitan Importance for Nature Conservation by the London Ecology Unit (Bexley Local Plan).

Table 1.1 Conservation Designations applied to the North Kent Marshes

	SMI	LNR	NNR	SNCI	SSSI	SAC	SPA	ESA	SLA	Ramsar
Erith	*									
Crayford	*			*	+					
Barnes Cray				*						
Dartford		*		*	+					
Stone										
Swanscombe										
Botany										
Denton										
Great Clane										
Filborough										
Shorne			**							
Higham								*		
Cliffe			*		*	*	*	*	*	*
Allhallows					*	*	*	*	*	*
Grain					*			*	*	*
Chetney						*	*		*	*

** Recently purchased by RSPB, future nature reserve.

+ Possible future designation.

SMI – Site of Metropolitan Importance

SNCI – Site of Nature Conservation Interest

LNR/NNR – Local or National Nature Reserve

In the autumn of 2000, the former Ministry of Defence firing range, which comprised 159ha of Shorne Marsh, was purchased by the Royal Society for the Protection of Birds (RSPB *pers com*) and under their stewardship will become a nature reserve.

1.2 The Landscape of the North Kent Marshes.

The North Kent Marshes form one of the most distinctive landscape elements of North Kent (Cobham 1995) and have been recognised for their landscape value, by being designated a 'Special Landscape Area' (AERC 1992). Fig 1.4 shows a typical view across the North Kent Grazing Marshes today. In the past, however the marshes were not regarded so favourably. One of the earliest descriptions of the marshes came from Dr. Johnson who visited the region in 1629. His description of the marshes on the Hoo Peninsula highlights the impression that he was not particularly enamoured with the area and its surrounds, he writes: -

'Having left our small boat we walked five or six miles, but discovered nothing that could afford us any pleasure. It was in the middle of a very hot day, and, like Tantalus, we were tormented by an intolerable thirst in the midst of water which was all salt' (Johnson cited in MacDougall 1980).

Fig 1.4 A typical view across the North Kent Marshes.

As part of his introduction to his history of Kent, Hasted (1797) wrote of the North Kent Marshes that 'the air in this county is various, according to the different parts of it: but on the north side of the great road leading from London to Dover, there is a long space of country, lying near the banks of the Thames and Medway, along the Swale, and adjoining the River Stour below Canterbury, in which the air is gross, foggy, and much subject to intermittens, owing to large tracts of low, swampy, marsh ground, among which there are such quantities of stagnating waters, as render the country near them exceedingly unwholesome, especially in the autumnal quarter'. These negative views are still evident today, where despite the many conservation designations, grazing marshes are still used for illegal dumping (Fig 1.5).

Fig 1.5 Illegal dumping on Dartford Marsh

The North Kent Marshes have always been isolated and under populated areas. Hasted (1797), described the Hoo Peninsula, 'there are now few but bailiffs and lookers who live in it; the farmers and occupiers of land dwelling in Rochester and Strood and elsewhere. Nor is there a gentlemen's house or a clergyman resident in it, owing to the distance of the roads and unwholesome air from the neighbouring marshes'.

The North Kent Marshes around Cliffe were well described by Dickens in Great Expectations as, 'the dark flat wilderness beyond the churchyard, intersected with dykes, mounds and gates, with scattered cattle feeding on it, was the marshes. The low leaden line beyond was the river. The distant savage lair from which the wind was rushing was the sea' (Dickens 1861). To many peoples minds this description depicts the scene, as it would have appeared over Cliffe Marsh from Cliffe church, a scene that may still be recognised today. Figures 1.4, 1.5 and 1.6 show three contrasting landscapes currently found across the North Kent Marshes; Fig 1.5 shows the illegal dumping, whereas Fig 1.6 shows the view across Cliffe Marsh. Dickens however, was not always so complimentary referring to them as 'the meshes' and describing them as 'a most beastly place, mud bank, mist, swamp and work'.

Fig 1.6 Cliffe Marsh from Cliffe church

It is not difficult therefore to conclude that in the past the North Kent Marshes were not highly regarded either in terms of their aesthetic appearance or in their life preserving qualities, i.e. the presence of malaria was a common feature of the marshes. Grazing as indicated by Hasted (1797) and Dickens (1861) served as the marshes only favourable activity. Although Dickens's description does imply an appreciation of the openness of the North Kent Marshes, an aspect of the landscape, which has become more and more eroded during the course of the twentieth century.

During the course of the twentieth century the landscape features of the North Kent Marshes, such as the openness and the meandering drainage channels have in many cases been significantly modified, directly altered and influenced by the surrounding land uses and in some instances completely lost. The main causes of such changes appear to be the increasing encroachment of agriculture, urban and industrial development (Thornton and Kite 1990). The proximity of the marshes to the River Thames as a busy shipping thoroughfare, the availability of port facilities have led to the development of oil refineries, power stations and associated overland infrastructure in the once isolated coastal marshes of North Kent. The construction of these facilities, along with the overhead transmission lines, the quarries, and munitions factories all project the view that these marshes are of limited value and their subsequent use for 'dirty industries', e.g. sewage works, landfill etc, have all affected the traditional landscape and wildlife apparently to its detriment (English Nature 1990), Fig 1.7.

Fig 1.7 The landfill on Swanscombe Marsh

The most recent landscape review of the North Kent Marshes undertaken by Cobham (1995) was a 'resource appraisal on the landscape as a key component in the proposed development of the Thames Gateway region'. The review characterised the areas of marshland as either having industrial/urban influence or industrial/urban dominance. The big open sky and long space of country of Dickens and Hasted are no longer suitable descriptions for the majority of the North Kent Grazing Marshes Figs 1.6 and 1.8.

Fig 1.8 Present day view of Stone Marsh showing industrial domination.

Despite all the changes that have occurred to the marshlands the North Kent Grazing Marshes remain as one of the last large refuges for wetland plants that were previously commonplace, (RSPB 1994), and of remaining landscape value as demonstrated by the conservation designations. The designation as an Environmentally Sensitive Area (ESA) recognises the conservation value of the traditional marshland landscape.

1.3 Geology and soils.

The North Kent Marshes lie to the north of the chalk outcrop of the Wealden anticline and comprise deposits from the Eocene age, which include Thanet Beds, Woolwich and Reading Beds and Bagshot Beds (AERC 1992). The southern boundary of the North Kent Marshes is marked by a ridgeline ranging from 20-100m in height and provides a marked change from the low undulating topography of the marshland landscape. Fig 1.9 shows the details of the geology.

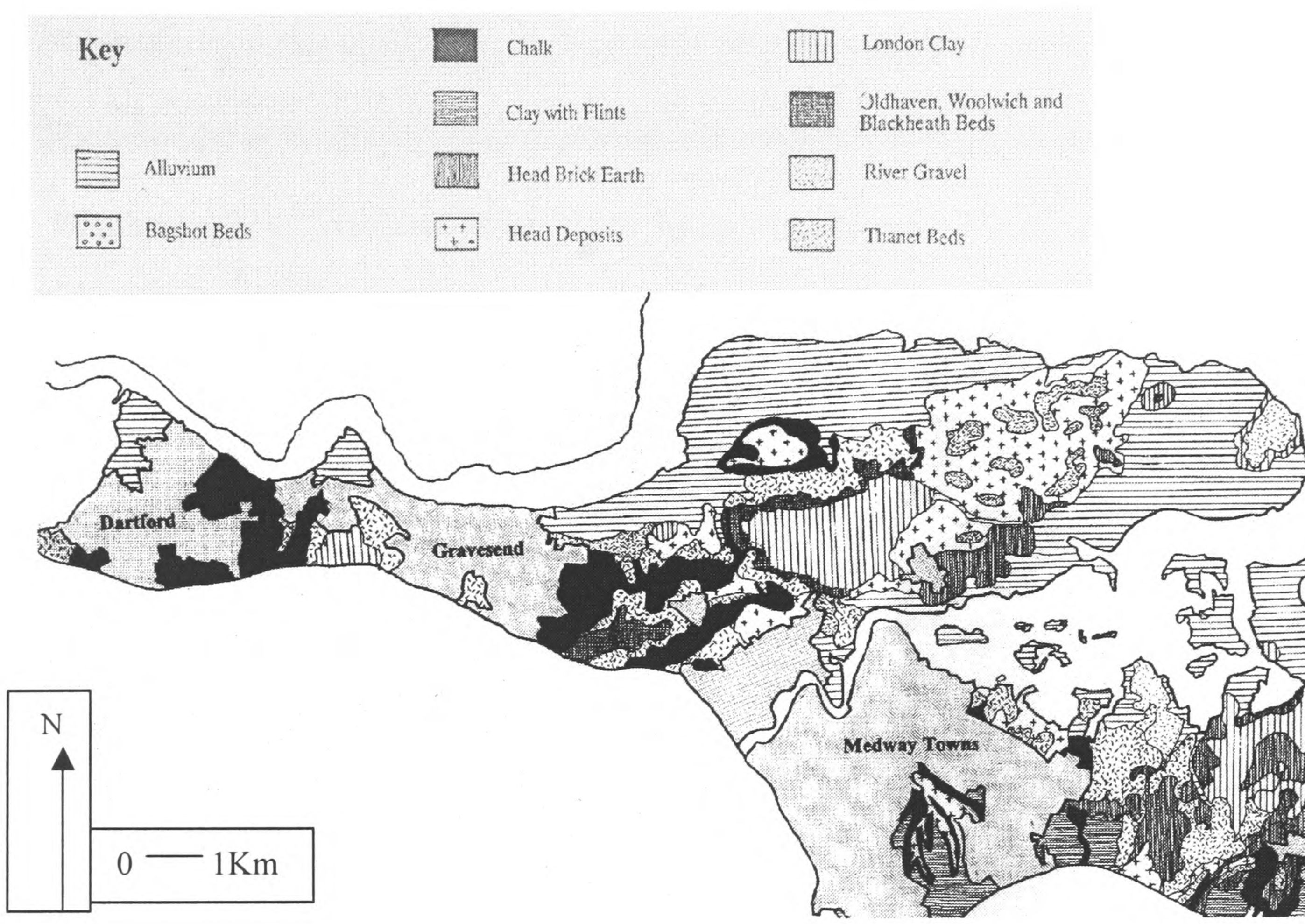

Fig 1.9 Geology of North Kent (from Cobham)

The low-lying marshes of North Kent are formed on marine alluvial clay, which overlies the Upper Cretaceous Chalk, with some small outcrops of chalk, London Clay, Brick Earths and gravel forming the more elevated landforms (Cobham 1995). The geology of the North Kent Marshes has been highly influenced by sea level changes occurring during the Holocene period, (8000 – 1750 YBP), which are characterised by a combination of eustatic sea level rise and isostatic downwarp (Devoy 1977). This has resulted in the development of a series of alluvial deposits overlaying late

Devensian gravels (ibid), the nature of which has been influenced by changes from a freshwater system to an estuarine one (Siddel 1999), with a lessening of the marine effect nearer the present day (Devoy 1977). The changes are evidenced in the sequence of peat deposits showing predominantly *Phragmites* and saltmarsh peat in the east and oak – alder fen wood peat upstream (Devoy 1977). For example, on some of the marshes, e.g. Erith and Dartford where the alluvial clay is interspersed with peat deposited prior to the last glacial period, the marshes developed over wet woodland (Pritchard 1976), the remains of which become exposed at low tide.

Soils developing over the underlying geology are mainly heavy silty clays or clay from the Downholland or Wallasea soil series (AERC 1992). On the Isle of Grain where the London Clay and Brickearth deposits predominate the soils are either loamy or stony loamy (AERC 1992).

Where outcrops of the chalk reach the banks of the Thames e.g. between Greenhithe and Swanscombe, and again between Swanscombe and Gravesend they form a natural barrier between successive grazing marshes, i.e. examples of natural fragmentation of grazing marsh.

1.4 Estuaries and Coastal Grazing Marshes.

1.4.1 Estuaries.

Estuaries have long formed geographical boundaries and often been the focus of human activity and as such have been much modified by man (Davidson et al 1991). The diversity of the British coastline has led to the development of many different types of estuary; from linear to embayments. A detailed discussion of the types of estuaries is beyond the remit of this thesis.

NERC (1975) defined estuaries as 'a partially enclosed body of water, open to saline water from the sea and receiving fresh water from rivers, land run-off or seepage, and subject to usually twice daily tidal rise and fall, and with mud and sand shoals forming in their shallow basins'. This is a broad definition but incorporates all of the most important elements of an estuary's physiology, and one, which is fitting of the Thames Estuary.

Estuaries contain a number of habitat types ranging from intertidal mudflats, saltmarsh, sand flats and sand dunes to coastal grasslands. Davidson et al (1991) estimates the area of British estuaries to be some 530,000 ha, of which 58.2% is intertidal, however it is unclear as to whether coastal grazing marshes are included within this total. The Greater Thames Estuary, which includes the South Thames Marshes, Medway and Swale estuaries, comprises 47,600 ha of intertidal habitat (Clarke et al 1991) of which 15,600 ha is coastal grazing marsh, approximately 32.8% of the total. Coastal grazing marshes therefore form an important element of the coastal and estuarine habitats complex.

1.4.2 Coastal Grazing Marshes.

There are many definitions for grazing marshes most of which refer to low-lying grasslands drained by a network of freshwater or brackish drainage ditches (Davidson et al 1991, Delaney 1991, and Kent Biodiversity Action Plan 1997). Whilst grazing marshes are recognised as a habitat of conservation value (UK Biodiversity Action Plan (1994), many of the key texts and authorities have not recognised grazing marshes as a distinct habitat type e.g. Tansley (1939) and Rodwell (1992). (See Section 3.1.1. for a review of the various definitions of grazing marshes).

The ditches provide drinking water for the cattle or sheep, act as barriers to keep the livestock within the fields and act as controls for the water levels. Grazing marshes are derived from saltmarsh and other intertidal habitats and may be considered to be secondary wetlands (Milsom et al 2000). In continental Europe, these types of grasslands are often referred to as polders (Joyce and Wade 1998).

Davidson et al (1991) recognised 59 grazing marsh sites in the United Kingdom as shown in Fig 1.9. The map highlights the distribution of coastal grazing marshes in the UK, with the majority to be found in England, and with the most extensive sites in the lowland estuaries of southern and eastern England, with the North Kent and Thames Marshes remaining as the largest block of coastal grazing marsh habitat in the UK (Mountford et al 1999). Grazing marshes are therefore, often considered to be a feature of coastal areas but amongst the best known, the Somerset Moors and the Pevensey Levels, are primarily inland and not coastal formations. This study however, focuses solely on coastal and estuarine grazing marshes.

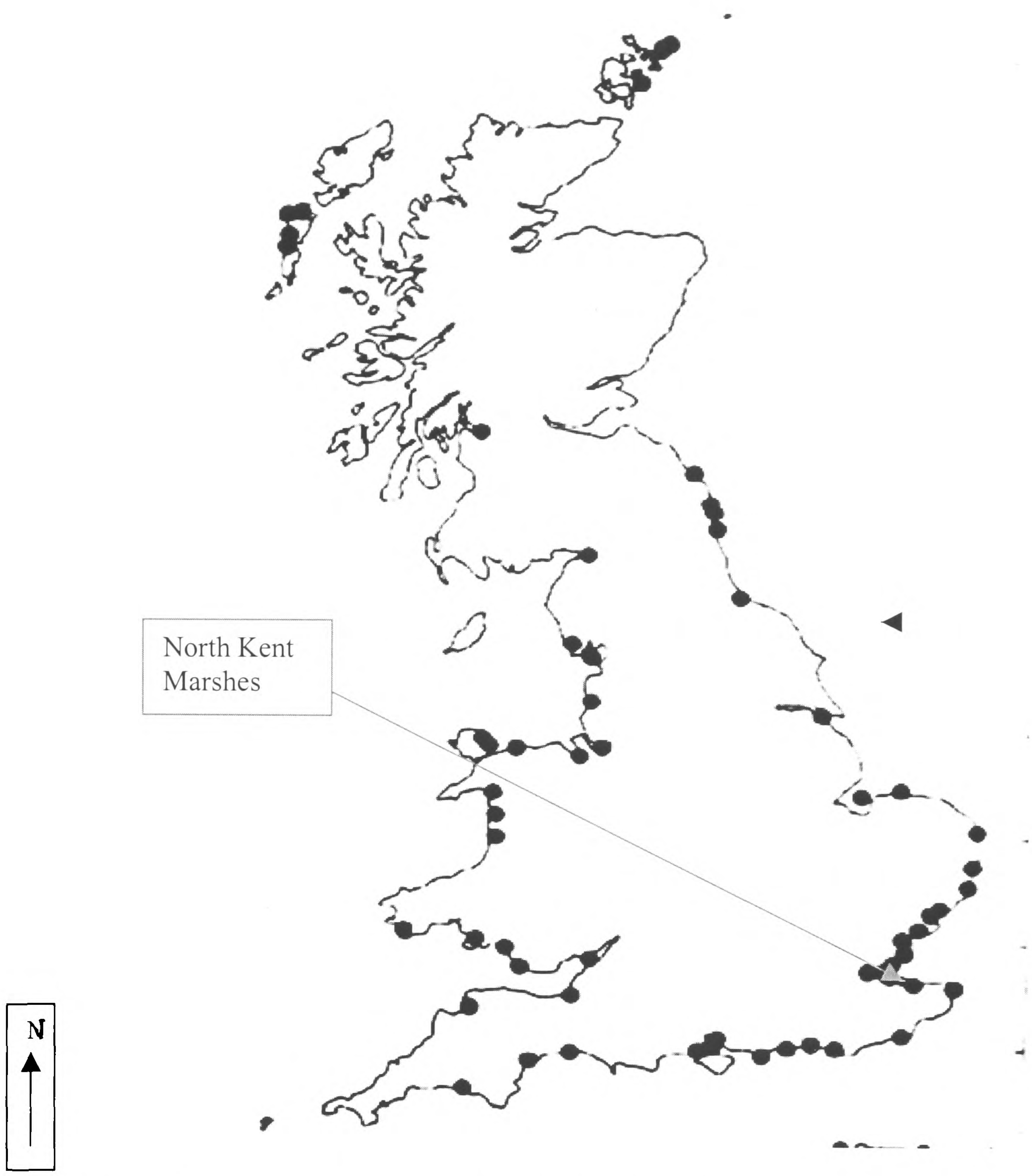

Fig 1.10 Coastal grazing marshes in the UK, not to scale, (after Davidson)

1.4.3 The Greater Thames Estuary.

The North Kent Marshes form a significant part of what is known as the Greater Thames Estuary, a complex of river mouths and tidal channels stretching from central London to Clacton in Essex and Whitstable in Kent. Together they form a single major ecological system, comprising some 476 square kilometres of intertidal habitats and 156 square kilometres (15,600ha) of grazing marsh (Clarke et al 1991). Within its boundaries, the Greater Thames incorporates a significant proportion of the national resource of sand, mudflats, saltmarsh and coastal grassland, i.e. 5.2% of the UK total. The Kent Wildlife Habitat Survey (1991), recorded 4877.4ha of semi-natural grazing marsh within the North Kent Marshes, which accounts for an estimated 25% of national total of this resource. Skinner (undated) stated that 40% of all grazing marshes in the UK are found in the Thames estuary.

1.5 Habitats of the North Kent Marshes.

Grazing marshes as the name implies are predominantly a mix of improved and semi-improved grasslands, which are managed by grazing, and are generally incorporated under the broader heading of lowland wet grasslands (Joyce and Wade 1998). Grazing marsh is the only type of lowland wet grassland that can be found within the North Kent Grazing Marshes, although a further range of habitats can be associated within grazing marshes themselves. The type of habitat found on grazing marshes may well be dependent on the grazing regime and management of the particular marsh, forming markedly different habitats associated with overgrazing, poaching, dunging and excess use of fertilisers. An additional range of habitats found on grazing marshes are associated with remnant saltmarsh features, e.g. rills and saltpans (Delaney 1991), or linked to the creation of the grazing marsh, e.g. embankments and counter walls (AERC 1992).

The presence of the ditches in grazing marshes give rise to a range of aquatic habitats, from the totally aquatic to transitional riparian habitats related to the influence of water on the surrounding land. Where the water table remains close to the surface, a range of swamp and fen habitats develop, as can be found on Dartford Fresh Marsh. A presence of saltmarsh plant communities is evidence to the continuing influence of salt water on and surrounding grazing marshes and is a key feature of grazing marshes. The salinity levels therefore, play an important role in determining the floral and faunal composition of the aquatic and surrounding habitats.

A further range of habitats identified on grazing marshes result from man's intervention and control on the formation of the grazing marshes and specifically relate to the embankments and counter walls, which have been constructed to control the influence of the sea and rivers, which used to periodically flood the marshes, and to delineate field boundaries (Milsom et al 1998). Embankment and counter wall habitats are of importance in the overall conservation value of grazing marshes as many of the rarer species of the grazing marsh flora, e.g. stinking goosefoot (*Chenopodium vulvaria*), hog's fennel (*Peucedanum officinale*) and pepper saxifrage (*Silaum silaus*) are found here.

As previously mentioned the management regime on a particular area also influences the type of habitat present. A lack of management on grazing marshes results in a range of scrub, ruderal and disturbed habitats prevailing. In some instances ecological succession has occurred on North Kent Grazing Marshes and small areas of woodland are now present on several marshes, notably on Dartford Marsh, see Fig 1.11. Management is therefore potentially a key feature in determining the quality of the habitat.

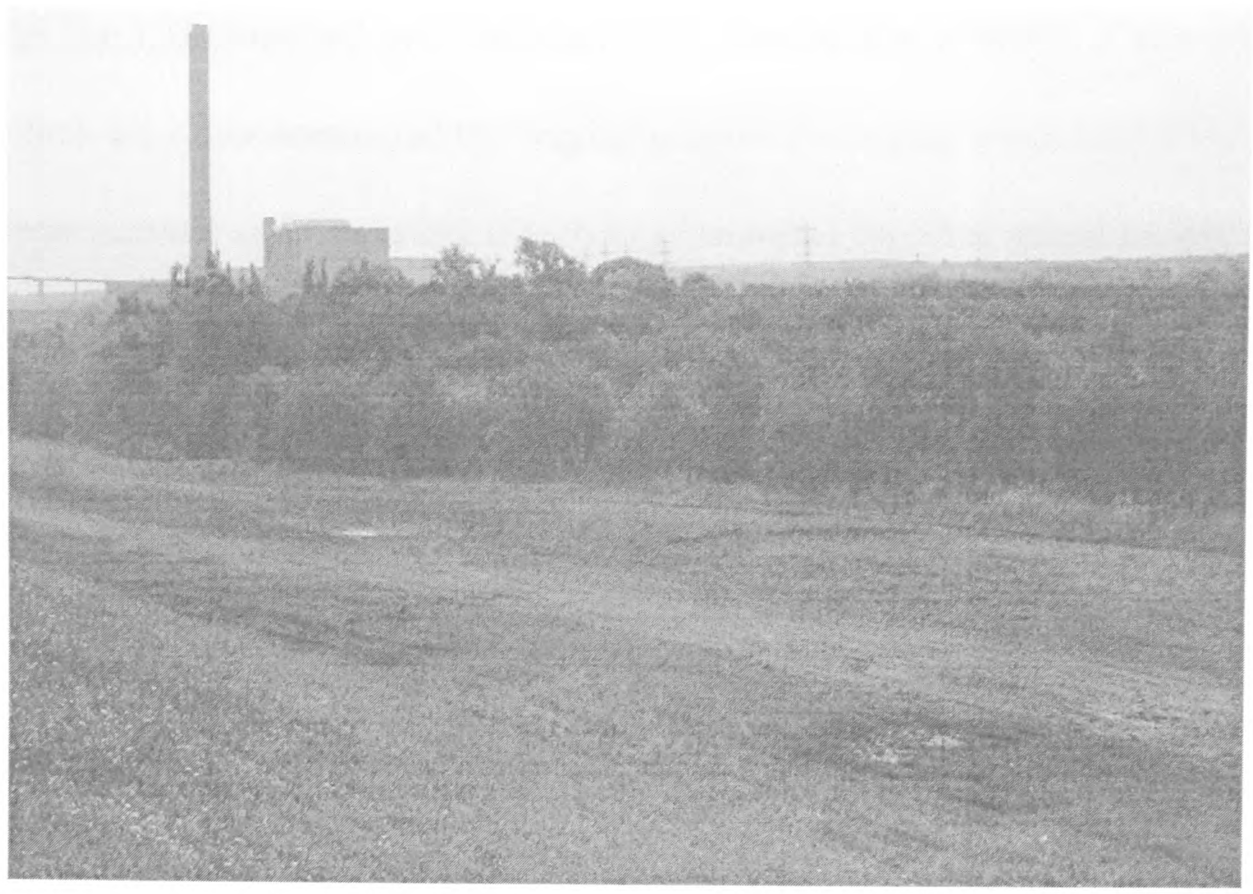

Fig 1.11 Succession on Dartford Marsh

1.5.1 Plants of grazing marshes.

Coastal grazing marshes predominantly comprise grasses that are typically dominated by the more common grasses of neutral soils and amenity grasslands (Davidson 1991). Rye grass (*Lolium perenne*), crested dog's-tail (*Cynosurus cristatus*) and bents (*Agrostis spp.*) are amongst the most common species recorded on grazing marshes.

The frequency and abundance of the different species that can occur on grazing marshes is dictated by the various environmental conditions occurring across grazing marshes. Influences such as salinity, waterlogging, grazing and nutrient enrichment will all affect the number and type of species present.

Waterlogged areas for example, will see the presence of grasses such as foxtail's (*Alopecurus spp*) and sweet grasses (*Glyceria spp.*) as well as rushes (*Juncus spp.*) and sedges (*Carex spp.*), (Mountford and Chapman 1993, Benstead et al 1997). Drier areas of grazing marsh are often dominated by rougher grasses for example false oat grass (*Arrhenatherum elatius*) and Cocksfoot (*Dactylis glomerata*) together with a variety of dicotyledonous herbs, such as bird's foot trefoil (*Lotus corniculatus*), grass vetchling (*Lathyrus nissolia*) and hairy buttercup (*Ranunculus sardous*), (Davidson 1991, Gee 1998).

Within the more saline areas, remnant saltmarsh species can be found, sea milkwort (*Glaux maritima*), saltmarsh rush (*Juncus geradii*), saltmarsh grass (*Puccinellia maritima*) and sea couch (*Elymus repens*). These species are remnants of saltmarsh vegetation and can often be found within the rills, which are remains of the smaller drainage ditches that once crossed the marshes (Gee 1998).

From a floristic point of view, the ditches provide a major interest of grazing marsh flora. Three species recorded within the North Kent Marsh ditch systems are nationally scarce, brackish water – crowfoot (*Ranunculus baudotii*) water-soldier (*Stratiotes aloides*) and soft hornwort (*Ceratophyllum submersum*), (Davidson 1991, Gee 1998). A range of taller emergent plants associated with these systems are also present on most grazing marshes, including common reed (*Phragmites australis*), common reed mace (*Typha latifolia*) and sea club rush (*Scirpus maritimus*), although an abundance of the two former species may indicate a lack of ditch management (Benstead et al 1997).

Grazing marshes also support a number of nationally rare and scarce plants, e.g. divided sedge (*Carex divisa*), slender hare's-ear (*Bupleurum tenuissimum*), sea barley (*Hordeum* *marinium*), least lettuce (*Lactuca saligna*), annual beard grass (*Polypogon monospeliensis*) and small red goosefoot (*Chenopodium botrydes*) (Davidson 1991, Kent BAP 1997, Jefferson and Grice 1998).

The North Kent Marshes therefore, provide a range of habitats dominated by flat grazed lowland wet grassland, throughout which, a number of nationally scarce and rare species are found. The RSPB (1994) referred to the North Kent Marshes as 'one of the last refuges for wetland plants which were previously commonplace'. As a result of the presence of a number of rare and scarce plants, birds and invertebrates a range of conservation designations have been given to the North Kent Marshes as recognition of their importance. Yet, despite these designations and the presence of rare species, the North Kent Marshes are still viewed negatively by many people and losses and fragmentation are still occurring.

1.6. Aims and Rationale.

Fragmentation is regarded as the main cause of habitat loss throughout the world and has been described by Wilcove (1982) as being the 'principal threat to most species in the temperate zone'. No region of the world has escaped the impact of the processes that cause fragmentation, or the attention of man, who is generally regarded as being the main reason behind the loss of the world's habitats and biodiversity, (see chapter 2 for further discussion on fragmentation causes and effects).

The North Kent Grazing Marshes are regarded as being one of the principal landscapes and ecosystems, not only of the south-east, but throughout the United Kingdom, and are regarded as being one of the Natural Areas of England (English Nature 1999). Although their formation owes much to man's intervention and his desire to protect lands and livestock, they to have since the mid-nineteenth century suffered increased fragmentation as man's requirements for and use of the land change. 'Death by a thousand cuts' is how English Nature (1991) described the process of fragmentation in North Kent.

There is however, no precise definition as to what constitutes a grazing marsh. Many of the leading authorities on vegetation ecology from Tansley (1939) to Rodwell (1992) have not recognised grazing marshes as a distinct community or habitat type within their categorisations of British vegetation. The Kent Wildlife Habitat Survey (1991) divided the North Kent Marshes into either neutral or semi-improved grasslands, whereas, the Kent Biodiversity Action Plan (1997) classified grazing marshes as semi-natural and semi-improved grasslands and that grazing marshes can incorporate areas of unimproved, semi-improved and improved neutral grasslands. There is therefore, no complete agreement as how to describe and define grazing marshes. Yet, grazing marshes are regarded as a priority habitat for conservation in Britain, (UKBAP 1994) but the literature provides us with no indication as to how they fit into the vegetation of Great Britain, other than being lowland wet grassland.

What therefore are the defining characteristics that make grazing marshes a distinguishable habitat type? What are the characteristic vegetation communities that can be used to distinguish grazing marshes, and measure their condition? Why, therefore are grazing marshes regarded so highly in conservation terms, when there is uncertainty as to what exactly constitutes a grazing marsh? These questions have all led to the development of the current research. (Section 3.1.1 discusses the definitions of grazing marshes highlighting a number of different features that can be used in their description, and provides a working definition by which the characteristics and features can be assessed and monitored).

The aim of this thesis is to determine the processes, causes and effects that fragmentation is having on this important and much neglected habitat. The research also attempts to identify the important indicators of grazing marsh habitats, and assess how indicators respond to fragmentation and can thus be used to identify the status of grazing marshes. Determination of these factors was carried out by quantifying the changes to the areas of grazing marsh, by considering either the presence or absence and/or the quality of a range of characteristics and features and by defining limits to acceptable change that have occurred, as discussed in Chapters 5, 6, 7 and 8.

The objectives of this thesis are to: -

- categorise the vegetation of grazing marshes in terms of the characteristic NVC plant communities, i.e. define grazing marsh communities;
- identify 'typical' indicators of the grazing marsh habitat, using floristic and landscape indicators;
- assess the response of these indicators to fragmentation;
- identify the processes and agencies that have led to fragmentation of the North Kent Marshes;

- identify the level of decline and change in status and area of the grazing marsh habitat in North Kent;
- test predictions of landscape ecology and fragmentation theory on the North Kent Marshes;
- recommend monitoring protocols for the North Kent Marshes.

The North Kent Grazing Marshes are an integral part of the Thames Gateway and will therefore be affected by the developments that have been proposed for the region, which will inevitably lead to further pressure, fragmentation and loss of grazing marsh habitat. The 'Vision for 2006' (Thames Gateway Organisation 2002), includes nothing on the status of the environment, therefore increasing concerns for the future of the North Kent Grazing Marshes. Assessing the effects of past changes resulting from fragmentation is therefore of particular importance in light of the current development plans, which will in all probability result in further fragmentation. The future of the North Kent Grazing Marshes as a key landscape and ecological feature of North Kent will depend on how the landscape characteristics and features react to further fragmentation.

Chapter 2 –Fragmentation

Introduction.

Fragmentation is regarded by many observers e.g. Wilcove et al 1986, Wiens 1995 as being the most important factor in the current worldwide crisis over the loss of habitats and the consequent loss of biodiversity. Saunders et al (1991), Harris et al (1992) regard human activity as being the major reason for habitat fragmentation and habitat losses. Anthropogenic actions having induced great changes in the natural landscape, so that where once 'large unbroken tracts of woodlands, grasslands, downland and wetlands dominated the landscape, habitats are now to be found as isolated fragments in a mosaic of agriculture, urbanisation, industry, roads and railways in varying sizes, shapes and quality' (Akbar 1997).

In recent years, fragmentation theories have been subsumed within the broader topic of Landscape Ecology, a field of study that has arisen from a realisation that ecological processes act over a wide range of spatial configurations (Farina 1998), and that the pattern of the landscape is as or more important than ecological processes. The theory of island biogeography, metapopulation dynamics, source – sink and percolation theory have all become important concepts in the discussion of fragmentation (Section 2.3) and its effects (Section 2.5).

This chapter discusses the many definitions of fragmentation, landscapes and ecosystems, considers the concepts, causes, processes and effects of fragmentation and relates them to the ecological characteristics, conservation and landscape value of grasslands and the North Kent Marshes.

2.1 Definitions.

2.1.1 Landscape Ecology.

Landscape ecology is a relatively new discipline introduced and developed during the seventies in Central Europe (Weins et al 1993). It is seen as a marriage between geography (landscape) and biology (ecology), and promotes a more holistic view of the interactions between these two subjects, specifically the influence that humans have on their environment (Farina 1998). Landscape ecology therefore considers physiography, topography and their spatial arrangement as key elements in determining the environment of plant communities, animals and man.

Selman (1993) defined landscape ecology as 'the study of spatial relationships and functional interactions between the component patches of an extensive and heterogeneous land area, and how they bring about changes of structure and function in the ecological mosaic over time'. Pickett and Cadenasso (1995) in defining landscape ecology regarded the effects of spatial heterogeneity as a causal factor in ecological systems. In effect therefore, these two statements are saying that the effects of fragmentation affect biological processes and landscapes both spatially (Pickett and Cadenasso) and temporally (Selman). Fragmentation of habitats however, causes a fundamental change to the spatial configuration of landscape patterns and features, which in turn alter the responses of key habitats and species to the landscape and ultimately affect the ecosystem processes over a period of time, i.e. temporal effects (ibid). The effects of fragmentation should therefore be considered to affect landscape features both spatially and temporally.

Three key elements therefore, underlie the study of landscape ecology and in particular fragmentation;

1. The study of the patterns in a landscape and the agencies and forces that determine those patterns;
2. The response of species to these patterns;
3. The nature of energy and nutrient flows between component parts of the landscape, (Green *pers. com.*)

The landscape characteristics and features of grazing marshes such as counter walls, embankments, drainage ditches, rills and tussocky grassland form the heterogeneous spatial configuration of the grazing marsh habitat. It is these components and their configuration, which are being affected by fragmentation. These components and their configuration are important for many of the key species associated with grazing marshes and therefore fragmentation of the components will ultimately affect the species, which are dependent on them. This study is therefore concerned with how fragmentation affects grazing marsh overall but also the effect of fragmentation on the components of grazing marshes both spatially and temporally. The scope of this thesis will deal primarily with the cause and effect of fragmentation on the pattern of landscape characteristics and features, the response of the vegetation communities to such changes and how such changes have affected the status of the North Kent Grazing Marshes. Sections 2.1.2, to 2.5 consider the causes, processes and the response of species to the changes brought about by fragmentation.

2.1.2 Fragmentation.

The Oxford English Dictionary (1993) defines fragmentation as 'the action of breaking or separating into fragments, or the state of being fragmented'. In a biological context, fragmentation may be described as 'the separation into parts which form new individuals or units' (ibid).

Within an ecological context, fragmentation has been defined in a similar manner to mean 'the breaking up of a habitat, ecosystem or land-use into smaller parcels,' (Forman 1995). Wilcove et al (1986), however, in a broader definition state that 'fragmentation occurs when a large expanse of habitat is transformed into a number of smaller patches of smaller total area, isolated from each other by a matrix of habitats unlike the original'.

Schonewald – Cox and Buechner's (1992) definition of fragmentation is expressed in terms of the breaking up of landscapes rather than habitats into 'increasingly subdividing natural areas into semi-isolated remnants.' By introducing the term 'natural areas', this definition then raises three questions: -

1. Whether man-made landscapes, such as grazing marsh, can be fragmented, as they are not deemed natural systems?
2. What is the difference between a landscape and an ecosystem?
3. What is meant by semi-isolated?

Fragmentation theory has been applied to semi-natural/man-made habitats such as Van Jaarsveld et al (1998) on grasslands and Holt et al (1995) on agricultural land, but is this appropriate? One of the aims of this project is to determine if the processes affecting the fragmentation of natural ecosystems also apply to semi-natural ecosystems of human origin. A review of the fragmentation literature indicates that the fragmentation of grasslands and other agricultural habitats have not received the amount of attention that has been afforded to fragmentation of other habitats such as woodlands, although Debinski and Holt (2000) recorded more experimental fragmentation studies in grasslands than in woodlands. The continual erosion of the North Kent Marshes, for agriculture, industry, urbanisation, mineral extraction or waste disposal is evidence that fragmentation of semi-natural human created ecosystem does occur. The 'death by a thousand cuts' of the North Kent Marshes referred to by English Nature (1991), highlights a concern that any development no matter how small may have disproportionably large consequences on the fragmented habitat in question.

One factor not covered in most of the definitions of ecological fragmentation is the nature of the original habitat. Fragmentation theory assumes that natural pre-fragmentation conditions were uniform (Haila 2002), or that large areas of homogeneous habitat become broken up into smaller pieces (Noss and Csuti 1997) and that fragmentation is involving a transformation from a homogeneous into a heterogeneous landscape. Many authorities however, regard all habitats as being heterogeneous in character, with 'even a relatively homogenous matrix being heterogeneous at a finer scale,' e.g. Forman (1997). Fragmentation should therefore be regarded as increasing heterogeneity of the landscape, not causing heterogeneity.

When defining fragmentation therefore, consideration must be given to what is being fragmented and as to which agency is causing the fragmentation. Essentially fragmentation is concerned with the break up of large tracts of an individual habitat type into smaller more discrete units of the same habitat type, surrounded by an alien environment, or something dissimilar to the original. In many of the definitions of fragmentation, (e.g. Wilcove 1986, Gustafson and Gardner 1996) the fragmenting agent or process is often considered to form the new matrix of the landscape. It is then a matter of debate as to whether fragmentation has occurred or if we should term this change as habitat loss and destruction e.g. Baudry (1989), Barrett and Peles (1994), Bender et al (1998). In landscapes, such as the North Kent Marshes, the fragmented habitat of the Outer Thames Marshes still forms the matrix and therefore definitions of fragmentation should reflect this fact.

For this research, the key definition of habitat fragmentation therefore is one that includes elements that relate to the break up of a habitat and the result of that break up, i.e. the process and product of fragmentation. Fragmentation in this instance is defined as 'the breaking up of relatively homogeneous habitat areas into smaller isolated and discrete homogeneous units within a heterogeneous landscape of varying habitats and fragmenting agents.' The existing fragmented habitat would thus form the matrix of the reconfigured landscape and not the isolating agent as suggested by Wilcove (1986).

2.1.3 Landscape.

Landscape is a term, which has been much defined. Traditional definitions come either from an ecological and physical standpoint or from an artistic and aesthetic outlook. The Oxford English Dictionary (1993) definition of a landscape is 'rural scenery, as seen from a particular viewpoint'. This definition implies that landscapes are an attribute of countryside, are aesthetically pleasing and that urban influence has little or no part to play in the character of a landscape. In the North Kent Marshes, many of the grazing marshes now have a decidedly urban or industrial influence, which becomes the dominant feature in the make up of some of the North Kent Marshes landscape, (Cobham 1995). Should the North Kent Marshes therefore, be considered to have a special landscape character of importance, as their designations imply?

Haber quoted in Farina (1998) defined landscape as 'a piece of land which we perceive comprehensively around us, without looking closely at single components, and which look familiar to us'. This definition albeit very general is not limited to rural scenery but introduces the concept of familiarity, although there is no reference to any features that may be of significance to the landscape as a whole. A broader definition of a landscape may therefore be 'a configuration of topography, vegetation cover, land use, and settlement patterns which delimits natural and/or cultural processes and activities,' (Green *pers. com.*). The introduction of influences, other than natural ones, provides a definition that is more applicable to the North Kent Marshes, which owe their origin to anthropogenic factors.

Forman (1997) defined landscapes in ecological terms as 'a mosaic where a cluster of local ecosystems is repeated in similar form over a kilometre wide area.' Similarly Doing (1997) defines landscape as 'a complex of geographically, functionally and historically interrelated ecosystems or organised land, (i.e. organised by nature and by man).' Dunning et al (1992) however defined landscapes in terms of habitats, i.e. 'landscape refers to a mosaic of habitat patches in which a particular patch is embedded', therefore also basing their definition in an ecological context. Dunning et al (1992) and Forman (1997) therefore regard ecosystems as being integral parts of a landscape. Whilst Doing (1997) and Green's (1996) definitions also include the geographic and human influenced factors, which establish the character of a landscape.

Cobham (1995) regards landscapes as relying upon their physiography, history, land management and scenic value in determining their character. Within the North Kent Marshes, Cobham (1995) defined four landscape types, which are predominantly determined by land-use, i.e. the history and past management form the integral defining characteristics. Although the influence of ecology and ecosystems on the landscape have been recognised by Cobham (1995) as being of importance, man's management is the primary defining feature. In the case of human influenced and semi-natural landscapes, this is an acceptable inference. Fragmentation may sometimes then be considered a positive force acting on man made habitats to create and to maintain a particular valued landscape.

When defining and describing landscapes, several questions need to be answered, including 'do landscapes repeat?', 'are landscapes unique to a particular region?', and on what scale should we recognise landscapes? These questions are applicable to the North Kent Marshes, which overall is regarded as being a landscape of conservation significance, but can each individual marsh be considered as a separate landscape entity or as part of a whole? Are the North Kent Marshes unique, or do they share all their characteristics with other grazing marsh systems? Should the North Kent Marshes be considered as a unit encompassing the whole Thames Gateway area, or as individual units? Thus, are fragmentation effects unique to the North Kent Marshes or are the effects applicable to all grazing marshes?

A revised definition applicable to this thesis states that a landscape is 'a series of interconnected ecosystems, which are a product of past and/or current geomorphology, physiography and human management, and are unique in their spatial arrangement of habitat and land use.' This definition recognises that landscapes such as the North Kent Marshes are a result of human activity modifying naturally occurring habitats and which were initially linked but which have become fragmented into repeatable smaller units.

Ecosystems have often been included as integral components of landscapes, as highlighted by some of the definitions e.g. Doing (1997) and Forman (1997) in Section 2.1.3. The following section considers the concepts of ecosystems.

2.1.4 Ecosystems.

The ecosystem is an important ecological concept first developed by Tansley (1935). He defined an ecosystem as 'the whole system (in the sense of physics) including not only the organism – complex, but also the whole complex of physical factors forming what is called the environment of the biome – the habitat factors in the widest sense'. Put more simply an ecosystem is a system of organisms functioning together with their non-living environment (Kormondy 1996).

Forman (1997) from a landscape ecology perspective defined an ecosystem rather more simply as 'a relatively homogeneous area of organisms interacting with their environment.' He appended this definition however, by saying that 'although this can apply at any scale, an ecosystem or local ecosystem refers to a patch, corridor, or area of matrix within a landscape.'

Modern ecology is increasingly adopting a landscape scale approach by considering ecosystems as elements of a landscape, both affecting and affected by their surroundings, i.e. the matrix. All ecosystems may therefore be identified as habitat islands within the landscape matrix. Changes within the surrounding landscape will therefore affect the composition and functioning of an ecosystem and vice-versa, thereby supporting Forman's (1997) definition of an ecosystem.

Fragmentation as a process is one of the key concepts in the study of Landscape Ecology, and through its agents, both natural and anthropogenic has resulted in the pattern of ecosystems and landscapes we see today. The next section considers the recognised causes of fragmentation.

2.2 The causes of fragmentation.

The process of habitat fragmentation occurs in natural systems, caused by activities such as volcanoes, fire, hurricanes, windfall etc., (Andren 1994). Such disturbance is recognised by many as being important for ecosystem/landscape diversity and dynamics e.g. Sousa (1984). Today however, anthropogenic activity via processes that include road building (Schonewald-Cox and Buechner 1990), agricultural expansion (Saunders et al 1991), drainage of wetlands (Williams and Hall 1987), industrialisation and urbanisation (Bolger et al 1997) are considered the main causes of habitat and landscape fragmentation.

Burgess (1988) gives several examples of naturally fragmented habitats, e.g. mountain peaks, bogs, freshwater lakes and desert watercourses. Although he acknowledges the role man's activities have had in disturbing, reducing and fragmenting all natural ecosystems, 'to a series of relics.' Burgess (1988) concludes by making the point that 'with few exceptions, terrestrial ecosystems exist as fragments of once more extensive and relatively contiguous communities.'

Some authors e.g. Harris et al (1992), Groom and Schumaker (1993), Quinn and Hastings (1988), Temple and Wilcox (1986), Saunders et al (1991), Kouki and Lofman (1998) and Bowers and Dooley (1999), consider fragmentation to be a purely human influenced process. For instance, Harris et al's (1992) definition regards fragmentation as 'an unnatural detaching or separation of expansive tracts into spatially segregated fragments'. The implication is therefore, that human activity is an unnatural event and is the defining feature of the fragmentation process; natural events therefore by implication play no part in the process. Whether humans carry out 'unnatural acts' that result in habitat fragmentation is not for discussion in this thesis.

Herkert (1994) endorsed the view that fragmentation of native habitats is a result of human activity, specifically agriculture and urbanisation. Feinsinger (1997) again implies that human activity is the main instrument of habitat fragmentation, stating that ‘when modern-day humans convert a landscape and reduce the original habitat to a small fraction of its former area, the term ‘habitat fragmentation’ is more commonly employed’. However, he introduces the term ‘habitat shredding’ to describe practices which ‘shred’ habitats into long narrow strips, rather than ‘fragmenting it into two dimensional isolates’. Examples of shredding can include natural vegetation surviving along the banks of watercourses or buffer strips between two different crops (Feinsinger 1997). This approach has tended to be applied to agricultural landscapes, although the grazing marshes of North Kent remain mostly as two-dimensional isolates rather than the long thin shreds envisaged by Feinsinger (1997).

Bender et al (1998) in contrast refer to habitat losses through human activity as habitat destruction and state that fragmentation occurs through natural forces. Although habitat fragmentation may be seen as an instrument of habitat destruction or loss, the action implies that some element of the habitat will remain, and thus habitat fragmentation and habitat loss should be considered separately. The action of habitat destruction implies that nothing remains of the original habitat. Human activity such as road construction or encroaching urbanisation will destroy part of a habitat and leave some fragments intact thereby man’s actions can cause fragmentation.

The above definitions of fragmentation of landscapes and habitats show therefore that the process is now regarded as being primarily anthropogenic in nature but may be caused by some type of natural disturbance event, i.e. volcanic activity, or an extreme weather event (Andren 1994). Anthropogenic or natural disturbances play a major role in determining the dynamics of a landscape, and therefore consideration needs to be given to the nature of disturbance that is causing the landscape fragmentation as does distinguishing between natural and anthropogenic factors. Three components scale, magnitude (intensity) and frequency, have been recognised as determining the effect of disturbance and have been defined by Tivy (1993) as follows: -

- **Scale or size** referring to the area over which the disturbance occurs. This may be a small isolated area such as that caused by tree fall in woodlands or over large areas as may be caused by volcanic activity. Human induced disturbance can take both forms i.e. localised wetland drainage affecting one field or over a larger area than a natural disturbance, which may in turn affect the whole biosphere such as is currently occurring with global atmospheric pollution.
- **Magnitude** refers to the intensity and the amount of change induced by the disturbance.
- **Frequency** is how often a disturbance event takes place; it may be a one-off event such as a volcanic eruption or a recurring or continuous event such as grazing.

Bazzaz (1983) defines disturbance as, 'a sudden change in the resource base (inputs) of a unit of landscape that is expressed as a readily detectable change in a population (ecosystem) response,' therefore, combining cause with effect. Sousa (1984) defined disturbance as a 'discrete, punctuated killing, displacement, or damaging of one or more individuals (or colonies) that directly or indirectly creates an opportunity for new individuals (or colonies) to become established'. Disturbance may therefore, be regarded as 'an event that significantly alters the pattern of variation in the structure and function of a system', (Forman 1997). None of these definitions however differentiates between natural and human created disturbance.

Natural disturbance can be regarded as being part of the 'balance of nature' and therefore, any action and reaction to the disturbance will not severely disrupt the general successional trends of an ecosystem as defined by Clements (1916). Bazzaz (1996), in fact regards disturbance as an 'integral component of all landscapes'. As Clements (1916) implies, ecosystems and species become adapted to natural disturbances and can therefore respond to what are generally smaller magnitude and less severe occurrences quicker than they can to human disturbance. Human disturbance may be of some benefit to ecosystems, e.g. grazing resulting in increased biodiversity (Chaneton and Facelli 1991). Human disturbance is however, generally perceived as having a negative effect on habitats and ecosystems through such activities as road building (Andrews 1990), drainage (Green 1996), urbanisation and industrialisation (Soule et al 1992). The resulting habitat loss and fragmentation occurs, because the intensity of the disturbance becomes too great leading to a change in the habitat, i.e. loss and fragmentation (Bazzaz 1983).

It is now generally recognised that disturbance and the reaction to a disturbance event are the major natural course of events affecting all ecosystems to a greater or lesser extent (Sousa 1984). Reactions of a landscape or an ecosystem to a disturbance event depend upon the degree and type of disturbance, and the susceptibility of the landscape/ecosystems to change and inherent resistance within them. These reactions can often be defined using the parameters of scale, magnitude and frequency, which will influence the outcome of the disturbance event (Tivy 1993). The type of disturbance that occurs also reflects the agent causing the disturbance. When disturbance events become greater than that to which habitats are adapted, disturbance may lead to further fragmentation, as is the case in the North Kent Marshes, a loss of stability and an increase in the fragility of the habitat; (see discussion on fragility and stability in section 2.4).

The term disturbance in many instances is used to signify natural disturbances (Lavorel et al 1997), whereas, disturbance that is caused by human activity is more often referred to by using the prefix human i.e. human disturbance. Bazzaz (1983) however, points out 'the distinction between humans and natural disturbance is less important than its consequences and the way species and habitats respond to it', i.e. in grasslands; human disturbance may often have a positive effect on biodiversity (Lavorel et al 1997). Disturbances however, are a major force in determining heterogeneity in a landscape (Forman 1997). Once a homogeneous system is disturbed, it will show an element of heterogeneity and hence increased biodiversity (ibid). Sousa (1984) regards disturbance as one of the major sources of both temporal and spatial heterogeneity, and therefore as fragmentation occurs as the result of disturbance, the heterogeneity of the landscape is increased.

Thus, over time, habitat fragmentation can be said to cause an increase in landscape heterogeneity (Kouki and Lofman 1998). Forman (1997) however, regards nothing as being homogenous as, 'even a relatively homogenous matrix is heterogeneous at a finer scale'. The extent, to which the natural state of a landscape is homogeneous or heterogeneous, therefore needs to be discussed. Doing (1997) regarded ecosystems as homogenous and landscapes as heterogeneous, further highlighting the differences between the two definitions. Grazing marshes are regarded as being an ecosystem and therefore homogeneous, but it is the grazing marsh matrix which is considered to be homogeneous. At the finer scale, the landscape features that comprise the grazing marsh provide the fine scale heterogeneity of habitats (see Section 3.1.1), described by Forman (1997). The influence and effects of fragmentation on the fine scale heterogeneity of grazing marshes is one of the themes of this thesis.

Distinctions should then be made between naturally patchy i.e. heterogeneous landscapes, which can be considered the normal condition of a landscape (Forman 1997), and fragmented and disturbed landscapes. Noss and Csuti (1997) defined the differences as follows: -

1) A naturally patchy landscape has a complex irregular patch structure, whereas a fragmented landscape has simplified patches all of the same size and composition;

2) Largely because of (1), a natural landscape has less contrast (less pronounced structural differences) between adjacent patches than does a fragmented landscape, and therefore potentially less intense edge effects;

3) Certain features of fragmented landscapes, such as roads and various human activities, pose specific threats to population viability.

Again, the question needs to be raised as to what is the normal condition of a semi-natural ecosystem such as grassland, and how is the position in the landscape influenced by fragmentation?

Human caused fragmentation therefore creates a landscape different from that shaped by the natural disturbances, which the component species have become adapted to over evolutionary time (Noss & Cooperrider 1994). This is because human disturbance is often different, more frequent (often continual), and/or more intensive than that of non-human disturbances to which ecosystems have been able to adapt and endure (Tivy 1993). Yet, the North Kent Marshes have not been around on a long enough time-scale and are adapted to a traditional management regime, which becomes disrupted by human induced fragmentation, i.e. normal management is continuous low magnitude disturbance to which the habitat is adapted. In contrast fragmentation is a high magnitude and intermittent disturbance of greater intensity, which will lead to a change in habitat type. The processes which lead to these changes is one of the themes of this thesis.

The concept of fragmentation has been applied in many different ways and too many different habitats. Most definitions, however, imply that the product of the fragmentation process is a landscape mosaic, which is comprised of a matrix of 'hostile' environments or dissimilar habitats, through which components of the original habitat cannot disperse e.g. Noss and Csuti (1997). These remaining isolated remnants of a habitat can be compared to islands in a 'sea' of different habitat and thereby compared to oceanic islands and the application of the theory of Island Biogeography (Gilpin and Diamond 1980). Wiens (1994) however regards fragments as 'rarely surrounded by an ecologically neutral or inhospitable environment', but are open to influences from the surrounding landscape or land usage. Fragmentation will therefore not only isolate habitat remnants from similar fragments, but also open the habitats to increased pressures from the surrounding landscape, which as Wiens (1994) comments 'may be more important than fragmentation processes'. In the case of the North Kent Marshes this can be the influence of surrounding land uses, e.g. roads, urbanisation, and intensive agriculture.

The fragmented landscape comprising isolated remnant habitats is referred to by Forman (1997) as a patch-corridor matrix, where the patch is the remaining habitat and the matrix comprises the fragmenting agent. As fragmentation affects a habitat, e.g. grazing marshes, that habitat at the beginning of a fragmentation event should therefore initially be regarded as forming the matrix of the landscape and not the fragmenting agent as implied in many of the definitions e.g. Wilcove et al (1986). Should the process of fragmentation continue to such an extent that the original habitat remains only as isolated individual patches within a landscape composed of dissimilar habitats then the fragmenting agent or agents will become the landscape matrix. The diverse appearance of the North Kent Grazing Marshes illustrates both eventualities, where the Inner Thames Marshes have been more extensively fragmented than have the Outer Thames Marshes. Examples such as the remaining fragments of Erith and Stone Marshes may well be described as surviving within a matrix of the roads and office developments that have been responsible for their fragmentation. The Outer Thames Marshes, however can still be described as comprising the matrix of the landscape, see Figs 2.1 and 2.2. As Weins (1994) remarks 'what we choose to term fragmented depends entirely on what we view as "habitat" and what as "matrix". Temporal factors are therefore, determining the form of the landscape matrix and not the fragmenting agent, i.e. fragmentation is an ongoing process that eventually affects more and more of the original habitat, as illustrated by the North Kent Marshes.

The most striking feature of today's landscape is the fragmentation of once continuous habitats and ecosystems into smaller isolated patches and fragments (Burgess 1988, Andren 1994). The implication within the definitions of fragmentation is that only

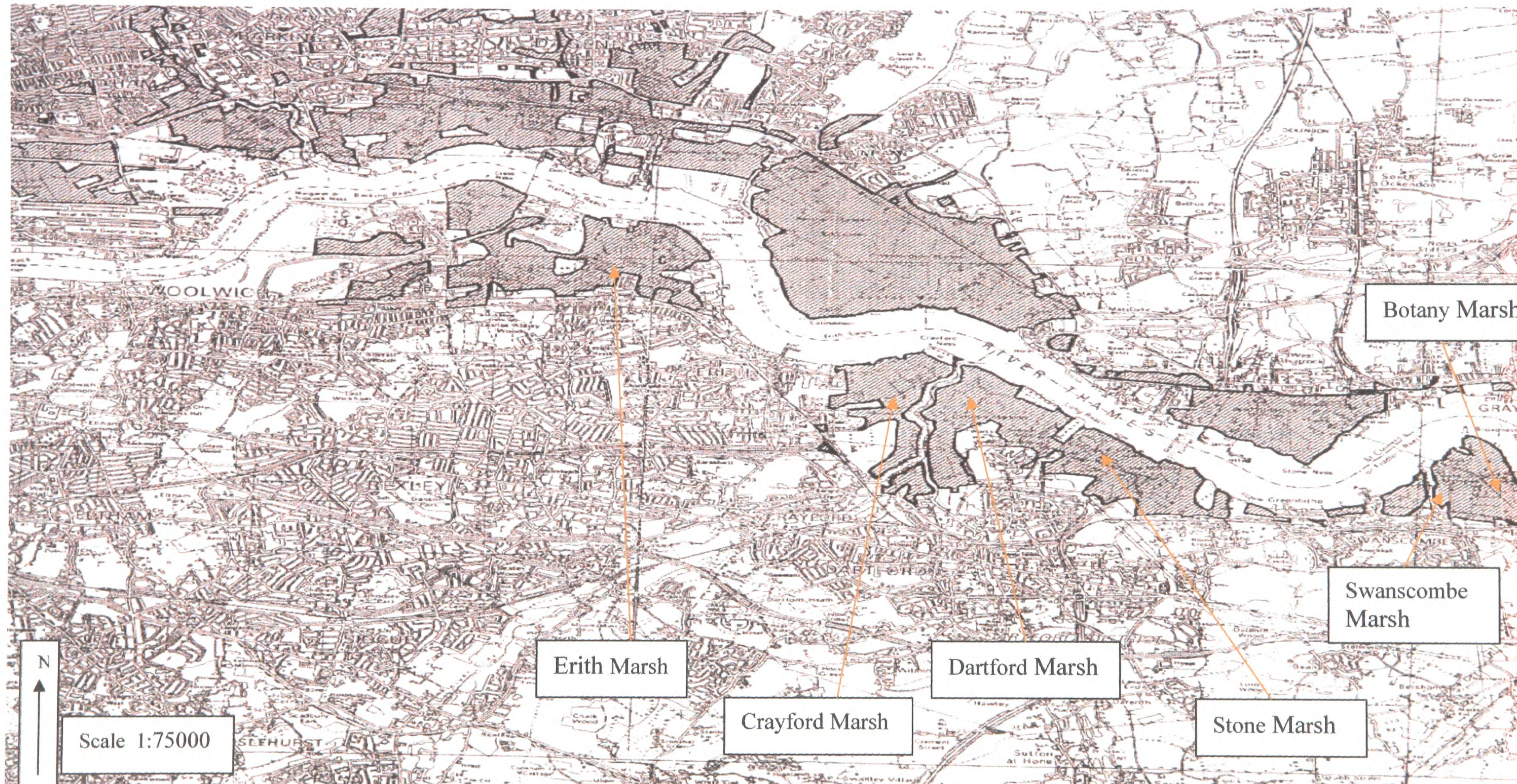

Fig 2.1 The Inner Thames Marshes

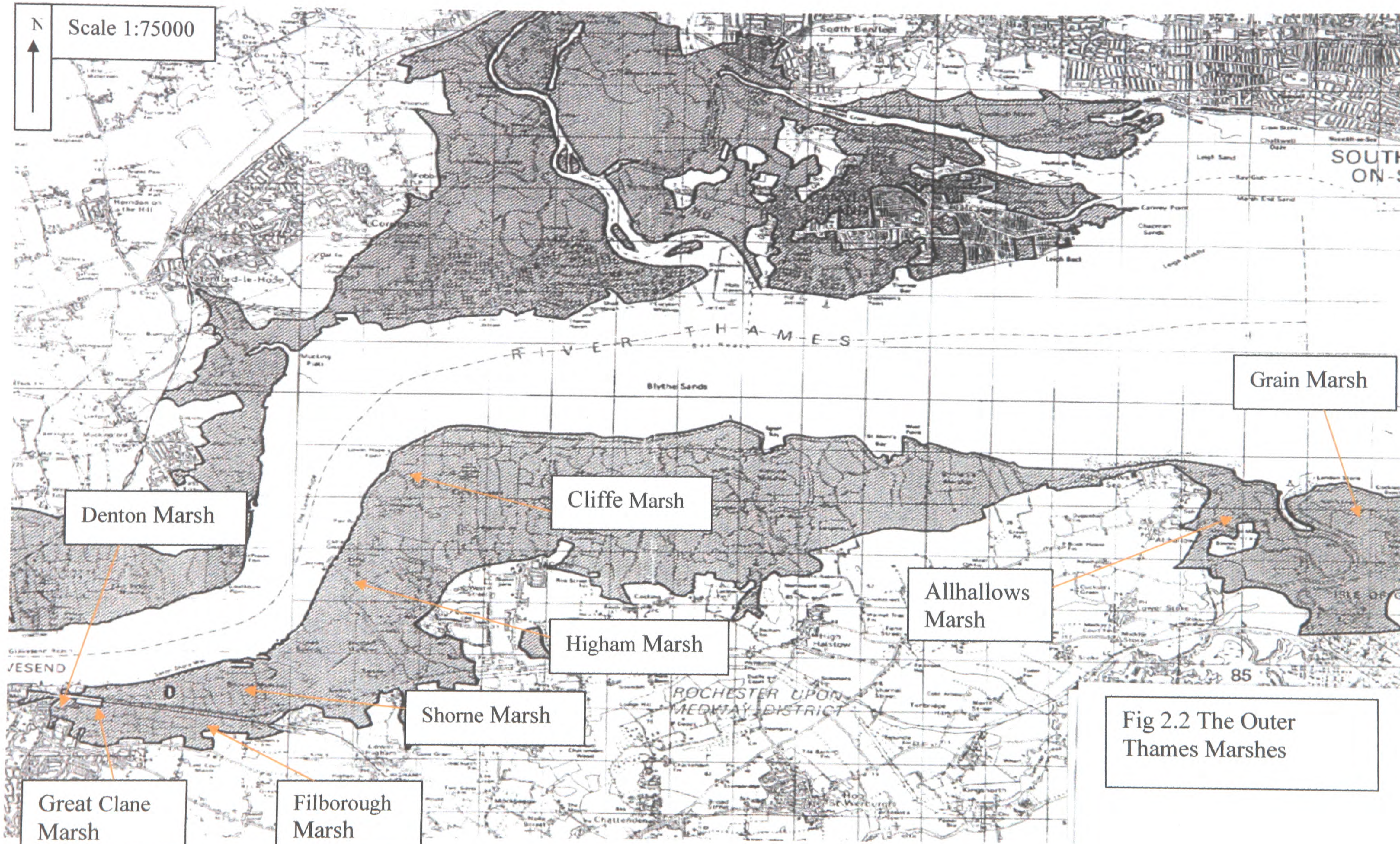

Fig 2.2 The Outer Thames Marshes

natural habitats have been subjected to the fragmentation process, and much of the literature tends to regard this as being the case e.g. Saunders et al (1991), Moilanen and Hanski (1998) and Harrison and Bruna (1999). If, fragmentation processes occur only in wilderness and large expanses of natural vegetation e.g. Saunders et al 1991, Kouki & Loffman 1998, then it raises the question as to whether the process can be discussed in respect of UK habitats, where the vegetation is all semi-natural. Relatively few studies have referred to the fragmentation of semi – natural systems, Webb and Vermatt (1990) on heathlands and, Herkert (1994), Soderstrom & Part (1999), in their studies of birds being notable exceptions. Yet, the assumption is that the process and effects of fragmentation do occur in semi-natural ecosystems is made, e.g. English Nature referring to the North Kent Marshes suffering 'death by a thousand cuts'. Grazing marshes being of purely anthropogenic origin fall into a further category, which has also not been considered in the literature, i.e. fragmentation of man-made managed habitats. Is fragmentation theory therefore applicable to semi-natural and man-made landscapes such as grazing marshes, and can the predictions of fragmentation theory be used to help manage grazing marsh?

There are very few, if any, ecosystems, habitats or landscapes throughout the world, which have not been affected by human intervention to some extent (Burgess 1988), and certainly there are none in Great Britain. Many habitats in England are now more fragmented than they were fifty years ago (Kirby 1995). It can therefore be argued, that the process of fragmentation must also be affecting semi-natural habitats and including those that result from management techniques and have created the plagioclimax communities we now regard as being natural e.g. grasslands and agricultural landscapes. Given the importance of grazing marshes to the landscape of North Kent, it must be accepted that changes to grazing marsh structure through fragmentation is an issue of concern and one in need of study. The loss of grazing marsh has been primarily due to disturbance of human origin (Thornton and Kite 1990), but future scenarios of sea level rise and global climate change may well introduce elements of natural disturbance in the years to come and further fragment the grazing marshes, or induce a return to the original saltmarsh. Reviewing the impacts of past fragmentation on the current state of grazing marsh fragments, can therefore, be used to predict the effects of future fragmentation.

2.3 Concepts relating to Fragmentation.

Many of the concepts relating to habitat fragmentation are concerned with, or dependent, on the theory of a species-area relationship, i.e. that a larger area of habitat will probably support a greater number of species, e.g. Preston (1962), Williams (1964), MacArthur & Wilson (1967). Lomolino (2000) referred to the concept as 'ecology's most general, yet protean pattern'.

The definitions of fragmentation outlined in Section 2.1.1 are based on the effects that occur when habitat areas are becoming smaller and more isolated. Fragmented habitats that become separated from similar habitat types by a succession of different habitats are also subject to the processes and conditions described by MacArthur and Wilson (1967). The Theory of Island Biogeography was derived to explain the species- area relationship on oceanic islands and has often been extended to fragmented terrestrial habitats, e.g. Quinn & Harrison (1988), Webb and Rose (1994), Baur and Erhardt (1995), Andren (1994 & 1997), or used as a predictive tool e.g. Shaffer (1990).

It has long been known that there is a link between the number of species and the size of a habitat, and that a reduction in the area of habitat is likely to lead to a reduction in the number of species present. In 1855 Alphonse de Candolle, a Swiss phytogeographer, predicted that, 'the break up of a large land mass into smaller units would necessarily lead to the extinction or local extermination of one or more species and the differential preservation of others', (cited and translated in Browne 1983, then quoted in Meffe and Carroll 1997).

A relationship between species numbers and area, particularly in respect of oceanic islands was commented on prior to de Candolle. Possibly the first recorded writings on the effect were by Johann Reinhold Forster, who worked as a naturalist on Captain Cook's second expedition to the Southern Hemisphere between 1772-1775. He wrote 'islands only produce a greater or lesser number of species, as their circumference is more or less extensive', (Forster 1778 in Meffe & Carroll 1997). Mayr (1965), Terborough (1973), Diamond and Mayr (1976) subsequently confirmed those early conclusions regarding the species area relationship, in respect of both oceanic islands and terrestrial habitat islands.

The Study of the species area relationship and its application to continental environments and habitat islands gained momentum in the early twentieth century, e.g. Arrhenius (1921), Gleason (1922), Cain (1938), Williams (1943 and 1964), Hopkins (1955), Darlington (1957), and Preston (1960). These works all refer to terrestrial habitat sites. The Equilibrium Theory of Insular Zoogeography as proposed by MacArthur and Wilson (1963) is however, often regarded as being the original key paper on the species-area relationship. MacArthur and Wilson published The Theory of Island Biogeography in 1967 in which they further established the principles of the species area relationship and this has also become a key work in this field of study. Although titled 'island biogeography', the work is primarily concerned with insularity of habitats and island effects on isolated populations of species and used examples of woodland fragments in Wisconsin as discussed by Curtis (1956), see Fig. 2.3, to illustrate their argument.

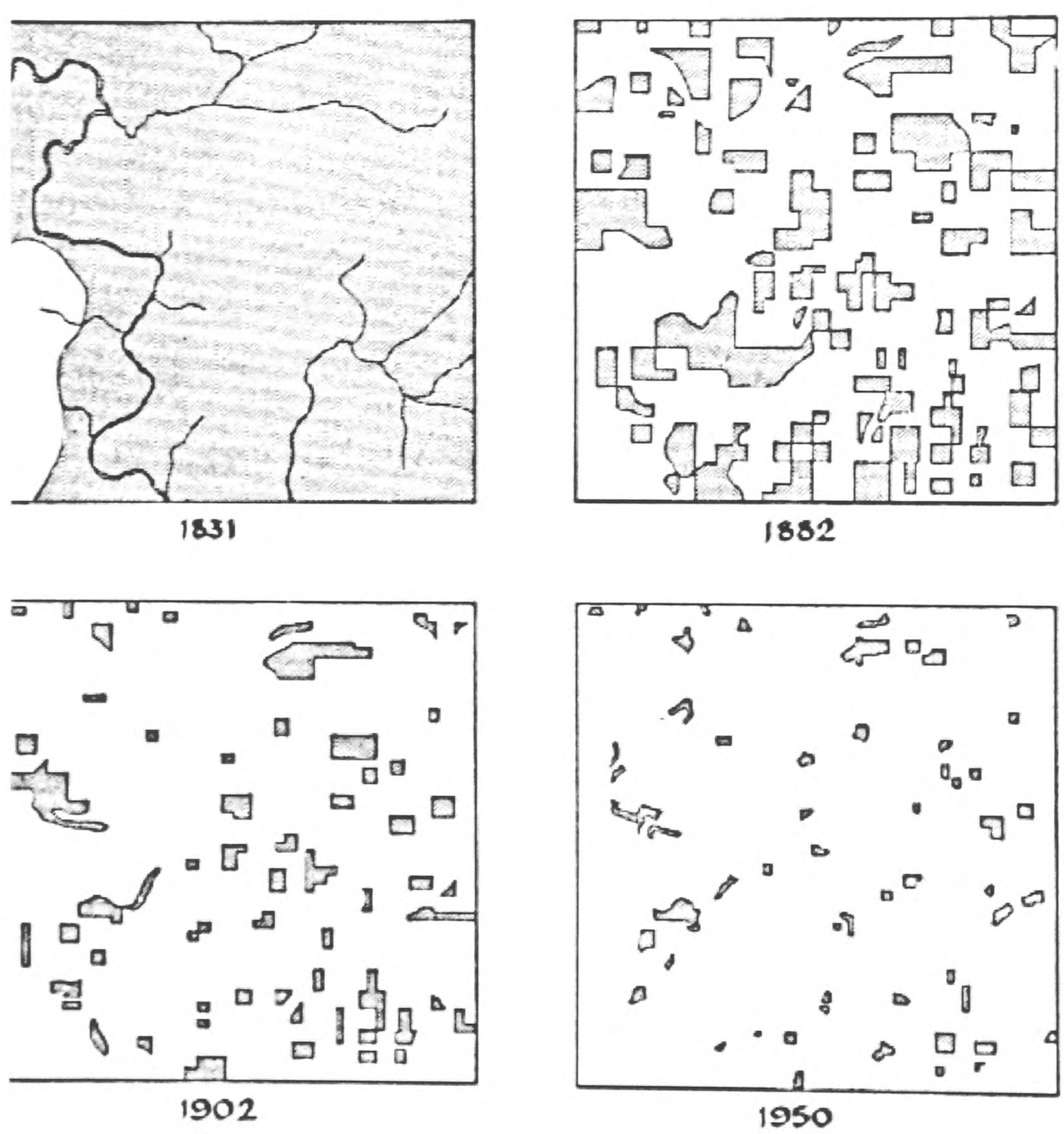

Fig 2.3 Fragmentation of woodland in Wisconsin (After Curtis 1956)

MacArthur and Wilson (1967) wrote that, 'many of the principles graphically displayed in the Galapagos Islands and other remote archipelagos apply in lesser or greater degree to all natural habitats. Consider, for example, the insular nature of streams, caves, gallery forest, tide pools, taiga as it breaks up in tundra and tundra as it breaks up in taiga. The same principles apply, and will apply to an accelerating extent in the future, to formerly continuous natural habitats now being broken up by the encroachment of civilisation'. This process is now synonymous with some of the definitions of fragmentation, (see definitions in Section 2.1.1).

In recent years, the proposals set out in the theory of Island Biogeography have been extended to cover terrestrial habitat islands and nature reserve design, e.g. Diamond (1975) and Shafer (1991).

Amongst the early attempts to discuss, the logarithmic nature of the species area relationship was the work of Preston (1962) and Williams (1964). This research led to two major hypotheses being proposed: -

1) the larger the area of habitat the more species it will contain;
2) larger areas will contain a greater number of habitat types.

The MacArthur and Wilson (1967) Theory of Island Biogeography builds on the work of Preston (1960, 1962), who proposed that the larger the area the greater number of individual species will be present. Williams (1964) hypothesis is based on the notion that environmental heterogeneity, i.e. diversity of conditions and habitats increases with increasing area. Specifically that as an area increases in size it will contain an increasing number of habitats, microhabitats or niches each of these supporting its own characteristic species. Species numbers will therefore increase with the increase in the size of an area. Alternately as an area becomes smaller, the less diverse number of habitats it will be able to support and consequently fewer species will be present

(Williams 1964). The argument appears to state that as an area becomes smaller the more homogeneous it becomes, and thus by inference increasing homogeneity will also show an area effect, i.e. decreasing species numbers.

It may be argued however, that large tracts of a homogenous habitat are as equally valuable as large heterogeneous habitat areas. In some habitats, large areas are required to support large numbers of individual species of birds, as in the case of birds such as waders and wildfowl on grazing marshes (English Nature 1996). The example of grazing marshes therefore, supports the overall species area relationship proposed by MacArthur and Wilson, although homogeneity is at the landscape level and at the finer scale, grazing marshes are heterogeneous (see Section 7.2). Given the importance of the North Kent Grazing Marshes to numerous bird species, is fragmentation reducing the viability of the North Kent Marshes purely through a reduction in area or will the increased heterogeneity resulting from fragmentation influence the value of the North Kent Marshes in this respect?

Considerable criticism has also been levelled at the MacArthur and Wilson theory, particularly in the late 1970's and early 1980's. Many criticisms notably Saur (1969), Boecklen and Gotelli (1984), Buckley (1985) and Budiansky (1995), regarded the theory as ignoring habitat heterogeneity; Saur (1969) additionally thought the theory was oversimplified. Gilbert (1980) wrote that 'quantitatively there was little evidence' to support the theory and that it was 'insufficiently validated'. Simberloff and Abele (1976) decided that the 'models may or do not incorporate potentially biological important facts', which was expanded by Simberloff (1978) stating 'the theory rests on the assumption that the number and composition of species on islands is solely the result of population phenomena and ignores any competitive effects'. Yet, MacArthur and Wilson (1967) is still used in landscape ecology as a basis for study in species-area relationships, e.g. Williamson (1989), Connor et al (2000), Lomolino (2000), and the use of their ideas in landscape ecology is therefore relevant to this study.

A body of opinion has developed which is beginning to challenge the strict interpretation of decreasing size leading to a decrease in species number, e.g. Quinn & Robinson (1987). Some of these studies reflect the opposite effect in that a smaller patch may well have more species than larger ones. Increases in the perimeter length and a resultant increase in edge effects have been regarded as being responsible for creating differing environmental conditions which in turn opens opportunities for more competitive species to colonise the habitat. If this is the case then fragmentation of grazing marshes may lead to a greater number of species being present on the smaller fragments, although the increase may be due to invasive 'alien' species, which may be linked to a loss of natural grazing marsh species.

The debate regarding the number of species present in a particular habitat relates not only to the area of a remaining fragment but also to the ratio of core to perimeter of the fragment, i.e. the contribution of edge effects to the habitat composition. Therefore, shape and orientation of the habitat are also factors that will influence species numbers, (Gutzwiller and Anderson 1992), as will the type of habitat, the habitat that comprises the matrix surrounding the patch or fragment (Battersby 1999), the number of habitat patches and the degree of isolation of each patch (Andren 1994). These factors will be linked to the agencies and processes of fragmentation in Section 2.5.

Since its inception the theory of MacArthur and Wilson has been applied to a variety of terrestrial habitat islands including, e.g. forests Galli et al (1979); mountains Cook (1974) and Johnson (1975); ponds Hubbard (1973); mangroves Simberloff (1969 and 1974), Simberloff and Wilson (1969). There are however, few papers on species area relationships in grassland habitats Quinn and Robinson (1987), Soule et al (1992) and Robinson et al (1995) being notable exceptions. Given the importance of the North Kent Marshes to the numbers of birds and invertebrates which use the marshes, changes to the area and edges of grazing marshes are of concern and ones in need of study.

Soule (1986) stated that the Theory of Island Biogeography has been applied to conservation problems mainly in the context of habitat fragmentation. This is no more evident than in the application of the theory to nature reserve design, which has been well covered in the literature notably by Diamond (1975), Wilson and Willis (1975), Helliwell (1976), Usher (1979). Simberloff and Abele (1974) also provide a very concise overview of the subject.

Many studies of fragmentation e.g. Lovejoy (1986) and Wilcove et al (1986) treat fragmentation as a spatial occurrence on a landscape scale. As Lord and Norton (1990) point out fragmentation is not restricted to any particular spatial scale, but the occurrence of fragmentation will also affect the continuity of processes within ecosystems and landscapes. Fragmentation studies should therefore, ideally also consider both temporal as well as spatial effects operating from the time when the initial fragmentation of the habitat commences.

The concept of fragmentation is also apparent in the Nature Conservation Review, Ratcliffe (1977), where one of the defining criteria for the value of a site in terms of conservation was the size (extent) of the habitat. Particularly in lowland Britain, it was acknowledged that 'semi-natural habitats tend to be highly fragmented' (Ratcliffe 1977), therefore confirming that the fragmentation process does affect semi-natural habitats.

Whereas fragmentation studies in woodlands and forests are indicative of their value to biodiversity and the threat that fragmentation poses, e.g. Harris (1984). Few if any studies are available for grassland habitats. Table 1.1 highlighted the importance of the North Kent Marshes in terms of their conservation value. As the North Kent Marshes are important for the large number of over wintering waders and wildfowl, it would seem imperative that large areas are conserved to accommodate the appropriate species numbers. A number of invertebrate and plant species are however; also important conservation features of the grazing marsh habitat, and their requirements would not necessarily be for such extensive open areas. Therefore, the smaller sites may be of equal importance in conservation terms for plants and insects as the larger more contiguous marshes, although the value must be scaled with their overall importance, i.e. there is no excuse to reduce the size of large patches. Rather than just a discussion on size therefore, the effects of fragmentation on grazing marshes may depend on how key features (Section 3.1.1) respond not only to fragmentation, but also to the influence of fragmenting agents (Section 7).

Haila (1990) summed up the value of MacArthur and Wilson's theory as being 'a deductive scheme highlighting the potentially important factors which affect island communities, i.e. a research programme not a strict explanatory hypothesis'. The Theory of Island Biogeography can therefore, be used to formulate the initial hypothesis for studies in the fragmentation of habitats, in that the fragmentation of grazing marshes will reduce their area and therefore, be of less value to key species for which the habitat has gained international recognition. If other predictions e.g. Quinn and Robinson (1987) are correct then the smaller fragments may well increase in floral diversity, which in turn may lead to an increase in invertebrates and small mammal numbers i.e. overall biodiversity, but it is unlikely that the wader and wildfowl numbers will be equally advantaged.

2.4 The Process of Fragmentation.

Fragmentation may occur as the result of an individual event i.e. the bisection of a habitat by a new road, or it may occur piecemeal over a period, e.g. logging individual plots in a forest area, or as 'death by a thousand cuts' to grazing marsh in North Kent (English Nature 1993). Andren (1994) defined three main components that comprise the effects of habitat fragmentation: -

1) the reduction of the total amount of a habitat type, or perhaps of all natural habitat in a landscape;
2) the apportionment of the remaining habitat into smaller more isolated patches;
3) the increasing isolation of habitat patches (Andren 1994).

Fragmentation theory implies that the product of fragmentation is a 'sea' of hostile environment surrounding the remnants of the original habitat (Gilpin and Diamond 1980). Where fragmentation occurs in stages, the overall heterogeneity of the habitat may remain for some time in its pre-fragmentation state and the overall abundance of species is unaffected in the short term, although the long-term stability of the habitat may well have been compromised. The process of fragmentation increases the space between the remnant fragments thus increasing isolation (Saunders et al 1991, Kouki and Lofman 1998), creating barriers between fragments (Andren 1994), and the disturbing factor or the newly created habitat becomes the matrix of the landscape. As Gibbs and Hochali (2002) stated 'habitat alteration occurs after fragmentation'.

These processes can then be allied to the concepts related to fragmentation in Section 2.3, i.e. Island Biogeography and later concepts e.g. metapopulations. Levins (1970) introduced the term metapopulation to describe a local cluster of spatially separate sub-populations, 'connected by the dispersal of individuals, in which there are local extinctions and colonisations' (Gilpin and Hanski 1991, Foreman 1998). The concept is related to Island Biogeography, as both consider colonisation and extinction as the main processes, the differences being that Island Biogeography relates to the number of species occupying an island and immigration from the mainland or a large habitat island to smaller islands. Metapopulation studies in contrast consider single species dynamics and dispersal between all local habitat patches or fragments.

Hanski (1998) viewed metapopulation theory as 'striking a compromise between theoretical and landscape ecology', where landscapes are perceived as comprising a network of suitable habitat patches or fragments to which 'local populations are connected by migration' (ibid). An increase in the number of fragments in a landscape resulting from fragmentation will therefore create an increase in the number of species converted to metapopulations. The increase in isolation and the creation of barriers to connectivity, which Andren (1994) regarded as one of the three main elements of fragmentation; will result in the loss of connectivity between fragments, which in turn will compromise the survival of metapopulations. Acknowledgement should be given however, to the possibility that some agents of fragmentation, e.g. road verges, may provide corridors along which metapoulations may disperse, whilst agents such as agriculture will provide a less inhospitable barrier. The implication is therefore as Foreman (1997) points out 'all spatial elements in the mosaic are important in the metapopulation concept. Although Hanski (1998) regards, 'the total amount of habitat in the fragmented landscape is often a good predictor of long-term metapopulation persistence'.

The effects of the fragmentation process result in the introduction and alteration of habitat components, i.e. core and edge, which will in turn affect the ability of the component species to cope with further change and pressures. As fragments become smaller and the edge to core ratio rises, fragments become more susceptible to stress and disturbance (Saunders et al 1991, Friedenburg 1998). Consequently, fragments become less liable to remain as a viable sample of the habitat type and will be likely to suffer long-term loss of component species populations, configurational and minimal structure, and hence the stability of the ecosystem will fail.

The effects of fragmentation processes on the core and edge of a habitat and upon its minimal and configurational structure therefore need to be considered. The minimal structure refers to the elements, which are essential for a habitat's survival, e.g. in a grassland these would include grasses, soil, rainfall, grazing intensity and how they are interlinked. The configurational structure relates to the hierarchical structure of the environment, i.e. the inter-relationship between the species and populations or the ecosystem relationship. Configurational structures of a habitat may change without affecting or threatening the habitat. The effects of fragmentation are therefore, going to be linked to changes in the minimal structure, leading to changes in the habitat type. In terms of grazing marshes, the landscape characteristics and features (defined in Section 3.1.1) form the configurational and minimal structures, and therefore how fragmentation affects these components is crucial in discussing the overall effects of grazing marshes. The configuration of these characteristics and features is important to the maintenance of grazing marshes and changes to this configuration through fragmentation is of concern, and one that has been overlooked in the literature, and is therefore in need of study.

In instances where the fragmentation of the landscapes, such as the North Kent Grazing Marshes, has proceeded due to intensification of agriculture, the resultant mosaic may not prove to be such a hostile barrier. The introduction of different forms of agriculture in the region has produced a modified version of the original landscape, but one with grassy vegetation still dominant and as such does not present such a restrictive barrier, i.e. a soft edge where the contrast between the habitats is small, (Forman 1997). This type of landscape alteration is known habitat variegation and is described as an alternative to habitat fragmentation (McIntyre and Barrett 1992), and occurs more within the Outer Thames Marshes than the Inner Thames.

Where the integrity of the habitat has not been greatly affected by fragmentation the habitat may be able to return to its original form if the fragmenting factor is removed (Turner et al 1993), e.g. the removal of an arable intrusion may revert to grazing marsh habitats. Reversion to the original management regime may be necessary to achieve this, e.g. RSPB management at Northward Hills on the Hoo Peninsula (RSPB *pers com*). Once fragments have become too small, they become more susceptible to stress and disturbance and as a consequence less liable to remain viable as a sample of the habitat type and will suffer long-term loss of component species populations.

The process of fragmentation therefore, acts to create isolated habitats, introduces barriers between habitat isolates, increases metapopulations, alters the minimal structure of the habitat and increases the amount of edge and edge to core ratio in that habitat. Several typologies have been produced to describe the process of fragmentation, e.g. Lord and Norton (1990), Harris et al (1992), Forman (1997). Harris et al (1992) defined five forces or processes that were considered to be acting on a habitat or landscape and which could be linked to the processes of or could be considered to be causes of fragmentation. Each process would eventually lead to different fragmentation effects in terms of the landscape pattern, ecosystem processes and biological diversity.

The five processes proposed by Harris et al (1992) are outlined below.

1) **Regressive fragmentation** is a force acting in a single direction along the frontal edge of a habitat. The grazing marsh edge is pushed back by successive events, increasing the width of the barrier between fragments.

Housing development alongside a new road could be thought of as an example of regressive fragmentation.

2) **Enveloping fragmentation** is seen as resulting from pressure around the whole perimeter of a habitat and an overall contraction of the habitat. Such a process may well increase the edge effects and increase pressure on the core.

3) **Divisive fragmentation** occurs when a habitat becomes physically divided into two or more distinct areas and influences the movement of organisms between the two fragments. Road building is an example of such a force and has occurred in several instances within the North Kent Marsh area, e.g. University Way was built across Dartford Marshes physically separating the fresh marsh from the main bulk of the grazing marsh.

4) **Intrusive fragmentation** occurs through alteration from within the habitat and directly affects the matrix or core of the habitat compromising the structural integrity. In contrast, the three previous processes impact indirectly on the matrix but impact directly on the perimeter. The draining of ditches or the altering of the level of the water table are examples of intrusive events that could cause fragmentation within grazing marshes.

5) **Encroaching fragmentation** is seen as resulting from pressures that are being applied to either side of a linear incursion; in terms of grazing marshes a river may be considered as an example of such an incursion. Therefore, the construction of embankments alongside rivers may result in encroaching fragmentation if development is allowed, but in any case may be considered a form of divisive fragmentation.

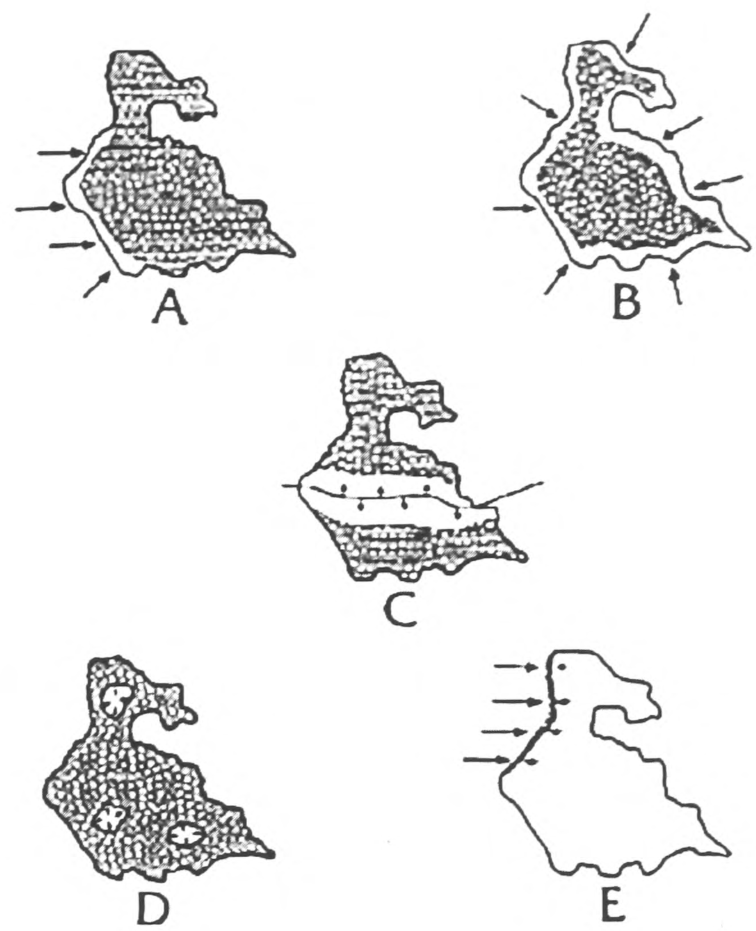

Fig 2.4 Fragmentation processes (After Harris et al 1991);
A) Regressive; B) Enveloping; C) Divisive; D) Intrusive; E) Encroaching.

Figures 2.4 illustrates the above five processes. Whilst theoretically useful, it would appear from the literature that research into the five processes of Harris et al (1992) is still insufficiently advanced to distinguish what the differing effects of each individual process are. For this thesis therefore it was decided to test the practicality of the processes described by Harris et al (1992) and by using the processes, to determine which has been predominant in the fragmentation of the North Kent Marshes, and how the processes have influenced the landscape character and features of the individual fragments.

Habitat fragmentation can therefore be regarded in terms of a series of fragmenting events, which occur over a wide range of scales, over varying periods of time and as a multidimensional problem. Fragmentation is thus a complex process with many variable factors, e.g. the event causing fragmentation, the individual species response, the response of the landscape characteristics and features and changes to the relationship between species and landscape. These events can then be seen to be acting both temporally and spatially, resulting in the fragmented landscapes and habitats that are concerning so many in the field of conservation and biodiversity.

Disturbance created by fragmenting events and processes on the North Kent Marshes acting both spatially and temporally has resulted in a mosaic of fragment sizes subject to further pressure from renewed development. It is the resultant effects of these events on the stability and structure of the North Kent Grazing Marshes that will be investigated in this thesis.

2.5 Effects of Fragmentation.

Reviews of fragmentation effects can be found in Wilcove et al (1986), Burgess (1988), Lord and Norton (1990), Saunders et al (1991), McIntyre and Barrett (1992), Robinson et al (1992), Andren (1994), Noss and Csuti (1994), Harrison and Bruna (1999), Debinski and Holt (2000) and Fahrig (2001). Conclusions on the effects of fragmentation generally regard it as having a negative influence on both species and ecological processes e.g. Kruess and Tscharntke (1994), Collinge (1996) and Farina (1998). The processes of fragmentation however, are less well covered in the literature. Notable exceptions include the effects of habitat fragmentation by roads Mader (1984), Andrews (1990) and Forman and Deblinger (1999). Jansson et al (2000) reviewed river fragmentation by dams. Harris (1984) discussed processes in forest fragmentation, as have Kouki and Lofman (1998).

2.5.1 Effects on ecosystem processes.

Reviews of the effects of fragmentation on habitats have tended to confine itself to biogeographic changes on species and/or on habitat loss e.g. Saunders et al (1991), and Harrison and Bruna (1999). In terms of conservation of habitats the ecosystem processes, which maintain these systems, are of equal or greater importance (Hobbs 1993), but the fragmentation effects on them are under represented in the literature.

Hobbs's (1993) study showed that alteration to hydrological regimes, nutrient cycling, radiation balances, wind patterns and soil movement may well play a vital role in the maintenance of a balanced ecosystem. In terms of the North Kent Marshes, the hydrological balance may well be regarded as the most important of the processes that needs to be maintained in order for them to continue to function as a wetland habitat. Any disruption therefore to this process will have detrimental effects to both the characteristic flora and fauna.

The majority of studies concerning ecosystem processes are based on the effects of road building e.g. Mader (1984), Andrews (1990), and Forman and Deblinger (2000). Findlay and Bourdages (1998), Jones et al (2000) however, focussed their discussions on the effects of roads on hydrology. Mader (1984) recorded how roads can influence changes in microclimates particularly temperature, humidity and radiation balances. Smith in Hobbs (1993) reported a distinct difference in surface and soil temperatures and humidity in road verge vegetation. These results indicate that marshes that have been dissected by new roads are likely to incur fluctuations in the ecological processes, which in turn will influence the water content of the soils and in the long run interfere with the hydrology of the marshes. The importance of hydrology on lowland wet grasslands is covered in Section 3.3. For example, Forman and Deblinger (2000) recorded that where roads crossed wetlands, drainage effects 'extended outwards for distances varying from 50m to 500m'.

Fragmentation of wetland habitats, such as the North Kent Marshes can also be affected by other means. Increased run off from new roads dissecting marshes may lead to the build up of pollutants and silt in the water courses, which again will alter the faunal and floral content in the drainage systems of the North Kent Marshes e.g. smothering of benthic organisms (Andrews 1990). Long-term effects of this process will also alter the ecosystem processes either of the marshlands through silting of the drainage ditches or through species loss. The connectivity that drainage ditches bring to grazing marshes also means however, that silts and pollutants etc. can be transported between sites. Build up of deposited material may also affect the surface wetness, causing drying of the surface and a change to the structure of grazing marshes. The effects of fragmentation on these key aspects of grazing marshes will are considered in this thesis.

2.5.2 Effects on vegetation.

The majority of studies of the effects of fragmentation on vegetation are concerned with forests and woodlands, e.g. Harris (1984), Peterken and Game (1984), Wilcove et al (1986), Reed et al (1994, 1995), Harris and Silva-Lopez (1992), Kirby and Thomas (1994), Thomas et al (1997), Laurance et al (1998), Benitez-Malvido (1998), Kouki and Lofman (1998), and Freidenburg (1998). The number and variety of these studies is evidence as to the pre-eminence of forest and woodland fragmentation in the conservation and fragmentation literature. As this thesis is concerned with grasslands, reviews of the findings from these studies have not been covered.

Similarly, in Great Britain, fragmentation in grasslands and agricultural landscapes is relatively poorly documented, where the majority of fragmentation studies that have been carried out are primarily concerned with the effects of fragmentation on other habitat types, e.g. woodlands (Thomas et al 1997), heathland (Webb and Vermaat 1990). 'Only a few studies explicitly focused on plant population and community dynamics' Debinski and Holt (2000), hence this study will consider the effects of fragmentation on an agricultural based landscape and vegetation communities.

Results from fragmentation studies have produced results which have often conflicted with the predictions of the species – area relationship, e.g. Simberloff and Gotelli (1984) and Webb and Vermaat (1990). The latter recording an increase in species diversity and abundance in smaller areas, whereas Simberloff and Gotelli (1984) found that a cluster of small prairie and woodland sites contained more plant species than one large site of similar area. Higgs and Usher (1980) in an earlier study reported similar results to Simberloff and Gotelli (1984) for plants in coastal habitats, limestone pavements, chalk quarry reserves and lowland heaths. Webb and Vermaat (1990) studying heathland vegetation concluded that as the habitat was generally dominated by a few species; small fragments attained a higher diversity of species through normal successional trends. Fragmentation thus led to some fragments becoming untypical of traditional heathland and as such unacceptable for conservation purposes. If this situation arises on grazing marshes, then the smaller fragments should contain a greater percentage of atypical habitat species.

Quinn and Robinson (1987) studying Californian annual grasslands, and Kemper et al (1999) looking at Renosterveld shrublands, showed that there was a greater variability in species composition in smaller fragments. Kemper et al (1999) did record however, that there was a significant decline in perennial grasses in smaller fragments. As perennial species comprise the major floral content of grazing marshes, an increase in the proportion of non-graminoid species may be highly indicative within the North Kent Marshes that the fragments continuing suitability as grazing marsh is becoming compromised.

Harrison (1997) in a study of Californian serpentine chaparral found that there was a positive relationship between patchiness and diversity, but only because 'patches supported occasional representatives of species that are not normally found on serpentine'. Holt et al (1995) in an earlier work on agroecosystems also concluded that clonal plant species were more prone to local extinction in smaller patches.

Robinson et al (1992) again concluded that clonal plants, i.e. those which, reproduce by vegetative growth, were less likely to persist in small patches than non-clonal plants, i.e. those which reproduce by seed dispersal, but they recorded that large patches containing vascular plants contained no more species than an average cluster of small or medium patches. McCollin et al (2000) suggested that fragmentation might lead to small-seeded plant species doing better than heavier seeded species. They base their assumption on the work of Eriksson and Jacobsson (1998) who state that local abundance will reflect colonisation success, competitive and dispersal ability. Fragmentation may therefore have a greater effect on plants with regenerative strategies rather than competitive and stress related species, as defined by Grime et al (1988).

Although greater species diversity has been recorded on smaller fragments, e.g. Quinn and Robinson (1987), the small fragments are not being considered as truly representative of that habitat type. The increase in species richness is due to the addition of 'alien' species Robinson and Quinn (1988), and Kemper et al (1999). Grazing marshes have a small suite of typical floral species, and therefore, changes in the floral structure due to fragmentation should be more apparent. The flora is however, dependent on the landscape features, which contribute to a traditional grazing marsh (Section 3.1.1), any increase in the number of species may therefore, be indicative of poor management rather than fragmentation and a loss of area.

From many of the above studies it appears that fragmentation of grasslands into smaller patches can lead to increase in floral species diversity (Harrison 1997), and the establishment of ruderal species in the disturbed edge environments (Kellman 1996, Holt 1997, Kemper et al 1999). Although these species may add to the overall biodiversity of a fragmented habitat, the question as to the effect of fragmentation on the quality of biodiversity or the conservation value of open habitats remains. If this is the case then the aim of conservation to protect habitats and rare species only, may need re-assessing.

Fragmentation studies on individual plant species has tended to consider the effects of fragmentation on reproductive success, (Costin et al 2001), population size (Heard et al 1998) and (Morgan 1999) or on genetics (Young et al 1996). These studies indicate that fragmentation thresholds exist, below which effects such as elevated inbreeding; reduced population gene flow and local extinctions will occur i.e. there is a minimal habitat size below which species will begin to become extinct (Dietvorst et al 1982). Although Costin et al (2001) found that the reproductive success in *Leucochrysum albicans* subspecies, *albicans* var. *tricolor* did not decline in fragmented populations. The effects of fragmentation on individual species may therefore depend more on management, initial population size, isolation and ecological interactions, e.g. plant – pollinator relationships. On grazing marshes therefore, there may be a minimal size below which reproductive success of the rarer species becomes compromised by the effects of fragmentation.

2.5.3 Effects of fragmentation on mammals.

An overview of the effects of habitat fragmentation and a summary of how the component animal species are affected is provided by Andren (1994), Harrison and Bruna (1999) and Debinski and Holt (2000).

Reviews of the effects of fragmentation on animals have primarily been concerned with rodent and small mammal species, particularly members of the *Microtus* family e.g. Ims et al (1993), Diffendorfer et al (1995) and Bowers et al (1996). Geuse et al (1985) recorded in Andren (1994) showed that there was a significant relationship between population density, patch size and isolation in bank voles, but no such relationship with wood mice. This difference may well be attributable to the differing natures of the habitat in which each species lives. Diffendorfer (1995), Collins and Barrett (1997), Dooley and Bowers (1998) and Bowers and Dooley (1999) have all carried out studies of fragmentation effects on the meadow vole (*Microtus pensylvaicus*), deer mice (*Peromyscus maniculatus*) and prairie vole *M. ochrogaster.* Diffendorfer (1995) and Dooley and Bowers (1999) concluded that fragmentation benefited small mammal species, and in particularly *Microtus spp* in open grassland habitats. These results contrasted an earlier study by Soule (1992) who stated that area and isolation adversely affected species richness in both small and large mammals in scrub habitats. The positive aspects of the relationship between fragment size and population density recorded by Diffendorfer (1995) and Dooley and Bowers (1998) was attributed to edge effects by Appledoorn et al (1992). The findings were later supported by Bowers and Dooley (1999), who indicated that edge habitats might well contain a higher quality home range and so support a higher population of the individual species.

The higher occurrence of small mammals in edge habitats may also in part be due to the spatial relationship between edge and connectivity to similar habitats (Barrett et al 1995). Fahrig and Merriam (1985) highlighted the importance of connectivity to the survival of white-footed mice (*Peromyscus leucopus*). Lawton and Woodruffe (1991) supported these results by showing that water voles (*Arvicola terrestris*) were less likely to be present in isolated sites. LaPolla and Barrett (1993) provided further evidence for the importance of connectivity by showing that corridors assisted the survival of water voles in agricultural landscapes. In all instances, however, it was seen that habitat fragmentation modified animal behaviour and movements, such modifications may be due to overcrowding effects or from increased inter and intra specific competition (Debinski and Holt 2000).

Studies on small mammals and in particular voles give important insights as to how fragmentation can affect the home ranges and how some of the worst effects can be mitigated. The North Kent Marshes, particularly the Inner Thames areas of Erith, Crayford and Dartford have been shown to have important populations of water voles (Wells *pers com.*). As a result the impacts of fragmentation on the North Kent Marshes will have implications on the survival of water voles, which are protected under the 1980 Wildlife and Countryside Act.

2.5.4 Effects on birds.

The effects of habitat fragmentation on bird species, in terms of both families and individuals, are amongst the best documented in the conservation literature e.g. Lynch and Whigham (1984), Bolger et al (1991), Lynch and Saunders (1991), Opdam (1991), Herkert (1994), Knick and Rotenberry (1995), Wiens (1995), Himsley et al (1996). As with the effects of habitat fragmentation the majority of bird studies have been concerned either with the fragmentation of forests e.g. (Bierregaard and Lovejoy 1989), and (Schmiegelow et al 1997) and woodland fragmentation e.g. (McCollin 1993). Brown and Dinsmore (1968), Lynch and Saunders (1991), Verboom et al (1991), Herkert (1994) and Knick and Rosenberg (1995) investigated the effects of fragmentation on bird communities within grassland and agricultural landscapes.

Studies of fragmentation in woodland and forest habitats have shown that there is a significant negative relationship between bird species richness, patch size, density and isolation. Lynch and Whigham (1984), Bierregaard et al (1992), Stoufer and Bierregaard (1995), Collinge (1996) and Donovan and Lamberson (2001) all recorded a decrease in bird species richness with a decrease in habitat area. Opdam (1991) reported that in these instances, it was the interior bird species, which were more adversely affected, and that fragment size was an important contributor to the variance in species numbers. As in the case of small mammals, it appears that the more generalist species are the ones, which cope better with fragmentation events, (Nour et al 1997).

Effects of fragmentation on bird communities in grasslands have shown similar results to those of woodland studies specifically that species richness decreases with area, (Soule et al 1988 and Bolger et al 1991). Herkert (1994) studying fragmentation in the midwestern grasslands of the U. S. A. recorded that 53% of the most common bird species were influenced by habitat area, and that 40% were influenced by vegetation structure. Further studies by Bollinger and Gavin (1992) and Herkert (1994) showed that the total number of breeding bird species increased significantly with grassland area and that disturbance, not just habitat fragmentation play an important role in influencing grassland bird species distribution. The results of these last two studies highlight the importance of maintaining large areas of grazing marsh to accommodate the needs of the bird species associated with grazing marshes.

Reichoff (1984, reported in Opdam 1991) stated that there was a critical minimum distance of 100km required between marshlands to conserve bird species in isolated marsh areas. Brown and Dinsmore (1986) found that 40% of marshland bird species were not present on sites under 5ha in area and therefore the influence of isolation and area were critical to the survival of marshland bird species. Some of the smaller remaining fragments of the North Kent Marshes are below or approaching this minimum critical size and their ability to support important numbers of waders and overwintering wildfowl is becoming seriously compromised. Vickery et al (1997) and Milsom et al (1998, 2000, 2002), discussed management of grazing marshes and the features that support the bird populations of the North Kent Marshes, recording that the numbers of individuals was often related to a range of features such as sward height, surface wetness and enclosure of fields. The combined effects of marsh size and the retention of the landscape features therefore are responsible for maintaining the waders and overwintering bird species that are associated with the North Kent Marshes. In this thesis, the effects of fragmentation on these features will be considered.

Further work by Pain et al (1997) on agricultural and pastoral grazing habitats showed that there was a relationship between bird species numbers and stocking densities, and in particularly sheep. Many bird species are influenced by habitat variables (Blake and Carr 1987), the more homogeneous swards produced by intensive grazing would appear to be less favourable to species diversity. O'Connor and Shrubb (1986) highlighted these problems by showing that at a density of more than two cows per acre, lapwings (*Vanellus vanellus*), snipe (*Gallingago gallingago*) and redshank (*Tringa totanus*) lose 60%, 80% and 93% respectively of their nests to trampling, so for some species, management may be as important or more important than fragmentation.

Milsom et al (2000) reported that heterogeneity of sward height tended to be more important than mean sward height in determining the probability of marshes being occupied by at least one ground nesting species and the probability increased with the complexity of the grass sward and surface topography. Factors such as roads (Reijnen et al 1996), hedges and power lines (Milsom et al 2000), which divisively fragment grazing marshes, tend to decrease the number of ground nesting species. Milsom et al (2000) in their summary indicated that the effect of area and type of fragmentation was highly significant in nearly all studies of bird species distribution on grazing marshes.

One example of how habitat variables can affect bird species numbers and abundance was carried out by Farina (1998) who showed that birds breeding in forest interiors and wintering in the tropics are more affected by the fragmentation of their feeding habitats. Extrapolation from this viewpoint may indicate therefore that birds wintering on the grasslands of North Kent or using the marshes as migration stopovers may well be greatly affected by their fragmentation. As the North Kent Marshes are of global importance for wintering birds, hence the conservation designations, fragmentation of the habitat becomes significant in international terms. But Kattan et al (1994) concluded the effect of fragmentation might well depend on the biogeography of the species concerned.

From the results of all the aforementioned studies, it appears that both size of a fragment and habitat management are critical issues in the resulting effects of fragmentation on bird populations. The North Kent Marshes are an important habitat for waders and wildfowl and therefore the maintenance of large areas will be as important as the management of any remaining fragment in order to maintain the required landscape features (Section 3.1.1). This study does not survey birds, but surveys of the plant communities and landscape features can indicate the suitability of remnant fragments to support important bird species.

2.5.5 Effects on invertebrates.

Numerous studies have been carried out into the effects of fragmentation on insects, arthropods and arachnids e.g. Webb and Hopkins (1984), Webb (1989), Falk (1994), Kirby (1994), Shreeve (1995). As with other fragmentation studies the majority have been conducted within woodlands and rainforests, e.g. (Klein 1989, Aizen and Feinsinger 1994, Didham et al 1996, 1997 and 1998), and have tended to focus primarily on either beetle or butterfly species.

Klein (1989) studying dung and carrion beetles in rainforest fragments recorded fewer, more rare and more dispersed species in smaller fragments, and it appeared that movement was interrupted by disturbances and edge effects. Didham et al (1996) reported that invertebrates in woodlands appeared to be quite sensitive to disruption of microclimates and other effects of fragmentation. The important role that invertebrates play in ecosystem processes e.g. plant pollination, nutrient cycling and decomposition means that the effects of fragmentation on these groups may be amongst the most profound effects of fragmentation on ecosystem dynamics (Hobbs 1993)

Collinge (1995) and Collinge and Forman (1998) studying a Colorado grassland found that insect species richness increased with area, but that abundance and species density showed no clear relationship with area. Baz and Garcia-Boyero (1995) found a similar result for butterflies in forest habitats. In addition, Collinge (1995) recorded that connectivity between patches enhanced invertebrate movement and increased species richness. By contrast, Quinn and Robinson (1987) and Robinson et al (1995) reported that there was no increase in insect species richness with increasing area in Californian grasslands.

The results of these studies are of relevance as both regional and nationally important invertebrate species are found on many of the North Kent Marshes (Plant 1991, 1992, 1993, Sinnadurai 1999). To maintain viable populations of species such as Roseli's Bush Cricket (*Metrioptera roeseli*) there appears to be a need to ensure the maintenance of corridors between the inner marsh areas.

2.6 Edge effects.

Edge effects occur at the junction of habitat islands and the surrounding landscape and are one of the most researched and studied effects of habitat fragmentation. Laurence and Yensen (1991) remarked that 'edge effects in fragmentation are remarkably diverse'. Amongst these diverse effects are changes in microclimate, increased predation, alterations to plant/pollinator interactions, herbicide drift and variations in light, wind and shading (Holt 1997). Edge effects may also provide a refuge for a range of species from generalist plants to agricultural pests and their predators, although in open grassland habitats many of the edge effects will be less marked. As with most studies in the field of fragmentation the majority of research into edge effects is concerned with forest edges, either in clearcuts e.g. Lovejoy et al (1986) and Murcia (1995), or the gradation from woodland remnants to agricultural surrounds e.g. Brothers (1993). There are few reviews concerning edges in grassland habitats, exceptions being where roads created edges, (Mader 1984, Andrews 1990 and Foreman and Deblinger 2000). The above reviews record that amongst the effects of increased edges and fragmentation are the introduction of edge effects to the core area of habitats leading to habitat loss and modification, isolation, increased disturbance and changes to hydrology (Andrews 1990, Findlay and Bourdages 2000).

Edges will be formed when a fragmenting agent divides a habitat, and the type of edge will depend on the fragmenting agent (Forman 1997). Forman (1997) further defined two types of edge: -

- Hard edges created by roads, urbanisation and industrialisation i.e. the nature of the agent introduces a distinct change between the habitat and its surroundings;
- Soft edges are ones where there is a definite gradation between two dissimilar habitats e.g. woodland to grassland.

Both types of edge are present in the North Kent Marshes, hard edges occur where fragmentation has been caused by roads or urbanisation and soft edges where arable production abuts the grazing marshes.

Roads have been a common cause of fragmentation on the North Kent Marshes (see Section 6.1), where they have been primarily responsible for isolating fragments by the creation of barriers between many marshland fragments and as the impetus for further fragmentation. Road construction has also increased the level of disturbance to the flora and fauna of many of the affected sites. Van der Zande et al (1980) showed that there was a decreased diversity and density of grassland birds by main roads for a distance of up to 930m from the road edge. A similar effect on some of the smaller fragments of the North Kent Marshes, notably Erith, Stone and Denton could make these marshes unsuitability for some of the important species characteristic of the marshes.

Forman and Deblinger (2000) recorded that where new roads cross-wetlands drainage effects could extend outwards from the road for distances between 50 m and 500 m. They added however, that measuring additional attributes such as sediment run off, water table and soil measurements might possibly show the effects of roads extending further into the wetland. Results indicate that for small grazing marsh fragments that have become isolated by road building problems could well occur with either drying out or waterlogging. Evidence from some of the smaller Inner Thames Marshes fragments indicate that drying out may be the greater effect. Where this is the case then the effects on the hydrology will affect the vegetation and the structure of the communities present.

Table 2.1highlights the impacts of fragmentation, covering effects on both habitats and species. Many of these effects can be tested within habitats like the North Kent Marshes and in this thesis adaptation to the effects on habitats, particularly changes in habitat type have been used, see Table 2.2.

Table 2.1: - Summary of the major effects of landscape fragmentation

MODIFICATION OF HABITAT

A) Changes in the size and shape of landscape elements
Decreased size of continuous habitat in remnant patches
Altered shape of continuous areas of patch interior habitat
Altered geometry of edges

Increased perimeter: area ratios of remnant patches

B) Changes in the connectivity and isolation of landscape elements

Increased degree of isolation of remnant patches for species, materials, or effects restricted to patch interior habitats

Increased connectivity of remnant patches for species, materials, or effects following edge or modified habitat

Increased access for activities, which may further damage core

C) <u>Changes in habitat type</u>

Increased amount of edge and modified habitat

Decreased amount of interior patch habitat

Changes in composition and geometry of edge habitats

Loss of sensitive species from small remnant patches

Altered balance of native and exotic species

Altered balance of weedy or edge and patch core species

Increased spatial and temporal variation in habitat quality for patch interior species

Increased habitat homogeneity within small remnant patches

Changes in the capacity of the habitat for populations of sensitive species

II <u>MODIFICATIONS IN THE QUALITY OF THE HABITAT</u>

A) Changes in the balance of patch core versus edge species and native versus exotic species;

B) Increased exposure of internal areas and further subdivision of landscape;

Direct removal of habitat;

Increased amount of edge in landscape;

Increased exposure to edge effects;

Increased fluctuation of microclimate and related processes;

Influx of foreign materials (toxins, rubbish, insects, etc.);

Disturbance of habitat (soil compaction, direct destruction of vegetation etc.);

C) Declines of populations of species that

Occur naturally at low densities

Have large area requirements

Do not do well in edge habitats

Are sensitive to human contact

Are unable or unlikely to cross barriers

Are sensitive to extinction resulting from fragmentation or disturbance

III MAJOR OBSERVED CHANGES

Peninsular effects and some island effects;

Altered population dynamics of many species;

Possible increased probability of further fragmentation;

Increase in absolute amount of edge in the landscape;

Decrease in the amount of edge that can support sensitive species;

Subdivision of habitats and metapopulation structure of patch interior species;

Altered patch dynamics; e.g. loss of species for which colonisation rates are less than local extinction rates;

Increased instability of ecological processes and increased fluctuation in habitat stability;

Adapted from Schonewald – Cox and Buechner 1992

Table 2.2 Adaptations of Table 2.1 that have been used in this thesis.

A.1. Modification to habitat through decreases in size to remnant fragments;

B.3. Modification to habitat through increased effects, which may further damage the core, i.e. disturbance at edges and further fragmentation;

C.1. Modification of habitat through increased amount of edge;

C.4/5. Modification of habitat through changes in species composition of characteristic vegetation communities;*

C. 7 Modification of habitat through changes to the landscape characteristics and features*.

* Indicates where variations have been made to the suggestions of Schonewald – Cox & Buechner.

2.6 Conclusion.

The theories and concepts proposed by MacArthur and Wilson (1965, 1967) suggest that there will be adverse effects to both species numbers and diversity, with a general decline in numbers being the result. The processes of fragmentation have caused the North Kent Marshes to become smaller and more isolated terrestrial habitat islands and as the theory suggests the result will mean that from a species number and diversity perspective they should become more impoverished. Contrary predictions e.g. Quinn and Robinson (1987), Kemper et al (1999), have shown that the decline in species numbers may not necessarily be the case, although the status of the species which account for the increased numbers are not always typical of the communities which constitute grazing marshes. Whether this change in the typical community structure, which has never been fully established in the literature, (see Section 3.5), is of importance to the maintenance of grazing marshes, the associated species and the overall landscape will be analysed and discussed in sections 6, 7 and 8. The atypical structure of the resultant vegetation communities can be used to analyse and test how fragmentation is changing grazing marsh structure and therefore the current research will be used to establish a protocol for monitoring grazing marsh status.

The point at which the integrity of a site eventually breaks down is however, unknown, as few studies have been conducted over a long enough period. This thesis aims to highlight the changes that have occurred due to the fragmentation process and indicate some of the possible consequences.

Chapter 3 – Lowland Wet Grasslands/Grazing Marsh

Introduction

Lowland wet grasslands occur on riverine floodplains, lake margins and in the coastal zone, and are therefore a lowland habitat (Joyce and Wade 1998). Jefferson and Grice (1998) define lowland wet grassland as 'land managed as pasture or hay meadow occurring in areas of high water table or subject to periodic flooding and at less than 200m above sea level'. Grazing marshes along with washlands, water meadows semi-natural floodplain grassland and lakeside-wet grasslands have been included under this wider heading of lowland wet grasslands e.g. Benstead et al (1997).

There has been much discussion as to how to categorise grazing marshes. The Kent Biodiversity Action Plan (1997) for instance divides grazing marshes into areas of unimproved, semi-improved and improved neutral grassland. In the Kent Phase One Habitat Survey, by contrast grazing marshes are described as semi-natural and divided into neutral and semi-improved areas. Blackstock et al (1999) in their review of surveys on semi-natural grassland communities however, did not include rye-grass (*Lolium perenne*) leys, which is a dominant element of grazing marsh and his summary therefore inferring that grazing marshes are improved grasslands. What cannot be disputed is that grazing marshes are of anthropogenic origin and therefore cannot be regarded as natural habitats.

Whichever definition is used it should be recorded that grazing marsh can encompass amenity, improved, and neutral grasslands which maybe either semi-improved or unimproved. Grazing marshes can also be grazed, mown or unmanaged, retain a brackish influence or not (Kent Habitat Survey 1991). As the Kent Wildlife Habitat Survey (1991) illustrates, it becomes difficult to determine an exact cut-off point for determining what is and what is not grazing marsh and therefore difficult to evaluate and monitor.

The prime function of grazing marshes has been to provide good pasture for domestic grazers. The species composition of the swards in managed grazing marshes has therefore been aimed at maintaining the best quality herbage that will produce the highest productivity. Grime et al (1988), record that the management of productive grasslands for both agriculture and amenity value is dependent on the introduction and maintenance of perennial rye grass (*Lolium perenne*), a characteristic component of coastal grazing marshes. As Stapledon and Davies (1940) record, as cited in Garrad (1954), 'as the rye grass content increases, there is a corresponding increase in productivity of the pasture as a whole'. On the best grazing lands perennial rye grass (*L. perenne*) with white clover (*Trifolium repens*) form the basis of these pastures (Garrad 1954). As the contribution of rye grass decreases, bent grass (*Agrostis spp.*) takes its place as the chief grass (ibid). The improvement in the grasslands has generally led to a species poor sward when compared to other unimproved grassland communities (Davidson 1991). Jefferson and Robertson (1996) recorded that England's lowland wet grassland is of lesser significance for conservation of rare vascular plants than other lowland grassland types.

This chapter considers grasslands and grazing marshes, their origins and history, the reasons for their importance, conservation value and the causes of losses. The vegetation communities and species of lowland wet grasslands and grazing marshes are discussed in the light of the landscape characteristics and features, which are considered as forming the mosaic of grassland communities of grazing marshes. Finally, a definitive definition of grazing marshes is proposed together with indicative key species, communities and landscape features that can be used to assess the status of grazing marshes.

3.1 Grassland definitions.

Grasslands have been defined as plant communities where a high proportion of the vegetation consists of a mixture of native grasses and dicotyledonous herbs largely in the absence of woody shrubs and where vegetation height is normally less than one metre, (Crofts and Jefferson 1994). English Nature regards grasslands containing 20-80% grasses within the sward as being in favourable condition (Robertson and Jefferson 2000). Lowland grasslands are generally classed as enclosed meadow or pastureland occurring at altitudes of 350m or less, (Crofts and Jefferson 1994). For the Nature Conservation Review, Ratcliffe (1977) defined lowland grasslands as 'an anthropogenic complex of plant communities characteristic of well-drained to damp soils at low levels, where recent land use has been mainly limited to grazing'. Grazing marshes occur in areas, which fall below the 5m datum (Dargie 1993), although the height at datum differs from that suggested by Thornton and Kite (1990). Grazing marshes are therefore usually included under the lowland wet grassland heading Benstead et al (1997).

Most grassland types in the UK are often referred to as being semi-natural. Tansley (1939) described this type of vegetation as 'communities of native plants, no longer moulded by "nature" alone'. Further more Tansley recognised two categories of semi-natural vegetation, one being natural vegetation modified by man's activities and the second comprising native species in communities initiated by man for his own purposes (ibid). Grazing marshes may be considered as an example of the second category, because of their origin as enclosed grasslands and subsequent improvement. Grazing marshes do however, contain some of the elements recognised in Tansley's (1939) first category i.e. remnant saltmarsh communities retained in grazing marsh habitats.

Grasslands have then further subdivided into three broad categories (Tansley 1939), based largely on the soil pH, these are calcicolous, calcifugous or mesotrophic. Calcicolous or calcareous grasslands are those found in areas primarily situated on calcium based sub-strata i.e. chalk or limestone (Tansley 1939). The soils of these grasslands tend to be shallow with a pH range between 6.5 and 8.5 (Duffey et al 1974). They are mostly used for grazing of sheep and cattle (Jefferson 1994). Tansley (1939) regarded the chalk grasslands as the 'most sharply defined and typical of the basic grasslands'.

By contrast, calcifugous grasslands have often been termed acid or acidic grasslands as they occur on acid rocks such as sandstone, granites and superficial deposits such as sand (Tansley 1939). Acid grasslands are the most widespread type of semi-natural grassland in Britain, occurring on a variety of soil types, often podsolic, with pH at or below five and at a wide range of altitudes from sea level to 1000m (Duffey et al 1974).

Mesotrophic grasslands are also often referred to as neutral grasslands (Rodwell 1992), and according to Tansley (1939) develop on soils that do not 'depart very widely from the neutral point (pH7), such as are derived from many lowland clays and loams'. Mesotrophic grasslands include a range of grasslands, which are periodically inundated (Jackson 2000). Grazing marshes are therefore included as an example of these grasslands.

Because of twentieth century agricultural improvements, unimproved semi-natural neutral grasslands are now rare, with few sites exceeding 20 hectares in size (Crofts and Jefferson 1994). Due to these improvements mesotrophic grasslands are now normally used for hay production and/or grazing, which has in turn given rise to many of the characteristics, i.e. heterogeneity of sward heights and community mosaics of this grassland type. Despite concern over the loss of more species rich examples from sward improvements, Rodwell (1992) recognises that a greater range of communities, thirteen main groupings and thirty-one sub-communities, still exist within the neutral grassland categories, see Appendix 1 for the list. Interpretation of Rodwell (1992) indicates that grazing marshes may include communities MG6 *Lolium perenne – Cynosurus cristatus* grassland, MG7 *Lolium perenne* leys, MG11 *Festuca rubra – Agrostis stolonifera – Potentilla reptans* grassland and MG13 *Agrostis stolonifera – Alopecurus geniculatus* inundation grassland.

Lowland grasslands as defined by Jefferson et al (1977) mainly comprise land managed as grazing or hay meadows that have a high water table and may be subject to and characterised by periodic inundation with fresh or brackish water. The term itself, according to Jefferson and Grice (1998), is one that has been introduced by ornithologists and tends to comprise principally of 'permanent grasslands that are periodically flooded' (ibid), with the flooding generally occurring during the winter period. Grazing marshes being subject to seasonal flooding are therefore an example of lowland wet grasslands.

Moffat (1994) summing up the survey for priorities in habitat conservation in England undertaken for English Nature defined lowland wet grasslands as a 'generic term encompassing a range of grassland and some swamp types including semi-improved and improved grassland. Habitats such as grazing marsh and washlands are included in this definition'. Jefferson and Robertson (1996) in defining lowland wet grasslands stated 'the complexity of the landscape in which lowland grasslands occur, and the use of differing definitions for habitats, indicates that an element of flexibility is desirable in the interpretation of what constitutes lowland grasslands'. What therefore, are the implications for management and monitoring from this flexible approach?

The term lowland wet grassland therefore incorporates, associated habitats, such as coastal grazing marshes, flood meadows and man-made washlands, the difference being in the geographical location, i.e. coastal. It appears implicit in the definition that all lowland wet grasslands have some form of human interference in their origins, therefore it can be contended that both grazing marsh and flood meadows are different forms of lowland wet grassland. The following section considers the inconsistencies and problems presented by the definitions of lowland wet grassland and grazing marshes.

3.1.1 Grazing marshes.

Mountford (1994a) states that 'grazing marshes have assumed a significant role in the conservation of British wetlands'. 'The traditional grazing marshes of Britain represent a stage in the conversion of 'virgin' land into farmland and as such support vegetation that is neither typical of primeval wetland or intensive cultivation,' (Moss 1907, Williams 1970, cited in Mountford 1994a). Williams et al (1983) describe grazing marshes as 'permanent pasture, intersected by a network of drainage channels, and with a high water table, which is frequently penned in summer'.

Three problems are encountered within the discussions of grazing marsh: -

- the inconsistency that occurs between the various definitions, and variation in the range of grasslands that are encompassed by the term;
- there is thus no agreement as to the area of grazing marsh that actually exists;
- grazing marshes are not included as a separate identity within the Kent Phase One study, Vegetation of the British Isles, Tansley (1939), The Handbook for Phase One Habitat Surveys (JNCC 1990), and the NVC, Rodwell (1992).

Current definitions of grazing marshes are varied, vague, inconsistent and inconclusive. With no common definition of grazing marshes, it becomes difficult to establish how grazing marshes are to be conserved and managed, and how conservation and management can be monitored. The following definitions are indicative of the inconsistencies and lack of detail that are to be found within grazing marsh descriptions.

Delaney (1991), in the Kent Phase One Habitat Survey defined grazing marsh as 'any grassland which has a demonstrable affinity to earlier salt marsh, by either the presence of an appropriate mosaic of plant communities, and or physical relics of saltmarsh i.e. rills or rillmarks'. Delaney's (1991) definition of grazing marshes presents two problems, firstly the statement 'appropriate mosaic of plant communities'. There is no definite agreement as to what constitutes an 'appropriate mosaic' and what species and communities are included in that mosaic, although ADAS (1997) and Benstead et al (1997) have provided some guidelines, which include mesotrophic grassland NVC communities MG6 *Lolium perenne – Cynosurus cristatus*, MG7 *Lolium perenne* leys, MG11 *Festuca rubra –Agrostis stolonifera – Potentilla reptans* and MG13 *Agrostis stolonifera – Alopecurus geniculatus*. Neither Tansley (1939) nor Rodwell (1992) included the term grazing marsh within their studies on the UK vegetation and grazing marsh is not distinguished as a specific NVC type. Therefore a definitive point of reference for grazing marsh communities is needed if the quality of grazing marshes is to be assessed and monitored (see Section 3.4.2). Secondly, Delaney makes no mention of the drainage ditches, which are considered a defining landscape feature of a grazing marsh, e.g. Cobham (1995).

The Kent Biodiversity Action Plan (1997) and the Essex Biodiversity Action Plan (1999) define grazing marsh as, 'periodically inundated pasture or meadow with ditches, containing standing, brackish or fresh water. It has demonstrable affinity to earlier saltmarsh, often with rills'. This definition however, does not go on to state or discuss what or how strong the affinity, apart from rills, to saltmarshes is. Similarly, Delaney (1991) only recognised rills as being a relic of the original saltmarsh. Yet, saltpans, anthills (Gee 1998), tussocky grassland (Milsom et al 2000, Vickery et al 2001), ditches

(Kent BAP 1997) and embankments (Davidson 1991, Cobham 1995) have all also been recognised as characteristics and features of grazing marshes, and should therefore be recognised in definitions of grazing marshes.

Features, such as rills, tussocky grassland, saltpans and anthills, are important in characterising grazing marshes and for creating the internal micro scale heterogeneity that can be used to assess the status of grazing marshes. Distinct vegetation communities associated with these features should therefore be present on grazing marshes and these would therefore constitute the 'appropriate mosaic' referred to by Dealney (1991).

Dargie (1993) incorporates grazing marsh within the category of lowland wet grassland, which he describes as being, 'very flat terrain containing a ditch network'. However, this definition also included inland river floodplains. In order to relate this to coastal locations a rider was added which delineated the boundaries in coastal areas (ibid). These Dargie (1993) took to be, an outer sea wall; or a line running on the lower side of contours which suggest a marked break of slope, usually the 5m contour. Although, Thornton and Kite in their 1990 study of the North Kent Marshes referred to the 25 foot contour, and AERC (1991) used the 10m contour to define the limits of grazing marsh.

Both English Nature (1994) and Benstead et al (1997) regard grazing marsh as being areas reclaimed from the sea or saltmarsh by the construction of sea walls. The reclaimed land produces a fertile soil and rich grazing pasture (Ratcliffe 1977). The maintenance of drainage ditches provides a means of controlling water levels throughout the year, a water supply for the grazing stock, and a barrier to their movement. Management of grazing marshes is then maintained through mowing and grazing by livestock, normally cattle or sheep. The term grazing marshes can therefore, be regarded as resulting from management practices and not from a distinct vegetation formation.

Dargie (1993) recognised that the problem in defining grazing marsh derives from the fact that the designation results more from land use rather than a distinct habitat type. This has led to the relevant definitions relating to the study approach, i.e. ecological, agricultural or landscape based, rather than having an overall descriptive definition.

This study of grazing marshes therefore required a definitive definition of grazing marshes to be established which acknowledged these different approaches and incorporated a description of the features and characteristics by which grazing marsh could be identified.

Another feature of grazing marshes not identified in any of the definitions, but discussed by Milsom et al (1998, 2000 and 2002) and Vickery et al (1997 and 2001) is linked to the importance of grazing marsh as breeding and feeding sites for birds. Tussocky grassland is recognised as a feature of grazing marshes that provides cover for nesting birds and sward heterogeneity and has been defined by Milsom et al (1998) 'as patches of grass at least 5cm taller than the surrounding sward'. The figure of 5cm however is lower than that suggested by the Benstead et al (1997) as a requirement for target bird species, e.g. Redshank (*Tringa totanus*), 'prefer short swards (<15cm), but require tussocky areas (c. 20cm) in which to nest', and lapwing (*Vanellus vanellus*) require 'close-cropped swards <15cm with tussocks'. Vickery et al (2001) support these requirements adding that 'the highest densities of lapwing on the Somerset Levels were in areas where the sward height was 10 – 15cm'. The implication is therefore that tussocks should exceed the 5cm figure suggested by Milsom et al (1998). For the purposes of this study therefore, the height of tussocks has been taken as being patches at least 10cm above the remaining sward.

The definition of grazing marshes should therefore include this characteristic. In addition, rills, which are relicts of saltmarsh drainage channels (Milsom et al 2002), contribute to the surface features of grazing marshes by introducing wet flushes, which again should be emphasised in any definition of a grazing marsh.

Many of the previous definitions of grazing marsh are therefore very reliant on two main factors: -

- That grazing marsh was formed by enclosure of saltmarsh during historical times, much of which is considered to have started during Roman times, and that remnants of their origin remain;
- The presence of drainage ditches and rills is an essential defining quality and not just the presence of open grassland.

Grazing marsh definitions should therefore reflect not only the above two characteristics, but also a range of characteristics and features including ditches, embankments, rills, tussocky grassland and a heterogeneous sward height. The result of this combination of features is to produce a mosaic of landscape characteristics and features which, gives rise to what can be termed as a homogeneous –heterogeneous configuration, which characterises the grazing marsh habitat. Homogeneous – heterogeneity for grazing marshes is defined as being 'a configuration where lowland wet grassland and drainage ditches comprise the homogeneous unit, and heterogeneity at the finer scale comes from the random occurrence of wet hollows, rills and tussocky grassland patches'.

A working definition of grazing marshes for this thesis is therefore: 'grazing marsh is lowland wet grassland below the 5m contour, enclosed within embankments and with physical evidence of former saltmarsh, i.e. drainage ditches, rills and anthills. There should be a dominance of grasses, which are interspersed with tussocky grassland, which with the rills, anthills etc. promotes the fine-grained heterogeneous sward which is periodically inundated by fresh or brackish water or both'.

With no clear definition as to what constitutes a grazing marsh, it then becomes difficult to calculate the area of the resource that remains. The UK Biodiversity Action Plan (1994) records 300,000ha (including coastal and floodplain grazing marsh), of which 10,000ha is semi-natural. The Kent Biodiversity Action Plan (1997), states that within Kent there is approximately 25% of the UK semi-natural grazing marsh, i.e. 2,500ha. Yet, the Kent Phase One Habitat Survey (1991) recorded 4,877.4ha of semi-natural grazing marsh. ADAS (1997) in its survey of the North Kent Marshes ESA, which covers part of the Outer North Kent Marshes, reported that there was 6,176ha of semi-natural grazing marsh. The problems encountered in calculating the area of grazing marsh, arise not only from the various definitions of grazing marsh, but also from different authorities using different heights as a starting point, e.g. Thornton and Kite (1990), the 25 ft contour, AERC (1991), the 10m contour, Dargie (1993) the 5m contour.

With no consistent estimate as to the quantity of the grazing marsh resource, it therefore becomes difficult to evaluate the losses and changes that are occurring both nationally and regionally, particularly when there appears to be no acknowledgment of these differences within the literature. Yet, despite these differences many authors have presented figures as losses of marshes, e.g. Thornton and Kite (1990), Kent BAP (1997). Without clear identification of the areas of grazing marsh that are still present, how therefore can losses be quantified and justified. The implications of these differences and how they may affect the conservation of grazing marshes is discussed in Section 9.

3.2 The origin and history of grasslands in the UK.

It is widely recognised Tansley (1939), Pennington (1974) and Rackham (1995) that the natural vegetation of the United Kingdom is woodland of some description, although altitude and latitude will have an effect, 'the prevailing climatic conditions, primarily the annual rainfall, being generally too high for the development of extensive grasslands', (Rackham 1995). The combination of climatic conditions, i.e. excess precipitation, and altitude will lead to the development of wetland ecosystems, such as found in the uplands of north west Britain. Lowland wetlands occur usually where 'flat country arrests the flow of rivers and encourages the formation of lakes' Green (1996).

According to Rackham (1995), natural grasslands would have been found at high altitudes, in dry areas such as Breckland and areas of infertile soil such as in Teesdale.

Green (1996) also thought that 'it was reasonable to assume that areas of high exposure to wind such as maritime cliff tops and uplands, together with places where infertile or toxic soils develop would provide conditions more suitable for the development of grassland and restrict the growth of trees'. In his History of the Countryside, Rackham (1995) refers to the pollen records, which appear to confirm that grasslands were rare before the arrival of humans.

At the end of the last glacial period, some 12,000 years before present (YBP), semi-arctic grasslands would have covered much of the country (Rackham 1995). The dominant grasses of the time appear to be mainly fescues (*Festuca spp.*) and meadow grasses (*Poa spp.*) species accompanied by a few herbs, notably mountain avens (*Dryas octopetala*) Green (1990).

Evidence from pollen analysis indicated that as trees and woodland returned, between the years 12,000 to 6,000 YBP grasslands became a rarity (Rackham 1995). With the appearance of Neolithic man, six thousand years ago, the pollen record shows a sudden reappearance of grasses and grassland herbs. Godwin (1944) was the first person to attribute the forest clearances to human intervention. Although Tansley (1939) suggests that the conversion of forest to grassland could not have taken place without the co-operation of the British climate, which is 'pre-eminently favourable to its development'.

Godwin (1944) as cited in Pennington (1974), noted the decline in tree species around Hockham Mere in Norfolk, coinciding with a rise in grasses and plantains, i.e. 'r' strategy species indicative of disturbance as defined by Grime et al (1988). The pattern of clearance was typical of a type that would arise through the practice of shifting cultivation. In many instances through the management of grazing herbivores, man created many new plant communities unlike any of their precursors, (Duffy et al 1974).

Palynological evidence indicates that the progress of deforestation was initially concentrated in chalkland areas (Godwin 1944). Turner (1965) further suggested that the low frequency of herb and grass species meant that most of the clearings were temporary in nature and that regeneration of woodland took place. From the Iron Age onwards however, (about 400 BC), the development of more efficient and easily produced tools allowed the clearance of woodland to become more widespread (Green 1990). Analysis of bones from Kent downland settlements of the Iron Age highlights an abundance of sheep remains, which again indicates that open grasslands were well established at this time (ibid).

There is much documentation of grassland creation by woodland clearance but less on creation through enclosure and drainage. The Romans are credited with the first drainage of wetlands, when they began to drain the Fens and Romney Marsh (Green 1996), and although there is evidence that the North Kent Marshes were beginning to be enclosed at this time, there is record as to when drainage began. By Norman times therefore, the once wild British landscape of forest and wetlands had been almost entirely converted to grasslands and agriculture. There is much documentation of grassland creation by woodland clearance, but less on the creation of grasslands by coastal enclosure and drainage.

As populations grew during the middle ages, the need for more land to be given over to agriculture became paramount; the net result was a continual loss of woodland and wetland and an increasing area of arable and pastureland. Wetland drainage became increasingly extensive from the seventeenth century onwards, as exploitation of their fertile soils was an easy way to increase productivity of the land (Green 1996).

The total area and use of grassland has also been affected by the prevailing industrial trends of the day, e.g. during the height of the woollen trade during the late fifteenth and early sixteenth centuries, more land would have been given over to the grazing of sheep (Duffey et al 1974). Government intervention through time has also had a significant influence on the areas of grassland predominating at any given time. For example the introduction of the Enclosure Acts during the fifteenth and sixteenth centuries, the Corn Laws, and their subsequent repeal in 1846, materially affected whether the area of grassland was grazed or converted to arable use. An early land use survey of 1696 showed uncultivated grazing to cover a quarter of the area of England and Wales; by 1901, this extent had almost halved, (Green 1990).

From the middle of the eighteenth century onwards, the marked increase in industrial growth and towns again affected how land was used. Many types of grassland would have been converted to arable production to feed the increasing population, so reducing the overall grassland areas. Grazing meanwhile reverted to the more marginal lands (Green 1996).

With the opening up of the American continent during the nineteenth century and the resultant availability of cheap grain, there was a significant fall in domestic wheat prices. To many UK farmers the production of cereal crops became uneconomical and this generally led to an increase in grasslands, which was further enhanced by the decrease in the size of the labour force (Duffey et al 1974).

The coming of the railways provided a further boost to the area of land under grass. This improvement in the ability to distribute their produce and in particular dairy products once again led to an expansion of dairying wherever conditions were suitable for grass growth (Duffey et al 1974). The establishment of the Milk Marketing Board in 1933, and the introduction of standard charges for collection, irrespective of location, again provided a boost to the grasslands set aside for dairying.

According to Sheail (1973), the government did not directly interfere in the balance of arable and grassland until 1917. The Food Controller and the Board of Agriculture of the time calculated that arable crops sustained four times as many people as animal products from the same area of land. As a result, the Board of Agriculture allocated quotas of grassland for each county that had to be ploughed up for arable production, but generally these targets were not met and much of the arable land that had reverted to grassland remained (Duffy et al 1974). There is however, no literature, which highlights the situation in North Kent.

During the 1930's the government, used subsidies usually by guaranteeing prices, to influence the proportions of land given over to arable production and grazing (Duffy et al 1974). The outbreak of the Second World War and the subsequent submarine blockade caused the Government to invoke unprecedented support to agricultural reclamation schemes (Murray 1955 cited in Duffy et al 1974). The need to produce more food led not only to the attempted reclamation of arable land that had reverted to grass during the depression, but also some older established grassland, (Duffy et al 1974). The North Kent Marshes however, remained as grazing lands, although as through much of Kent there appears to have been changes, with a decrease in sheep grazing and an increase in cattle grazing (Garrad 1954). The post World War II period saw a growth in the rate of reclamation of wetlands through improved methods of drainage and in the use of fertilisers. The growing use and efficiency of tractors was another factor in aiding the change to arable production and along with drainage and artificial aids was responsible for the dramatic change of the British countryside after the war. Garrad (1954) recorded that much of the North Kent Marshes are 'wet and entirely under grass, which varies in quality, with better attention to drainage these marshes could be improved'.

After the war, the Agriculture Acts of 1947 and 1957 again provided the impetus for the further conversion of grasslands into arable production (Duffy et al 1974). The increased use of mechanisation, chemical pesticides, herbicides and fertilisers and the introduction of government subsidies all had the effect of encouraging the farmer to plough up extensive areas of permanent grassland for cereal production. It was during this period that much of the once extensive grazing marshes of the Thames estuary came under threat and heralded the significant decline in the overall area. For example the western marshes of Erith – Swanscombe 'were close to London and most of them have now been purchased by industrial concerns' (Garrad 1954).

Since 1970, the Common Agricultural Policy of the European Union has dominated UK agricultural policy (Potter 1991). During this, period farmers responded to the introduction of grants and subsidies in a positive manner increasing arable land, and increasing the number of livestock (DETR 1998). The net result of these grants and subsidies was to increase the areas of arable production usually at the expense of grasslands and to increase the livestock numbers grazing on these reduced grassland areas, thereby introducing an element of degradation through overgrazing and increased inputs of fertilisers. From an environmental viewpoint, it is doubtful that these actions could be described as positive.

The subsequent over production that arose from the introduction of subsidies under the Common Agricultural Policy (CAP), has been generally perceived to have had a negative effect on the environment. In 1989, optional set-aside was introduced whereby farmers could reduce the areas of land under arable production in return for compensatory payments. Under the MacSharry reforms of 1993, set-aside became mandatory (Green 1996). One of the aims of set-aside was to make land available for amenity or wildlife through restoration schemes, e.g. The Habitat Scheme. Areas of Dartford Marsh and Botany Marsh are under set-aside schemes and the results of the surveys in this study do not suggest that set-aside was a particularly successful scheme.

The introduction of Agri-Environment Regulation (EC Regulation 2078/92) was a far more positive move towards conservation in agriculture. The Environmentally Sensitive Areas (ESA), set up under the regulation compensates farmers for farming in a more traditional nature and to a set of proscriptions aimed at less intensive production, pollution control and habitat reconstruction (Green 1996). Part of the study area is incorporated within the North Kent Marshes ESA, which was designated in 1993, (See Fig 3.1 for boundary of ESA). Grazing within the North Kent Marshes ESA is by both cattle and sheep, although over the last five years numbers of cattle has reduced due to the problems with BSE (Elliott *pers com*). One of the aims of this thesis is to compare the quality of grazing marsh within the ESA with the grazing marshes that have not been incorporated in the scheme.

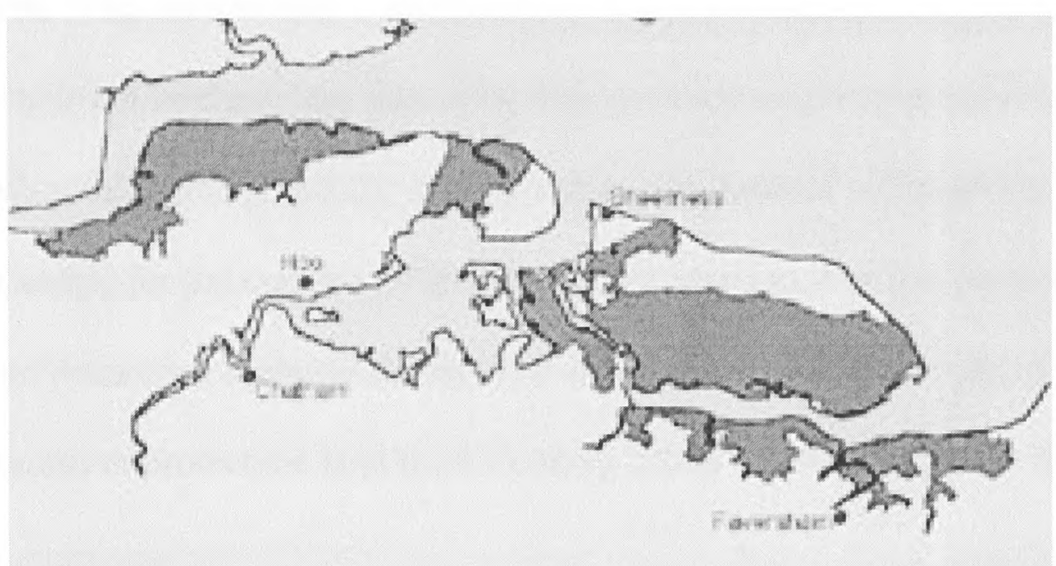

Fig 3.1 Extent of the North Kent Marshes ESA not to scale, (from ADAS 1997)

Grasslands in the UK are therefore mainly regarded as being of human creation through deforestation and maintained by grazing, mowing or by reclamation, as is the case with grazing marshes (see Section 3.2.1). Grassland maintenance however, owes much to the management techniques employed, and they are therefore referred to as a plagioclimax or deflected climax vegetation type, which is regarded as the end point of an organic succession under the influence of factors other than climate (Tivy 1993). Thus when sheep and cattle graze they eat off and trample down seedlings and ground vegetation, thus preventing the regeneration of the original habitat type (Small et al 1999), e.g. existing tree vegetation gradually dies and is replaced by invading plants, which then form a continuous turf maintained by grazing, as is the case with grazing marshes.

Management is therefore, a determining factor that can be used to maintain a balance between fragmentation and its effects on the ecology of the North Kent Marshes. In this study the value of management in maintaining the remnant fragments will be assessed and monitored.

3.2.1 Grazing Marsh Creation.

Grazing marshes are anthropogenic in origin and arise from the 'inning' and reclamation of saltmarsh. The process may occur naturally when a barrier encloses a marsh and over time, the enclosed land may dry out, or by the construction of embankments to enclose ('in') existing saltmarsh (Fig 3.2). The most common form of reclamation, which has been responsible for the creation of the North Kent Marshes, has two elements, firstly digging and deepening drainage ditches to lower the water table, and secondly raising banks or bunds to protect the land from flooding saline water (Prichard 1976).

Fig 3.2 Embankment and 'inning' on the North Kent Marshes.

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The process of grazing marsh creation has been ongoing since Roman times (Pritchard 1976, MacDougall 1980). Since Roman times reclamation of the marshes by enclosure has continued at infrequent intervals, but often in periods following severe flooding episodes e.g. during the 1920's (Thomas 2001). The last major reconstruction period occurred in the post World War II period with up to 35% of grazing marsh being converted to arable (Williams et al 1983) and the extension of embankments after the 1953 flood. (Section 4.2 looks at the creation of the North Kent Marshes in more detail). Creation of grazing marsh from saltmarsh may therefore be regarded as an early form of fragmentation of the saltmarsh habitat. The study of fragmentation of grazing marshes is therefore considering the fragmentation of a habitat that itself is the product of anthropogenic fragmentation of saltmarshes.

Davidson et al (1991) however, in the Nature Conservancy Council's (now English Nature), review of Nature Conservation and estuaries defined grazing marsh as 'areas of flat low lying grassland drained by complex networks of freshwater or brackish drainage ditches'. They commented that most grazing marsh in its current form originated in the post war period with the introduction of pumped drainage and is therefore less than two hundred years old. The dates recorded by Davidson et al (1991), in respect of periods when grazing marsh was formed are in disagreement with many other authorities e.g. Prichard (1976), Macdougall (1980). This maybe in part because Moss (1907) was referring to the Somerset Levels in his paper and would not therefore be regarded as a coastal grazing marsh. It would appear however, that from the historical records that grazing has been carried out within coastal areas from a much earlier period than that suggested by Davidson, e.g. MacDougall (1980) who recorded that most of the North Kent Marshes had been reclaimed by this date, see Section 4.2.

The formation of grazing marshes generally creates three distinct habitat types. The grazed areas of lowland wet neutral grasslands which have different communities resulting from the mosaic of features, the drier embankments and in the drainage ditches. There has however, been a number of studies surveying and categorising the ditches, e.g. Charman (1981), English Nature (1995). The remaining characteristics and features of grazing marshes i.e. vegetation communities, rills etc, (see Section 3.1.1), are less well covered in the literature. For the purposes of this thesis therefore, it was decided to concentrate on the matrix of the grazing marsh, i.e. the grassland areas, in order to establish the 'appropriate mosaic' of vegetation communities by which grazing marshes can be defined and monitored.

3.3 Wet grassland distribution and loss.

Wet grasslands are to be found throughout the United Kingdom, and are characterised by periodic but not perpetual flooding with either fresh or brackish water, a high water table and regular management (Joyce and Wade 1998). The priority areas of importance are however, to be found in the lowlands where land is periodically flooded or waterlogged (Jefferson and Grice 1998), which have seen the greatest loss of habitat in the post war period (Benstead et al 1997). In the past waterlogging in coastal areas would have occurred with both fresh and saline water, but today is mainly confined to fresh water, due to the construction of sea defences and the loss of saline influence. Wet grasslands provide an important habitat for plants, birds both native and migrant, and invertebrates (Ratcliffe 1977, Fuller 1982). Fig 3.3 shows the location of major Lowland Wet grasslands in the UK identified by JNCC.

Fig 3.3 Lowland Wet Grasslands in the UK not to scale (after JNCC).

Wet grasslands may comprise of a number of distinct grassland types including semi-natural floodplain grassland, washlands (i.e. embanked areas for the purpose of flood storage), water meadows, lakeside wet grasslands and managed grasslands on drained soils (Tansley 1939). In the United Kingdom such grasslands that occur within coastal zone are often termed grazing marsh as their origin defines (i.e. reclamation of saltmarsh Section 3.2.1), although grazing marshes as such are not restricted to coastal areas, e.g. the Somerset levels are an example of an inland grazing marsh.

3.3.1 The loss of grasslands.

Neutral grasslands are amongst the most threatened habitat types in the UK. Fuller (1987) reviewing the 1984 Nature Conservancy Council report on Nature Conservation in Great Britain quoted that 'the loss of neutral grasslands (i.e. semi-natural grasslands on fertile clays and loams in the lowlands), represented the biggest of all Britain's habitat losses in the preceding forty five years'. By the mid 1980's, an estimated 95% of all lowland neutral grasslands lacked significant wildlife interest and that only 3% had been left undamaged by agricultural intensification, (Nature Conservancy Council 1984). This compares very unfavourably with figures for other habitat types e.g. 30-40% for ancient woodland, 40% lowland heaths, 50% lowland fens, and 60% lowland raised mires, although limestone grasslands have also suffered a similar decline with a loss of some 80%, (Nature Conservancy Council 1984). There is little literature updating these figures although Jefferson (2001) reported that the area of semi-natural acid and calcareous grasslands fell by 10% and 19% respectively between 1990 and 1998. Furthermore, 58% of semi-natural grasslands were in favourable or unfavourable recovering status (ibid).

Historically wet grasslands were considered to cover an area of 1,200,000 ha in England and Wales (Benstead et al 1997). Today this has been reduced to a figure of 220,000 ha, most of the loss being in the post World War II period due to agricultural improvement and land drainage (ibid). Of the remaining wet grassland, Thomas et al (1995) estimate that only 20,000ha remains agriculturally unimproved and of high conservation value. Blackstock et al (1999) however estimate that only between 9,000 – 17,500ha of wet grassland and between 7,500 – 15,000ha of unimproved neutral pasture and hay meadow remain. This survey does not however include figures for NVC communities MG6

Lolium perenne – Cynosurus cristatus, MG7 *Lolium perenne* leys, and MG11 *Festuca rubra – Agrostis stolonifera – Potentilla reptans* grassland, (see Section 3.1.1), communities that are considered to constitute the matrix of coastal grazing marshes, i.e. lowland wet grasslands (ADAS 1997, Benstead et al 1997). From the results of such surveys therefore it is difficult to ascertain not only how much of the wet grassland resource, (including coastal grazing marsh), originally existed, but also how much still survives, as discussed in Section 3.1.1.

The primary reason for the loss of grasslands, and in particular wet grasslands, was identified by Green (1990) as intensification of agriculture. Jefferson and Robertson (1996) however, regard lack of appropriate management, i.e. a lack of grazing or mowing management or incorrect intensity of such management. Intensification of agriculture was often facilitated by the improvement in sea defences and land drainage in order to increase grass production, an increased exploitation of grassland areas or conversion of permanent grasslands to arable crops (Fuller 1987). These effects were achieved through increased use of fertilisers, increased cutting frequency and increased stocking densities. In turn, this has led to problems such as, increased trampling causing soil compaction and subsequent deterioration and eutrophication of waterways from fertiliser use. The reduction in the number of plant species is generally attributed to competitive exclusion of slower growing species, resulting from increased fertility (Green 1990). Slow growing species are less responsive to the additional nutrients and are out competed by ones that are more competitive (ibid). The loss of botanical diversity is often reflected in a decline in invertebrate numbers, as their particular food plants are lost.

O' Connor and Shrubb (1986) reviewed effects of the intensification of grassland management on bird populations. Changes in management practice involved earlier and more frequent cutting greatly affects ground - nesting birds, such as the corncrake (*Crex crex*), and the decline in its numbers has been attributed mainly to this factor. Other ground nesting birds vulnerable to increased stocking rates. Lapwings (*Vanellus vanellus*), Snipe (*Gallingago gallingago*) and Redshank (*Tringa totanus*) may lose 40%, 60%, and 72% respectively to trampling at a stocking density of one cow per acre, (O'Connor and Shrubb 1986). At two cows per acre, these percentages rise to 60%, 80% and 93% respectively. Additionally even swards created by more intensive grazing produce less suitable nesting areas, particularly snipe (*Gallinago gallinago*) that prefer tussocky grasslands for concealment. Table 3.1 summarises the effects of agricultural intensification on lowland grasslands.

Table 3.1 Summary of Agricultural Impacts on Lowland Grasslands

Management	Impact on biota
Fertiliser use	Reduction in plant species richness
Change from hay to silage	Reduced breeding success for birds, especially waders. Reduction in seed return and consequent long Impact on recruitment in semi-natural swards
Cessation of grazing, cutting or undergrazing	Vegetation decline, often reduction in species number, and nature conservation value decline Change in vegetation structure reduces habitat suitability for breeding waders.
Overgrazing	Nest trampling leading to reduced breeding success. Reduced species richness in unimproved wet meadow communities.

Adapted from Jefferson & Grice (1977)

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These effects reflect the impacts on the biotic features of lowland grasslands and lead to changes in the structure and biodiversity of lowland grassland habitats. The facts reviewed in this section have been primarily responsible for habitat loss rather than habitat fragmentation per se of lowland wet grasslands. Agricultural improvement of lowland wet grasslands to increase productivity could be interpreted as creating grazing marsh grasslands. Losses of grazing marsh then result from conversion to arable production or through changes in land use. The following section considers grazing marshes and the reasons for their loss.

3.3.2 Grazing Marsh Distribution and Loss.

Grazing marshes can be found throughout the United Kingdom, for example Morecambe Bay and Romney Marshes, with the largest concentration in the south-east of England, and the North Kent Marshes the largest remaining areas (see Fig 1.5). The coastal grazing marshes of North Kent are regarded as being distinct from those of other parts of the country because of 'the extensive brackish influence exhibited', (Gladding 1990). This influence being, 'due partly to residual brackish conditions derived from former saltmarsh, but also to the small size of their catchments and low rainfall which means that salt is only flushed slowly from marshland by fresh water from surrounding higher ground' (ibid).

Losses of grazing marshes have been ongoing since their creation. Severe flooding for example would often breach the early embankments, although these losses would be only temporary. Historically losses of grazing marshes have often corresponded to the state of British agriculture, i.e. conversion to arable production would occur in times when greater food production was required, e.g. during the Napoleonic wars, with a return to grazing marsh during agricultural depressions (Williams and Hall 1987). Losses prior to World War II are discussed further in Sections 4 and 6.

The post war period has seen grazing marshes come under increased pressures from improved drainage and conversion to arable or intensive grassland management, (Williams and Hall 1987, Mountford and Sheail 1982, 1989). Losses of grazing marsh throughout the UK have been significant during the last sixty years and include 64% in the Greater Thames, 48% in Romney Marsh and 37% in Broadland (JNCC 2001). The above figures show therefore that the North Kent Marshes, as part of the Greater Thames, have suffered the greatest losses in terms of percentage reduction in area, yet they remain as the largest fragments of grazing marsh in the UK (English Nature 1994). The reasons for these losses have been attributed to agricultural intensification, eutrophication, neglect and ecologically insensitive flood defence works (JNCC 2001). Green (1971) identified agricultural intensification as the main threat to the North Kent Grazing Marshes, which conflicts with Jefferson and Robertson (1996), who attributed losses to lack of management. Thornton and Kite (1990) however attributed losses to unsuitable and in some instances a lack of management, as well as identifying areas of grazing marsh in North Kent that have been lost to industrial development, overgrazing, eutrophication and other pollution episodes. Green (1990) however attributed 48% of the losses to North Kent Grazing Marshes to arable conversion. Table 3.2 highlights the loss and fragmentation of grazing marsh across parts of the North Kent Marshes between 1935 and 1989.

Table 3.2 Land uses to which grazing marsh has been converted 1935 – 1989

	Area converted (ha)	% of total converted	% of grazing marsh converted
Urban	524	19	10
Formal open space	62	2	1
Arable	1785	65	33
Improved grassland	5	<1	<1
Open water	351	13	7
Woodland	39	1	<1
Total converted	2766	100	52

(Adapted from Thornton and Kite 1990)

3.4 Grassland communities.

Grassland communities developed under the influence of grazing pressures as the forests were cleared or land was reclaimed, i.e. wetland drainage. Establishment of grasslands occurred as species were recruited from forest glades and a variety of refugia such as coastal, wetland and upland areas, which had remained clear of trees during the postglacial forest climax (Green 1990).

The structure and floristic composition of the grassland communities varies depending on the substrate and the prevailing ecological conditions, such as intensity of grazing. Tansley (1939) commented that 'the enormous variety of the habitats and composition of the British natural and semi-natural grasslands made it impossible to classify all the various communities of grasslands, taking into account every local variation'. Subsequent studies e.g. Poore and McVean (1957), Gimingham (1972), Duffey et al (1974), Ratcliffe (1977) and Rodwell (1992) refined and further sub-divided these broad categories. The National Vegetation Classification (NVC) sub-divided Tansley's three broad categories into thirteen mesotrophic (MG), fourteen calcicole (CG) and twenty-one calcifuge (U) communities, each with a range of sub-communities. Within this classification, lowland wet grasslands have been included within the mesotrophic grassland communities MG6, MG7, MG9, MG11 and MG13. A further range of grassland communities have been included by Rodwell (2000) within the open vegetation communities (OV), which include amenity grasslands, six assemblages charcterised by *Poa annua* in gateways and trackside and communities of spoil and waste ground.

Rodwell (1992) wishing to provide a classification familiar in other parts of Europe recognised a greater number of neutral or mesotrophic grassland communities, particularly with regard to Tansley (1939). Eighteen different groupings were identified by Rodwell (1992) under five headings, which included: -

- two types of *Arrhenatherum elatius* grasslands (MG1 and 2);
- four types of generally well drained pastures and meadows (MG3, 4, 5 and 6);
- six long-term leys and related swards (MG7a-f);
- three kinds of ill-drained pasture with a poor fen element (MG8, 9, 10 and 11);
- three grass dominated inundation communities (MG 12 and 13);

Mesotrophic grassland communities have been described by ADAS (1997) and Benstead et al (1997) as being the components of grazing marshes. The community descriptions and definitions given by Rodwell (1992) then provide a basis by which the matrix communities that constitute grazing marshes (see Section 3.1.1) can be established.

Rodwell (1992) in the National Vegetation Classification (NVC) introduces two categories of wet grasslands under the general heading of mesotrophic grasslands, which are referred to as ill drained permanent pastures and inundation grasslands, but grazing marsh is not used as a specific term to describe the overall habitat type. The main feature of poorly drained pastures is the 'preponderance of moisture tolerant or moisture loving plants', (Rodwell 1992). The poorly drained pastures include three main communities, MG8 *Cynosurus cristatus – Caltha palustris* grassland, MG9 *Holcus lanatus – Deschampsia cespitosa* grassland and MG10 *Holcus lanatus – Juncus effusus* rush pasture. Amongst the more commonly associated species are rough meadow grass (*Poa trivialis*), creeping bent (*Agrostis stolonifera*), creeping buttercup (*Ranunculus repens*), silverweed *Potentilla anserina*) and curled dock (*Rumex crispus*), the latter providing a link with the vegetation of periodically flooded ground, Rodwell (1992).

Three communities have been recognised by Rodwell (1992) as representative of inundation grasslands. Two of these MG11 *Festuca rubra – Agrostis stolonifera – Potentilla anserina* grassland and MG12 *Festuca arundinacea* grassland both show a common occurrence of salt-tolerant plants such as saltmarsh rush (*Juncus geradii*), sea milkwort (*Glaux maritima*), and sea sandwort (*Honkenya peploides*). They are therefore regarded by Rodwell (1992) as extending the mesotrophic grasslands to reclaimed saltmarshes where there is periodic inundation with brackish or salt waters, and have been regarded as an equivalent of grazing marsh (Benstead et al 1997).

The third community MG13 discussed by Rodwell (1992) is the *Agrostis stolonifera – Alopecurus geniculatus* grassland, which is associated with fresh water margins. Yorkshire Fog (*Holcus lanatus*), rough meadow grass (*Poa trivialis*), creeping buttercup (*Ranunculus repens*), floating grass (*Glyceria spp*), curled dock (*Rumex crispus*) and clustered dock (*R. conglomeratus*) are commonly associated with this community.

In general, the above mesotrophic communities are characterised by the frequency of cocksfoot (*Dactylis glomerata*), meadow fescue (*Festuca pratensis*), red fescue (*F. rubra*), Yorkshire fog (*Holcus lanatus*), smooth meadow-grass (*Poa pratensis*), rough meadow-grass (*P. trivialis*), common mouse-ear (*Cerastium fontanum*), ribwort plantain (*Plantago lanceolata*), meadow buttercup (*Ranunculus acris*), and white clover (*Trifolium repens*).

Hydrology and the pH are the major influences on the botanical interest of lowland wet grasslands (Jefferson and Grice 1998). Tolerance of individual species is influenced by the degree of inundation i.e. the length of time that an area is covered by water (Tansley 1939). Characteristic species of such grasslands can be divided into groups reflecting their ability to withstand greater periods under water; although Rackham (1986) records that many of our native species do tolerate a degree of waterlogging.

An association of *Glyceria spp*. mainly *G. fluitans* and marsh foxtail (*Alopecurus geniculatus*) usually dominates wetland meadows. Where the water table causes a more marshy grassland situation hard rush (*Juncus effusus*) and soft rush (*J. inflexus*) become typical. Alternatively, with a lower water table reed canary-grass (*Phalaris* *arundinacea*) becomes the more dominant species. Associated meadow grass species will again vary with the degree of soil moisture, *Poa trivialis* on damp soil and *P. Pratensis* on drier soils.

Where the soils become totally inundated, common reed (*Phragmites, Typha*) and sedges (*Carex spp.*) become more dominant. Celery-leaved buttercup (*Ranunculus sceleratus*) is often associated with clustered dock (*Rumex conglomeratus*), broad-leaved dock (*R. obtusifolius*) and common water-plantain (*Alisma plantago-aquatica*). Studies now show that species tend to have a characteristic and limited range of tolerance to water tables. Community composition may therefore, be determined by such seasonal effects as the timing and duration of flooding (Mountford & Chapman 1993).

Comparisons can be made in respect of the species which Tansley (1939) and Stapledon (1925), cited in Tansley (1939), regarded as being consistent with neutral grasslands and old meadows and pastures. Both authorities stated that perennial rye grass (*Lolium perenne*), creeping bent (*Agrostis stolonifera*), common cat's ear (*Hypochaeris radicata*), autumn hawkbit (*Leontodon autumnalis*), ribwort plantain (*Plantago lanceolota*), creeping buttercup (*Ranunculus repens*) and meadow buttercup (*R. acris*) form a large part of the flora. Tansley (1939) regarded neutral grasslands to be dominated by a range of grasses comprising perennial rye grass (*Lolium perenne*), cocksfoot (D*actylis glomerata*), timothy (*Phleum ptatense*), common bent (*A. tenuis*) and crested dogstail (*Cynosurus cristatus*). The presence and dominance of these species within the matrix of the North Kent Marshes would therefore indicate that neutral grasslands are the main component of the grazing marsh mosaic.

Grime (1988) recorded that many of the species associated with lowland wet grasslands were in decline, or their future status was uncertain. This applied particularly to floating sweet grass (*Glyceria fluitans*) and redshank (*Polygonum persicaria*). The apparent decline of *Phragmites australis* is attributed to lowering water tables, wetland destruction and competition, whereas, reedmace (*Typha latifolia*) was one of the few species regarded as being on the increase (Grime et al 1988).

3.4.1 Grazing Marsh Communities.

The lack of a definitive definition and recognition of grazing marshes as a distinct habitat type makes it difficult to review and determine the typical grazing marsh community composition. As ADAS (1997) pointed out the grassland type found in the North Kent Marshes 'appears to have been overlooked in much of the phytosociological literature'. Jefferson (undated) however, recognised that coastal and floodplain grazing marshes 'embrace a wide range of NVC types, including grasslands, mires, swamps and aquatic communities'.

The North Kent Marshes Monitoring Report (ADAS 1997) indicated that grazing marsh community matches with NVC communities were poor, but that MG6 (*Lolium perenne – Cynosurus cristatus* grassland), MG7 (*Lolium perenne* leys) and MG11 (*Festuca rubra – Agrostis stolonifera – Potentilla anserina* grassland) were amongst the best fit. The presence of divided sedge (*Carex divisa*), meadow barley (*Hordeum murinium*) and common couch (*Elymus repens*) are regarded as reasons for the poor fits (ibid). The three communities referred to by ADAS (1997) may therefore be regarded as being indicative of the communities found across the North Kent Marshes, and will be compared to the results of the surveys for this thesis.

Coastal grazing marshes are usually dominated by the more common grasses of neutral soils (Davidson 1991), for example perennial rye grass (*Lolium perenne*), crested dog's-tail (*Cynosurus cristatus*), and meadow barley (*Hordeum secalinum*), but can be low in floral diversity (Kent BAP 1997). ADAS (1997), in the North Kent Marshes Monitoring report, refer to semi-natural grazing marsh as being grasslands very low in species diversity, containing a few broad-leaved herbs. Where agricultural improvement has been less widespread, a number of vascular plant species that are rare and scarce both nationally and internationally can occur (Davidson 1991, Gee 1998, Jefferson and Grice 1998). For example divided sedge (*Carex divisa*), sea clover (*Trifolium squamosum*), sea barley (*Hordeum marinum*) and slender hare's-ear (*Bupleureum tenuissimum*) are nationally rare and may all be found within these habitats (Gee 1998), and are characteristic of many sites on the North Kent Marshes. Most of the rare plants associated with grazing marshes are of continental origin and therefore have this marked southeast distribution in the UK (Davidson et al 1991).

Grazing marshes retain however, an appropriate mosaic of physical relics of saltmarsh, together with an undulating surface of anthills, rills, relict saltmarsh creeks and shallow pools, that are related to the characteristics and features (see Section 3.1.1) which create the range of habitats that are important in maintaining diversity by providing habitats for a number of plant species. Grass vetchling (*Lathyrus nissolia*) and bird's foot-trefoil (*Lotus corniculatus*) can be found on the drier mounds created by anthills (Gee 1998).

The wetter rills can support annual beard grass (*Polypogon monospeliensis*) and pink goosefoot (*Chenopodium botryoides*) both scarce annuals (MAFF 1997). Whilst on the embankments and counter walls hog's fennel (*Peucedanum officinale*) and slender bird's foot-trefoil (*Lotus angustissimus*) are often frequent and may be particularly characteristic of such sites (ADAS 1997).

Fragmentation of grazing marshes may well result in changes to the vegetation communities and the species content of these communities. In this study, changes to the species content and the constancy at which they occur within the communities will be used as an indicator to the effects and extent of fragmentation.

3.5 Conservation Importance of Lowland Wet Grasslands and Grazing Marsh.

The mosaic of habitats, which comprise lowland wet grasslands, are regarded as a high priority habitat type for bird species, (Jefferson and Robertson 1996). Over forty bird species of conservation concern in the UK are at least partly dependent on lowland wet grasslands (Benstead et al, 1997, Joyce and Wade 1998). Table 3.3 lists the birds of conservation concern that use wet grasslands.

Ten of these species are red list, of high conservation concern, whilst the remainder are amber listed, medium conservation concern (Benstead et al 1997). Amber listed species such as, redshank (*Tringa totanus*), lapwing (*Vanellus vanellus*), snipe (*Gallinago gallinago*), oystercatcher (*Haematopus ostralegus*) and kestrel (*Falco tinnunculus*) and red list species such as skylark (*Alauda arvensis*) are all found across the North Kent

Grazing Marshes. The presence of large numbers of waders has been responsible for the designation of the North Kent Marshes as an SSSI, SPA and a Ramsar site.

Table 3.3 Birds of conservation concern that use wet grassland, (Species in bold are those of importance in the North Kent Marshes).

Season	Red List – high conservation concern	Amber list – medium conservation concern
Winter	Hen harrier, merlin, twite	Bewick's swan, whooper swan, bean goose, pink-footed goose, white-fronted goose, barnacle goose, brent goose, wigeon, shoveler, gadwall, pintail, peregrine, golden plover, common gull, short-eared owl, fieldfare, redwing
Summer	Quail, corncrake, black-tailed godwit	Garganey, pintail, spotted crake, ruff, oystercatcher, whimbrel, curlew, **redshank**
All year	Grey partridge, skylark, tree sparrow, linnet	Teal, shoveler, pochard, kestrel, **lapwing,** ruff, **snipe**, barn owl, kingfisher, goldfinch

Adapted from Benstead et al (1997)

Lowland wet grasslands are also of importance to a great variety of invertebrates, particularly aquatic species (Drake 1998). The high diversity of invertebrates is often associated with the habitat heterogeneity of, damp hollows; temporary pools drainage channels and the variation in vegetation around the margins of these features, (Joyce & Wade 1997). The marsh fritilliary butterfly (*Eurodryas aurinia*) is a globally threatened species associated with wet grasslands, whereas, grazing and brackish marshes are important for coleoptera. Many of the North Kent Marshes SSSI designations result in part from the rare invertebrate assemblages (EN *pers com*), e.g. up to three Red Data Book species, thirty-seven nationally notable and twenty-one regionally notable invertebrate species have been recorded on the Inner Thames Marshes of Erith, Crayford and Dartford (Plant 1991, 1992 and 1993).

The configuration of lowland wet grassland, embankments and drainage ditches are of importance for mammals, e.g. water vole (*Arvicola terrestris*), and particularly on the North Kent Marshes (Wells *pers com.*). Fragmentation of grazing marshes and the resulting changes to the habitat configuration identified in this study will therefore have implications for the survival of water voles.

The botanical importance of grazing marshes is of lower conservation interest when compared to that of birds and invertebrates, although the aquatic vegetation present in many of the ditch systems is a notable exception. There is however, a suite of plant species that are both nationally and locally rare present within the grazing marsh sward. Divided sedge (*Carex divisa*), sea barley (*Hordeum marinum*), sea clover (*Trifolium squamosum*), slender hare's-ear (*Bupleureum tenuissimum*) and annual beard-grass (*Polypogon monspeliensis*) are all nationally rare species that can be found across the North Kent Marshes (Davidson 1991, ADAS 1997, Jefferson and Grice 1998). Other species such as small red goosefoot (*Chenopodium botryodes*), and stinking goosefoot (*C. vulvaria*) are nationally rare Red Data Book species, which are found on grazing marsh sites (Kent BAP 1997), associated with rills and embankments, whilst least lettuce (*Lactuca saligna*) is another nationally rare species is associated with the Inner Thames Marshes, being found primarily on the river embankments. The main vegetation interest is with the aquatic flora of the drainage ditches, where nationally scarce species such as water-soldier (*Stratiotes aloides*), fen pondweed (*Potamogeton coloratus*), spiked water-milfoil (*Myriophyllum spicatum*) and whorled water-milfoil (*M. verticillatum*) can be found (Benstead et al 1997, Kent BAP 1997).

Wet grasslands and grazing marshes also provide a number of important environmental functions (Joyce and Wade 1998). In the past coastal areas, have provided protection against flooding and help to reduce the impact of erosional forces and improve groundwater recharge (Dister et al 1990 cited in Joyce and Wade 1998). Inland wet grasslands are important floodwater retention areas. They are also seen as areas that can improve water quality through the filtration and retention of suspended materials (Brinson et al 1984 cited in Joyce and Wade 1998). Within the coastal zone, grasslands are seen as making an important contribution to the landscape character of estuaries. There is however, a conflict of interest when discussing the importance of coastal grasslands. Despite the acknowledgement that they provide protection to the agricultural and urban hinterlands, the rich fertile soils also provide a basis for grazing and intensive food production.

Maintenance of drainage ditches to protect rare and scarce species may however, conflict with the need to use the ditches for flood control. In the latter instance, the ditches would need to be regularly cleared of vegetation and so not only would the aquatic vegetation become compromised but there would also be effects to the invertebrate populations, which rely on the ditch vegetation.

3.6 Conclusion.

Lowland wet grasslands and grazing marshes in particular have never been fully or adequately described in the literature, although English Nature has designated grazing marshes as one of thirty-eight key habitat types (Jefferson 2002), thus highlighting the conservation importance of the habitat. The various definitions (Section 3.1.1) give no clear indication as to what features and communities should constitute a typical grazing marsh. Under the Habitats Directive 92/43/EEC and the UK Biodiversity Action Plan (1994) grazing marshes are a key habitat of conservation priority as identified by the Biodiversity Steering Group, and is one of the first habitats to have a costed Habitat Action Plan (Mountford et al 1999). The JNCC report on Biodiversity Broad Habitat Classification (Jackson 2000), however includes no description or definition of grazing marshes, therefore on what is the costed action plan to be based?

Grazing marshes and the North Kent Marshes in particular continue to be vulnerable to agricultural intensification, urbanisation, industrialisation, road and rail building, all agents of fragmentation, and neglect. Yet, if there is no clear definition of the habitat, or what factors are being used to determine if a lowland wet grassland area is a grazing marsh or some other similar habitat type? In fact, the terms lowland wet grassland and grazing marsh in many instances appear to be interchangeable. Section 3.1.1 concluded with a working definition for grazing marshes that identified the components that should be present on the typical grazing marsh. One of the aims of this thesis is to establish how fragmentation has affected the characteristics and features, and whether the status of grazing marshes is a result of fragmentation or if other factors are involved.

Sections 3.4.1 and 3.4.2 discuss the indicative vegetation communities and plant species that arise from the configuration of landscape features and characteristics that are typical of grazing marshes. A further aim of this thesis is to establish the typical vegetation communities of grazing marshes, and by using the characteristics and features which define grazing marshes, the changes to the vegetation communities can be establish and discuss how fragmentation has affected the components, the position in the landscape and the conservation value of grazing marshes.

Chapter 4 The North Kent Marshes – Past and Present

4.1 Introduction.

The coastal marshes of North Kent form a distinctive element of the North Kent landscape, containing features of visual, historical and ecological value (Cobham 1995). Within the Kent Structure Plan, the North Kent Marshes are recognised as one of seven Special Landscape Areas in Kent (AERC 1992). Originally, the North Kent Marshes are believed to have formed a continuous area of marshy grassland and saltmarsh that extended from the Inner Thames Marshes of Deptford in the west to the Isle of Thanet in the east (Harper 1914). Chalkin (1965), refers to there being in the seventeenth century 'unenclosed meadows all along the Thames shore from Greenwich in the west to the Isle of Grain near Rochester.' The grazing marshes still form an integral part of the coastal plain of North Kent, and the River Thames estuary (Clarke et al 1991), but survive in a much fragmented state, with the largest parcels being found to the east of the county and on the Isle of Sheppey.

Much of the seventeenth century marshland, referred to by Chalkin (1965) have now been lost to development, in particular the western marshes around Woolwich and Plumstead, Greenwich and Deptford, which were described above as 'unenclosed meadows' (ibid). Harper (1914) recalled the growing fragmentation of the marshes as urbanisation encroached along the banks of the Thames between Greenwich and Woolwich, 'all the way from Greenwich to Woolwich, a matter of three miles, run the electric trams; the river going in a bold loop almost due north, along Blackwall Reach. A fine broad, new road runs across the dreary flats to the Blackwall Tunnel; and all along these once solitary levels great modern factories are springing up'. Where urban expansion has encroached onto the River Thames banks e.g. at Erith and Gravesend no evidence of marshland exists.

Grazing marshes arose from the reclamation and fragmentation of the original saltmarsh that fronted the River Thames (see Section 3.1.1), which was reclaimed by the construction of embankments and counter walls. Isolated patches of saltmarsh have survived at Crayford, Dartford, Swanscombe and along the coast at Higham and Cliffe. The counter walls and embankments are now recognised as significant landscape characteristics (Cobham 1995), and survive as characteristic features of grazing marshes. Remnants of the original saltmarsh include ditches, dykes and fleets, used to drain the enclosed marshes, still remain after fragmentation and are again characteristic of grazing marsh (Section 3.1.1). Features such as rills, salt mounds, anthills, tussocky grassland and wet flushes are all features which give rise to the homogeneous heterogeneity of the grazing marshes.

The North Kent Marshes are often referred to as two distinct areas (Garrad 1954), the Inner Thames Marshes that comprise Erith, Crayford and Dartford along with the Essex marshes at Rainham, Wennington and Aveley, and the Outer Marshes of Denton Marsh to Chetney Marsh (see Figs 2.1 & 2.2). For the purposes of this study Stone Marsh, which was once contiguous with Dartford Marsh, and Swanscombe and Botany Marshes, which although an isolated group, are closer in proximity to the Inner Marshes and will therefore be included within this grouping. Of the Outer Thames Marshes, Shorne, Higham, Cliffe, Allhallows and Chetney are now incorporated within the North Kent Marshes Environmentally Sensitive Area (ESA). The ESA designation requires that the marshes are managed and maintained by grazing the marshes in a more traditional manner (Green 1996), i.e. the objectives are 'to maintain and enhance the landscape, wildlife and historic value of the area by encouraging beneficial agricultural practices', (ADAS 1997). Other conservation designations, which have been applied to the North Kent Marshes, are highlighted in Table 1.1 (see Section 1.1).

There are other large extents of contiguous grazing marsh found around the Swale estuary and along the Thames Estuary between Faversham and Whitstable (Fig 3.1). These larger areas were not considered in the current study because the research focuses on those sites that have suffered the greatest fragmentation.

4.2 Creation of the North Kent Grazing Marshes.

Grazing marshes were created by the enclosure of former saltmarsh, subsequent drainage and agricultural improvement (Gee1998). In North Kent, creation of grazing marsh results from the building of a sea wall adjacent to the River Thames. The process of enclosing or 'inning' marshland throughout North Kent is one that has been thought to be ongoing since Roman times (Prichard 1976), although evidence is scant. Traces of Romano-British piles were discovered when the foundations to the Crossness Outfall Works at Erith were constructed, (ibid).

There is little evidence that following the Roman occupation and during the dark ages (600-1100AD) that there was any further enclosure of the North Kent Marshes. The construction of embankments was a laborious and long-term process (MacDougall

1980), and the circumstances of the day were not particularly conducive to this type of endeavour (Hasted 1797)

MacDougall (1980) recorded that some of the earliest sea wall construction occurred around Cliffe Marsh in the eleventh or twelfth centuries by the monks of Christ Church who regularly farmed the land for both arable production and with livestock, predominantly sheep. The monks had 'a number of manors situated close to the marshlands, and whenever this was the case, they built numerous sea walls, in order to extend the lands they owned', MacDougall (1980), and so 'put great effort into land reclamation' (ibid). From early in their history therefore, the North Kent Marshes have been seen as an economic resource.

Further evidence that enclosure of the Thames saltmarshes occurred prior to the thirteenth century is provided by Prichard (1976) who recorded that during the thirteenth and fourteenth centuries Lesness Abbey had financial difficulties due to the cost of maintaining the river walls and draining the marshes around Erith. Notably in the period 1230 –1240, a great deal of money was spent repairing the walls after disastrous floods.

From the late fourteenth century, these newly reclaimed grazing lands were usually rented out. Prior to this, the monks had taken responsibility for the sea walls, but with the leasing out of more land, they had less incentive to maintain them. Because of the reduced maintenance more frequent flooding occurred, and resulted in many farmers leaving the land.

During the next four hundred years, little interest was shown in making economic use of the marshes (Hasted 1797). This was probably due to the presence on the marshes of *Anopheles maculipennis atroparvus*, a mosquito capable of transmitting and carrying malaria. The construction of sea walls helped to create stagnant water conditions, which was necessary for the mosquito's breeding, and is often cited as the reason for the spread of disease.

In 1532, the Statute of Sewers gave rise to the Commission of Sewers, which became the basis of administration for the marshes for nearly four hundred years, until it was superseded by the Drainage and Catchment Boards, created under the Land Drainage Act (Cracknell 1953). The first Commission of Sewers in the North Kent region was established at the beginning of the seventeenth century covering the Gravesend to Sheerness region (ibid), and came to an end in 1946. Under the auspices of the Commission of Sewers however, many miles of embankment were constructed and maintained along the North Kent coast (ibid).

Gillham and Holmes (1950) record that several Acts of Parliament were passed between 1545 and 1600 authorising the embanking or 'inning' of small areas on the Isle of Grain. They go on to state that in 1601 Queen Elizabeth I signed an Act authorising the enclosure of many thousands of acres of marshland throughout Kent and other counties. Baldwin (1984) recorded that also during the seventeenth century the river walls that enclosed Crayford Marsh were largely built, though further to the east, there is evidence of Saxon and Roman works, indicating that the construction of the embankments was a process that continued over many years.

A writer of the nineteenth century, referred to in the literature as 'a son of the marshes' recalls that 'in the days of his youth the older marsh folk told him that the great sea-wall was built by Dutch settlers who came there in the seventeenth century', (Gillham & Holmes 1950). Although there are several other references to Dutch engineering prowess, it seems likely that their main contribution to the North Kent embankments was to improve, maintain and fortify many of the existing structures rather than extending the areas of marshland (ibid).

Henry Pye, who took over St. Mary's Farm, on Cliffe Marsh in 1845, is credited with pioneering much of the drainage and improvements that occurred during the following fifty years, and effectively ending the threat of the ague or malaria. Garrad (1954), records that Henry Pye after he had successfully drained the marshes of Cliffe 'went into corn growing, until low prices beat him'.

Spurrell (1885) cited by Cracknell (1953), stated that, 'the effective embankments in the estuary of the Thames as we see them today are of no great antiquity. They are the result of piece-meal enclosures, which have been advanced side by side and at right angles to the course of the stream'. The construction of new embankments or repairs to existing walls was therefore carried out as and when money was available or when a flood episode had made the construction of new walls desirable (ibid). As Webb and Webb (1922), state, 'usually new walls were built to deal with particular emergencies and often only temporary'.

In 1948, the River Boards Act transferred the responsibility for the upkeep and maintenance of the North Kent Marsh embankments to the appropriate River Board (Cracknell 1953). The last major repair works to the river walls were undertaken after the disastrous floods of 1953. Responsibility for their upkeep was later transferred to the National Rivers Authority, which was succeeded by the Environment Agency in 1994.

The last reclamation of saltmarsh occurred during the 1960's when Broadness saltmarsh on the Swanscombe Peninsula was enclosed and used for landfill. Prior to this time, the literature suggests that all major enclosure had been completed by the middle of the nineteenth century. Since 1960, the existing walls have either been raised or reinforced further reducing the influence of the Thames Estuary on the grazing marshes. As Gilham and Holmes (1950) pointed out however, additional areas of marshland may have at one time been reclaimed and so it is difficult to establish an exact figure for grazing marsh that may have existed prior to 1897.

A survey carried out between 1950 and 1951 estimated that the North Kent Marshes from Erith to the Isle of Grain covered an area of some 15,000 acres (6073 ha) (Garrad 1954). He described the marshes as 'being of high agricultural standard and are grazed by sheep and cattle'. MacDougall (1980) estimated that almost half of the Hoo Peninsula (including the Isle of Grain) was marshland and saltings used extensively for sheep grazing.

Garrad (1954) drew a distinction between the inner marshes of Erith, Dartford, Stone and Swanscombe and those that occur further east. The primary difference recorded by Garrad (1954) being based on soil type, with the inner marshes comprising primarily of loam overlying clay and with alluvial soils on the outer marshes of Shorne, Higham and Cliffe Marshes. Additional comments in Garrad's (1954) report showed that although the inner marshes provided good grazing, primarily for dairy farming, they were also being purchased by industrial concerns and so lost to agriculture. Some of these marshes were also being used for market gardening at this time. The marshes further east Garrad (1954) described as being 'wet and almost entirely under grass, which varies greatly in quality', although he concluded that with better drainage the marshes could be improved.

Stapledon and Davies (1940) in their grassland survey of Kent classified the permanent grasslands of Kent into nine zones, dependent on the quantity of perennial ryegrass (*Lolium perenne*), bent grass (*Agrostis spp.*) and fescues (*Festuca*). The majority of the North Kent Marshes fell within group 3, chiefly *Agrostis* with ryegrass pastures, although they were further divided into two sub-groups.

Cliffe Marsh came under group 3a, chiefly bent grasses (*Agrostis*) with ryegrass pastures, with second rate ryegrass pastures, ordinary *Agrostis* pastures and a few high-grade ryegrass pastures occurring in a descending order of frequency. The remaining marshes, Dartford, Stone, Shorne and Higham were to be found in-group 3b, with the ordinary *Agrostis* pastures occurring in greater frequency than the second rate ryegrass pastures, with the occasional first-grade rye grass pasture.

The report of Stapledon and Davies (1940) inferred that Cliffe Marsh was better quality agricultural land than the other marshes. None of the marshes however, was considered to be of the highest quality agricultural land, which was described as being first-grade ryegrass pastures as found on parts of Romney Marsh (Garrad 1954). The report generally concluded that the only rich permanent grassland within Kent occurred on the marshes (including the North Kent Marshes) or in the river valleys (ibid), highlighting the high agricultural and economic value of these areas.

4.3 History of the North Kent Marshes.

Hasted (1797) gives some of the earliest accounts of North Kent Marshes in his History and Topographical Survey of Kent. The accounts of the Thames Marshes include all the sites covered in the present study as well as documenting areas of Inner Thames Marsh that are no longer recognisable as marshland. For example, Deptford, Greenwich, Woolwich and North Woolwich were in the eighteenth century open marshland and included within the county of Kent (Fig 4.1). The loss of marshlands in these areas however, occurred at a much earlier date than those covered in this study, e.g., Deptford is recorded as having been an important port and centre for shipbuilding from the time of Henry VIII (1509-1547) and it rose in importance with the growth of the Royal Navy (Harper 1914). As Hasted (1797) records in 1656, 250 acres of meadow in Deptford were purchased for the construction of a private dock. These docks remained in existence until 1869, but nothing now remains of this once flourishing industry (ibid).

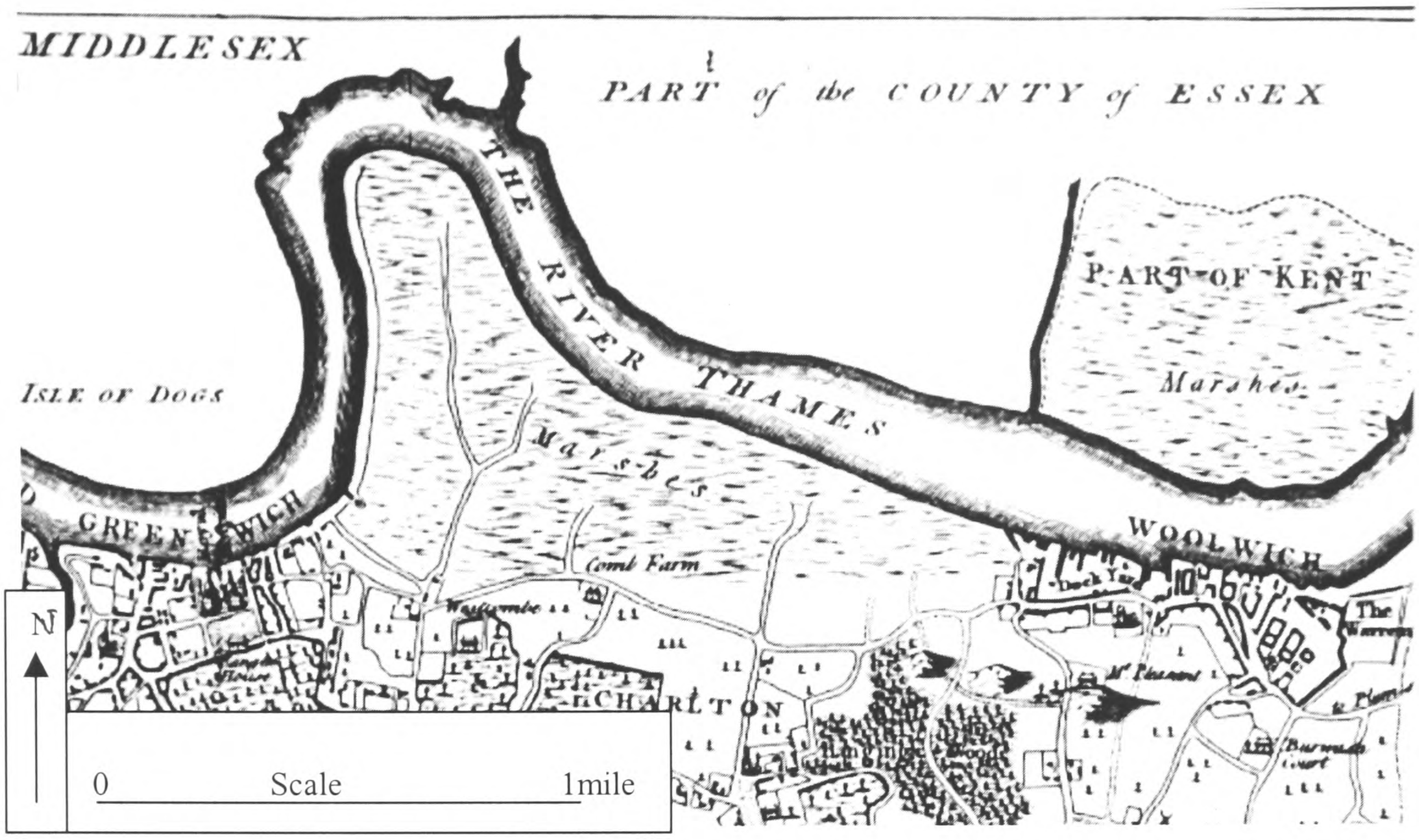

Fig 4.1 Deptford and Woolwich Marshes in 1797 (after Hasted).

In the vicinity of Woolwich, Hasted (1797) records that during the reign of James I (1603-1625), many acres of marshland were flooded, and these had not been recovered at the time of his writing. Prior to this date, in the reign of Henry III many commissions for repairing breaches in the walls were issued (Hasted 1797), indicating that enclosure of the grazing marshes in West Kent had occurred at a much earlier date. By Hasted's time the upkeep and repair of the embankments was the responsibility of the Commission of Sewers, whose authority extended from Lombard Wall to Gravesend, an early example of centralised management of the North Kent Marshes.

Hasted (1797) states that Deptford was an area 'fruitful to the herbalist', because of the many species of plant found on the marshes, which included species such as lesser water parsnip (*Berula erecta*), Deptford pink (*Dianthus armeria*), cudweed (*Filago vulgaris*), wild bugloss (*Lycopis arvensis*) and wild water hemlock (*Oenanthe crocata*). Further downstream at Greenwich, Hasted (1797) documented further early losses of

Thames side marshlands, and recorded species such as common scurvey grass (*Cochlearia officinalis*), kidney vetch (*Anthyllis vulneraria*) and sea rush (*Juncus maritimus*) growing along the riverbank. These accounts highlight the biodiversity that once existed across the whole of North Kent and which has been greatly reduced by the fragmentation of the North Kent Grazing Marshes.

Plumstead Marsh in the eighteenth century covered an area of some 2000 acres of good pastureland (Hasted 1797). During the nineteenth and twentieth centuries, the marsh was beginning to be developed into a munitions factory, the Woolwich Arsenal, although Harper (1914) still records the Plumstead Marsh as being 'wide and extensive'. Since the mid 1960's, the Thamesmead estate has been constructed over much of the Plumstead and Erith Marshes. Many of the old drainage channels have however, been incorporated into the design of the estate being converted into canals and lakes with the water flow regulated by the Thamesmere Pumping Station. The large expanses of grassland have, however been completely lost.

4.4 The History and Current Status of the Study Sites.

4.4.1 Erith Marsh.

Prichard (1976) records some of the earliest construction of embankments occurring on Erith Marsh during the Roman occupation. There is little further documentary evidence as to the condition of the embankments until the thirteenth and fourteenth centuries when Prichard (1976) recorded that the monks of Lesness Abbey were responsible for the upkeep of the river walls. In 1587, more effective embankments were constructed, although 500 acres were still under water (Hasted 1797), but by 1606, the whole of the marsh was effectively enclosed. According, to Chalkin (1965) this work was carried out by William Burrell, who then under an agreement with the landowners received half of the land enclosed.

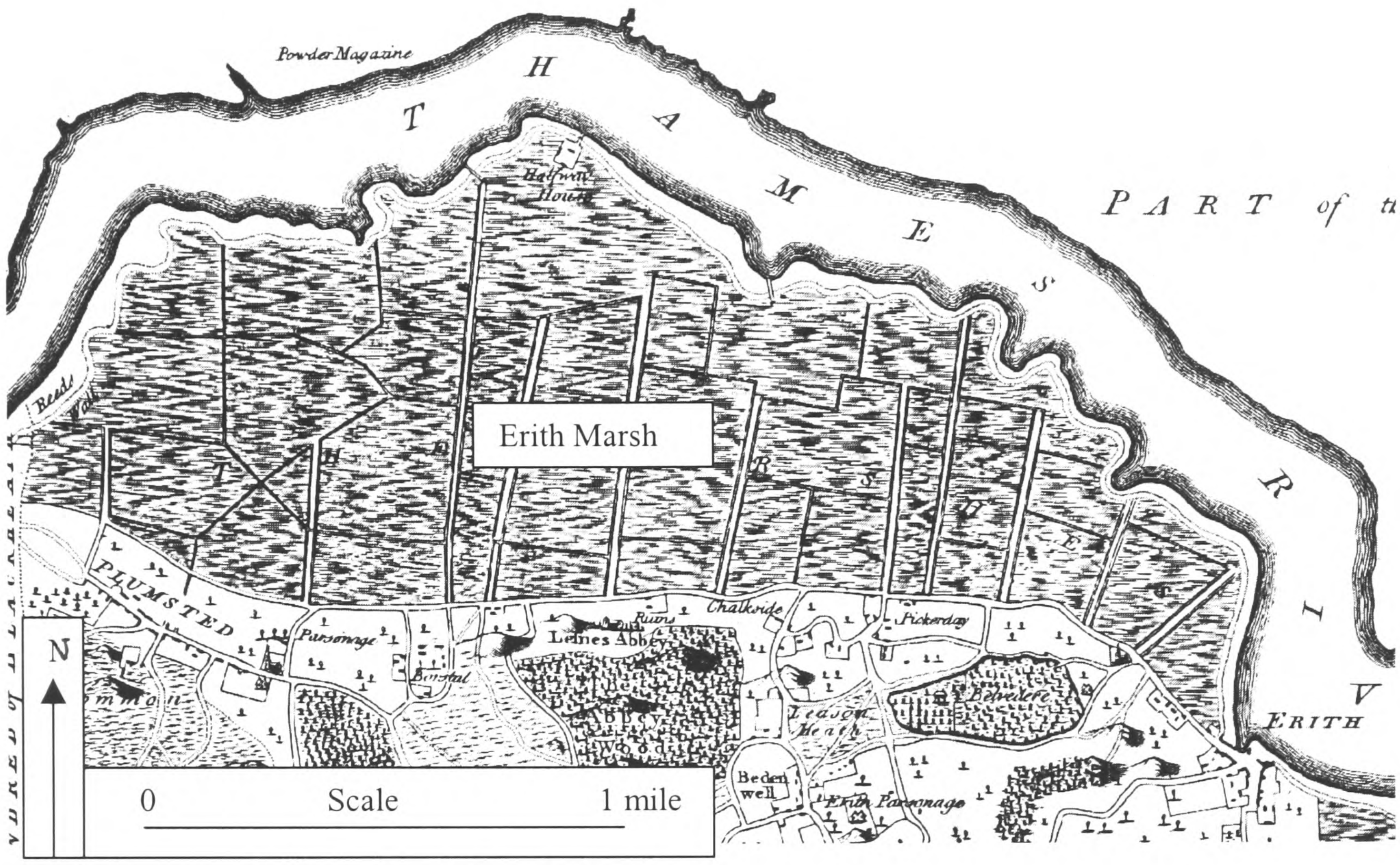

Fig 4.2 Erith Marsh in 1797 (after Hasted)

Figure 4.2 shows the extent of Erith Marsh in the eighteenth century when they were continuous with Plumstead Marsh. According to Hasted (1797), the marshes were 1550 acres (627ha) in area, although most of this was ploughed for corn. This indicates that at least part of the marshes in this region have been enclosed for a considerable period, and according to Hasted (1797) perhaps as early as 1279. A survey of 1829 (Kite undated), showed that a variety of crops were being grown on Erith Marsh, including oats, wheat and beans, whilst some fields were kept as pasture and meadows. Tithe maps of 1843 indicate that up to 66% of the marshes were in arable production at this time (ibid).

The first recorded losses of Erith Marsh occurred during the nineteenth century with the construction of the Royal Arsenal munitions factory. Completed in 1890 the factory occupied 324 hectares (800 acres) of marshland, (Prichard 1976). A further 54 ha (135 acres) was lost during the 1860's with the construction of the Crossness sewage treatment works (ibid).

When the Royal Arsenal was closed, the land was sold to the Greater London Council who then earmarked the land for development (Prichard 1976). In 1975, the construction of urban development, now known as Thamesmead Town was commenced on the former Royal Arsenal site, and eventually occupied approximately 1200ha of former marshland. The construction of the waterfront was described as a 'major disaster' (Anon 1976), because it occasioned the destruction of the 'single most important waterfowl site on the Inner Thames'.

The remaining fragments of Erith Marsh lie in the north of the London Borough of Bexley, to the east of the Thamesmead estate, (Fig 4.3). 'Together with Crayford and Rainham Marshes, they form the last remaining grazing systems within the Greater London area' (Bexley UDP 1994). According to the London Ecology Unit (1985), Erith Marsh is 'a site of conservation priority', because of the location within the Greater London area and an important number of invertebrates (Environment Agency 1997). Erith Marsh was therefore designated as a site of Metropolitan Importance and the southern area is designated Metropolitan Open Space. Currently Erith Marsh comprises horse grazed neutral grasslands, with reedbeds, dykes, tall rough grassland and small areas of developing scrub. The sea wall and embankments are now somewhat separated from the grasslands by the Ford Motor Company Depot, and their survival appears to be an historical accident, (Thornton 1989).

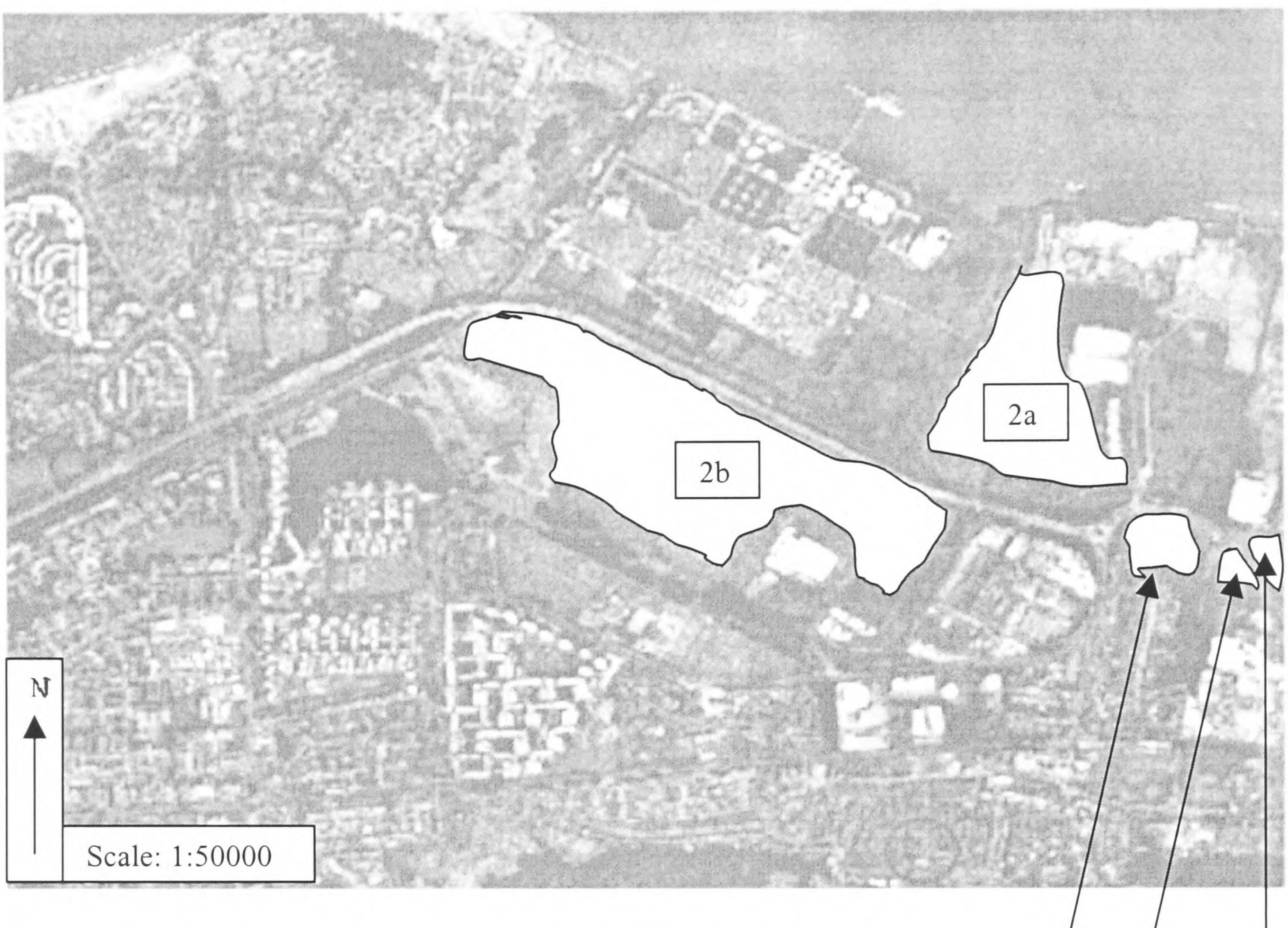

Fig 4.3 The current status of Erith Marsh, showing the individual fragments.

Connectivity between the remaining fragments 2a/2b and 2c/2d is maintained by drainage ditches (Fig 4.3), although a lack of management, particularly on fragment 2b is allowing the ditches to become overgrown and choked by emergent vegetation, e.g. *Phragmites australis* and *Scirpus maritimus*. Fragmentation has also caused the isolation of ditches and hydroseral succession is threatening the survival of the ditches as less maintenance is carried out. Erith Marsh as a whole however, remains under threat from further development of distribution centres and industrial estates.

4.4.2 Crayford Marsh.

Crayford Marsh has always been separated from Erith Marsh, although as the village of Erith has grown, so has the barrier between the marshes grown. Fig 4.4 shows the extent of Crayford Marsh at the time of Hasted (1797), who recorded an area of some 500 acres (202ha) of marsh generally used for grazing and unploughed. The area covered by Crayford Marsh from the time of Hasted to the present day (Fig 4.5) appears to have varied considerably, e.g. Howbury Farm is shown on modern maps to be on the edge of the marsh. The map of the Hundreds (1797) records the farm as being surrounded by orchards. Early maps imply that at one time Crayford Marsh extended inland along the banks of the River Cray to the recreational parkland that now surrounds Hall Place. Crayford Marsh however, certainly extended westward of the North Kent Railway Line, and the construction of this line in the mid nineteenth century was one of the first fragmenting episodes to affect Crayford Marsh.

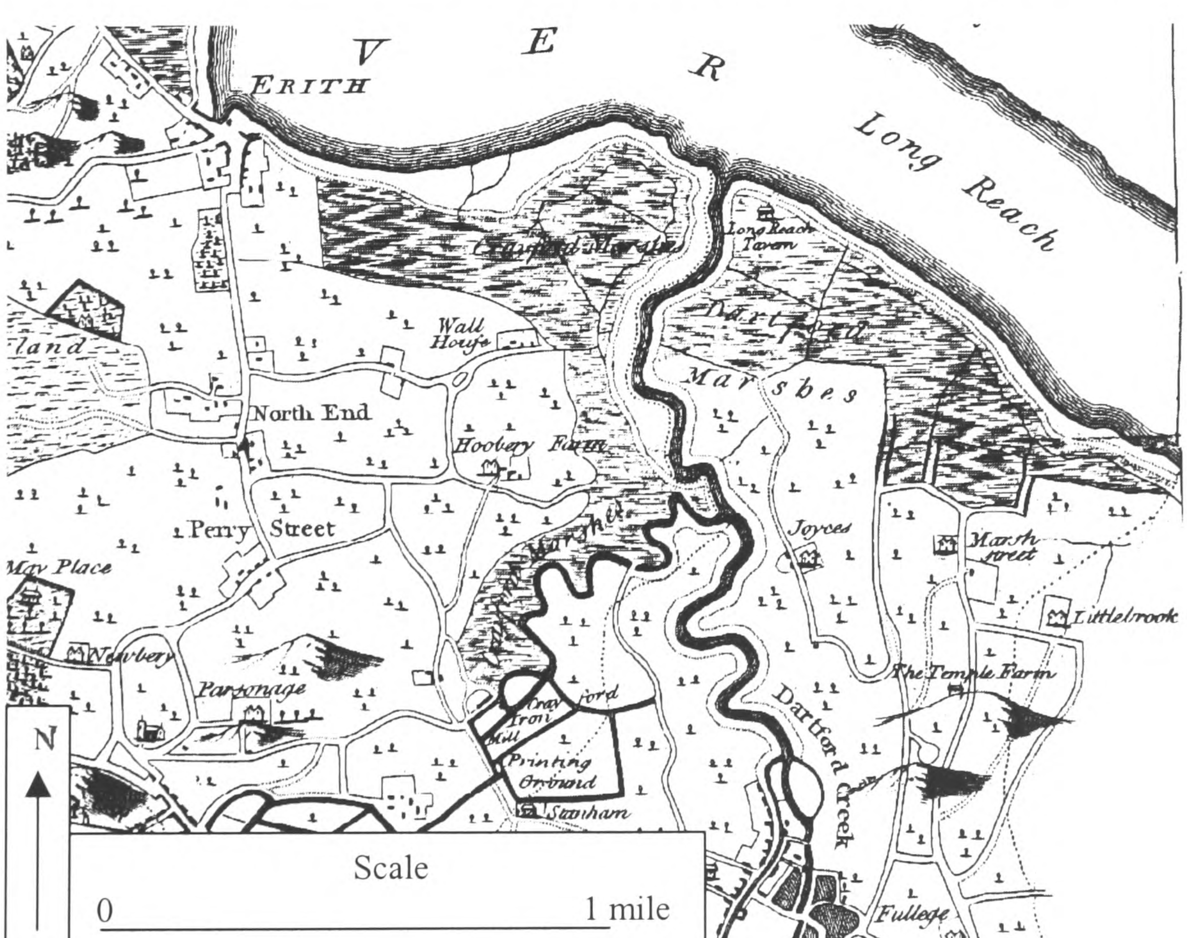

Fig 4.4 Crayford Marsh in1797, (after Hasted).

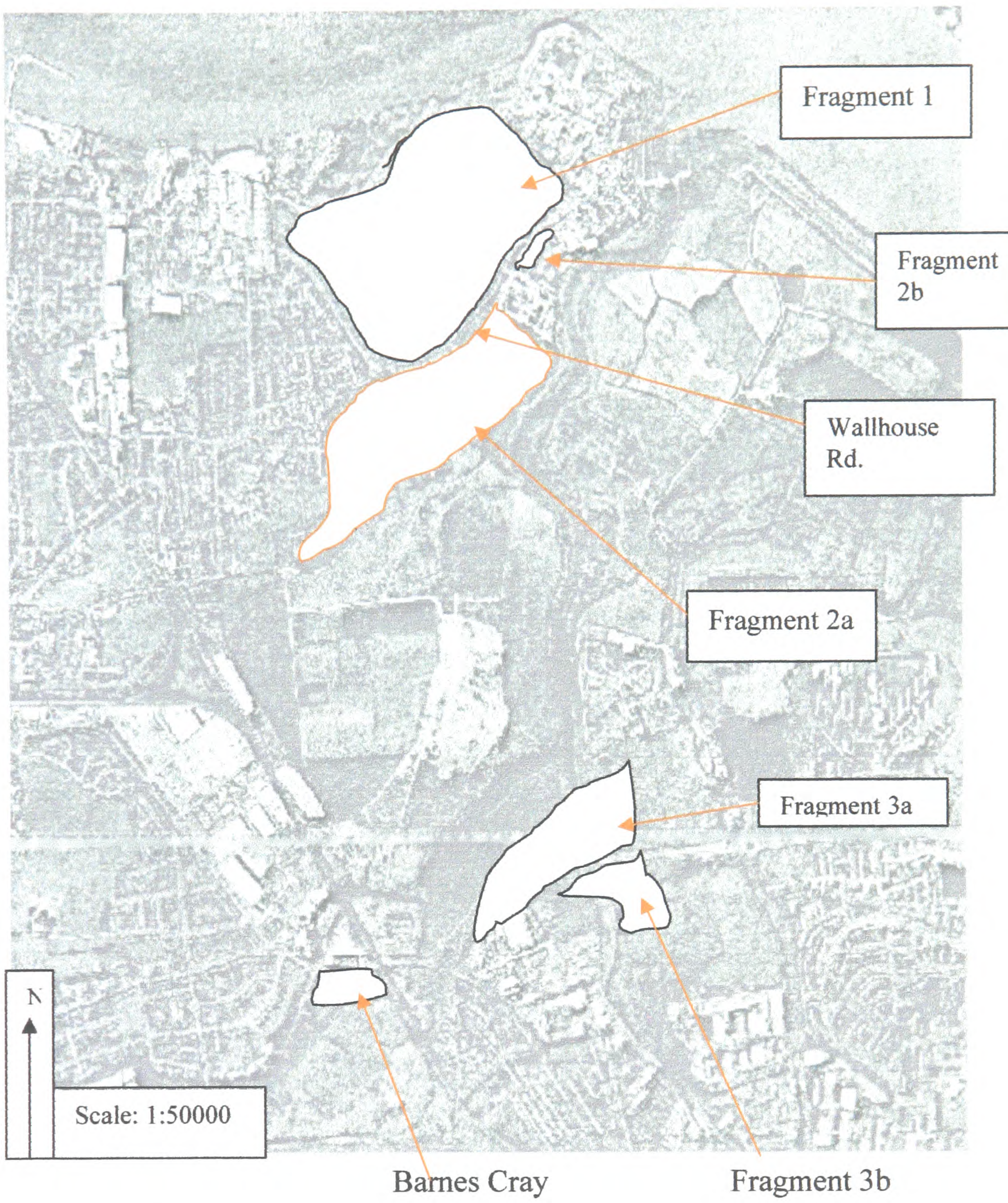

Fig 4.5 The current status of Crayford Marsh, showing the individual fragments.

Grazing Marsh is today also found between the Rivers Cray and Darenth, where Hasted (1797) records orchards in the same area, indicating therefore that there have long been land use changes between grazing and alternative farm production. A government Bill passed in 1840 allowed the two rivers to be improved to allow navigation by heavy barges and as suggested by Morris and Wright (1992) 'must have considerably altered the rivers and the marshes'. It is probable therefore, that the land between the two rivers was converted to marshland at this time. It is apparent therefore, that Crayford

Marsh once covered a far greater area than at present and that it encompassed many areas not now regarded as marshland, but also vice-versa, as previously described. Currently therefore, Crayford Marsh cover an area of some 110 ha in the north east of the London Borough of Bexley.

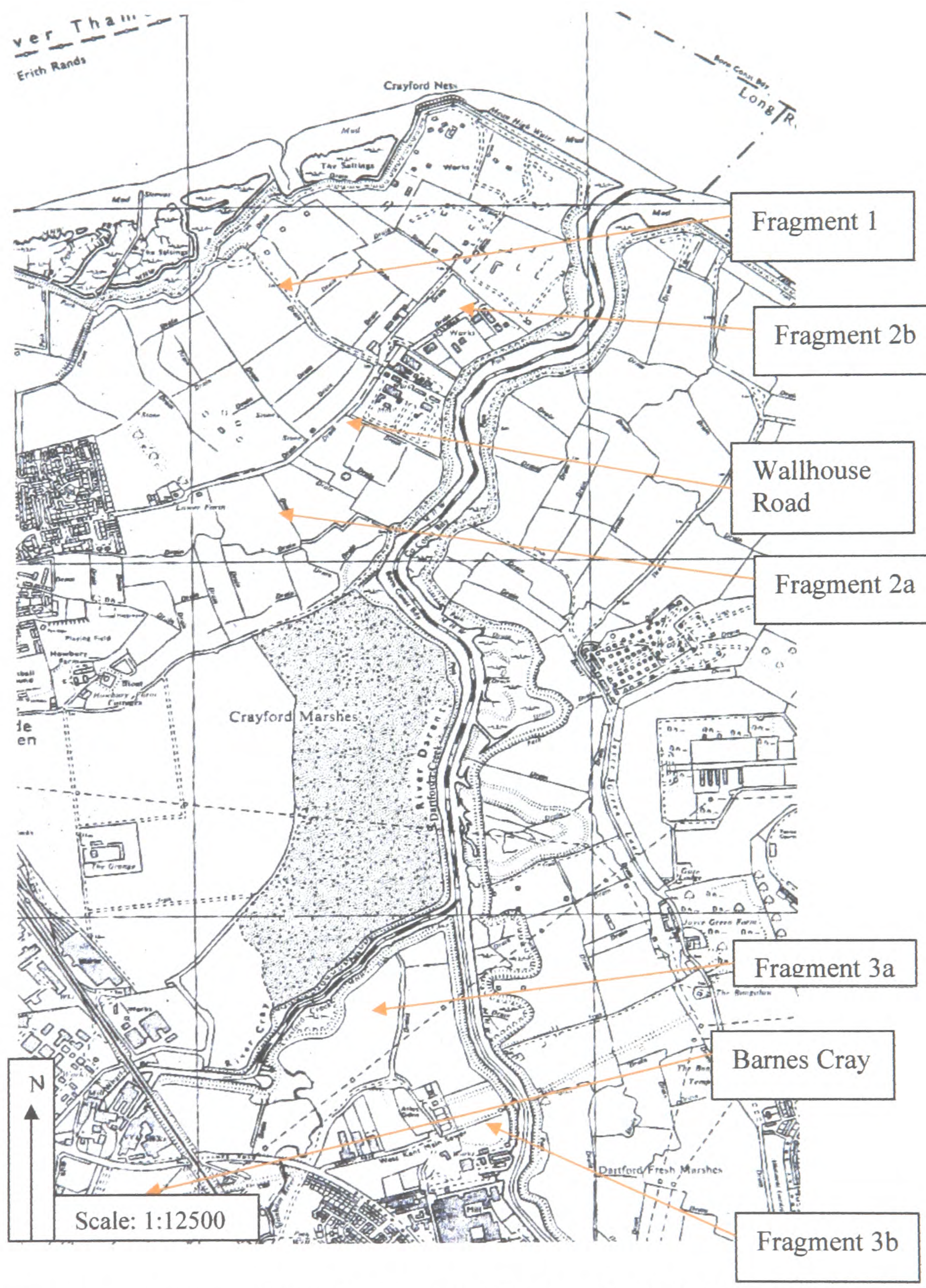

Fig 4.6 The current status of Crayford Marsh, showing the individual fragments (after Pardon).

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Morris and Wright (1992) recorded that until the beginning of the twentieth century Crayford Marsh had been grazed by sheep and cattle. Crayford Marsh is now, grazed by horses, which Plant (1991) suggested may be over grazing the marsh. Poor managed scrub is developing around the existing remains of the World War II concrete pillboxes and anti-aircraft battery, and overgrown hedgerows are beginning to invade some ditch sides. Currently, therefore there is a conflict in the extent of grazing, which is causing degradation to the grazing habitat, but is also allowing succession to continue.

Amongst the habitats found on Crayford Marsh are 'a suite of coastal habitat types – estuary mudflats, saltmarsh, reed swamp, grazing marsh, wet meadow, ditches, and banks' (English Nature 1999). The remaining area of saltmarsh encompassed within Crayford Marsh is the largest area surviving in Greater London (English Nature 1999). The remaining areas of marsh contains a variety of habitats; improved, semi-improved and unimproved neutral grasslands, with interconnecting fresh and brackish dykes, hedgerows and scrub, an area of saltmarsh and intertidal mud. The rough grazing land comprises a range of mainly perennial grass species with meadow barley (*Hordeum secalinum*), creeping bent (*Agrostis stolonifera*), and perennial rye grass (*Lolium perenne*) being the most common. These grasses are interspersed now with many species associated with disturbed ground and ruderals, e.g. plantains (*Plantago spp.*), ragwort (*Senecio spp.*), cat's ears (*Hypochoeris spp.*) and dandelion (*Taraxacum spp.*). The species diversity of the marsh is however beginning to suffer because of poor water level management, Sinnadurai (1999).

Ditches are intermittently managed (Environment Agency 1997), and therefore vary in quality, from those that have been cleared showing a good variety of emergent and bank vegetation to those that require clearing and are choked by common reed (*Phragmites australis*). In some instances, particularly to the south of the divisive Wallhouse Road (Fig 4.6), the ditches have become filled in and dominated by the perennial grasses.

The area of the marshes known as Barnes Cray Meadows (Fig 4.6) still comprises wet grassland, grazed pasture and a well-defined ditch system but is no longer considered by many as part of Crayford Marsh, although still being represented on the maps as Crayford Marsh. The meadow shows a variety of species, which are comparable to grazing marshes, notably rye grass (*Lolium perenne*) and bents (*Agrostis spp.*), but also present are species often associated with poorly drained grassland, such as redshank (*Polygonum persicaria*), great willowherb (*Epilobium hirsutum*) and jointed rush (*Juncus articulatus*). Recent proposals to develop Thames Road into a dual carriageway now threaten the future of this fragment (Bexley Council 2000). Barnes Cray is however, designated a site of Nature Conservation Interest (SNCI).

Currently Crayford Marsh is incurring losses from further urban encroachment and pollution problems, which are threatening the conservation value of the site (Sinnadurai 1999). Poor water level management is also compromising the species diversity of the marsh. Further inappropriate development is likely to occur unless better management techniques are introduced. One of the problems with co-ordinating the management of Crayford Marsh however, is the split ownership with currently four parties holding an interest. Sinnadurai (1999) recorded that 'Crayford Marsh was subject to limited management and gradually being degraded by mismanagement and encroachment of inappropriate development'. The current usage is however generally consistent, with horse grazing being carried out by a variety of tenants, although cattle have been grazed in the recent past (Baldwin 1984). A proposal to designate the marsh as an SSSI, because of the range of coastal habitats, ditches, and invertebrate assemblages, should ensure the future and prevent further attrition of the grasslands (English Nature *pers com.*).

4.4.3 Dartford Marsh.

The Domesday Book records no marshland in the Dartford area, but it does mention meadowland, which may have existed in the marsh (Geikie undated). Some of the earliest records of usage and ownership of Dartford Marsh dates back to the twelfth century when the Knights Templars were granted land to the north east of Dartford (Dartford archive). In 1195, an area of 7 acres (2.8ha) was recorded as flood meadow and by 1311 this area had increased to 46 acres (18.6ha) of meadowland, primarily through it is believed drainage and enclosure (Dunkin). Mair (1953) records that in 1333 Hamo de Hythe, Bishop of Rochester, instructed a new wall to be built in the Littlebrook area. The construction of this new stretch of embankment is said to have increased the area of enclosed marsh by some one hundred acres (ibid). Much of this area is now lost under the Littlebrook power station complex. As Mair (1953) reflected, 'with the coming to Stone Marsh of the Kent Electric Power Station there was lost not only the ancient right of way to the river but also the fine grazing marshes of Snipes, Allen, King Cup, Confords and River'. He went on to say 'a few years later, occurred a further loss when early producing fields like Barley Dale, Chalk Dale, Oaten Dale, White Gate, Hollow, Bank and Home were sacrificed to the needs of a new housing estate'.

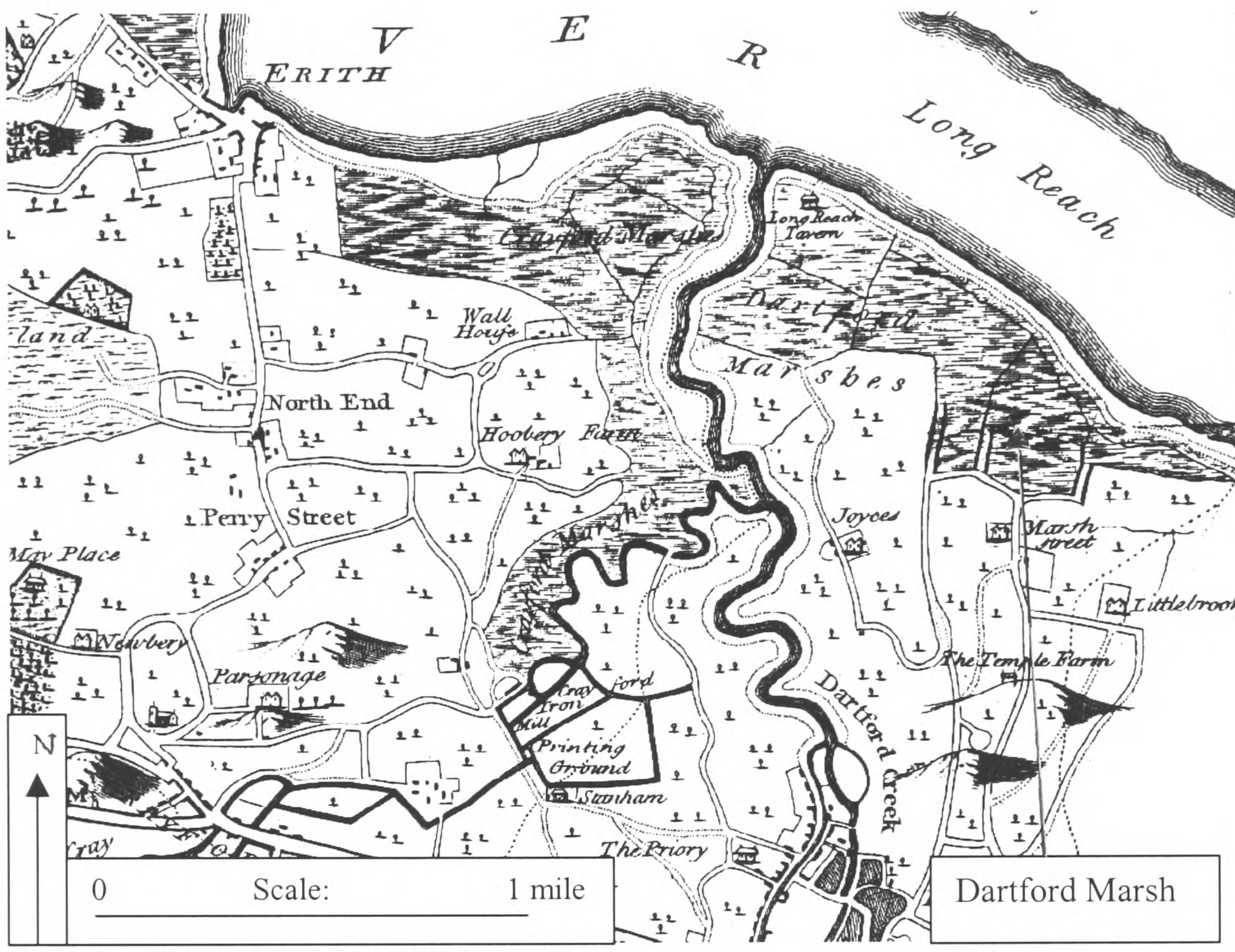

Fig 4.7a Dartford Marsh in 1797, (after Hasted)

Figs 4.7a and 4.7b shows Dartford Marsh and Stone Marsh in the eighteenth and nineteenth centuries, with the orientation of the Dartford Marsh running east – west parallel to the River Thames. Inland, around Joyce Green is recorded on the Hundreds Map as orchards. Later Ordnance Survey maps (Fig 4.8) shows Dartford Marsh as two distinct areas, the Dartford Saltmarsh in the north adjacent to the River Thames and Dartford Fresh Marsh which occupied the area to the south of the West Kent main sewer. The different usage of the term marsh may explain the differences recorded on the maps. Hasted (1797) uses marsh to refer to saltmarsh and excluding areas that at this time were not exclusively of this habitat type, whereas, much of what is now described as grazing marsh appears to have been drained by this time and used as orchard.

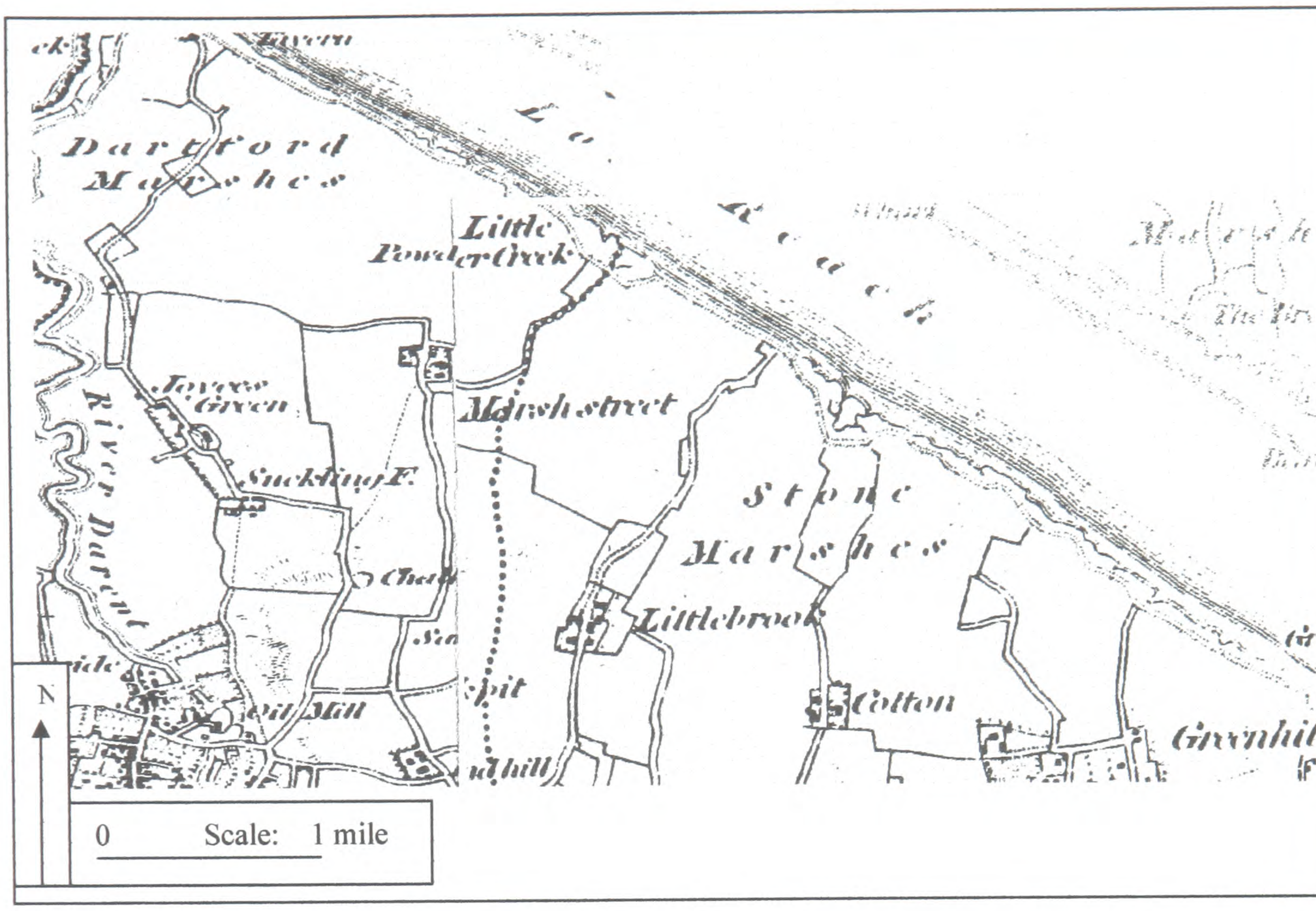

Fig 4.7b Dartford and Stone Marshes, showing the two marshes as one contiguous marsh (from Hull).

Dartford Marsh (Fig 4.8), formerly known as Dartford Saltmarsh, occupies an area of open land approximately 340 hectares in size lying to the north of Dartford town, and are one of the last areas of semi-natural landscape on the Thames floodplain. The marshes are bounded by the River Thames to the north and the River Darenth to the west. The recently closed Joyce Green Hospital, Longreach Sewage Works and Littlebrook Power Station and its associated lakes lie on the eastern boundary with University Way since 1991 forming a distinct southern boundary and fragmenting agent separating the saltmarsh and fresh marsh.

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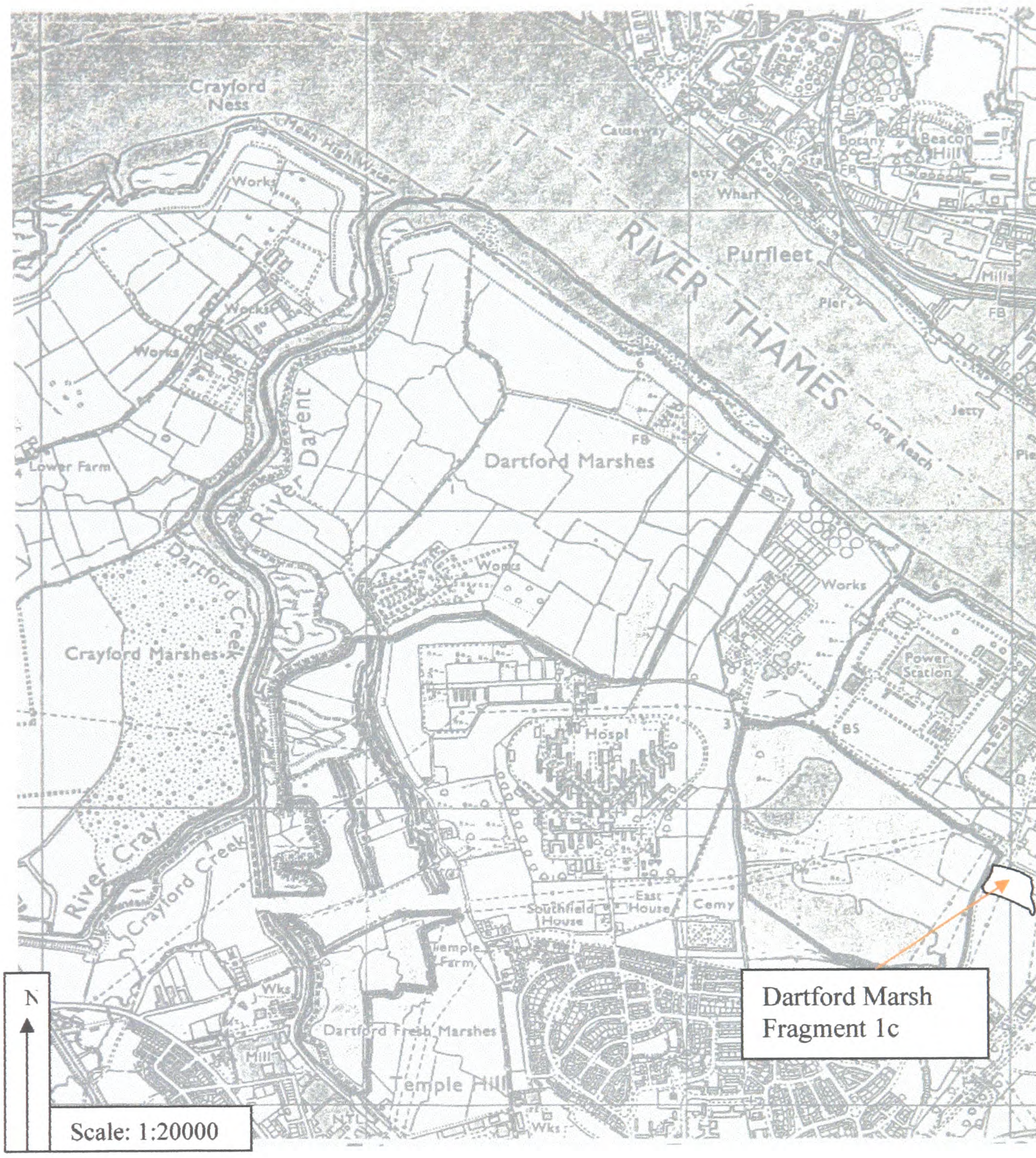

Fig 4.8 Dartford Marsh in 1960's, (from Kent Trust for Nature Conservation).

The main body of Dartford Marsh (Fig 4.8) comprises semi-improved neutral lowland wet grassland, interspersed with traditional drainage ditches. Sinnadurai (1999) commented however that the grazed areas were too short to be of particular value and that a high level of management is required to improve the quality of habitat features. Pardon (1985) described Dartford Marsh as having 'the most extensive and well maintained drainage system of the three Inner Thames systems, (Dartford, Crayford and Rainham)'. Dartford Marsh is currently managed for permanent fodder crops and grazed by dairy cattle, juxtaposed with an arable rotation, with pigs grazing a small central part of the farm (Geikie *pers com.*).

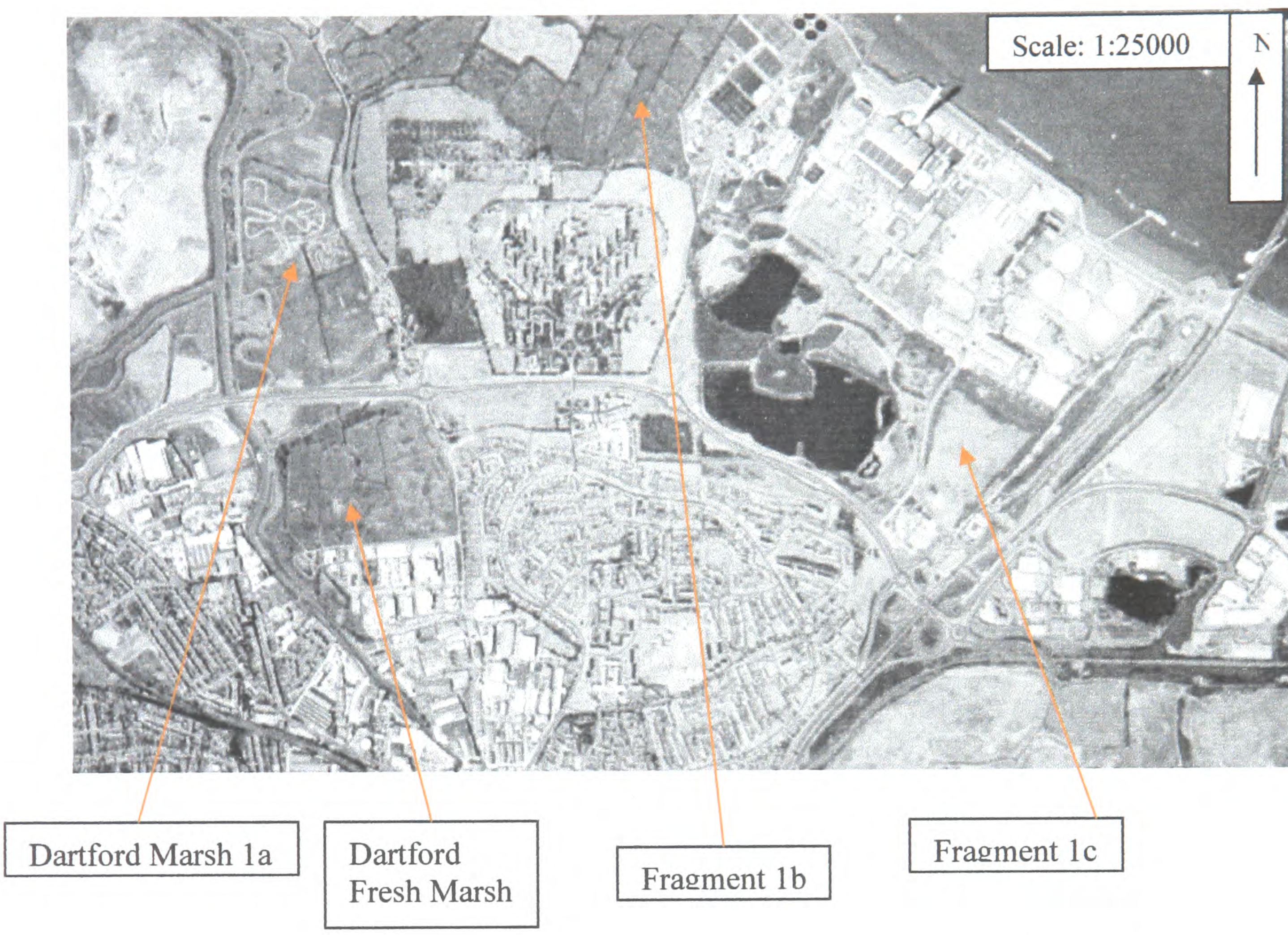

Fig 4.9 The current status of Dartford Marsh, showing the individual fragments.

Interspersed within the farmed area of Dartford Marsh are recreational sites used for clay pigeon shoots, model aircraft flying and a moto-cross circuit. The latter activity is spreading unofficially to the floodbank areas of the river causing damage and disturbance to this particular characteristic (Fig 4.10).

The eastern part of Dartford Marsh, to the north of the Joyce Green Hospital, and occupying the area of the old Long Reach Tavern and isolation hospital, is currently unmanaged (Fig 4.11). This area of former grazing marsh is now set-aside and separated from managed areas by successional woodland. The fields are now dominated by rank grasses, such as false oat grass (*Arrhenatherum elatius*), ruderal

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herbs and mature hedgerows, mainly hawthorn (*Crateagus monogyna*) and willow (*Salix sp.*). The ditch system in the unmanaged area although still evident is choked by emergent vegetation and overgrows by hedgerows and trees and in much need of restoration.

Fig 4.10 Damaged embankments on Stone Marsh.

Fig 4.11 Unmanaged areas Dartford Marsh, fragment 1b.

Figs 4.8 and 4.9 show the current extent of Dartford Marsh. The fireworks factory, although no longer considered as part of the marsh, represents an area that may in the future affect the water quality of the marsh (Geikie *pers com.*). The nature of the contaminants means that alterations to the water table could mobilise them into the drainage ditch system of the main marsh, and affecting the ecology of the water-courses. The drainage ditches as on Crayford Marsh provide habitat for a wide range of aquatic flora and invertebrates, which have led to a proposal to designate the site a SSSI (English Nature *pers com.*).

Dartford Fresh Marsh comprises 22ha to the south of University Way, and is bounded to the west by the River Darenth, housing to the east and the Glaxo - SmithKlein pharmaceutical site to the south (Fig 4.12). The Fresh Marsh comprises a mosaic of wet marsh, marshy grasslands, semi-improved neutral grasslands and standing water all dissected by a network of ditches. The reasons for the standing water are not immediately obvious but in some extent may be due to the ombrogenous nature of the site.

Fig 4.12 Dartford Fresh Marsh and industrial surrounds.

Floating sweet grass (*Glyceria fluitans)* dominates large areas of Dartford Fresh Marsh; whilst in the areas of standing water common reed (*Phragmites australis*) and great reedmace (*Typha latifolia*) are characteristic. The drier banks where, they have been built up from dredging comprise mainly ruderal species dominated by common nettle (*Urticia dioica*) and creeping thistle (*Cirsium arvense*). The central grazed area is comparatively species poor dominated by couch grass (*Agropyron*) and creeping thistle (*C. arvense*). There is also evidence that this area is also mown as a management technique for controlling the thistle (personal observation).

The eastern side of the fresh marsh comprises stands of marsh foxtail (*Alopecurus geniculatus*), creeping bent (*Agrostis stolonifera*), and rough meadow grass (*Poa trivialis*), with floating sweet grass (*Glyceria fluitans*) in the wetter areas. Evidence for the lack of grazing is highlighted by the numerous stands of hard rush (*Juncus inflexus*) and soft rush (*J. effusus*). The river embankment dominates the western end of the fresh marsh and comprises semi-improved neutral grassland dominated by false oat grass (*Arrhenatherum elatius*) and couch grass (*Elymus repens*). Yorkshire Fog (*Holcus lanatus*), cock's-foot (*Dactylis glomerata*), creeping cinquefoil (*Potentilla reptans*) and bird's foot trefoil (*Lotus corniculatus*) are also common.

Dartford Fresh Marsh is also interspersed with tree cover, crack willow (*Salix fragilis*) in the wetter areas and hawthorn (*Crataegus monogyna*) and elder (*Sambucus nigra*) in others often forming a hedge line marking the junction of the SNCI area and the land owned by Glaxo – Wellcome. The understorey of the hedge comprises common nettle (*Urtica dioica*), cleavers (*Galium aparine*), false oat grass (*A. elatius*) and rough meadow grass (*P. trivialis*), with hemlock (*Conium maculatum*) becoming prominent in the open areas.

A further isolated small fragment of wet grassland (Dartford 1c, Fig 4.9 & 13) occurs adjacent to the south of the Littlebrook Power Station and bounded to the east by the Dartford Tunnel approach road. The fragment is all that remains of the grazing marshes known as Snipes, Allen, King Cup, Confords and River as recorded by Mair (1953). Dartford Marsh 1c retains many relics of former grazing marsh. Particularly notable are the rills and runnels that indicate the old course of saltmarsh inlets. Saltmarsh vegetation is also evident, stands of sea aster (*Aster trifolium*), sea lavender (*Limonium vulgare*) and sea purslane (*Halimione portulacoides*) being particularly prevalent. South of this fragment, the adjoining grassland has recently been vacated by travellers and is currently in a very disturbed state. Litter and the ruts from vehicular access have damaged the site.

Fig 4.13 Dartford Marsh Fragment 1c.

4.4.4 Stone Marsh.

Evidence collected by Mair (1953), indicates that the sea wall around Stone Marsh was completed during the reign of Henry III (1216-72). The embankment gave way during a very high tide in 1897, and a new wall was constructed on the riverside of the original wall, a feature that is still visible today, (Fig 4.14).

From the Maps of the Hundreds (1797) Dartford and Stone Marshes are recorded as being one contiguous marshland (Fig 4.7). This situation remained until the construction of the Dartford Tunnel and approach roads fragmented the two marshes in 1963.

Fig 4.14 Embankments on Stone Marsh.

In 1866, Stone Marsh is recorded as being 'only suitable for minimal grazing' (Dartford Archive 2001). The next two years saw the first major fragmentation, with the rise of the cement production industry, (Dartford Archive 2001). When the cement industry ceased production, the industrial areas reverted to derelict marshland, although the inference is that they were not returned to grazing (ibid). During this post World War 2 period Stone Marsh covered an area of 320 acres and extended along the riverside to the village of Greenhithe. The grasslands of Stone Marsh were described as being of high botanical interest with a high number of rare species (Anon 1976). In 1980, the Marshes were described as having a high level of habitat diversity (KWT *pers. com.*), although a survey of the species indicates that ruderals were beginning to become predominant.

Fig 4.15 and 4.16 shows the current remnants of Stone Marsh. Today much of Stone Marsh has been used for development of light industrial units and modern offices and very little of the original grazing marsh is in evidence. Undeveloped areas have largely reverted to scrub and are dominated by ruderal plant species, such as white melilot (*Melilotus alba*) and Canadian fleabane (*Conyza canadensis*).

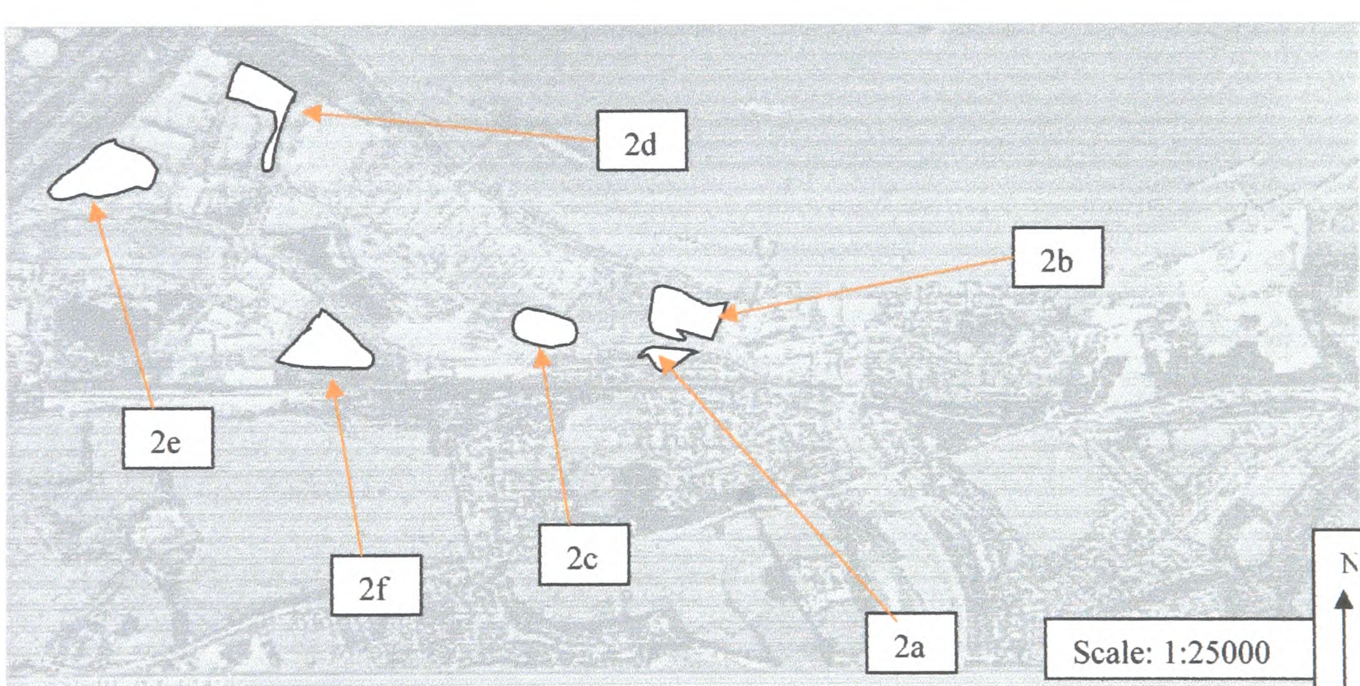


Fig 4.15 The current status of Stone Marsh, showing the individual fragments.

Drainage ditches remain as evidence of the existence of former grazing marsh, but these are isolated and fragmented. Mostly lying along the western and northern edges of the marsh, the ditches are beginning to become overgrown by emergent vegetation. Two ditches remaining in the eastern part of the marsh lie in separate small fragments recently separated from the main area by Crossways Boulevard, both are unmanaged and dominated by *Phragmites australis*.

Fig 4.16 Development on Stone Marsh.

The other remaining characteristic of the former Stone Marsh is the river embankment, which still forms a prominent feature above the general level of the surrounding land. The embankment comprises a sea wall and counter wall with a dry ditch, approximately ten metres wide, between the two walls. The floral composition of the embankments is typical of many of the riverside embankments found throughout North Kent. Sea Couch (*Elymus pungens*) is the predominant species on the river side of the embankment. The ditch between the two banks comprises species tolerant of the intermittent waterlogging that occurs and includes yarrow (*Achillea millefolium*), bird's-foot trefoil (*Lotus corniculatus*), black meddick (*Medicago lupulina*) and hare's-foot clover (*Trifolium arvense*) are amongst the more common species found on the embankment. Amongst the more specialist species pepper saxifrage (*Silaum silaus*) occurs as a prominent feature. Parts of the embankment are beginning to be colonised by Japanese Knotweed (*Reynoutria japonica*). Additional management will be required in the near future if this species is not to overrun the remaining marshland fragment. Further building and road construction since the field studies were carried out have led to the almost complete destruction of the marshes.

4.4.5 Swanscombe/Botany Marsh.

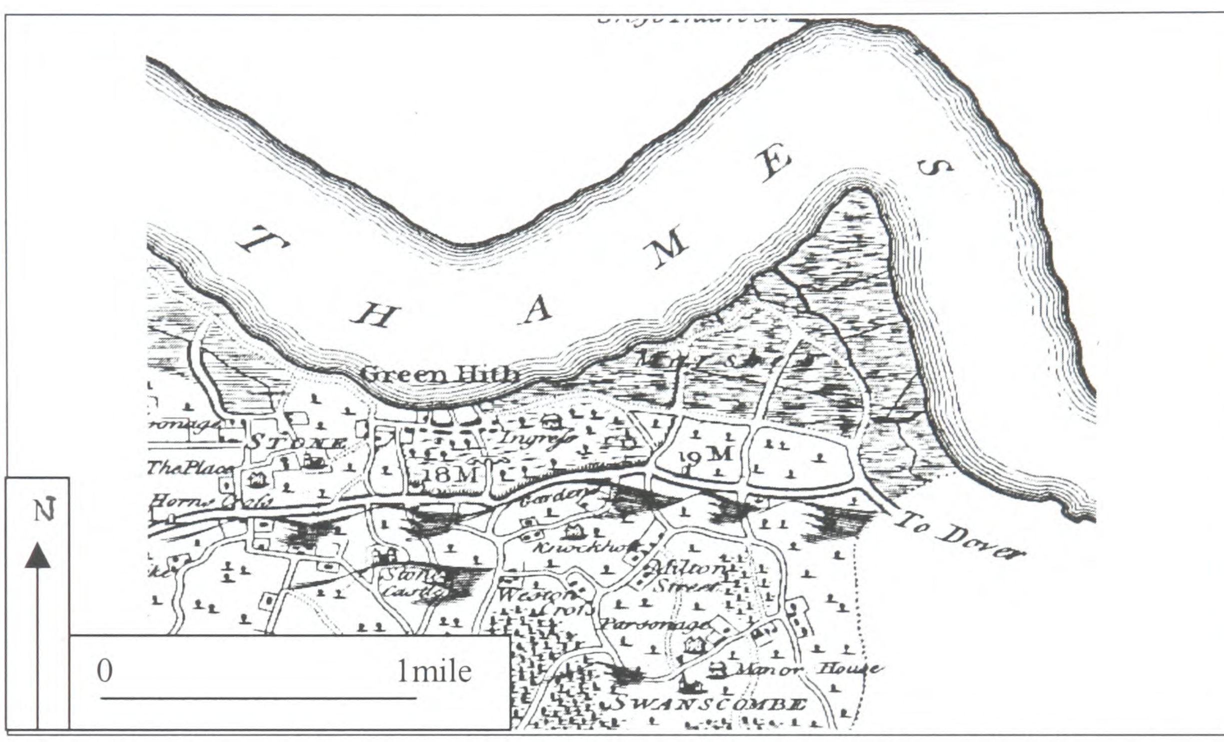


Fig 4.17 Swanscombe peninsula in1797, (after Hasted).

Fig 4.17 shows Swanscombe and Botany Marshes forming a peninsula of land encroaching into the River Thames as it loops northwards. The geological characteristics of North Kent indicate that the peninsula has always been naturally fragmented from the other North Kent Marshes. Both at Greenhithe to the west and Northfleet to the east outcrops of chalk extend out to the banks of the Thames. The northern extent of the peninsula, known as Broadness Saltmarsh, has been entirely reclaimed and is now used as a landfill site. Some restoration of the landfill site has occurred, but generally, the area is being reclaimed by ruderal species, although sea milkwort (*Glaux maritima*) was found to be present. The reclamation of this site has almost fragmented Swanscombe Marsh into two separate marshlands; there remains however, a narrow strip of marsh connecting the two fragments as well as two ditches and the embankment. Lack of management and continued development of scrub and succession will inevitably result in total fragmentation and two separate areas of marshland being created.

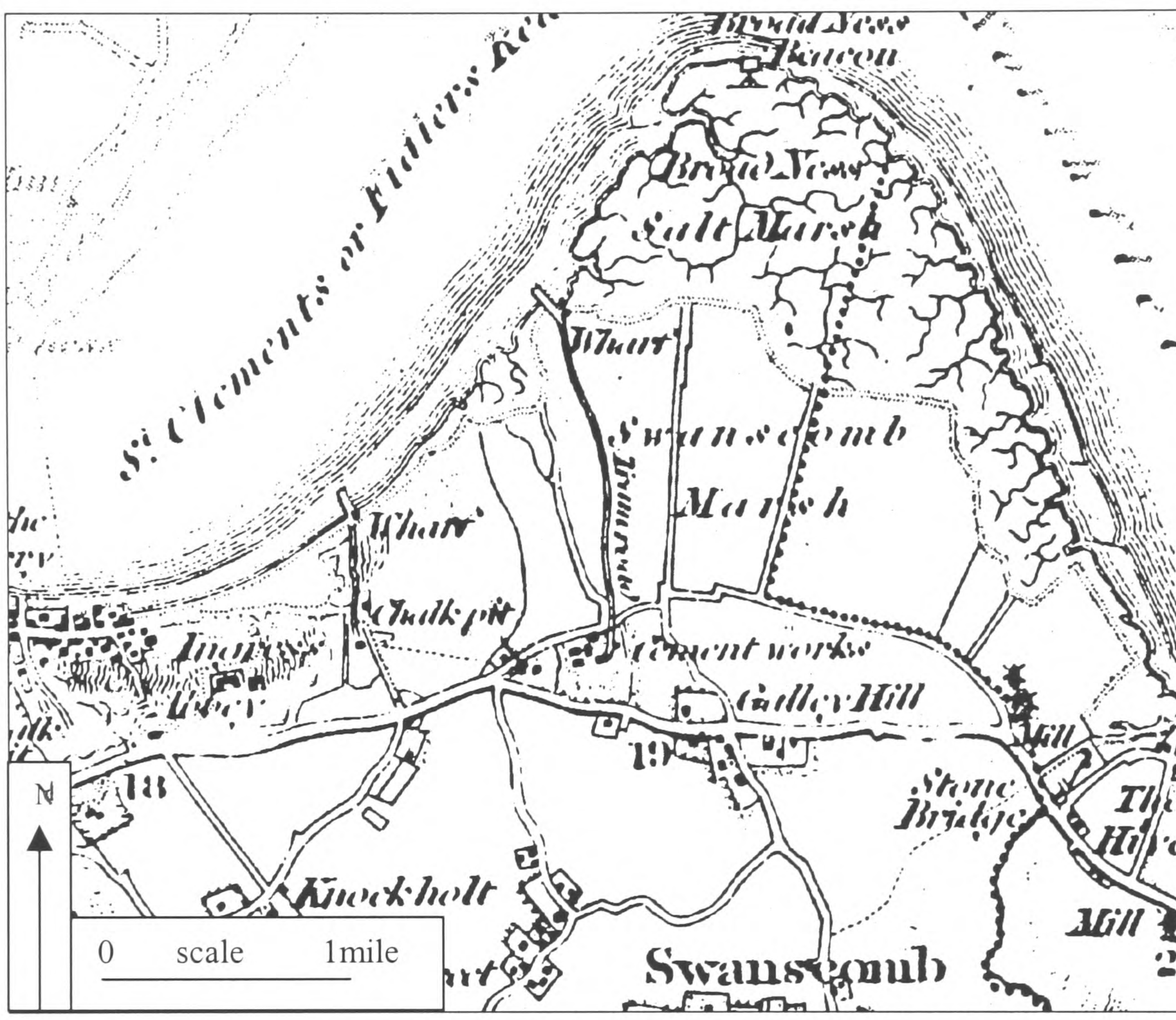


Fig 4.18 Swanscombe Peninsula in the late nineteenth century (from Hull)

A survey of grasslands (Stapledon and Davies 1940) classified Swanscombe Marsh as seaside and estuarine saltings. This indicates that prior to World War 2 there must have been a much greater saline influence on the marshes and more evidence of saltmarsh than currently exists. Where saltmarsh remains, in creeks on the north of the peninsula, it has been described as 'some of the best remaining saltmarsh in the Thames Estuary' (Anon 1976).

Botany Marsh has been converted to arable production, although the marsh is now under a set aside scheme, and at the time of surveying was unmanaged. The flora of the marsh now consists of a suite of ruderal species, e.g. bristly ox-tongue (*Picris echoides*), prickly lettuce (*Lactuca serriola*) and creeping thistle (*Cirsium arvense*) as well as reverting wild oat (*Avena fatua*).

The ditches on both Swanscombe and Botany Marsh have remained in a favourable if unmanaged condition. There is a good range of emergent vegetation in the ditches (Anon 1976), e.g. sea-club rush (*Scirpus maritimus*), water plantain (*Alisma plantago-aquatica*), bur-reed (*Sparganium spp.*) and common reed (*Phragmites australis*) are all present in all the ditches. These compare very favourably with some of the other Inner Thames Marshes, e.g. Crayford and Dartford, and it is probable therefore, that similar assemblages of invertebrates may be present, although no evidence of any surveys of either marsh flora or invertebrates were discovered.

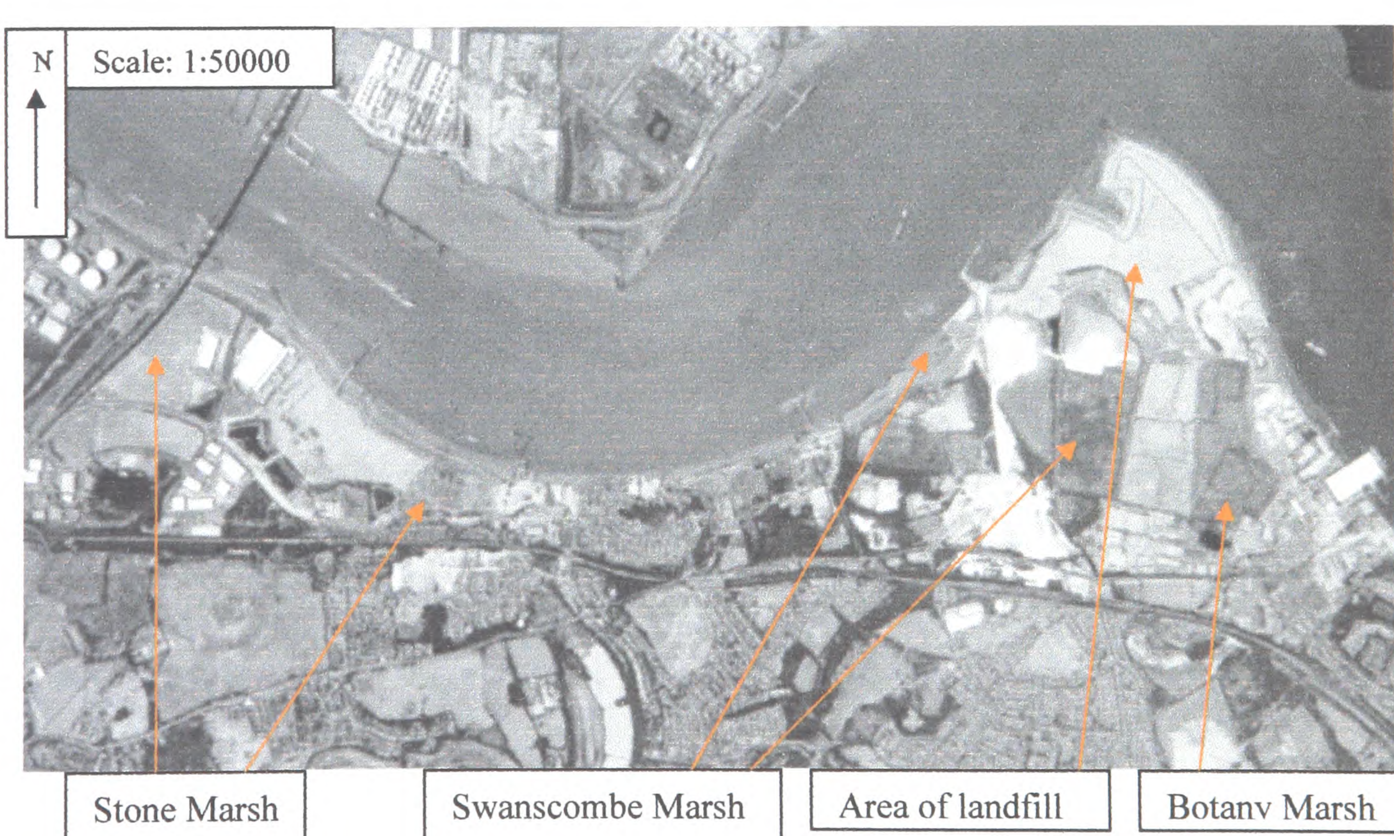


Fig 4.19 The current status of the Swanscombe Peninsula.

Waterlogging is evident in two separate areas of Swanscombe Marsh probably resulting from the effects of landfill operations. Ground conditions have allowed the development of an area dominated by *P. australis*, with hard rush (*Juncus inflexus*) and soft rush (*J. effusus*) common. The second area is showing evidence of hydroseral succession with white willow (*Salix alba*) becoming common. Figs 4.19 and 4.20 show the current extent of Swanscombe and Botany Marsh.

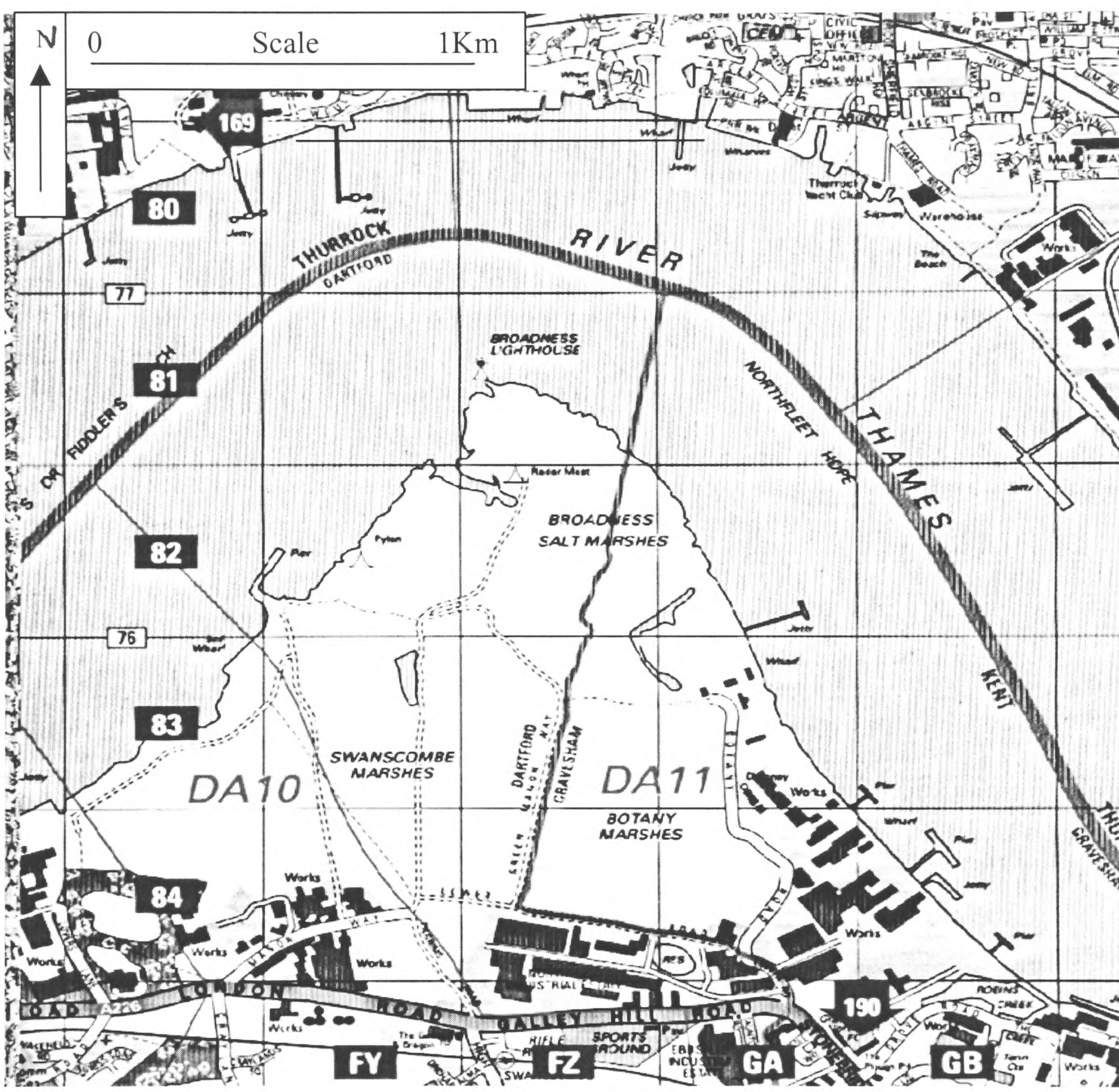


Fig 4.20 The current status of Swanscombe and Botany Marshes, (from Collins).

4.4.6 Denton Marsh.

Denton Wharf and the entrance to the now abandoned Thames–Medway Canal now separate Denton Marsh to the east of Gravesend from the banks of the Thames (Fig

4.21). Prior to the construction of the wharf in the late nineteenth century, the marsh would have been continuous with Shorne, Filborough, Great Clane and West Court Marshes. Denton is also the place where reputedly Pip smuggled the convict Magwitch out of the country in Dicken's Great Expectations (Baldwin 1984). There are however, very few references to the history of Denton Marsh in the literature, although it is recorded in Bull (1992) that Denton and Westcourt Marshes were grazed by dairy cattle prior to the last war, although, by 1935 much of the land had been sold to Gravesend Council for housing development.

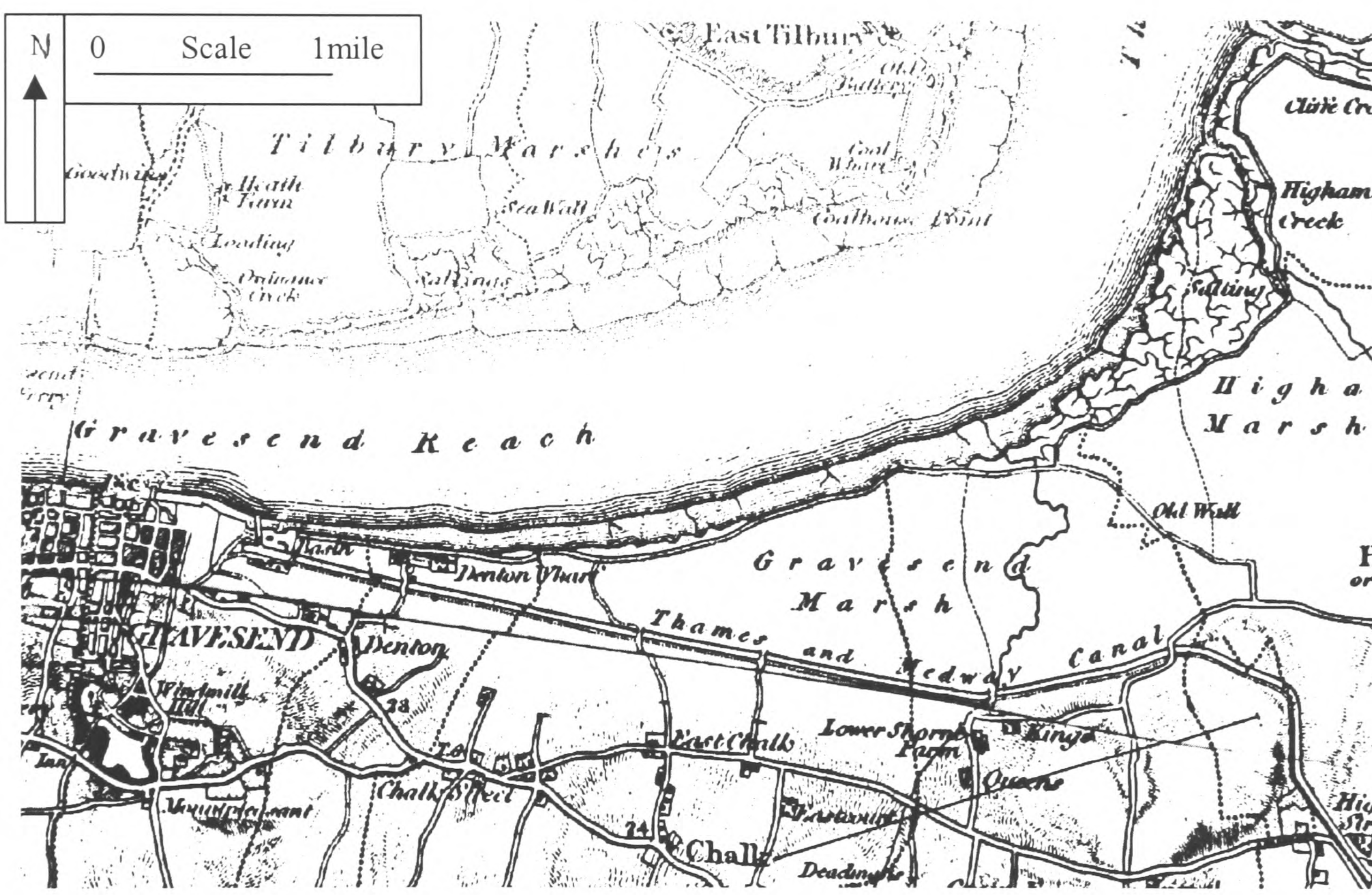


Fig 4.21 Gravesend Marsh (now Shorne and Eastcourt Marshes), showing division by the Thames-Medway Canal, (from Hull).

Denton Marsh is surrounded by post World War II development surviving as an unmanaged area of neutral grassland. Vegetation still shows evidence of semi-improved neutral grasslands through the presence of rye grass (*Lolium perenne*), crested dog's-tail (*Cynosurus cristatus*), bent grass (*Agrostis spp*) and clover (*Trifolium spp.*). Large stands of ruderals, e.g. dock (*Rumex spp.*), plantains (*Plantago spp.*), bristly oxtongue (*Picris echoides*) and prickly lettuce (*Lactuca serriola*) are more prominent on Denton Marsh than the other Outer Thames Marshes. The lack of recent management has led to the marsh becoming used as a dump by fly-tippers, although there have been efforts made to control the dumping. An area of 5 acres (2ha) to the north of the marsh has been set aside for restoration, but again a lack of organised management has allowed this area to become overgrown by ruderals and emergent aquatic plant species.

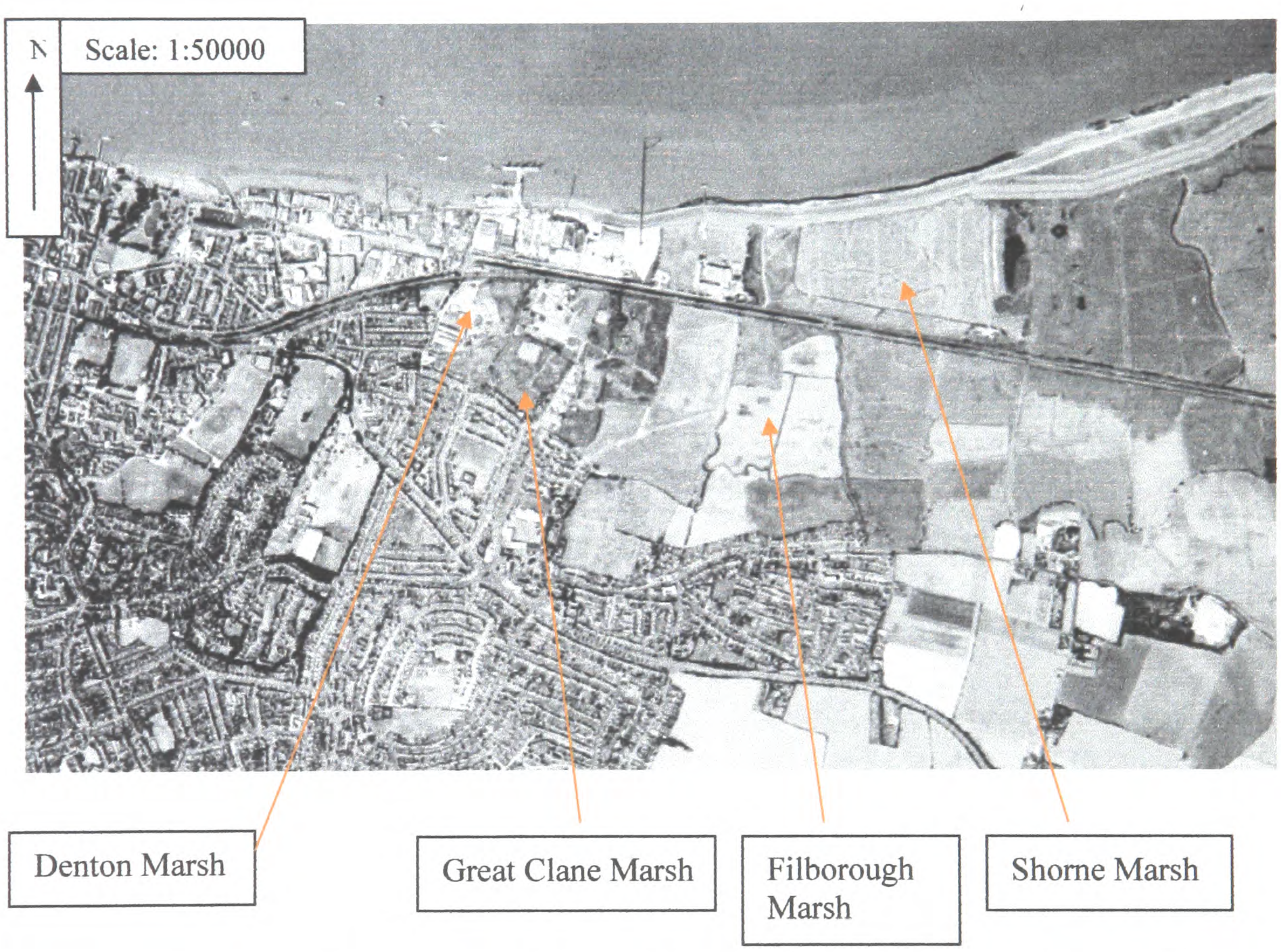


Fig 4.22 The current status of Denton, Great Clane, Filborough Marshes.

<u>4.4.7 Filborough Marsh</u>.

Filborough Marsh (Fig 4.22 & 4.23) was isolated from the larger Shorne and Higham Marsh system by the construction of the Thames Medway canal (Fig 4.21), a boundary that was subsequently enlarged with the arrival of the North Kent Railway Line. As late as the 1960's Filborough Marsh formed a continuous marshland system with Great Clane, Westcourt and Denton Marshes. The encroachment of post war housing and related infrastructure resulted in the isolation of Denton Marsh and the conversion of Great Clane Marsh to arable production have been responsible for the fragmentation of this once continuous system of marshes. There is no other evidence in the literature as to the history of Filborough Marsh.

The area of Filborough Marsh has remained constant throughout the study period and only its separation from the other marshes has affected its integrity. Today the marsh management is primarily through grazing by cattle with associated hay production and comprises semi-improved grasslands dominated by rye grass (*Lolium perenne*), meadow barley (*Hordeum secalinum*) and bents (*Agrostis spp.*). The perimeters (edges) are largely unmanaged hedge, primarily hawthorn (*Crateagus monogyna*), which provides a barrier between Filborough Marsh and the arable fields of Great Clane Marsh to the west and the road to the south. The northern edge of Filborough Marsh, adjacent to the railway line a suite of ruderal species has become established, one of the features of edge effects (see Sections 6.8.2 and 8.4). Dredging from ditch management has been left to form bunds alongside the ditches, and these have provided a habitat for nettle (*Urtica dioica*), and creeping thistle (*Cirsium arvense*) to become established, from where they are beginning to encroach onto the main areas of marshland.

The ditches on Filborough Marsh are maintained and all have a range of emergent vegetation that is similar to other marshes of North Kent, e.g. common reed (*Phragmites australis*), sea club rush (*Scirpus maritimus*), soft hornwort (*Ceratophyllum submersum*) and spiked water-milfoil (*Myriophyllum spicatum*).

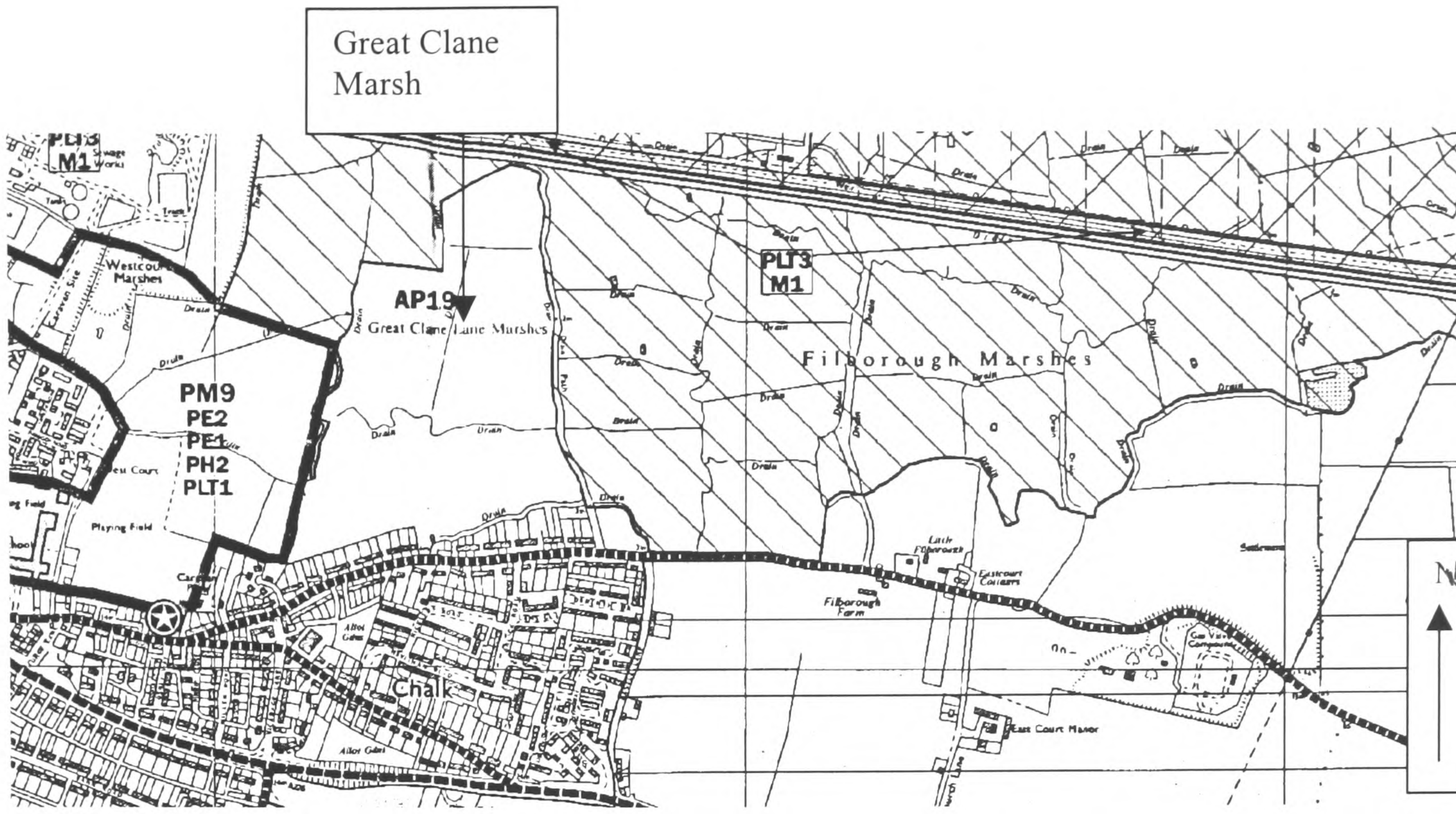


Fig 4.23 The current status of Filborough and Great Clane Marshes, (not to scale).

4.4.8 Shorne Marsh.

Fig 4.21 shows Shorne and Higham Marshes at the end of the nineteenth century, when the former was known as Gravesend Marsh. Shorne Marsh (Fig 4.22) forms the westerly extent of both the North Kent Marshes Environmentally Sensitive Area and Thames Estuary and Marshes SSSI, and is contiguous with Higham Marsh. Separation from the westerly marshes of Westcourt and southerly Filborough occurred with the construction of the railway and canal in 1842, as previously referred to. There is little documented historical account of Shorne Marsh, with the exception of the recognition that the marshes were a weak link in the defence of the country and so therefore Shornemead Fort was built in 1796. There is some evidence recorded in Bull 1992 that Eastcourt Marsh, (now incorporated in Shorne Marsh), at the beginning of the twentieth century were used for market gardening as opposed to grazing, but since the end of the Second World War, grazing has been the main use of Shorne Marsh.

Shorne Marsh is grazed by cattle on the easterly areas and the sward, which is rough and tussocky is dominated by the perennial grasses such as, rye grass (*Lolium perenne*), crested dog's tail (*Cynosurus cristatus*), meadow barley (*Hordeum secalinum*) and creeping bent (*Agrostis stolonifera*). The rare and characteristic divided sedge (*Carex divisa*) is also present. Scattered hawthorn scrub however, is increasingly developing in isolated stands, which is resulting in the drying out of some ditches and a reduced botanical interest associated with areas where rills and ditches have dried out (RSPB *pers com.*). The increased scrub was also recorded as reducing the amount of suitable habitat for target bird species (ibid).

The ditches vary from those that are well maintained showing a good range of emergent vegetation, to those subsidiary ditches which are often species poor, particularly to the west of the site, where they have become choked or dried out. Greater botanical interest appears to coincide with the deep, wide main channels. English Nature (1994) reported in a study of the Shorne Marsh ditches that modification had occurred to two ditches by the installation of a main drainage channel running east west across the site, and that this had probably resulted in a decrease in the number of saline emergents present in them. The RSPB (*pers com.*) however reported that the ditches held some of the best aquatic flora on the North Kent Marshes. The ditches of Shorne Marsh were also recorded as providing habitat for water vole (*Arvicola terrestris*) and the scarce emerald damselfly (*Lestes sponsa*) (ibid).

The recent purchase of the Milton rifle ranges (Fig 4.24) by the RSPB will lead to an increase of the grazing marsh areas of Shorne Marsh. Management has already commenced (RSPB *pers com*), which has involved the clearance of hawthorn scrub and the excavation of dried up and choked ditches to improve the water levels.

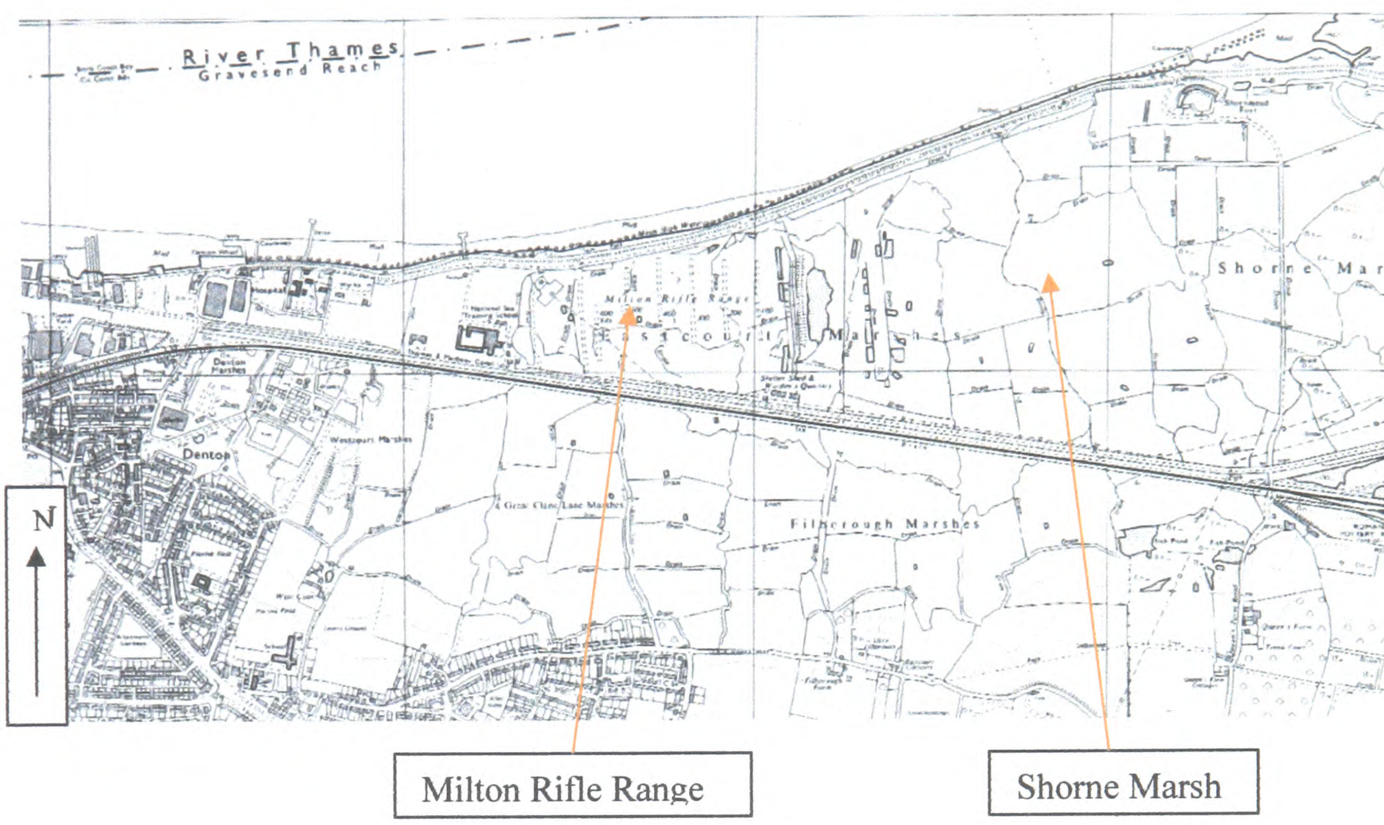


Fig 4.24 Shorne Marsh showing the Milton Rifle Range (recently purchased by RSPB), [not to scale]

4.4.9 Higham Marsh.

Higham Marsh (Fig 4.21 and 4.25) retains much of the traditional grazing marsh character of flat, open pasture with 'huge skies' and extensive views, expressed by Hasted (1797) and Dickens (1861). There is no other recorded history of the marshes documented. The industrial complex of Canvey Island forms a backdrop to these views, but due to the dividing presence of the River Thames, the marshland landscape is not overwhelmed and dominated. Fig 4.25 shows the current layout of Higham Marsh.

Fig 4.25 The current status of Higham Marsh, showing the individual fragments.

Typical characteristics of grazing marsh are the rough tussocky semi-natural grassland, currently predominantly grazed by cattle. The grasslands are predominantly semi-improved neutral and dominated by perennial grasses such as rye grass (*Lolium perenne*), crested dogstail (*Cynosurus cristatus*), meadow barley (*Hordeum secalinum*), timothy (*Phleum bertolonii*) and creeping bent (*Agrostis stolonifera*). The pattern of drainage ditches, dykes, embankments and counter walls are also typical of the North Kent Marshes.

There is evidence however, that some areas are currently undergrazed and that the lack of management is causing change to the grazing marsh structure. The presence of shrubs and trees, most notably hawthorn (*Crateagus monogyna*) being evident particularly either side of the causeway where they have colonised the unmanaged ditches. These western reaches of the marsh are similar in character to the adjacent reduction in the botanical interest of ditches and decline in the amount of surface water are also affecting Higham Marsh.

4.4.10 Cliffe Marsh.

The cement industry developed in the North Kent region due to the availability and abundance of raw materials. The upper chalk outcrops in this area are particularly suitable for cement making, being largely free of flints and thick overburden of gravels and sand. The other major raw material is clay and the alluvium of the flood plain has long provided a source of this material. Cliffe Marsh was a particularly good early source. The location of these raw materials close to the River Thames was also an attraction as it provided easy access for movement of materials.

In 1860, the Cliffe Cement Works were established using local chalk and clay from the Medway estuary. Francis and Sons superseded the Cliffe Cement Company and continued the cement making tradition that had been established. The use of chalk in industry has played a major part in the development of Cliffe Marsh. In 1793, a canal was built linking Cliffe Creek to the quarries to carry the quarried chalk to the main river artery, one of the first human induced fragmentation events recorded. In the 1930's, during a period of agricultural recession, Associated Portland Cement bought large areas of Cliffe Marsh as a source of clay for extraction and use in the cement industry. The development and expansion of the cement industry and the resulting extraction of mud during the late nineteenth century resulted in massive erosion of the marshes, and resulted in a lowering of the water table due to the constant sinking of wells, (Cracknell 1953).

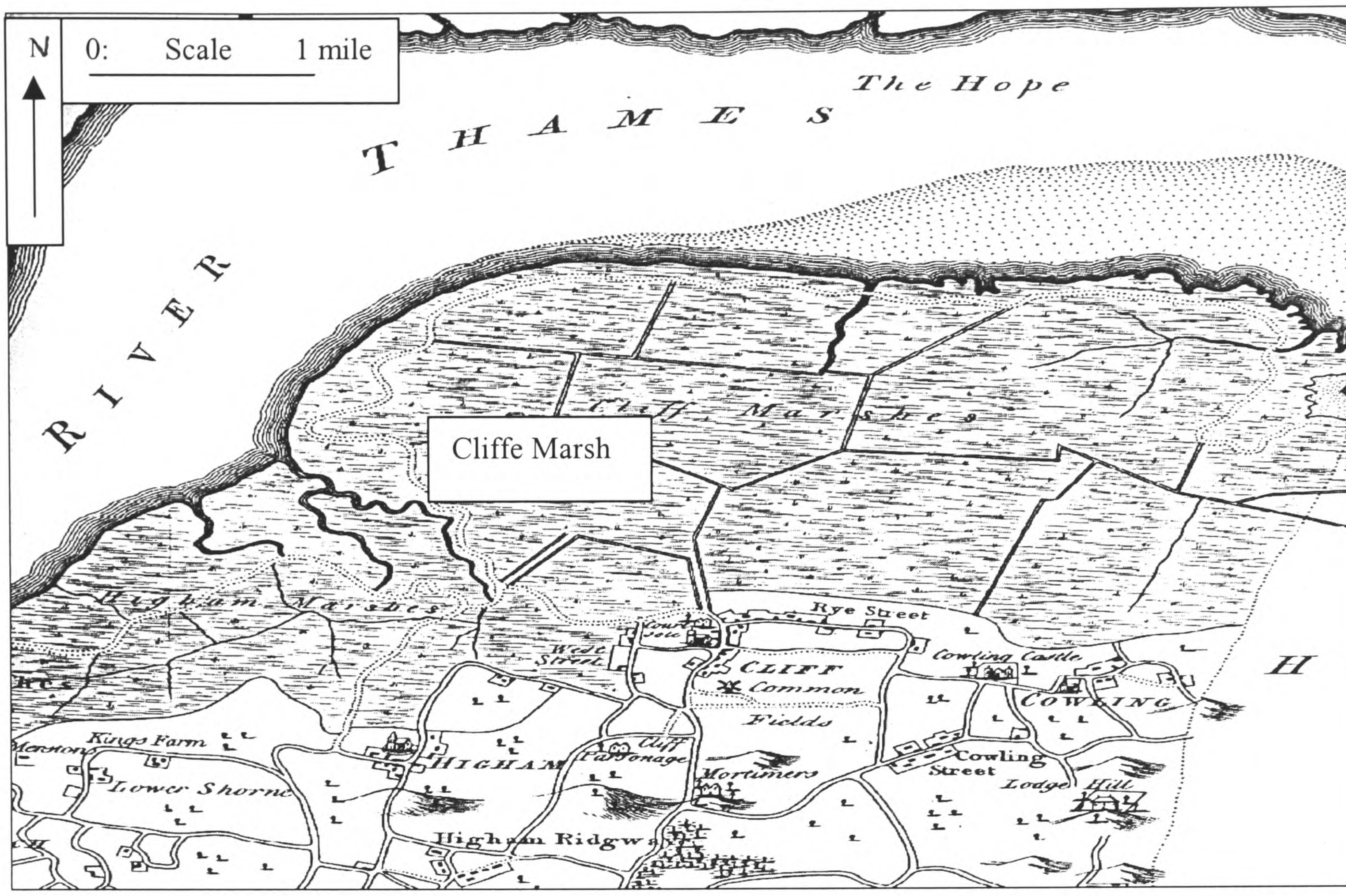


Fig 4.26 Cliffe Marsh in 1797 (after Hasted).

In 1901, Curtiss and Harvey Ltd. proposed the erection of a factory on Cliffe Marsh using the old battery site. In 1907, sixty acres were purchased and developed as a factory together with the construction of two jetties and a loading wharf. The access road to the site and the trees that were planted as protection to the surrounding area are still present today, and together with the ruins of some of the buildings are all that remain of the industry, which ceased production in 1922.

Cliffe Marsh (Fig 4.26 and 4.27) is the largest surviving area of grazing marsh within the study area, although it has incurred a number of fragmenting events. They form part of a much larger contiguous system along with Cooling Marsh, which covers some 1530 ha bordering the south side of the Thames estuary. Both grazing marshes lie behind the reconstructed sea wall, rebuilt after the great flood of 1953, which is in all probability causing a change in the salinity of both marshes, which Ratcliffe (1977) referred to as having been converted to neutral grasslands.

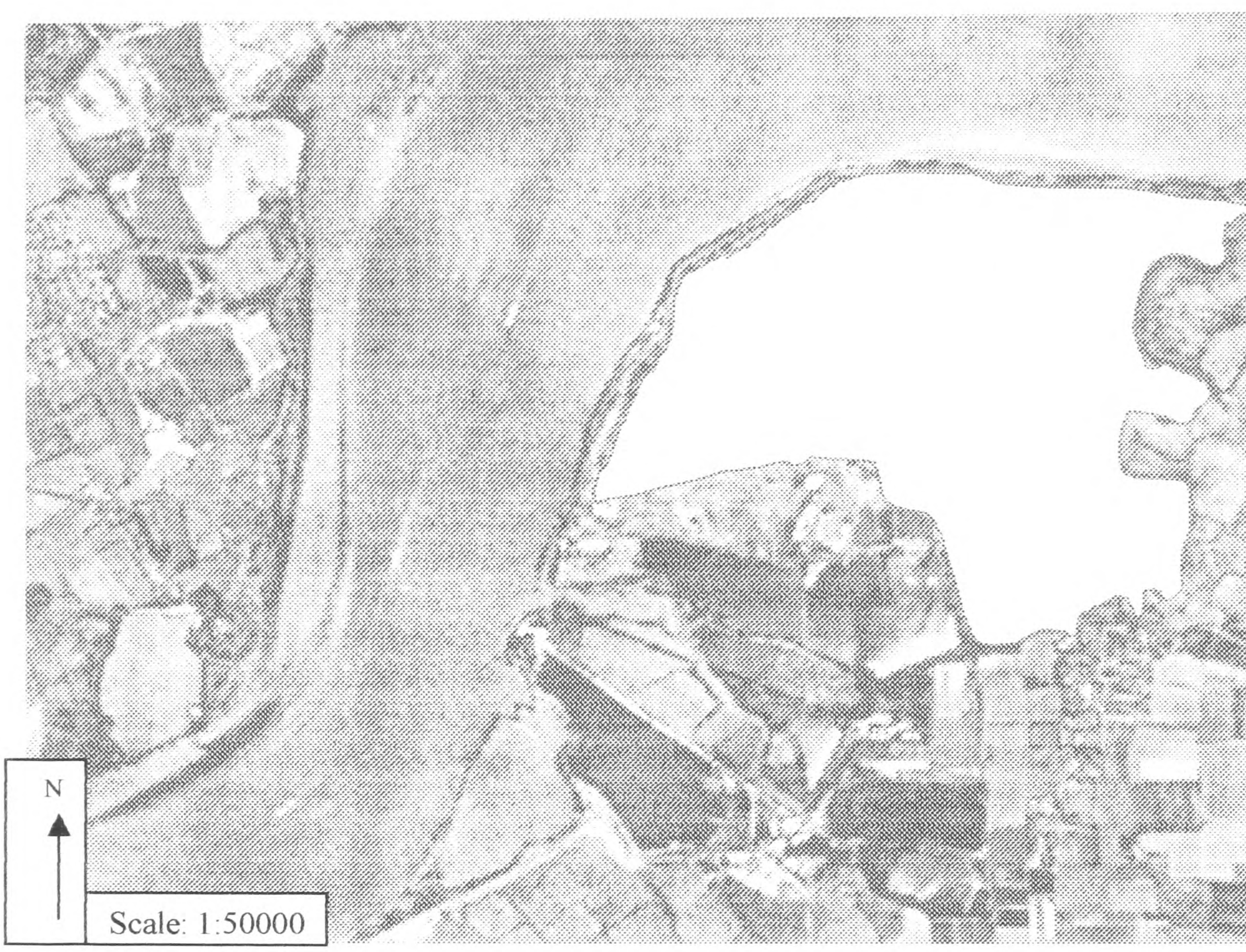


Fig 4.27 The current status of Cliffe Marsh.

Management of Cliffe Marsh is carried out under proscriptions, which emanate from being part of the North Kent Marshes Environmentally Sensitive Area (ESA). Both cattle and sheep are grazed on Cliffe Marsh, with sheep being the main grazer, although the level of grazing is at present below the ESA proscription. The current economic situation in the beef market has meant that the number of cattle has fallen in recent years due to the BSE debate and the discontinuation of cattle grazing by one of the graziers on parts of the marsh, (Elliot *pers com.*).

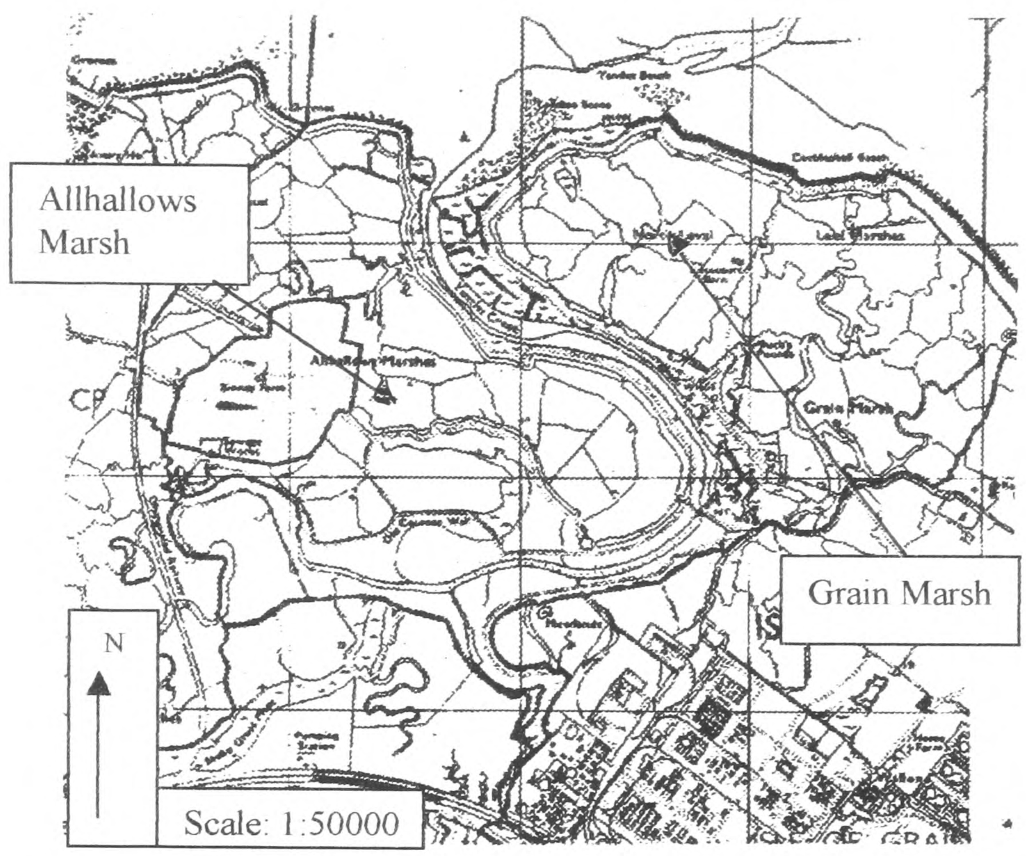
4.4.11 Allhallows Marsh.

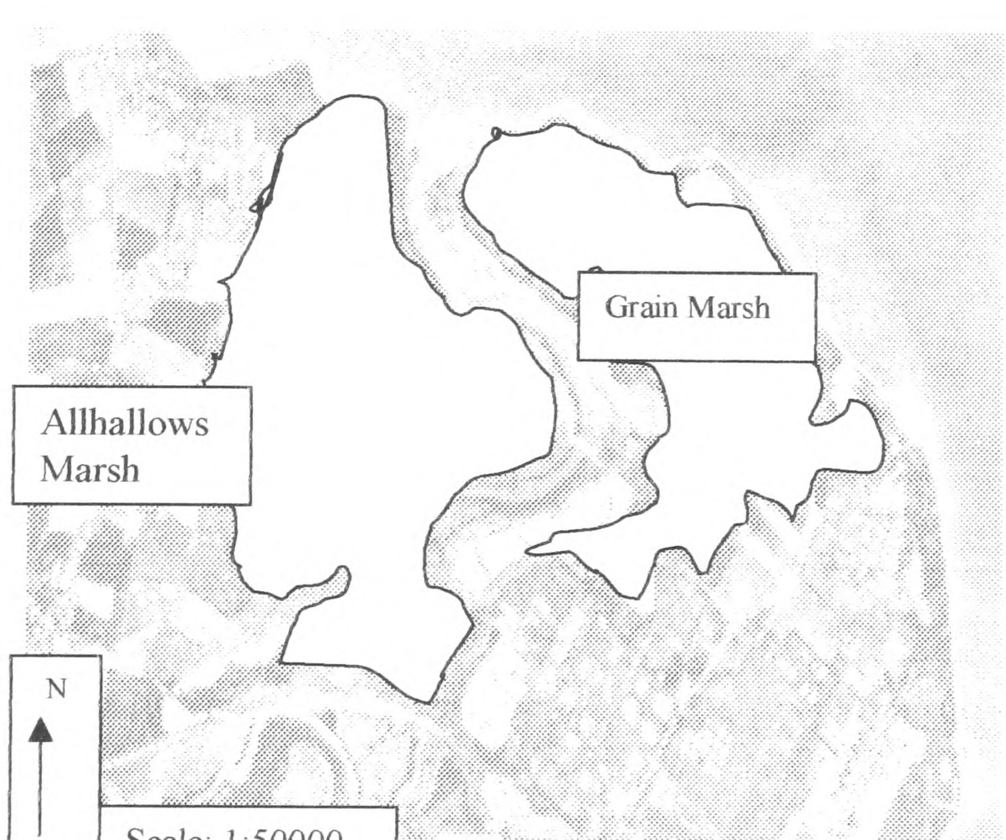
There is little literature concerning the history of Allhallows Marsh, which according to the Historic Kent Archive has been regarded as an agricultural outpost. Figs 4.26 and 4.27 show the extent of Allhallows Marsh at the time of Hasted and currently. Allhallows Marsh forms part of the North Kent Marshes Environmentally Sensitive Area and falls within the Hoo Peninsula Special Landscape Area. Cattle predominantly graze Allhallows Marsh with an area around Binney Farm given over to arable production. Allhallows Marsh now comprises an area of some 500ha of predominantly non-saline grazing marsh (Ratcliffe 1977), primarily of ornithological interest. According to Ratcliffe (1977), the area is the main site in this country for annual beard – grass (*Polypogon monspeliensis*).

The villages of Allhallows and Lower Stoke and the connecting infra structure separates Allhallows Marsh from St. Mary's Marsh in the west and Yantlet Creek forms the eastern boundary separating the marsh from Grain Marsh. The main A228 road to the south provides a boundary to the southern marshes of the Isle of Grain. Development of a Holiday Camp in the 1930's has been the only threat to the integrity of Allhallows Marsh, and although remaining the camp never became the major attraction that it was intended to be.

4.4.12 Grain Marsh.

There is little recorded history of Grain Marsh before the nineteenth century, when the area received royal patronage, although this resulted in the construction of road and rail links, which began to fragment the marshes. The petrochemical industry has been responsible for the further fragmentation and loss of the marshes on the east end of the Isle of Grain. MacDougall (1980) records that oil was first bought to the peninsula by the Admiralty in 1908, and since this time construction of storage facilities and infrastructure has continued to erode the area of grazing marsh.





Figs 4.28 a & b The current status of Allhallows and Grain Marshes.

Following the Second World War, development of oil refineries in 1944 and 1953 and the Kingsnorth Power Station in 1954, has brought about the largest loss of large areas of marshland (Section 6.2.1).

The remaining grazing marsh is situated at the east end of the Hoo Peninsula (Fig 4.28a & b), and is owned by the Ministry of Defence and maintained for their purposes. The marsh remains part of the North Kent Marshes ESA, and is grazed, primarily by cattle, but is currently showing signs of under management.

4.4.13 Chetney Marsh.

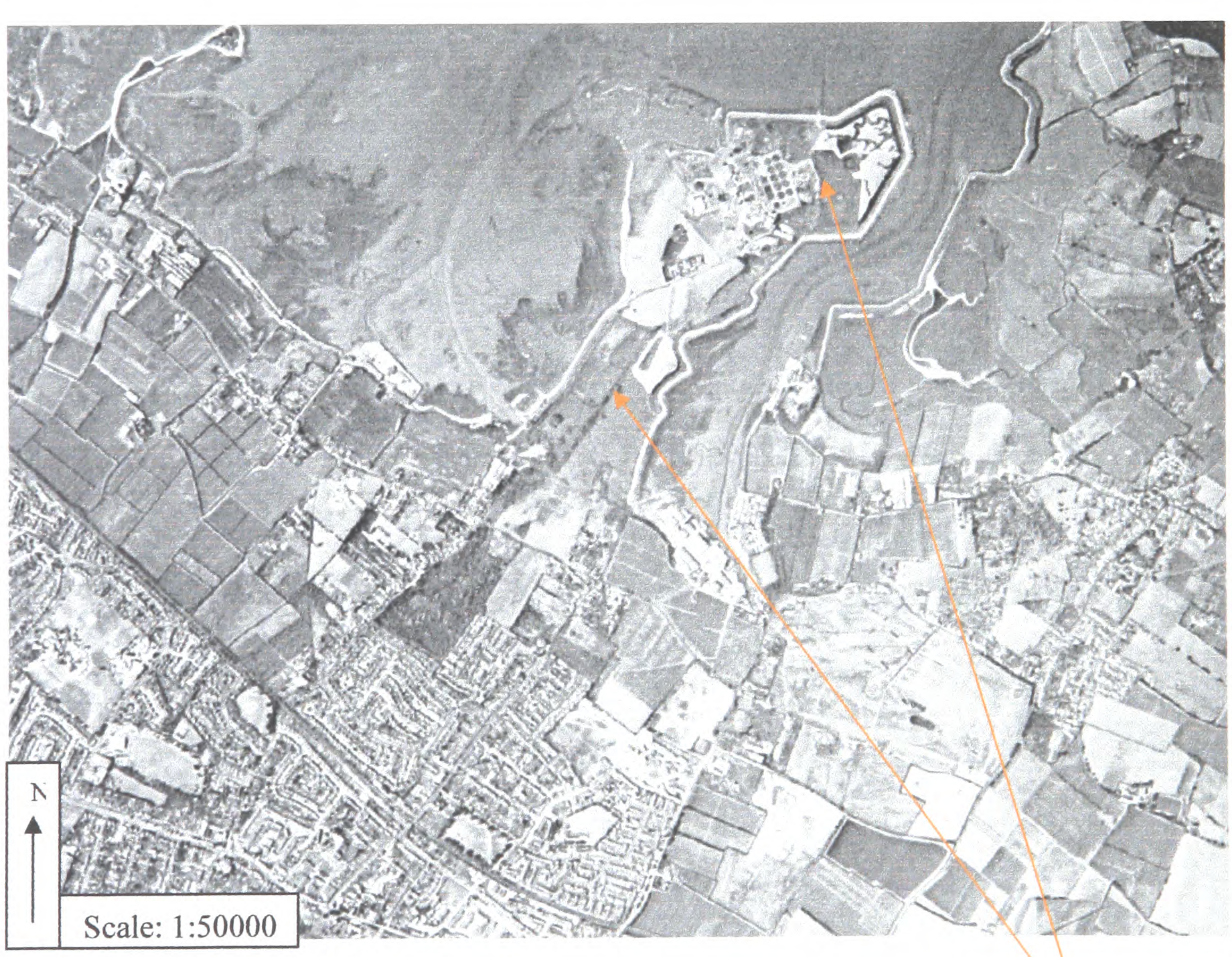


Fig 4.29 The current status of Chetney Marsh

Chetney Marsh (Fig 4.29) forms a peninsula of some 520ha, which protrudes into the Medway estuary and forms a boundary separating the western part of the Swale from the estuary. Harrison (1970) records that the final enclosure of the marsh was not completed until the mid nineteenth century, although reclamation is thought to have started in Roman times (Williams et al 1983). Prior to 1972, the peninsula was primarily used for sheep grazing. After this date, a substantial area was under-drained and converted to arable, with 40% of the area having been converted by 1982 (Williams et al 1983). There was also a change in the grazing regime with cattle superseding sheep during the same period. Cattle grazing are now the major occupation on Chetney Marsh and have largely replaced arable production. English Nature now manages land on the north of the peninsula as a bird reserve.

4.5 The area and changes in area of the North Kent Marshes.

Kent contains only some 3% of the total grazing marsh area of the UK, but overall 25% of the semi-natural grazing marsh, (Kent Biodiversity Action Plan 1997). The North Kent Marshes are now diminishing in area; Thornton and Kite (1990) recorded a decrease of 65% in the size of the Inner Thames Marshes between 1935 and 1989. In terms of area, this equates to a decline from 13300 ha of grazing marsh in 1935 to some 4600 ha in 1989. Doody et al (1991) stated that 75% of all grazing marsh in the greater Thames estuary has been lost since World War 2. There is still much disagreement however, over what area of grazing marsh remains and as to what the maximum extent of grazing marsh in North Kent, e.g. 4877.4 ha recorded in the Kent Habitat Survey and 6176ha recorded by ADAS in the ESA report.

Studies of land cover changes in Kent show that 54.8% of grazing marsh recorded in 1961 had been lost by 1990, 53% of this loss was due a change to arable land (KCC 1995). During the period 1935 – 1989, Thornton and Kite (1990), however state that the most important causes of decline in grazing marsh were conversion to urban land use and arable farmland, which were responsible for 35% and 25% decline respectively. Table 3.2 shows the areas of land-use to which grazing marsh has been converted, according to Thornton and Kite (1990).

The Kent Wildlife Habitat Survey (KCC 1995) identified 4877.4 ha of semi-natural grazing marsh throughout Kent, which was then further sub-divided into two major categories, neutral grassland comprising 2255.6ha mainly found around the Swale estuary. The remaining, 2621.8 ha, was categorised as semi-improved neutral grassland, which were found throughout the remainder of North Kent, i.e. Cliffe, Shorne, Higham, and Dartford. The total of semi-improved grazing marsh in the Kent Habitat Survey is comparable to the area of remaining marsh established by Thornton and Kite (1990) at 2634ha, although exact comparisons are difficult to make, as the areas covered by the two studies are different.

The reduction of grazing marsh across North Kent has been an ongoing process since the beginning of the twentieth century, although the loss of grazing marsh has not proceeded at a constant rate; neither has it been consistent throughout the region. According to Thornton and Kite (1990), the peak period in the rate of reduction occurred between 1968 and 1972, with losses of 320 hectares per year. Table 4.1 shows the change in extent of the Thames estuary grazing marsh between 1935 and 1989.

Since 1982, the loss of grazing marsh has generally stopped and there has in fact been a small increase in the overall area (Thornton and Kite 1990). Increases have largely been through the negotiation of management agreements, notably through the ESA scheme, and through the RSPB reserve at Northward Hill, where 248 hectares of arable land is being converted back to grazing marsh. Losses to grazing marshes are however; still occurring e.g. Stone Marsh, where former marshland has been built on during the preparation of this thesis. Further increases in grazing marsh area are now anticipated through the targeting of areas for restoration and re-creation by English Nature (Mountford et al 1999). The Kent Biodiversity Action Plan (1997) meanwhile has set a target of an additional 4253 ha of grazing marsh in the next fifty years, the majority of which (70%), is to be converted from amenity and improved grasslands

Table 4.1 The change in extent of grazing marsh in North Kent 1935 -1989 (after Thornton and Kite 1990).

	1935	1968	1972	1981	1989
Grazing marsh surviving from previous date.	4899	4076	3551	2470	2328
Area converted to grazing marsh.		37	17	80	306
Total area of grazing marsh	4899	4113	3568	2550	2634
Per cent of 1935 grazing marsh area.	100	84	73	52	54

Whilst much attention has been drawn to the physical loss of grazing marsh within the North Kent Marshes, other influential changes, brought about by urbanisation and intensified agriculture have occurred. Cobham (1995) has highlighted these in his descriptions of the North Kent Marshes (Section 1.2). One notable feature is the increase in visual intrusion particularly from overhead transmission lines, which have led to classifications of many of the North Kent Grazing Marsh landscapes as being either urban/industrial influence or urban/industrial dominance.

Losses of grazing marsh have not been confined to agricultural intensification or industrialisation. Crayford and Swanscombe Marshes are examples of losses where former marshland has been used for landfill operations. Landscaped mounds have intruded upon the open flat landscape, which in the case of Crayford Marsh is being predominantly re-sown with perennial rye grass (*Lolium perenne*), and at Swanscombe overgrown with many ruderal species. Such intrusions result in the loss of the traditional open marshland character as well as the landscape features discussed in Section 3.1.1.

In the past land drainage and agricultural improvements have been the major causes of loss to traditional marsh areas. Benstead et al (1997) estimates that 69% of losses are because of conversion to arable, with a further 28% lost to the built environment. Whilst Thornton and Kite (1990) record that since 1935, 50% of grazing marsh has been lost to urban development and 36% to agricultural expansion. In addition to this overall habitat loss, there has also been considerable fragmentation of the once almost continuous marshes. By 1989 only nine sites of over 100 hectares remained, the rest being a preponderance of small relict sites, (Thornton and Kite 1990). Together with the decline and neglect of traditional marshland features, ditches, timber fences etc., there is a gradual eroding of the wild and unspoilt character of the North Kent landscapes, i.e. there is a loss of both area and quality.

4.6 The Importance of the North Kent Marshes.

Table 1.1, in Section 1.1, showed the conservation designations granted to the North Kent Marshes highlighting their importance. The designations acknowledge the declining nature of grazing marsh as a national resource and recognition of their value as an internationally important conservation area. The North Kent Marshes are also an important constituent of the Greater Thames complex of tidal channel, saltmarsh, intertidal mudflat and grazing marshes. Clarke et al (1991) stated that the Greater Thames Estuary is one of the five most important areas for wintering waders in Europe. Furthermore, the North Kent Marshes study estimates that the Medway and Swale areas are responsible for 37% of the total for wintering waders (AERC 1992).

Twenty-six species of breeding bird have important populations within the Greater Thames, which includes the North Kent Marshes, including pintail (*Anas acuta*), garganey (*Anas querquedula*), pochard (*Aythya farina*), avocet (*Recurvirostra avosetta*), ruff (*Philomachus pugnax*), black–tailed godwit (*Limosa limosa*), redshank (*Tringa tetanus*) and lapwing (*Vanellus vanellus*) (Clarke et al 1991). In recognition of this importance the North Kent Marshes are recognised as a Special Protection Area (SPA) under the EC Birds Directive 79/409/EEC and as a Ramsar site of international importance. Blake and Carr (1987) suggested however, that over wintering and migratory bird species were more affected by fragmentation, which would suggest that fragmentation of the North Kent Marshes may have adverse effects on the large bird populations which over winter on them. Further fragmentation of the North Kent Marshes should therefore be avoided if these designations are to remain meaningful.

Williams et al (1983), using Chetney Marsh as an example, showed that the process of converting grazing marsh to arable production was having a detrimental effect on the number of breeding wetland birds, particularly wildfowl, redshank and lapwing. The main reason for the change in bird numbers was that the area was being rendered unsuitable for nesting because of the loss of grazing marsh features such as tussocky grassland and rills (ibid).

A major feature of grazing marshes is the presence of numerous ditches, which were constructed as drainage to control water levels and wet fences to control stock movement. The ditches provide a habitat to a variety of aquatic plant species and invertebrates, which, contribute to the conservation importance of the North Kent Marshes. Surveys of the ditch communities, e.g. English Field Unit (1981) and (1995), have highlighted the presence of rare and nationally scarce plant species. Three nationally rare species recorded in these surveys have been divided sedge (*Carex divisa*), small goosefoot (*Chenopodium chenopodiodies*) and water-soldier (*Stratiotes aloides*) (Gee 1998). The main reason for the importance of the ditches and the aquatic species found in them is the response of species to the salinity gradients found across the marshland sites. A feature that Gladding (1990) said was due to the 'extensive brackish influence' found on the North Kent Marshes.

Floristic interest is however, not confined to the ditch communities alone. Divided sedge (*Carex divisa*) has been found to be a consistent member of the grassland communities on many of the individual marshes (ADAS 1997). The Red Data Book species, the nationally rare marsh sowthistle (*Sonchus palustris*) was also found by the author on the Inner Thames Marshes during the course of this survey.

The river embankments and counter walls are another important habitat of the North Kent coastal marshes. Notable species found to occur here include least lettuce (*Lactuca saligna*), a species listed under Section 8 of the Wildlife and Countryside Act 1981, hog's fennel (*Peucedanum officinale*) and small red goosefoot (*Chenopodium botryodes*), both of which are nationally rare (Gee 1998).

The Inner Thames Marshes of Crayford and Dartford have been found to be of particular interest in respect of their invertebrate populations (Plant 1991, 1993). Both Red Data Book and nationally scarce species of Odonata, Lepidoptera, Coleoptera, Hymenoptera, Diptera and Arachnida have all been found to be present on these sites. Species recorded include both those favoured by freshwater conditions, such as the ruddy darter dragonfly (*Sympetrum sanguineum*) and brackish conditions, such as the water beetle *Ochthebius exaratus* (Plant 1991). A suite of invertebrate species is also associated with other habitat types often found within the coastal grazing marsh mosaic. Saltmarsh species such as the money spider (*Baryphyma duffeyi*), fen and reedswamp species, such as the silky wainscot moth (*Chilodes maritimus*), grassland species represented by the digger wasp (*Alysson lunicornis*) and the rare Roesel's bush cricket (*Metrioptera roeselii*) are also to be found within the Inner Thames Grazing Marshes (Plant 1991, 1993). The presence of these invertebrates has led to the recommendation that Crayford and Dartford marshes should become Sites of Special Scientific Interest (SSSI), (EN *pers com.*).

4.7 Traditional Management Uses in the North Kent Marshes.

The traditional uses of the North Kent Marshes involve a range of agricultural uses that include permanent pasture and rough grazing, together with arable production, the latter covering 35% of the North Kent Marshes (ADAS 1997). Although, grazing predominates, stocking rates are relatively low, due to the physical constraints of the area (AERC 1991). Table 4.2 shows the graziers for each of the individual marshes in the study, together with any conservation designations that are aimed at influencing the management of the marsh.

Table 4.2 Types of current management on the study sites

Marsh	Grazing			Conservation	
	Sheep	Cattle	Horse	ESA	SSSI
Erith (I)			*		
Crayford (I)			*		**
Dartford (I)		*	*		**
Stone (I)					
Swanscombe (I)			*		
Botany (I)					
Denton (O)			*		
Filborough (O)		*			
Shorne (O)	*	*			
Higham (O)	*	*		*	
Cliffe (O)	*	*		*	*
Allhallows (O)		*		*	
Grain (O)				*	
Chetney (O)	*	*		*	

* Current ** Proposed I – Inner Thames Marshes O – Outer Thames Marshes

The study sites currently show a variety of grazing regimes; in the main grazing animals are sheep (28.5%), cattle (50%) or horses (35.7%). Two marshes, Stone and Botany are currently not grazed. In the past however, grazing has been predominantly cattle and sheep (Garrad 1954, MacDougall 1980, Baldwin 1984), with horses only being introduced as late as the beginning of the twentieth century. This is in marked contrast to the northern marshes of Essex where use has alternated between pasture e.g. between

1875 to 1939 and arable, notably 1750 to 1875 and 1939 to 1952 when war and agricultural policy dictated the need to return to mixed farming (Williams and Hall 1987).

Boys (1865) cited in Garrad (1954) writing about the marshes of Cliffe and Cooling records, 'the whole is used for fattening cattle and sheep. Some marshlands are grazed by Welsh bullocks for fattening and in some parts the graziers buy the lean sheep from the flocks of east Kent and fatten them for market'. The records produced by Garrad (1954), highlight the different grazing regimes that were current on the North Kent Marshes up to 1951. Sheep grazing was found exclusively in the east of the study area on Cliffe Marsh with smaller numbers on Higham and Shorne Marshes, and cattle grazing practised throughout the North Kent Grazing Marshes, with the exception of Swanscombe Marsh.

The importance of the marshes grew in this respect as the population of London increased and with the growing need to feed the populace. By the middle of the nineteenth century, the North Kent Marshes were making a considerable contribution to the domestic food supply, and then came the agricultural depression of the 1870s' so other uses were sought for the marshes.

ADAS (1997) identified four objectives for the North Kent Marshes ESA: -

- To maintain and enhance the landscape quality and wildlife conservation value;

- To maintain and enhance the wildlife conservation value without detriment to the landscape by maintaining high water levels in the ditches;
- To maintain and enhance landscape quality through management of characteristic elements;
- To maintain and enhance archaeological and historic features.

The objectives of the ESA involve the management of characteristics and features of grazing marshes that have been recognised in this thesis as being representative of good grazing marshes (Section 3.1.1). Maintenance of the Outer Thames Marshes should therefore provide a guide to the standard a typical grazing marsh should achieve, against which the grazing marshes of the Inner Thames can be assessed.

4.8 Non Agricultural uses of the North Kent Marshes.

Developments of activities other than agriculture have been responsible for the historical fragmentation and loss within the North Kent Grazing Marshes. Industries such as cement manufacture, explosives manufacture, mineral extraction, waste disposal and power generation have all caused fragmentation of the North Kent Marshes since the beginning of the nineteenth century. Table 4.3 shows the alternate uses, which have been carried out, on the North Kent Marshes.

The North Kent Marshes have been predominantly used for the grazing of sheep and cattle (Garrad 1954, MacDougall 1980) see Section 4.7. Urbanisation and industrialisation, which has fragmented the North Kent Marshes has left a visual impression of a poorly integrated development policy, (AERC 1991). Most prominent on the urban fringes neglect, dereliction and poorly maintained features (Fig 4.30) e.g. scrapyards adjacent to Crayford Marsh or lack of screening for caravan sites e.g. Allhallows Marsh have given the impression of the marshes as being unproductive and prime areas for exploitation by other means (ibid).

Table 4.3 Historical uses of the North Kent Grazing Marshes since 1800.

Marsh	Cement	Defence	Mineral extraction	Power generation	Waste disposal	Recreation	Arable	Explosives
Erith (I)	*			*	*	*		
Crayford (I)		*			*	*		
Dartford (I)		*		*	*	*	*	*
Stone (I)	*		*	*				
Swanscombe (I)	*				*			
Botany (I)							*	
Denton (O)					*			
Filborough (O)								
Shorne (O)		*				*		
Higham (O)		*	*			*		
Cliffe (O)	*	*	*			*		*
Allhallows (O)						*	*	
Chetney (O)						*	*	
Grain (O)				*		*		

I – Inner Thames Marshes O – Outer Thames Marshes

Fig 4.30 Scrapyards encroaching on to Crayford Marsh

The Inner Thames Marshes have been particularly affected in the respect often being used for purposes that are not considered suitable for areas sited closer to urban centres (Prichard 1976). For example, waste disposal has occurred on 35.7% of the marshes in this study, a use that reflects the perception that the Inner Thames Marshes are of little value.

Over the whole of the North Kent Marshes, evidence remains of many of the former, industries that have been attracted to these sites, e.g. the fireworks factory on Dartford Marsh. Cement production was an early industry on the North Kent Marshes, occurring on 28.6% of the marshes in this study, utilising the availability and abundance of raw materials, i.e. chalk, clay and alluvium. From the end of the nineteenth century, Stone and Cliffe Marshes were centres for the cement industry (MacDougall 1980, Dartford Archive 2001). Little evidence of the cement works remain on Cliffe Marsh, but for Stone Marsh the industry was the beginning of the long-term fragmentation.

The River Thames has often been regarded as a weakness within the defence capabilities of the nation and so the marshes were seen as prime locations for the development of defensive sites, with 35.7% of the sites in this study having defensive installations. Whereas no major fragmentation has been associated with these installations, they have led to a change in topography, increased the range of habitats present and introduced intrusions into the open landscape of the grazing marshes. For example, where installations are still present across Crayford, Dartford and Shorne Marshes, their presence has created opportunities for a range of stress tolerant competitive species, e.g. hawthorn (*Crateagus monogyna*) and ivy (*Hedera helix*, to become established, Fig 4.31.

Fig 4.31 Pill boxes and scrub development.

The manufacture of explosives is another use, which has been of past economic importance on the North Kent Marshes and has been responsible for some of the earliest fragmentation. The northeast corner of Crayford Marsh, now an industrial estate, was originally an ammunition factory opened in 1889 (Thomas 2001). In the early twentieth century, both Cliffe and Dartford Marshes became sites for the manufacture of explosives. These structures have all lead to loss of landscape character as well as affecting the integrity of the marshes. Protective tree screens on Cliffe and Dartford Marshes remain as visual intrusions and as foundations for the establishment of new habitats. Dartford Marsh presents a range of other problems that arise from the manufacture of explosives on marshland sites. The land on which the factories were established is now contaminated and it is possible that contaminants may seep into the ground waters and eventually contaminate the drainage ditch system (Gieckie *pers com.*).

Waste disposal and in particular, sewage works have become a feature on some of the inner marshes and represent the long held perception that the Thames Marshes are dumping grounds for London's waste. Four sewage works are currently sited on the grazing marshes of North Kent, with three on the Inner Marshes at Erith, Dartford, and Swanscombe and at Denton Marsh amongst the outer marshes.

Swanscombe and Crayford Marshes have become the sites for landfill operations, primarily for category three wastes that pose little or no pollution risk. The landfill site on Swanscombe Marsh occupies the western riverfront and the old Broadness Saltmarsh. The result is a conspicuous area of higher ground that is being recolonised by generalist plant species. In contrast the site of the landfill on Crayford Marsh, is being landscaped as work proceeds. The result is again a conspicuous area of higher ground sown with rye grass (*Lolium perenne*), which in character bears little resemblance to the former grazing marsh, except with regard to the major vegetation cover. Incursions of landfill sites are therefore causing losses to grazing marshes through changes in hydrology and soils and a reversion to dry grassland or ruderal sites on the disposal areas.

Although regarded primarily as grazing land records do indicate that some marsh areas have been used in the past for alternative agricultural produce. Garrad (1954) recorded that the production of market gardening produce was present on all the marshes in the study area up to 1951, along with smallholdings producing fruit on Cliffe, and Higham Marshes. There is also evidence from his work that hops were grown on Stone Marsh up to 1835.

The large areas of open countryside, with close proximity to many centres of population have made the North Kent Marshes important for recreational activities, 64.3% of the study sites are associated with one or more activities. Formal recreation may take the form of organised walks, bird-watching, wildfowling, which are linked to the ecological value of the marshes. Walking and rambling are usually confined to footpaths and recognised rights of way, e.g. The Saxon Shoreway. The abandonment and lack of management on some of the Inner Thames Marshes has however, made many of the footpaths difficult to use, and the footpaths become amongst the first areas where invasive species such as bramble (*Rubus fruticosus*) and nettle (*Urtica dioica*) become established.

Dartford Marsh has a scramble track, a clay pigeon shooting club and is the home to a model aircraft club. Although these are formal recreations they can lead to management problems, e.g. the shooting club still use lead shot, as they do not recognise Dartford Marsh as a wetland (Gieckie *pers com*). In future, this could lead to problems with lead deposits contaminating the ditches.

Cliffe and Cooling Marshes are also frequented by wildfowlers, who also own part of the land on the latter and manage land throughout North Kent. Cliffe Marsh is the site of an RSPB reserve, and English Nature own land on Chetney Marsh for similar purposes. In many respects the aims of the RSPB, English Nature and the wildfowlers are similar and aimed at retaining the North Kent Marshes as an important area for birds.

The organisations also share concerns over the growing number of informal activities that are beginning to occur across the North Kent Marshes (AERC 1992). Water-bikes, high-speed powerboats and motorcycling are frequently seen adjacent to the coast or on the marshes themselves. The growing use of scramble bikes on Shorne and Higham Marshes produces deep ruts, bare ground and disturbance to wildlife (personal observation). On Dartford Marsh, formal motor scrambling occurs and the noise disturbance across the marsh is considerable.

Continuation of both formal and informal recreational activities will naturally cause conflict between various user groups, e.g. between conservation and off road cycling. There will also be a need for maintenance to control erosion of footpaths and embankments, where they are heavily used by walkers, horses and mountain bikes. The recreational use of the North Kent Marshes if allowed to become excessive may also begin to compromise the open landscape and adversely affect the landscape character and features of grazing marshes. Further studies would be needed to study the impact of recreation on the North Kent Marshes.

Chapter 5 Fieldwork, Methodology and Methods of Analysis

5.1 Introduction.

The Island Theory of Biogeography, MacArthur and Wilson (1963, 1967) and the concept of metapopulations (Levins 1969, Hanski 1998, 1999) have formed the basis of much of the research into fragmentation (e.g. Andren 1994, 1996, Collinge 1996, Harrison and Bruna 1999). The Island Theory of Biogeography is often cited as an example of how the species/area relationship can be used in the study of isolated terrestrial habitat islands and fragmented habitats (e.g. Diamond and Mayr 1976, Quinn and Harrison 1988). In this study the Theory of Island Biogeography is being used as 'a research programme' as discussed by Haila (1990), and to test whether fragmentation is reducing the viability of the North Kent Marshes either through a reduction in area or increased heterogeneity resulting from fragmentation.

Criteria established by Ratcliffe (1977), in the Nature Conservation Review, priorities for habitat conservation (Moffat 1994), the habitat restoration handbook (Mitchley et al 2000) and English Nature rapid assessment protocols (2000) all provide methods by which the conservation value of fragmented and isolated habitats may be assessed. This study uses adaptations of the above conservation criteria, priorities and protocols to assess and compare the landscape characteristics and features of the grazing marsh fragments, see Sections 5.2.2, 5.3.2 and 5.3.4.

Landscapes studies e.g. O'Neill et al (1997), Ritters et al (1997) and With (1997) use scales and indices in an attempt to quantify the varying elements and diversity within landscapes and to assess the effects of fragmentation. Edge density, i.e. total length of edge, contagion, i.e. extent to which pixels are aggregated, and corrected perimeter-area, which relates the shape of a patch to the idealised shape of a reserve, are all examples of such indices (Farina 1998, Hargis et al 1998). Such indices are designed to 'quantify two distinct components of landscape diversity: composition and configuration', (Li 1993). Landscape metrics, is the term that is now often used to describe this method of analysing landscapes (e.g. Ritters et al 1995), and such methods are usually dependent on computer models, remote sensing and Geographic Information Systems (GIS), to interpret and measure the differing landscape patterns.

Haines–Young and Chopping (1996) point out that indices provide a 'conceptual framework, but much simpler divisions or categories may be used', e.g. indices can be categorised under the headings of area, edge, shape, proximity to nearest similar habitat type, and species diversity (ibid). Fragmentation studies that are carried out using the above five categories have the advantage of being simpler and maybe carried out directly through both fieldwork and map interpretation (Haines-Young and Chopping). Blaschke and Petch (1999), and Hargis et al (1998) reflected on problems associated with the current use of landscape indices, particularly with respect to landscape spatial arrangements. Brandt (1998) was of the opinion that 'quantitative measures used in isolation can lead down blind alleys… and be dangerous by simplifying complex structures and processes'.

A summary of the indices that have been applied to landscapes and a review of their contribution to management, particularly of forested landscapes were produced by Haines – Young and Chopping (1996). Hargis et al (1998) however, stated 'all landscape metrics are interrelated by their dependency on the same basic measures, size (area), perimeter length and inter patch distance'. The number and scope of these indices can therefore, generally be reduced to three broad categories of measurement, see Table 5.1 and Tischendorf (2010) for a fuller review.

Table 5.1 Categories of indices and measurements

Type of index	Measurement
Area	Habitat area, including shape and core
Linear	Boundaries, perimeters, connectivity, proximity
Topological	Relationship between landscape elements

Landscape characteristics and features and therefore the landscape arrangement, (i.e. topology), are one of the strands of study within this thesis, together with area assessments of the remaining fragments. The approach adopted was therefore to consider field and ground-based observations in respect of the landscape elements and map-based quantification of the areas, rather than a GIS approach.

Table 5.2 Techniques and methods used in this thesis and their source.

Source	Technique/method
Kent and Smart (1981)	Habitat inventories
Harris et al (1992)	Types of fragmentation
Moffat (1994)	Priorities for habitat conservation
Simmons et al (1999)	Ecological and land character indicators
Mitchley et al (2000)	Key habitat attributes
English Nature (2000)	Condition assessments

Techniques and methods of field and habitat assessment used in this thesis have been adapted from a range of sources as shown in Table 5.2.

5.2 Rationale and Study approach.

5.2.1 Rationale.

The Nature Conservation Review (Ratcliffe 1977) used ten criteria to determine conservation value of a site in the UK; size; diversity; naturalness; typicalness; rarity; history; fragility; position in an ecological unit; potential value and intrinsic appeal. For this study, size and history, typicalness in terms of landscape characteristics and features, and the position in the ecological unit, i.e. the vegetation communities were measured, either quantitatively or qualitatively. Size and history were used because of the availability of previous data, e.g. Thornton and Kite (1990), against which the current study could be compared, and as an indication of the pattern and extent of fragmentation. As the literature is unclear as to what is typical of a grazing marsh and where grazing marshes fit into the ecological unit, the aim of this thesis is to establish criteria for typicalness and the position in the ecological unit of grazing marshes.

The loss of grazing marshes throughout the Thames Estuary has been recorded by Ekins (1990) and Thornton and Kite (1990), as well as being commented on in the Kent Habitat Survey (1992) and the Kent Biodiversity Action Plan (1997). The area of a habitat has always been regarded as a key factor in maintaining integrity, structure and value in terms of the number of species (MacArthur and Wilson 1967) and population size a habitat can support. Fragmentation of the North Kent Marshes, particularly within the Inner Thames Marshes has continued since the studies of Ekins (1990) and of Thornton and Kite (1990). An evaluation of the current situation with regard to the amount and quality of remaining grazing marsh was required.

Chetney, Cliffe and Allhallows Marshes were considered by Ratcliffe (1977) as key coastal and lowland grassland sites within the Nature Conservation Review. These sites therefore can be regarded as being a guide to typical grazing marsh sites against which typicalness of other fragments could be judged. In this study, typicalness is used to define the characteristics and features that a grazing marsh should contain, or the ideal marsh. To assess typicalness therefore, reference was made to the definition of grazing marshes, given in Section 3.1.1 and to the features considered to be of importance to grazing marshes, e.g. Milsom et al (1998, 2000) and Vickery et al (2001).

Remnant marsh characteristics such as rills (Delaney 1991, Kent Biodiversity Action Plan 1997), counter walls (Milsom et al 1998) and embankments (Cobham 1995) have been recognised as indicators of the original saltmarsh, which was reclaimed to create the grazing marshes and therefore used as positive indicators. Drainage ditches are regarded as being an essential feature of grazing marshes (e.g. NCC 1991, Biodiversity Action Plan 1997), an evaluation of their condition has therefore, been included within the survey. The status of rills, drainage ditches, embankments and counter walls have been used in this thesis as evidence of the presence and current quality of the remaining grazing marsh fragments. In addition, grazing marsh features such as homogeneity, tussocky grassland, and wet flushes are regarded as important features for the presence of key bird species e.g. redshank (*Tringa totanus*) and lapwing (*Vanellus vanellus*) (Williams et al 1983, Milsom et al 1998). A record of the status of homogeneity, tussocky grassland and wet flushes is therefore needed as part of the assessment of the overall conservation value of grazing marsh fragments.

To determine the overall grazing marsh landscape, Cobham's (1995) classification of grazing marshes into marsh with urban/industrial influence or urban/industrial dominance was adopted. Early accounts of the North Kent Grazing Marshes e.g. Hasted (1797), Dickens (1861), highlighted openness as a characteristic of the North Kent Marshes. The extent to which surrounding land uses influence or dominate a grazing marsh fragment provides a measure of the extent to which the openness of the grazing marsh landscape has been affected and changed by external factors.

An objective of this thesis is therefore to identify the typical landscape characteristics and landscape features of grazing marshes and place grazing marshes within a defined ecological unit by classifying the vegetation communities within a recognised category e.g. NVC (Section 8.6).

As there are no formal classifications of grazing marsh communities in either Tansley (1939), Ratcliffe (1977) or Rodwell (1992) the decision was made to include within this a survey of the grassland vegetation with the aim of determining the typical community composition of grazing marshes in North Kent. As grazing marshes are being regarded as the matrix of the landscape (Section 2.1.2), analysis of the matrix habitat 'may be crucial for understanding the dynamics of remnant fragments' Debinski and Holt (2000). By evaluating the composition and structure of the matrix, the consequences of fragmentation can be assessed.

Invasive plant species are regarded here, as evidence of the deterioration of grazing marsh quality and their presence may result from changing land management or land use, fragmentation or edge effects altering the composition and structure of the matrix. The suite of invasive species generally represents those regarded as being ruderal or tolerant of disturbance e.g. *Rumex spp, Cirsium spp, Plantago spp* and *Urticia dioica* (Grime et al 1988). Presence of these species may therefore, indicate a change or lack of site management, overgrazing, increased or over application of fertilisers. The increased occurrence of the suite of invasive plant species was determined by comparing their abundance in the vegetation samples with the NVC community lists and diagnostic tables (Rodwell 1992, 1998), for each individual fragment, see Section 5.3.3.

The edges of habitats are of particular importance as they define the extent of the habitat and provide habitat variation (Elton 1966). Fragmentation results in an increase in the edge length and the increases will therefore, enhance the edge effects, which in turn are influential as areas in which competitive and invasive species can gain a foothold to the fragmented habitat. Determining the character of the edge was deemed important within this study in order to differentiate where a boundary occurred and whether this was formed by the fragmenting agent or was a natural feature of the habitat. For example, a road forms a divisive fragmenting agent and for the most part has a well-defined edge, whereas a track across a site may have become overgrown in parts and takes on some of the characteristics of the adjacent habitat and is therefore, less of a boundary. It therefore needs to be determined whether tracks are fragmenting agents and that the habitat on either side of the track is an individual habitat fragment. For the purposes of this study however, it has been decided that to be a divisive fragmenting agent, a track/river would need to be continuous across the whole of the habitat with no incursion of the habitat across or around the ends of the agent, and that the fragmenting agent should be a continuous barrier over 5m wide. Similarly, ditches are an integral part of a grazing marsh, but in some examples e.g. Milsom et al (2000) they have been regarded as separating grazing marshes into individual field units, i.e. a fragmenting agent. In this study however, the ditches are regarded, as a key feature of grazing marshes and cannot be a fragmenting agent.

The aims of the current research are therefore, to firstly, describe the processes and agencies that have led to the fragmentation of the North Kent Grazing Marshes, secondly, to quantify the changes in area and perimeter that have occurred, and thirdly, categorise the typical vegetation communities of grazing marshes, identify the typical indicators and to assess the response of grazing marsh characteristics, features and indicators to the fragmentation process.

As it was not possible to survey all the remaining fragments in the North Kent Marshes a sample of fragments was chosen, the choice being determined by: -

- Location, i.e. the need to compare the Inner Thames Marshes, (Erith, Crayford (including Barnes Cray), Dartford (including Dartford Fresh Marsh), Stone, Swanscombe and Botany) and the Outer Thames Marshes (Denton, Filborough, Shorne, Higham, Cliffe, Allhallows and Chetney);
- Management, to compare marshes managed under the North Kent Marshes Environmentally Sensitive Area scheme with those that were outside the ESA;
- That a representative sample of fragment sizes and isolation were considered;
- Access to the site; e.g. Grain Marsh was not surveyed for vegetation or landscape as the author could not obtain permission to access the site.

5.2.2 Study approach.

The approach used in this research project was divided into three stages: -

- consideration of the historical effects of fragmentation, i.e. changes in size and methods of fragmentation;
- a quantitative assessment of the landscape characteristic and features highlighted in Section 3.1.1, including typicalness;
- an autecological vegetative study to establish the 'appropriate mosaic of communities' that comprise grazing marshes.

The three strands of the study, historical, landscape and ecological, involve the collection of a range of qualitative and quantitative data on grazing marshes which include an assessment of the area, landscape, fragmentation characteristics and the vegetation composition. Qualitative assessment is defined as both intuitive and subjective, relying on the observer's judgement to produce a result. Quantitative assessment however, is more objective and seeks to produce results from information derived from value rating the status of the relevant characteristics and features. The results of the surveys will then provide an indication of how fragmentation is affecting each fragment and the status of the grazing marsh habitat.

In the past species/area relationships have received the greater emphasis when considering habitat loss and fragmentation, there is now a need for assessment of the overall effect that fragmentation has on the whole landscape. For the purposes of this thesis therefore, it was necessary to differentiate between landscape characteristics and landscape features. Landscape characteristics are defined as those parts of a grazing marsh, which comprise the macro components, e.g. homogeneity, ditches, embankments and surrounding land-use. The landscape features are those components, which make up the fine scale heterogeneity of a grazing marsh, i.e. rills and anthills, tussocky grassland and height of the sward. A combination of the landscape characteristics and features gives rise to what can be termed the homogeneous – heterogeneous configuration, of grazing marsh, which is defined as 'a configuration where lowland wet grassland and drainage ditches comprise the homogeneous unit of the matrix, heterogeneity at the finer scale comes from the random distribution of wet hollows, rills and tussocky grassland patches'. The characteristics and features were scored in accordance with a scale, which reflected their current status, see Section 5.3.4.

Botanical data was obtained from vegetation surveys carried out on each site and each fragment of every site. The results were analysed to determine goodness of match to National Vegetation Classification (NVC) communities, see Section 5.3.3. The NVC is based on 'a series of multivariate classifications of data derived from quadrat surveys' (Sanderson et al 1995) and provides a framework of classification within which, the community types found can be evaluated against distinct categories of natural and semi-natural vegetation (ibid). The communities obtained from the current surveys were compared to the community composition tables of Rodwell (1992) by the MATCH computer programme, which provides a measure of the closeness of the observed vegetation stand to that of the NVC community type.

The Ministry of Agriculture Fisheries and Food (MAFF) identified some possible NVC groupings for the North Kent Grazing Marshes in the 1997 North Kent Marshes Environmentally Sensitive Area Monitoring report. These groupings fell within the mesotrophic grassland communities and fitted, albeit poorly, (ADAS 1997) with: -

MG6 *Lolium perenne – Cynosurus cristatus* grasslands,

MG7 *Lolium perenne* leys,

MG11 *Festuca rubra – Agrostis stolonifera – Potentilla anserina* grassland.

Similarly, Benstead et al (1997) produced a specification for grazing marshes and a range of target communities, which included the above as well as MG9 *Holcus lanatus - Deschampsia cespitosa* grassland. These communities were used as a guide in determining the typical communities of the grazing marsh mosaic.

5.3 Methodology.

The overall methodology reflects the three types of ecological evaluation approach outlined by Kent and Smart (1981): -

The evaluation approach consisting of two elements: -

- a subjective analysis of the key grazing marsh characteristics and features, together with an analysis of the major fragmenting processes and agents, management type and surrounding land uses; see Appendix 2 for the sample analysis sheets;
- historical analysis, which evaluated the types and agents of fragmentation and the changes in the area and perimeter of the study fragments.

The inventory approach; used on each fragment to describe the site characteristics in terms of whether the key elements of grazing marsh habitat are present or absent their condition if present was recorded on a six-point scale, see Section 5.3.4 for details.

An indicator species approach; used on each site to highlight the key grazing marsh floristic species, both the dominants e.g. perennial rye grass (*Lolium perenne*) and the key target and characteristic species, e.g. divided sedge (*Carex divisa*) and problem or invasive species, e.g. creeping thistle (*Cirsium arvense*).

The following sections, describe the methodology used in the three elements of the surveys.

5.3.1 Historical surveys.

Harris et al (1992) discussed five processes that can lead to fragmentation of a habitat (Section 2.4), division, regression, intrusion, envelopment and encroachment. The proposed processes of Harris et al (1992) were used in the current study to classify the fragmentation process, which has affected each site, as they provided a theoretical typology to fragmentation. The historical analysis took the form of a map-based study that was used to determine which of the methods of fragmentation and which agents of fragmentation were responsible for fragmenting the individual marshes.

For this study, four map sets of different dates were used and compared. Firstly, the twenty-five inch to one mile Ordnance Survey second edition, published in 1897, secondly, the twenty-five inches to one mile seventh series, published between 1957 and 1960 were compared to the latest 1: 25000 editions (1999), together with the more recently published local 1: 20000 street atlases (2000) and aerial photographs. The starting date of 1897 and the seventh series maps were used, as they were the most complete set of the Ordnance Survey maps of the study area that were available.

The second strand of the historical survey involved a quantitative study of the changes to the areas, edges and isolation of the North Kent Marshes and remaining fragments, using the same map sets as described above. Grazing marsh loss over the study period could then be ascertained and compared to previous studies, e.g. Thornton and Kite (1990). The indices measured are recorded in Table 5.3. The indices were chosen as they were features which have 'ecological and environmental consequences and are easy to calculate and rarely problematic' (Haines-Young and Chopping 1996). In all instances maps with the largest available scale was used for measuring area and edge length in order to achieve the highest level of accuracy.

Edge – area ratio, this index is sometimes referred to as the edge density and will vary according to the size of the habitat fragment, the larger the ratio becomes the more dominant the edge feature is in relation to the core habitat area (Farina 1998). Expressed in terms of m/ha, the edge – area ratio is a primary outcome of habitat fragmentation (Hargis et al 1998). The measure is reflective of landscape patterns in which landscapes with the smaller patches or irregular shapes will have a greater ratio (Hargis et al 1998). This ratio then becomes a good tool for evaluating effects of habitat shape and the influence of external factors on the habitat fragment. However, it must be acknowledged that the scale of the maps used may influence the accuracy at which the width of the edges can be defined and measured.

Table 5.3 Description and definition of indices used in the present study

Index type	Index definition/description
Total area	Total area of fragment in hectares measured using a planimeter
Total edge	Length of perimeter of fragment adjoining the fragmenting agent. The perimeters were traced and the lengths calculated using cotton thread to represent the fragment shape.
Edge density	Length of edge per hectare
Corrected edge-area ratio	Corrected index for solving the size problems of the edge/area ratio and varies between 0 for a perfect circle to infinity for an infinitely long and thin fragment (Farina 1998). The ratio is calculated using the formula: - $CPA = \frac{0.282 \times length}{\sqrt{area}}$
Proximity	Distance between fragments, measured in metres using scale rule. Both distance to nearest fragment (intra-distance) and nearest marsh (inter-distance), measured from nearest edge to nearest edge.

Corrected perimeter – area ratio, calculated as a measure of the irregularity of the shape as compared to a circle, which is deemed the preferred shape of a habitat remnant in respect of core – area ratio and edge – area ratio (Farina 1998).

The proximity, i.e. the distance between fragments gives information regarding isolation of habitats both in terms of fragmentation within individual marshes (inter – distance) and between grazing marshes (intra – distance) in the broader landscape. Isolation of remnant fragments is regarded as being a crucial factor in the immigration and emigration of species to and from the fragments (MacArthur and Wilson 1967) and the maintenance of species/area relationship. Fragmentation introduces barriers between fragments and individual marshes; the agent of fragmentation therefore, will be an important factor in enhancing the isolation effect.

5.3.2 Landscape Surveys.

The landscape surveys undertaken throughout the period between 1998 and 2000 used an approach requiring, a semi-landscape analysis which involved surveying the criteria, attributes and key features that are characteristic of coastal grazing marsh (see Section 3.1.1), including the management regime. An attribute was defined as 'a characteristic of a habitat, biotope, community or population which most economically provides an indication of the condition of the feature to which it applies' (adapted from JNCC 1998).

Grazing marsh definitions see Section 3.1.1; refer to certain landscape characteristics and features of grazing marshes, i.e. drainage ditches, rills or affinity to old salt marshes (Delaney 1991, Kent BAP 1997). As discussed in Section 3.1.1, however, there are additional characteristics and features, i.e. homogeneity, embankments and counter walls, the effects of the surrounding landscape influences, tussocky grassland and invasive species which are deemed to be indicative of a grazing marsh and therefore need to be assessed, and surveyed as key features of grazing marshes.

The defined characteristics and features were measured on scales, based on the concepts of the least acceptable change (LAC) as discussed by Stankey et al (1985), the priorities for habitat conservation (Moffat 1994) and English Nature's assessment protocols (English Nature 1999, 2000), see Section 5.3.4 for details of the scoring system.

The surveys were carried out by use of the random walk method (Fig 5.1) as described in Coleman et al (1988). The method was determined by the access that was available to the individual sites and the positioning and location of the drainage ditches, which made the random walk method a more practical proposition, than the 'W' walk described by Mitchley et al (2000).

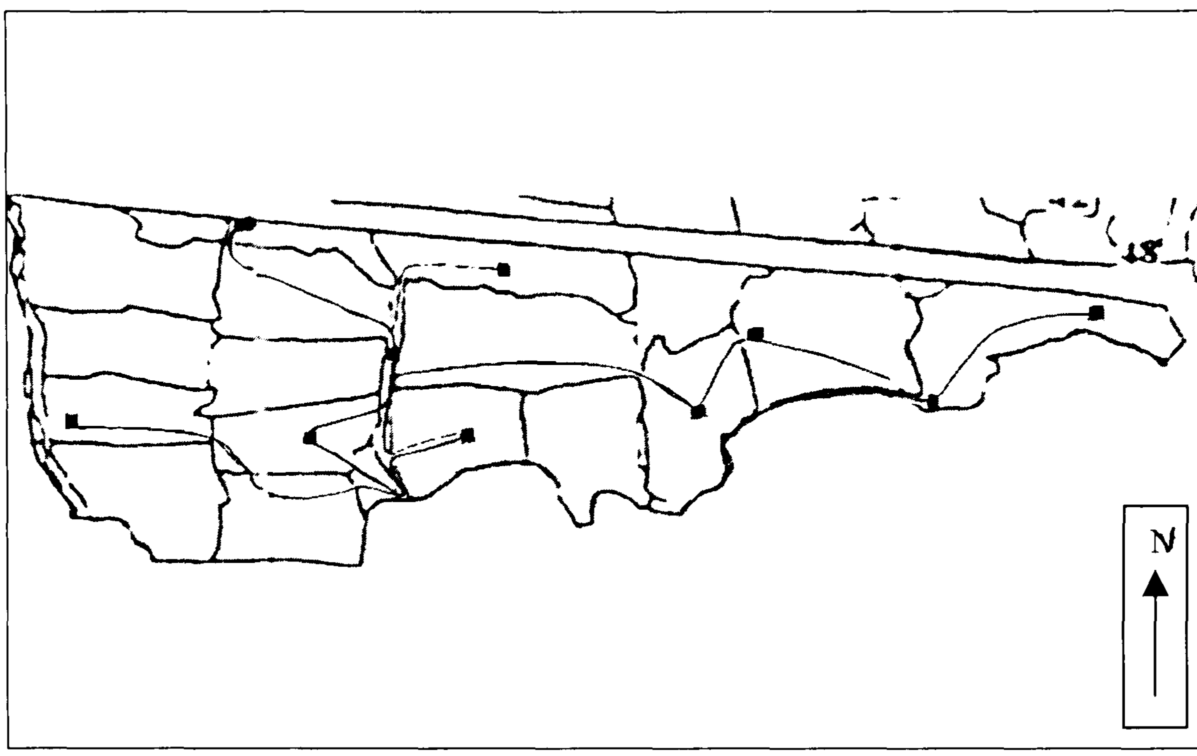


Fig 5.1 Random walk on Filborough Marsh (not to scale).

The condition of the target attributes was assessed against a six-point (0 - 5) scale created for this study or by using the DAFOSA scale at various points along the walk, as adapted from the method developed by Stankey et al (1985), Moffat (1994) and Mitchley et al (2000), see Section 5.3.4 for the details of the scoring system. At each site the indicators present within the 'search area', roughly equivalent to a quadrat size of 2 x 2 metres for the micro features. For the larger characteristics, the condition and presence of embankments and drainage ditches were recorded over an adjoining 10m length, whilst the influences of the surrounding land use were recorded at the landscape scale. See Appendix 2 for an example of the form used in this survey.

5.3.3 Vegetation survey.

For all of the fragments surveyed (Section 5.2) vegetation samples were located within stands of vegetation judged visually to be 'floristically and structurally homogeneous' Rodwell (1992). All of the fragments surveyed showed characteristics of mosaic structures, although in instances the transition zones were somewhat blurred. Thus, using local knowledge, pre survey site walks through and ecological theory the areas to be surveyed could be stratified to take into account environmental variables and ecological patterns (Haila and Margules 1996).

The vegetation sampling was carried out between May and August 1998, when the flora was best developed (Kent and Smart 1981). Sampling of the vegetation was carried out by means of a stratified random method, using randomly selected one metre square quadrats over each fragment. Stratification was carried out after a visual survey of the fragments had determined the 'variations in physiognomy and the structure of the vegetation' (Kent and Coker 1992), i.e. the study sites were divided into areas based on the major variations in the vegetation. Randomness was achieved by using a 'random walk procedure' through the previously stratification of the fragments. The vegetation data within each of the 778 quadrats (Table 5.4) was recorded using the DAFOR scale, this being the 'most subjective and descriptive method of vegetative description' (Kent and Coker 1992). DAFOR is the scale adopted by English Nature, for their Lowland Grassland Condition Assessment Protocols (Robertson and Jefferson 2000): -

D	Dominant
A	Abundant
F	Frequent
O	Occasional
R	Rare

The number of quadrats taken on each fragment was proportional to the area, i.e. one quadrat per one - three ha. Where the fragment/marsh showed high homogeneity at the landscape scale the ratio of 1 quadrat/3ha was used. A minimum of ten quadrats per site was taken (Table 5.4). The exceptions to this format were Dartford Fresh Marsh, where results from a previous individual site study were used, Cliffe, Allhallows and Chetney Marshes where surveying permission was not granted over the whole site.

Table 5.4 Number of quadrat samples taken in each fragment surveyed.

Site	E2a	E2b	E2e	C1	C2a	C3a	C3b	BC	D	Dfm	S2a	S2b	S2c	S2d
	25	25	10	25	24	16	16	12	70	115	10	10	16	10
Site	Sw	B	De	F	Sh	H1a	H1c	Cl	A	Ch				
	40	30	14	24	102	52	16	80	30	24				

5.3.4 Key to scoring.

A number of the key attributes have been determined which can be used to characterise grazing marshes were described in Section 5.3.2. 'Attributes are measurable qualities or properties of the habitat, including permanent and transitory qualities, both positive and negative, which are associated with a successful site', (Mitchley et al 2000). It is important therefore, to choose attributes or indicators that reflect and provide a basis for identifying change. The characteristics and features surveyed were discussed in Section 3.1.1 and 5.3.2. Each characteristic and feature, with the exception of the surrounding land use (see 5.3.4b) and tree/scrub cover was assessed at each of ten points on a standard walk by considering the surroundings within a 10m radius. The overall site score was averaged, calculated and classified on the following scales, Table 5.5.

Table 5.5 Classification of DAFOS scoring.

Dominant	Highly visible and occurs at a high abundance across the site, usually above 75% of cover.
Abundant	Present and visible over most of the site with between 50% and 75% cover.
Frequent	Visible over most of the site but is variable in occurrence.
Occasional	Present throughout the site but occurs at less than 25% over.
Scarce	Feature covers less than 10% site and is difficult to observe

The scoring systems devised for the characteristics and features listed below have been adapted from English Nature protocols for monitoring grasslands (Robertson and Jefferson 2000 and Mitchley et al 2000). Landscape characteristics and features reflect what is defined in this thesis as typicality for the grazing marsh habitat in the North Kent Marshes. Although these characteristics and features when considered individually may not be unusual, their combination and spatial configuration can be used to determine the quality of the habitat as a whole. Examination of the full range of characteristics and features is aimed at reflecting the impact of fragmentation and highlight changes to the ecology of grazing marshes. All the characteristics and features have been assessed as having equal value to the composition of grazing marshes because the presence of each is necessary to define the presence of grazing marsh, and therefore decline in any particular attribute is regarded as representing a devaluing of the whole grazing marsh fragment.

The scoring systems for the eight criteria, which comprise the typicality, landscape characteristics, landscape features, positive and negative indicators in identifying grazing marshes is listed below: -

a) Homogeneity:-

At the landscape level homogeneity is deemed the overriding visual characteristic of grazing marshes (Fig 5.2), and is where the habitat is composed of similar constituents throughout, and is uniform in appearance at the landscape scale. In contrast, heterogeneity (Fig 5.3) represents the visual change at the landscape level and a growing complexity in the grazing marsh structure measured as a 'departure from homogeneity' Li (1995). Grazing marshes are inherently a simplified matrix at the landscape scale of improved/semi-improved grassland interspersed by drainage ditches, and therefore on the scale in Table 5.6 should score five. Homogeneity however is relative and not absolute, and therefore scores over four would be considered as a standard.

Table 5.6: scoring for homogeneity

0	heterogeneous
1	low homogeneity <10% of the fragment
2	10 – 30% homogeneity of the fragment
3	30 – 60% homogeneity of the fragment
4	60 – 85% homogeneity of the fragment
5	homogeneous >85% of the fragment

The percentages in Table 5.6 are adapted from the Priorities for Habitat Conservation in England (Moffat 1994) to assess the percentage of an area that is homogeneous. Overall percentage limits vary to incorporate six levels of classification as opposed to the four included by Moffat (1994).

Fig 5.2: Homogeneity (Score 5)

Fig 5.3: Heterogeneity (Score 0)

b) Marshes with urban/industrial influence/dominance: -

As discussed by Cobham (1995), the surrounding land-use has become a characteristic of the grazing marshes of North Kent, through either the influence (Fig 5.4) or dominance (Fig 5.5) of urbanisation and industrialisation. Scoring of the two classifications described by Cobham (1995) has been assessed by estimating the visual impact of surroundings on the grazing marsh landscape at each of the ten points on the random walk. The definitions and scores for influence and dominance used were adapted from Cobham (1995): -

- Influence – marshland character of openness is affected by peripheral features, or by features such as power lines, isolated industry within the marshland.
- Dominance – marshland character is overwhelmed by the surroundings or the fragmenting agent.

Fig 5.4: Urban/industrial influence.

Fig 5.5: Urban/industrial dominance.

Other surrounding land uses e.g. agriculture or nature conservation have not been recorded here as their visual impact on the aesthetic quality of the North Kent Marshes is taken to be complimentary rather than adverse, although their impact may increase the heterogeneity of the landscape as a whole. The influence/dominance on the marshes of the urban/industrial surrounds is also considered of importance due to the nature of the edge that is associated with the features. Edge effects produced by the urban/industrial influence will be more likely to create hard edges and barriers to dispersal than agricultural or conservation surrounding land uses. Table 5.7 shows the scoring for urban/industrial influence or dominance.

Table 5.7: Scoring for Urban/industrial influence and dominance

0	no influence or dominance;
1	surroundings dominant/influential from <25% of points on random walk;
2	surroundings dominant/influential from 25% – 50% of points on random walk
3	surroundings dominant/influential from 50% - 70% of points on random walk
4	surroundings dominant/influential from 70% - 90% of points on random walk
5	Surroundings dominant/influential from >90% of points on random walk.

c) Ditches:-

Table 5.8: Scoring for Ditches.

0	destroyed: - little or no visual evidence of ditch system;
1	partially destroyed: - some elements of the ditches remain, irretrievably altered; no management;
2	unfavourable declining: - all elements of the ditch system are in decline;
3	favourable declining: - all ditches showing evidence of decline, but retrievable
4	favourable improving: - most ditches are managed, but some features on some ditches are not controlled, e.g. emergent vegetation choking a minority;
5	favourably managed: - all ditches are managed.

Fig 5.6: Ditch score 0

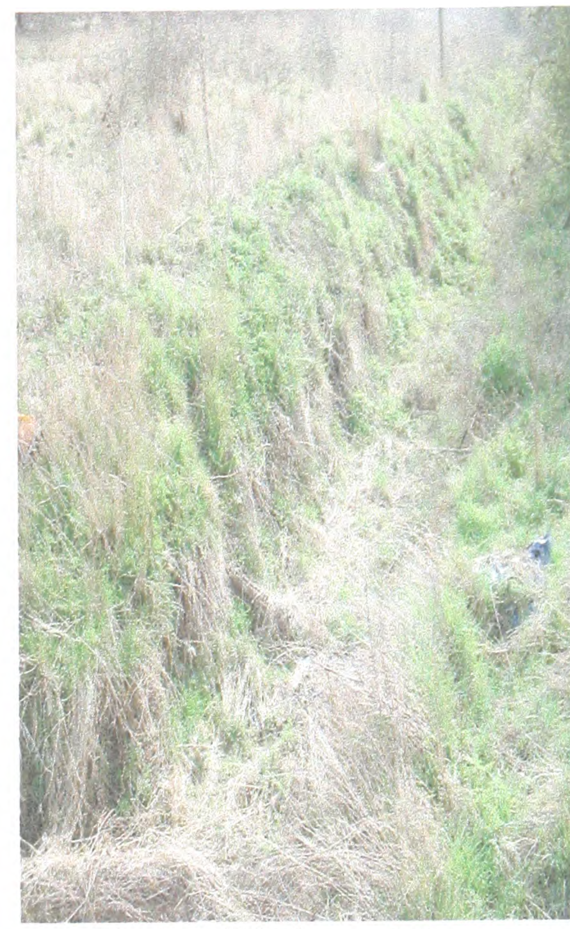


Fig 5.7: Ditch score 1

Fig 5.8: Ditch score 2

Fig 5.9: Ditch score 3

Drainage ditches are one of the characteristics of grazing marshes (Dargie 1993, Kent Biodiversity Action Plan 1997). The scoring for the drainage ditches reflects the level of management and status in terms of emergent vegetation, i.e. whether the ditch is choked or overgrown, as well as providing visual evidence of nutrient enrichment or presence of dumped materials, see Figs 5.6 – 5.11. The scores were adapted from the protocols for monitoring lowland grasslands (Robertson and Jefferson 2000), and included a provision for a fragment having fewer ditches present than recorded in 1897. Ideally all ditches should score 5, but scores of 4 and above are acceptable.

Fig 5.10 Ditch scoring 4

Fig 5.11 Ditch scoring 5

d) <u>Embankments/counter walls</u>: - are man-made characteristics used to enclose the former saltmarsh (embankments) (Cobham 1995), or act as boundaries between land-holdings (counter walls) (Milsom et al 1998). Many of the rarer species of plant associated with grazing marshes are found within these habitats, e.g. stinking goosefoot (*Chenopodium vulvaria*), small red-goosefoot (*C. botryodes*), pepper saxifrage (*Silaum silaus*) and least lettuce (*Lactuca saligna*), and therefore their presence is essential to the grazing marsh ecological importance. Table 5.9 shows the scoring for embankments and counter walls based on the limits of acceptable change (Stankey et al 1985) and monitoring protocols for lowland grasslands (Robertson and Jefferson 2000).

Table 5.9: Scoring for embankments and counter walls

0	absent: - no evidence of feature recorded;
1	partly destroyed: - some elements of the walls remain, but irretrievably altered; no management (Fig 5.12);
2	unfavourable declining: - all elements of the walls are in decline;
3	favourable declining: - all walls showing evidence of decline, but are retrievable through management (Fig 5.13);
4	favourable improving: - most walls are managed, but some features on some walls are not controlled, e.g. ruderal vegetation and rank grasses;
5	favourably managed: -both features intact and managed, (Fig 5.14 and 15).

Fig 5.12: Embankments with elements in decline (1)

Fig 5.13: Embankments declining but retrievable (3)

Fig 5.14: Favourably managed embankments.

Fig 5.15: Favourably managed counter walls.

e) Sward height.

The range of heights present is indicative of the grassland structure and has been deemed of value for a range of bird species associated with grazing marsh, e.g. Milsom et al (1998, 2000) and Vickery et al (2001).. Measurement of sward height will also be of value in assessing the level of management that is currently practiced on the individual fragments, and an early indication of changes to the plant community assemblage.. Sward height across the surveyed fragments was measured to the nearest half centimetre using a 2m rule. Samples were taken at ten points along a random walk as described in section 5.3.2. The range of sward heights was recorded and the average height for each fragment calculated and compared to the mean (See Section 7.7.1).

f) Tussocky grassland (as defined in Section 3.1.1)

Tussocky grassland has been included as a quantified feature of grazing marshes because of their importance as a component of the heterogeneous homogeneous structure that characterises grazing marshes by providing height to the structure, and for birds (Milsom et al 2000). Scoring is based on DAFOSA, and the categories use the limits set in the

DAFOR scale. Abundance and dominance are interpreted as not being the preferred state of the grazing marsh as the overall score may then reflect a lack of management or under-grazing of the fragment, (See Table 5.10).

Table 5.10: Scoring for tussocky grassland.

0	Absent (Fig 5.16)
1	Sparse - <10% cover in 10m radius
2	Occasional – 10%-25% cover in 10m radius
3	Frequent – 25% - 50% cover in 10m radius (Fig 5.17)
4	Abundant – 50% - 75% cover in 10m radius
5	Dominant - >75% cover in 10m radius (Fig 5.18)

Fig 5.16: Tussocks absent (score 0).

Fig 5.17: Tussocks frequent (score 3).

Fig 5.18: Tussocks dominant (score 5).

g) Rills

Rills are the remnants of smaller saltmarsh channels that comprise the wetter areas of lowland wet grassland and are important features in the heterogeneous-homogeneous structure of grazing marshes. They have also been scored using DAFOSA, and the categories use the limits set in the DAFOR scale. A high score for dominance or abundance may reflect changing conditions on the fragment, e.g. impeded drainage (Table 5.11), and is therefore not regarded as an ideal score. For the ideal grazing marsh the score for rills should reflect coverage of between 25 and 50%, i.e. a score of 3.

Table 5.11: Scoring for rills.

0	Absent (Fig 5.19)
1	Sparse - <10% cover in 10m radius
2	Occasional – 10% - 25% cover in 10m radius (Fig 5.20)
3	Frequent – 25% - 50% cover in 10m radius
4	Abundant – 50% - 75% cover in 10m radius
5	Dominant - >75% cover in 10m radius

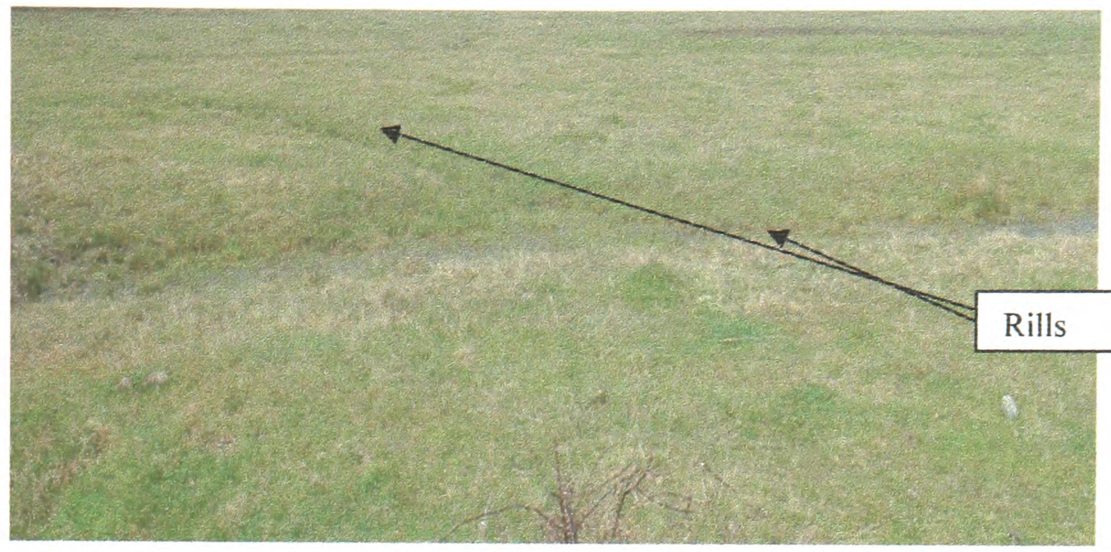


Fig 5.19: Rills sparse (score 1).

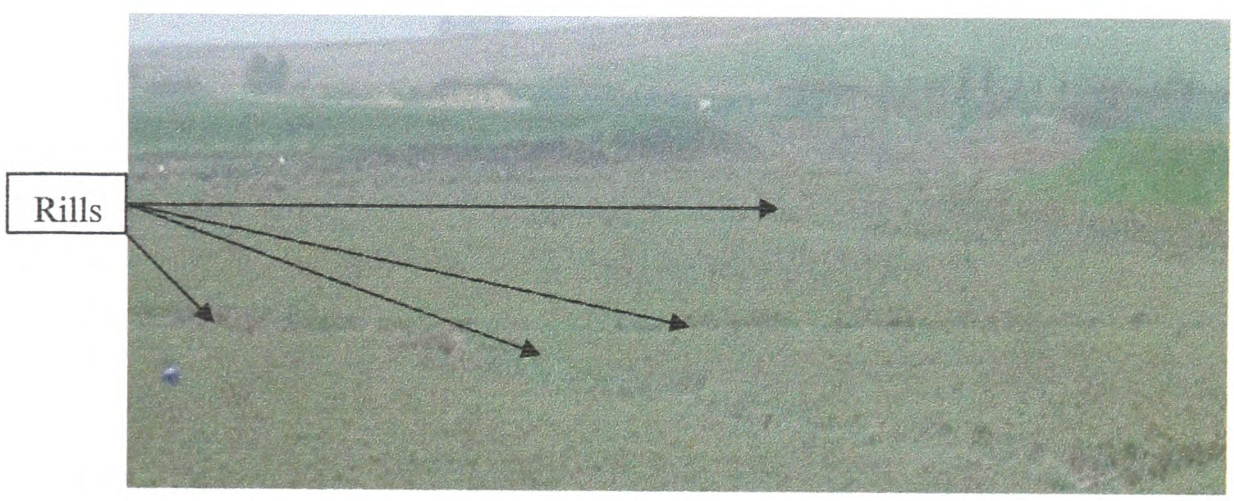


Fig 5.20: Rills frequent (score 3).

h) <u>Invasive species</u>: - are those species, which exhibit competitive and ruderal establishment strategies as defined by Grime et al (1988). Although invasive species appear within the NVC diagnostic tables (Rodwell 1992), they are usually at a constancy of I or II. Where they occur at a constancy of three or above, i.e. occurring in over 40% of the samples, there is an indication that factors other than grazing marsh management are causing the more competitive and ruderal species to become prevalent on the fragment. Increased edge effects as discussed in Section 7.3, brought about by fragmentation being the main cause, however, increases in species such as ragwort (*Senecio jacobaea*) may indicate over-grazing. A high score for invasive species or ruderals above the constancy indicated in Rodwell (1992) is an indicator of a decline in the grazing marsh status. The scores were recorded as the cover within a 1m x 1m quadrat, (Table 5.12) and are based on the limits set in the DAFOR scoring system. Figs 5.20 – 5.22 illustrate differing covers of invasive species, and Table 5.13 highlights some of the characteristic and invasive species found on grazing marshes.

Table 5.12: Scoring for Invasive Species.

0	Absent (Fig 5.21)
1	<10% cover
2	10 – 25% cover
3	25 – 50% cover (Fig 5.22)
4	50 – 75% cover
5	>75% cover (Fig 5.23)

Fig 5.21: No invasive species (score 0).

Fig 5.22: Invasive species (score 3).

Fig 5.23: Invasive species (Score 5).

Table 5.13 Characteristic and invasive species of grazing marshes.

Species	Characteristic	Invasive
Lolium perenne	*	
Agrostis stolonifera	*	
Cynosurus cristatus	*	
Trifolium repens	*	
Festuca rubra	*	
Senecio jacobaea		*
Rumex crispus		*
Chenopodium album		*
Urtica dioica		*
Epilobium hirsutum		*
Ranunculus repens		*
Poa annua		*
Plantago lancelota		*

h) Scrub, trees and hedgerows:

Benstead et al (1997) regard pollards as a grazing marsh feature; generally an increase in the coverage of scrub etc. indicates a lack of management and the occurrence of successional processes. Ideally scrub, trees and hedgerows should be absent from grazing marshes.

5.4 Methods of Analysis.

5.4.1 Historical analysis.

Quantitative analysis carried out on the historical data involved the construction of tables for each Ordnance Survey series map and for each individual site and fragment. The tables indicated the methods and agents of fragmentation occurring prior to 1897, between 1897 and 1960 and from 1960 to 2000 see Section 6.1. The individual effects of the fragmentation processes and agents were analysed as to their effects on the landscape characteristics and features by comparing the scores recorded for each fragment.

The area, perimeter and the distance to the nearest marsh and/or fragment were measured (Section 5.3.1) and the results tabulated, see Section 6.2. Evaluation involved a quantitative desk study in which the areas and perimeters of individual grazing marshes and fragments present at the end of the nineteenth century were compared to the situation in 1960 and the present day. The changes both in total area/ perimeter and the percentage changes that have occurred to the marshes and individual fragments were then calculated. The overall results were then compared to those of previous studies, e.g. Thornton and Kite (1990).

5.4.2 Landscape analysis.

The landscape surveys were carried out during the summers of 1998 to 2000. In addition, this survey was used to confirm the nature of the fragmenting agent, i.e. industrialisation, urbanisation etc., and the nature of the surrounding land use, current management of the site and the presence and nature of any connectivity to adjacent grazing marshes. The details of the survey were used to determine if the individual fragmenting agents or processes have their own unique effect on grazing marsh characteristics and features.

The average score for each characteristic and feature was plotted on a bar chart to indicate the individual score for every fragment. The relationship between the area of the individual fragments and the scores for the landscape characteristics and features was recorded on graphs. Due to the large variation in fragment size, the areas were plotted on a log scale. Tests for correlation were carried out to see if there was any relationship between fragment size and the status of the characteristics and features. Results were discussed in terms of whether fragmentation had influenced their status or if other factors were present or absent. The score recorded at individual survey points will reflect the grazing marsh status at that particular point and can indicate where areas of concern within the surveyed fragment occur, e.g. a high score for tussocky grassland may indicate that areas of the grazing marsh are being under-grazed.

5.4.3 Vegetation analysis.

Results of the analysis are presented in the form of tables representing: -

- The ten best matching NVC community types for each site and each fragment, based on the MATCH constancy values described in section 5.3.3.
- Analysis of the NVC community types with respect their ranking and occurrence on the individual fragments;

- Analysis of the changes in area, perimeter and isolation of the grazing marsh sites and individual fragments since the 19th century, as detailed by the relevant Ordnance Survey maps, see Section 5.4.1;

Classifying the surveys was carried out by using the MATCH computer programme to compare the plant communities found in the samples to the plant communities recorded within the National Vegetation Classification. The MATCH programme works by comparing the constancies of communities and species in each sample of the data with those recognised in the NVC. Using the Czekanowski coefficient of similarity, the highest matching communities are identified by comparing constancy profiles between samples. The Czekanowski coefficient produces a range of values from 0 (complete dissimilarity) to 1 (total similarity), (Kent and Coker 1992) by using the formula:

$$C = \frac{200\,\Sigma \min(x_j, y_j)}{\Sigma x_j + \Sigma y_j}$$

where x_j is the constancy (on a scale of 1-5) for species j in the community diagnosis and y_j is the constancy of the same species in the data: $\min(x_j,y_j)$ is the lesser of the two values, (Malloch 1999).

The results of the vegetation surveys were compared using the coefficient of similarity of matches, and producing tables for the closest ten NVC communities and sub-communities for each individual fragment, see Appendix 3. Tables (Section 8.3), have been constructed to show the communities present in each individual fragment and individual quadrat, together with the Czekanowski co-efficient showing the similarity of the quantitative data, together with the most commonly occurring communities and their position in the top ten ranking. Analysis of the data will highlight the most consistently occurring and best-matched communities, for each fragment and every quadrat on every fragment.

Since the NVC descriptions compiled by Rodwell (1992), have no mention of grazing marsh communities, it was therefore, decided to analyse the vegetation data and obtain the closest match to the groupings identified by Rodwell and represented within lowland wet grassland categories, defined in Chapter 3. The communities highlighted by ADAS (1997) and Benstead et al (1997), were also used as a guide to establish the grazing marsh mosaic of communities. By tabulating, the data for each site and the individual quadrat samples produced by the MATCH computer programmes (Malloch 1992), and with reference to keys, tables and descriptive text from the NVC, the resultant communities can be assessed against the mosaic of key grazing marsh communities. The results of the data will highlight variations that are caused either by fragmentation, or attributable to regional variations in the species content of the North Kent Grazing Marshes.

Further analysis was carried out by constructing tables of the individual species with the highest constancy from the best-matched communities in the data sets. Using the diagnostic tables prepared by Rodwell (1992, 2000), the differences between the expected and observed values of the individual species was determined. This analysis highlighted the presence or absence of key species within the community description and whether key species are present at a greater or lesser constancy than recognised within the NVC. The constancy values range from I, rarely occurring species (0 – 20% of the samples) to V, for species, which occur in 80 – 100% of the samples. For the purpose of these results consideration will be given primarily to those species, which occur in 41-60% of the samples or more, i.e. a constancy of III or greater. There may, however be need to comment on species recorded at a lower constancy. In the final constancy tables, a comparison of the survey data with the NVC community the adjusted DAFOR scores are used to 'determine discrepancies between the amounts of each key species and under/over represented species found in the survey data and the amount found in the NVC community' (Dodd et al 1994). These differences will then be assessed against predictions of the effects of fragmentation.

5.5. Summary.

The aims of the analysis are therefore to: -

1. Identify the main processes and agents that have been responsible for the fragmentation of the North Kent Grazing Marshes; (Section 6.2 – 6.5)
2. Record the changes in area, edge length, edge/area ratios, compare them to previous surveys; (Section 6.6).
3. Describe the effects of fragmentation on the current landscape features and characteristics, i.e. the matrix of the North Kent Grazing Marshes, (Section 7).
4. Establish the component vegetation communities, which comprise the grazing marsh matrix; (Section 8.1).
5. Analyse the effects of fragmentation on the vegetation communities, identify differences in the composition of the key communities, by comparison with the diagnostic tables of the NVC (Rodwell 1992, 2000) and identify the factors that may be responsible for the differences; (Section 8.2 – 8.4)

Chapter 6 Historical Analysis

6.1 Introduction.

The historical analysis considers firstly the agents of marsh fragmentation, i.e. road, rail, canal, industry, urbanisation, agricultural intensification and their relative impacts on the North Kent Marshes both collectively and individually. Secondly, the types of fragmentation is analysed using the typology of Harris et al (1992) to determine which of the processes has had the greatest effect on the North Kent Marshes, and whether processes act collectively or individually. The overall impact of the agencies and processes of fragmentation has been to reduce the overall area of marshland and reduce the marshes to remnant fragments. The third strand of the analysis therefore considers these losses of area and compares the losses to previous data, e.g. Thornton and Kite (1990).

6.2.1 Fragmenting agents pre 1897- Results.

Prior to human influenced fragmentation, natural fragmentation i.e. isolation occurring between two areas of grazing marsh due to non-human causes, occurred on the North Kent Grazing Marshes. The River Cray provides a natural barrier 40m wide between the fragments 2 and 3 of Crayford Marsh (Fig 6.2.1 and 6.2.2). Swanscombe and Botany Marshes situated on the Swanscombe Peninsula (Fig 6.2.3) are isolated from Stone Marsh in the west and Denton Marsh in the east by natural chalk intrusions, which support different habitats. The development of settlements at Greenhithe and Gravesend on these intrusions has further isolated the grazing marshes and created a stronger barrier between the marshes.

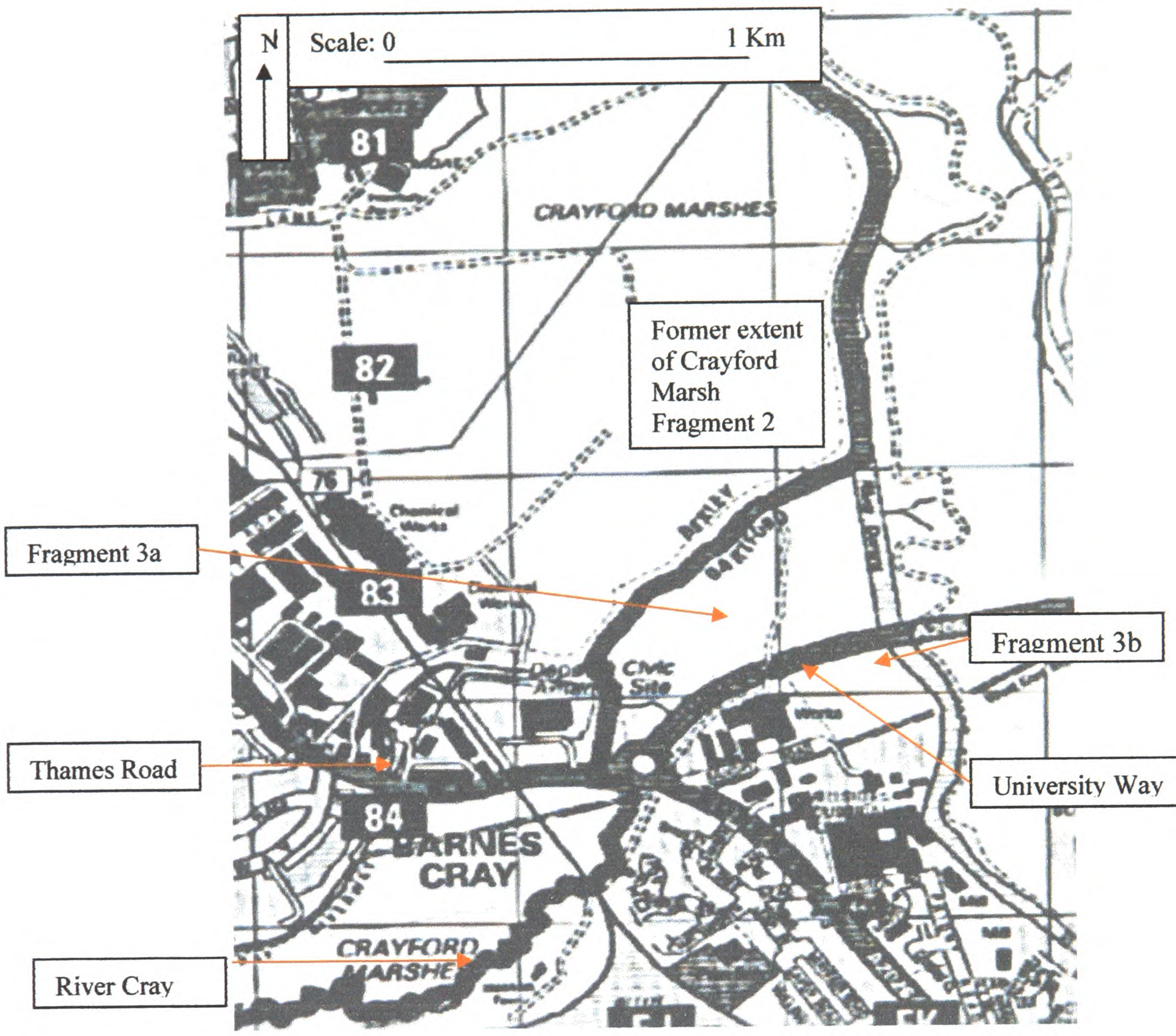


Fig 6.2.1: Crayford Marsh showing the natural division by R. Cray and divisive fragmentation by new roads, (from Collins).

Before the nineteenth century, the North Kent Marshes were criss-crossed by a network of small tracks and paths providing access to the small farm buildings and jetties that were sited across the marshes. Such tracks are regarded as being too small to act as fragmenting agents, because they would be similar in composition to the surrounding marshes and should not form a barrier to movement across the marshes. Fig 4.4 shows Erith Marsh at the time of Hasted (1797) clearly indicating the presence of small tracks.

Fig 6.2.2: Crayford Marsh fragment 3a showing University Way

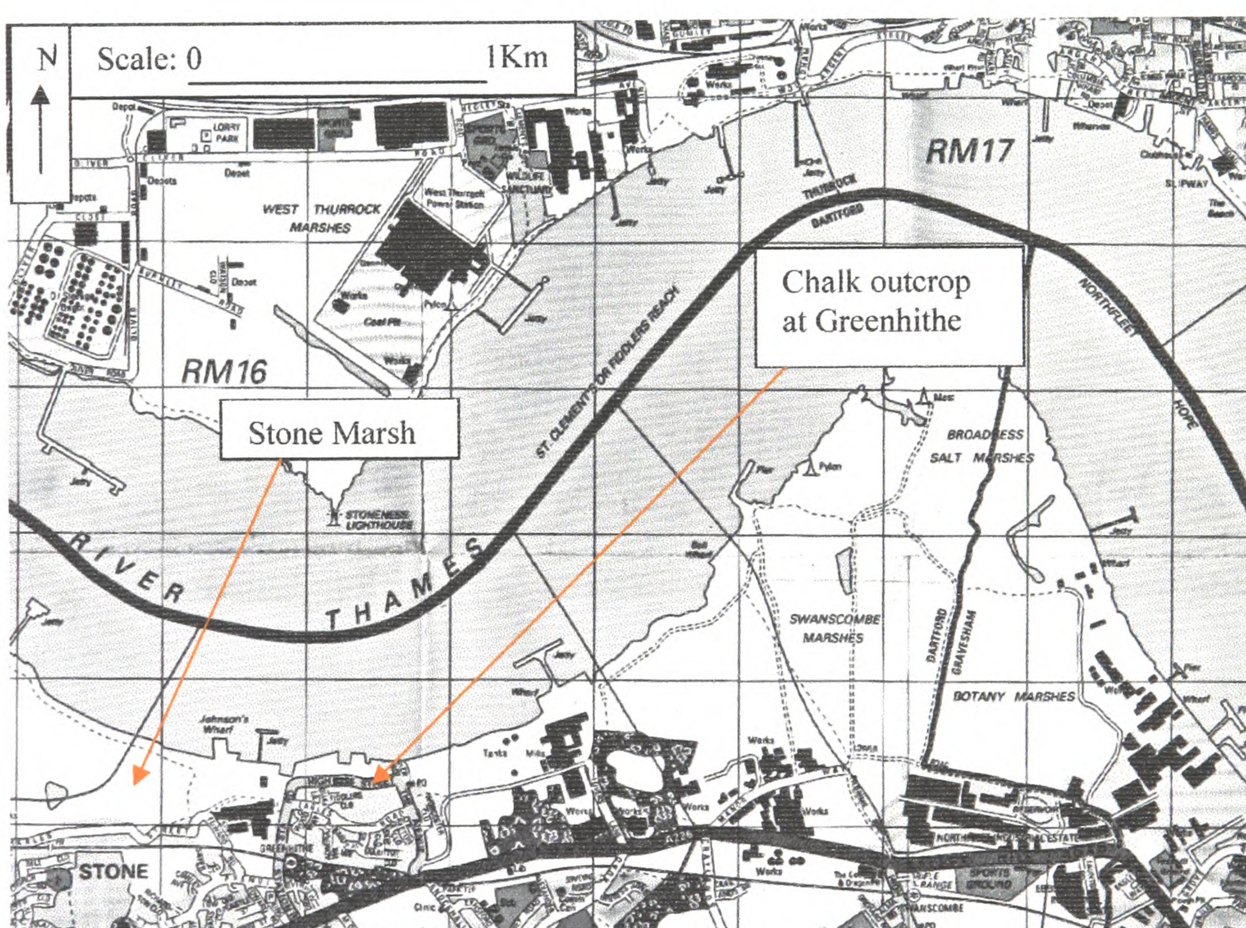


Fig 6.2.3: Natural fragmentation of Swanscombe Peninsula (from Collins).

Prior to the issue of the first Ordnance Survey Series, there is some documentary evidence of fragmentation (e.g. MacDougall 1980, Dartford Archive 2001, Thomas 2001). An example of early fragmentation was the construction of the Thames –

Medway Canal in 1824, which was responsible for fragmenting one of the largest contiguous tracts of grazing marsh present at that time. The area recorded by Hasted (1797) as Gravesend and Higham Marshes was divisively fragmented by the canal construction into two separate fragments, Shorne and Higham Marshes to the north, Denton, Great Clane, Westcourt and Filborough Marshes to the south (Fig 6.2.4). The barrier created by the canal was subsequently strengthened by the construction of the North Kent Railway Line parallel to the canal in the late nineteenth century.

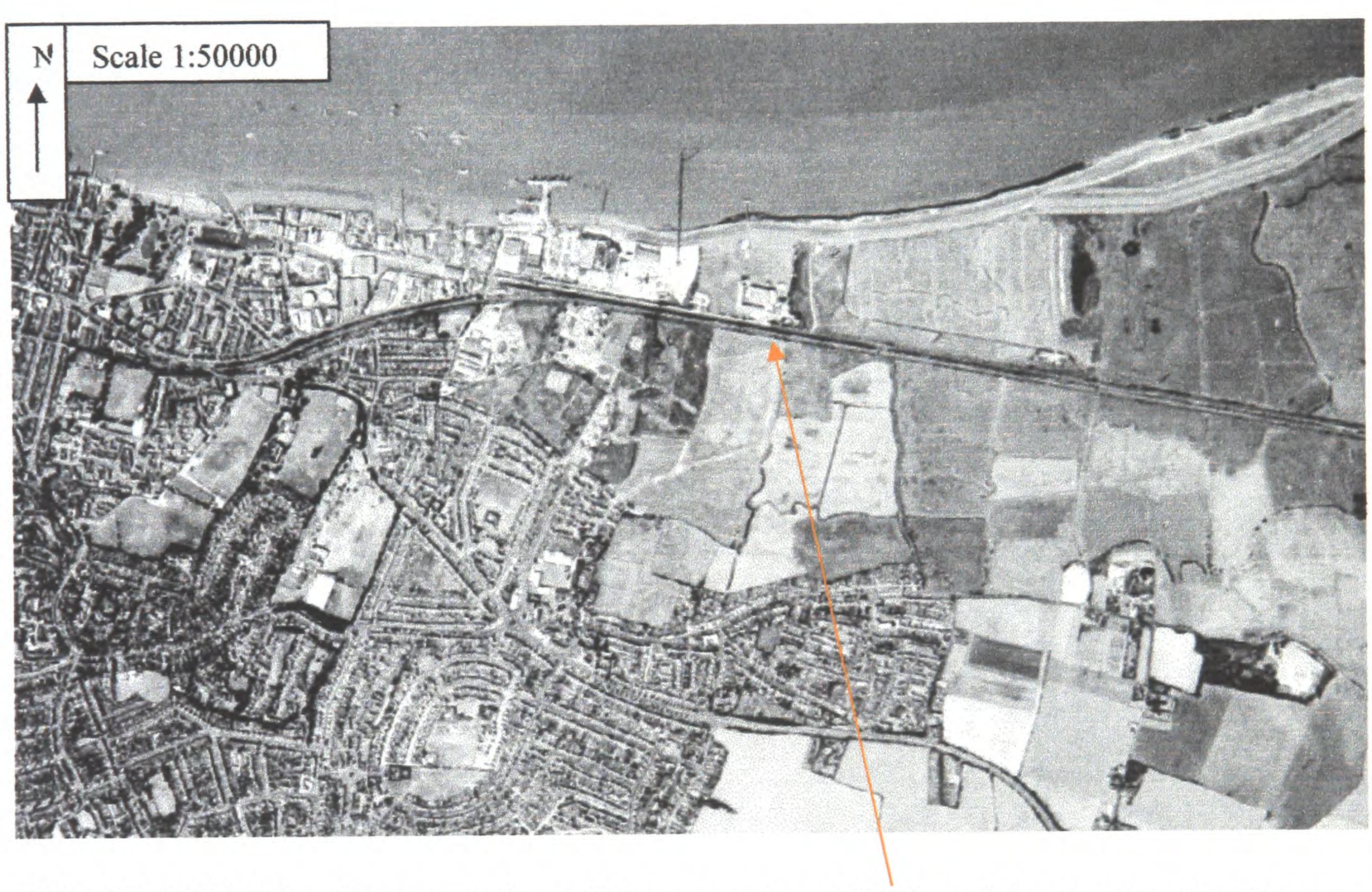


Fig 6.2.4: Divisive fragmentation of Gravesend and Higham Marshes by the Thames – Medway Canal (1999).

Cliffe Marsh was also divisively fragmented by a canal constructed in 1897 between the chalk quarries of Cliffe to the River Thames for the transport of chalk. The canal was lost when areas became used for mineral extraction. The mineral workings now act as a barrier between Higham and Cliffe Marshes.

Table 6.1 records the agencies, which were responsible for the fragmentation of the North Kent Marshes recorded on the Second Series Ordnance Survey Maps of 1897, see Section 5.2. It is evident from the table that prior to 1897 infrastructure projects were responsible for many of the earliest fragmentation episodes on a majority of the marshes. 86.7% of the individual grazing marshes of North Kent were affected by divisive fragmentation, which was due to the construction of roads, railways or canals. Roads caused divisive fragmentation on seven marshes either by fragmenting one larger marshland, e.g. Erith, or isolating two individual marshlands, e.g. Botany and Northfleet, and were responsible for 46.6% of fragmenting episodes.

Table 6.1 Agencies responsible for fragmenting events recorded on the Second Series Ordnance Survey Maps 1897.

Marsh		Road	Rail	Canal	Industry	Utilities	Natural	No of agents
Erith	I	*			*	*		3
Crayford	I	*	*		*		*	4
Dartford	I	*						1
Stone	I	*			*			2
Swanscombe	I						*	1
Botany	I	*			*			2
Northfleet	I	*			*			2
Denton	O			*				1
Great Clane	O			*				1
Filborough	O			*				1
Shorne	O			*				1
Higham	O			*				1
Cliffe	O			*	*			2
Allhallows	O							0
Grain	O	*	*					2
Percentage of marshes fragmented by each agent		46.6% (85.7% I) (12.5% O)	13.3% (14.3% I) (12.5% O)	40.0% (0% I) (75% O)	40.0% (71.4% I) (12.5% O)	6.7% (14.3% I) (0% O)	13.3% (28.6% I) (0% O)	

I – Inner Thames Marshes, O – Outer Thames Marshes

The 40.0% of fragmentation caused by canal construction however, does over emphasise the importance as a fragmenting agent, where the construction of one canal created five separate marshes. In contrast, different roads affected seven marshes, six of which are within the Inner Thames Marshes; canal construction was responsible for fragmentation solely on the Outer Thames Marshes. Rail construction has been of lesser importance as a fragmenting agent and was responsible only for the fragmentation of Crayford Marsh amongst the Inner Thames Marshes and Grain Marsh in the Outer Thames Marshes. In each case rail construction was accompanied by road construction following the same corridor thereby increasing the width of barrier between the respective fragments.

Industrial development was responsible for fragmentation on 40.0% of the marshes surveyed, with the Inner Thames Marshes (71.4%) being affected more than the Outer Thames Marshes (12.5%). The construction of Utilities prior to 1897 occurred only on Erith Marsh.

The number of agents acting on the individual marshes is greater for the Inner Thames Marshes with an average of 2.14 acting on each marsh, than the Outer Thames Marshes where there is an average of 1.13 agents per marsh. Most affected were Crayford Marsh fragmented by four agents and Erith Marsh fragmented by three agents. Allhallows Marsh was the only study site that was unaffected by fragmentation prior to 1897.

6.2.2 Discussion.

It is acknowledged that many earlier maps, e.g. the maps of the Hundreds in Hasted (1797), showed some evidence of minor incursions across the marshes, however, large-scale fragmentation of the North Kent Marshes began only during the nineteenth century as a result of the increased movement of the population to London and the south east. As the population increased so did the need for housing, employment, transport and communication. The result was a need for land upon which these requirements could be fulfilled and so habitat loss and fragmentation of the North Kent Marshes began and in particular to the Inner Thames Marshes.

Fig 6.2.5: Piers on Swanscombe Marsh

The construction of roads, railways and canals was due to the need to connect the growing industries to the existing piers and jetties found along the Thames embankment. The marshes at Erith, Stone and Swanscombe were all particularly susceptible to these types of development, because of the number of suitable landing points that these marshes possessed (Fig 6.2.5). For example, three roads were constructed across Erith Marsh (Fig 6.2.6), following tracks shown on the maps of the Hundreds, which linked riverside piers and wharves to the newly opened North Kent Railway Line and the improved road system which ran along the southern edge of the marsh. Erith Marsh was thus sub-divided into three large fragments. The improved road system allowed industrial development to occur on the fragmented marshland, with fragment 3 (Fig 6.2.7) the first to be exploited.

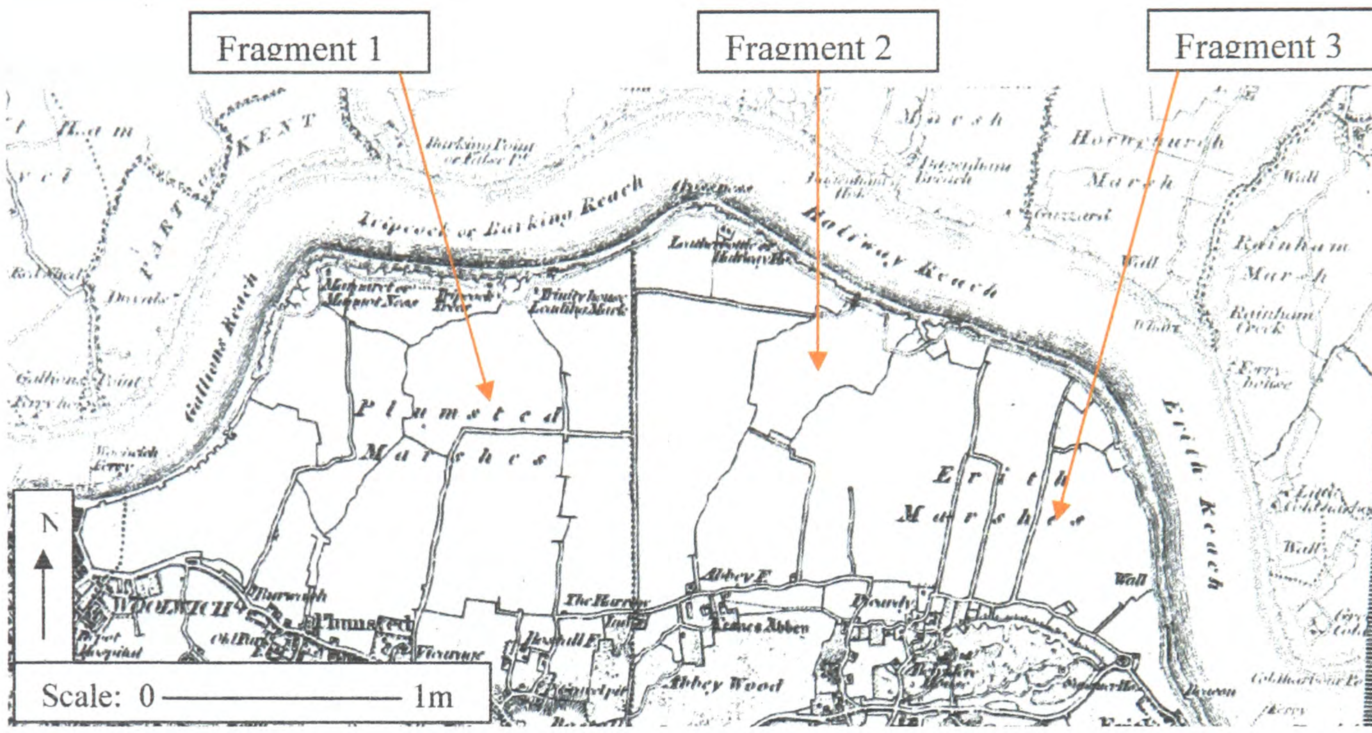


Fig 6.2.6: Divisive fragmentation of Erith Marsh in the 19th century, {from Hull).

Fig 6.2.7: Erith Marsh fragment 3 as it looks today.

Divisive fragmentation by railway construction was another major agent fragmenting the North Kent Grazing Marshes, although only two marshes were affected i.e. Crayford and

Grain. The opening of the North Kent Line to Dartford in 1849 (Pritchard 1976) divisively fragmented Crayford Marsh and isolated the smaller fragment now known as Barnes Cray from the main marsh, (Fig 6.2.8). Rail Construction facilitated further fragmentation to both Erith and Crayford Marshes as industry developed causing further intrusive and encroaching fragmentation. In the east of the study area Grain Marsh was divisively fragmented by the construction and expansion of the railway industry, when the Hundred of Hoo railway opened in 1882 (White 1976), to connect the newly constructed Port Victoria to the ferry to Queenborough on the Isle of Sheppey.

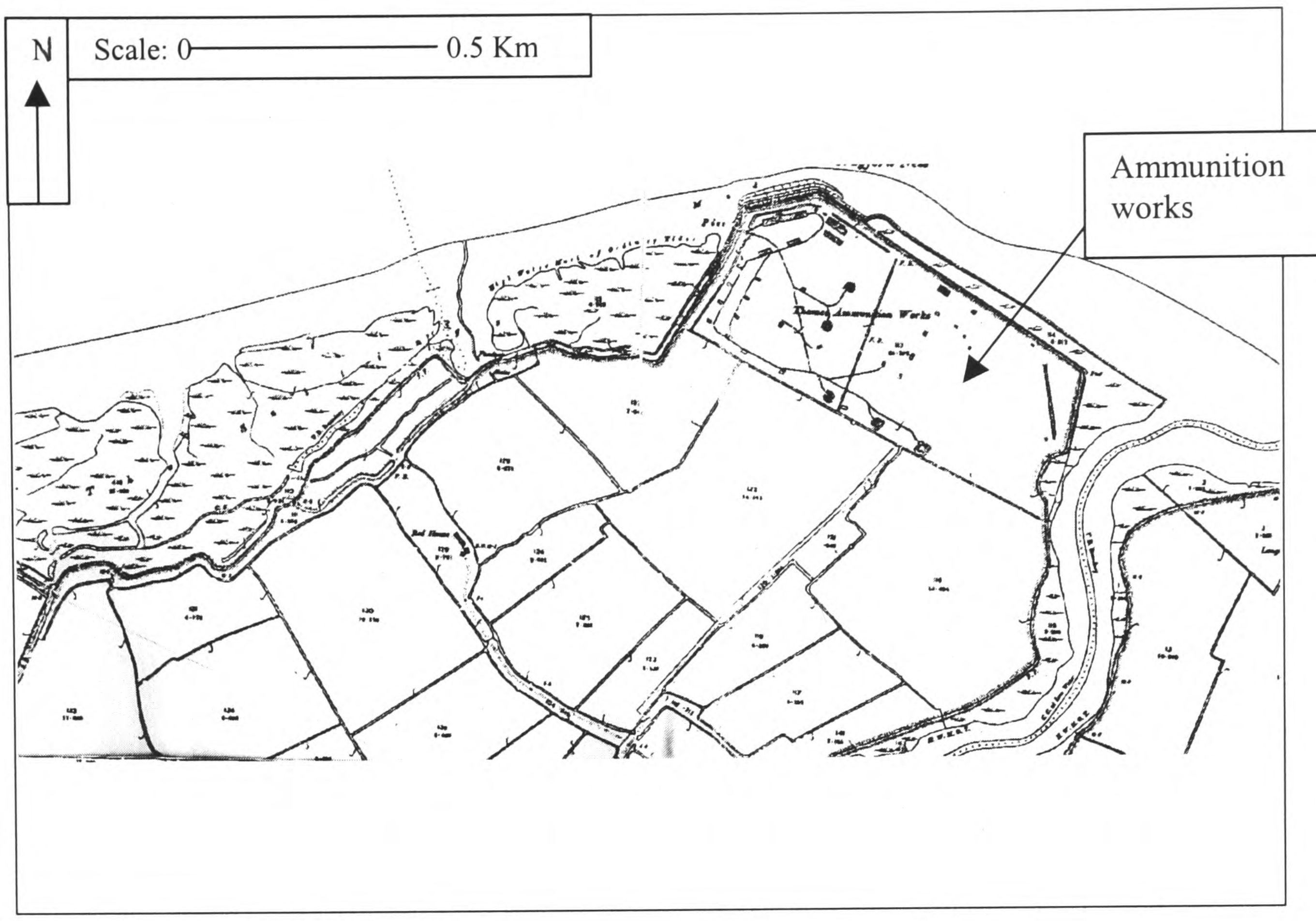
Fig 6.2.8: Divisive fragmentation of Barnes Cray by road and rail.

All of the Inner Thames Marshes, except Swanscombe Marsh were fragmented by road building prior to 1897, many of these roads following the routes of older and smaller cart tracks, e.g. Erith and Crayford Marshes. Erith and Stone Marshes were the most fragmented, both being divided into three fragments and Crayford Marsh divided into two equally sized fragments (Crayford 1 and 2a). Road construction on the Swanscombe Peninsula was responsible for separating Northfleet Marsh from Botany

Marsh, where ultimately the construction of the Britannia Metal Works resulted in the total loss of Northfleet Marsh.

Fragmentation through industry was a more important factor on the Inner Thames Marshes where Erith, Crayford and Stone Marshes were all early sites for industrial development. For example, early fragmentation was recorded by Thomas (2001), who stated that development occurred on Crayford Marsh as early as 1889, with the construction of an ammunition works, the site now occupied by the Thameside Industrial Estate (Fig 6.2.9). Erith Marsh was fragmented by two separate events; in 1860, the construction of Crossness Sewage Works on fragment 2 and in 1880 BICC built their first factory on fragment 3. The use of the marshes for such 'dirty and dangerous' industries was as Thomas (2001) recorded because of their situation away from centres of population. Isolation and openness of the marshes therefore often were contributory causes to fragmentation.

Four cement works were constructed on Stone Marsh, (intrusive fragmentation), during the period between 1866 and 1897, all being linked by tramways (divisive fragmentation), (Dartford Archive 2001). The increase in industrial activity led to residential development, which regressively fragmented Stone Marsh along the southern edge. Cliffe Marsh was the only Outer Thames Marsh affected by fragmentation resulting from industrial development, and as with Stone Marsh resulted from the manufacture of cement, beginning in1860 (MacDougall 1980).



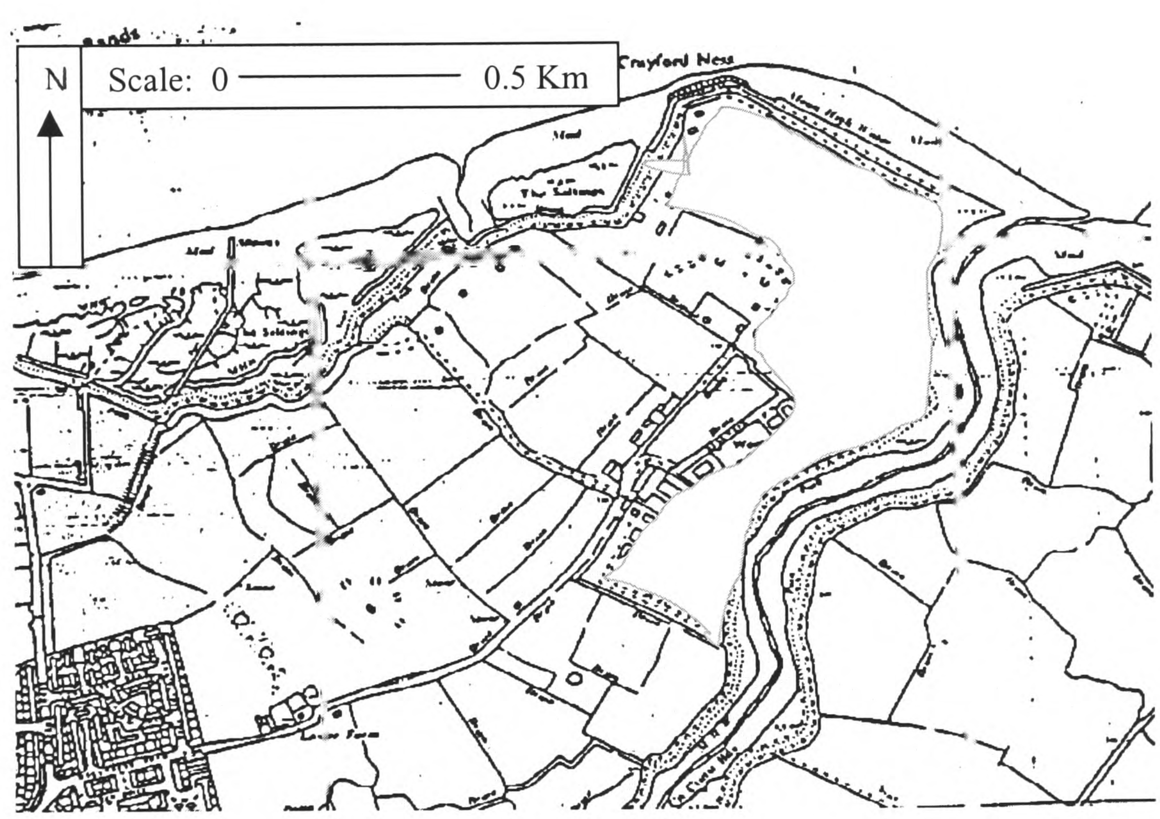


Fig 6.2.9: Intrusive fragmentation Crayford Marsh 1897 (Ordnance Survey) and present day (from KTNC) highlighting the increase in area of intrusive fragmentation.

Dartford Marsh in contrast to Erith and Crayford Marshes suffered no such industrial development pre 1897 and remained largely intact until later in the twentieth century. Although a new road to the Longreach Tavern which followed an old cart track evident from the maps of Hasted (1797), had divisively fragmented Dartford Marsh into two separate fragments by 1897 (Fig 4.7a). Similarly the early maps of Hasted (1797) show that a track known as Marsh Street possibly divided Dartford and Stone Marshes, later maps of 1897 however (Fig 4.7b), indicate that the track was not wide enough to constitute a major fragmenting agent, and therefore at the beginning of the study period, Dartford and Stone Marshes still formed one contiguous marsh (Hull 1988).

Prior to 1897 small-scale industry was being developed, primarily on the Inner Thames Marshes. As methods of communication and transport improved, there was an increasing need to connect the industries to the new transport networks, which led to the divisive fragmentation. Pre 1897 fragmentation therefore, is linked to the economic development of the region, with the areas nearer to the larger centres of population, i.e. the Inner Thames Marshes, being more extensively fragmented than the Outer Thames Marshes.

Table 6.2 shows the agencies that were responsible for the fragmentation of the North Kent Grazing Marshes from 1897 to the present time. Eight of the Inner Thames Marshes (57.1%) as shown by the table have tended to be fragmented by a combination of three or more agencies. With the exception of Grain Marsh, the Outer Thames Marshes have been fragmented by two or less agents. There has been no fragmentation on Filborough and Shorne Marshes. The table shows that whereas prior to 1897 infrastructure, i.e. roads etc were the major cause of fragmentation, in the period after 1897 industrial development became more important, responsible for 21.9% of fragmenting events.

6.3.1 Subsequent fragmenting agents – post 1897 Results.

Table 6.2 Agencies responsible for fragmentation of North Kent Marshes post 1897

Marsh		Road	Rail	Urban	Agriculture	Industry	Utilities	Mineral extraction	No of agents
Erith	I	*		*		*	*		4
Crayford	I	*		*		*	*		4
Dartford	I	*			*	*	*		4
Stone	I	*				*		*	3
Swanscombe	I					*	*		2
Botany	I				*	*			2
Denton	O	*		*			*		3
Great Clane	O	*		*	*				3
Filborough	O								0
Shorne	O								0
Higham	O	*	*					*	3
Cliffe	O				*			*	2
Allhallows	O		*		*				2
Grain	O			*		*	*		3
Percentage of marshes fragmented by each agent		15.6% 66% (I) 37.5% (O)	3.2% 0% (I) 25% (I)	15.6% 33% (I) 37.5% (O)	15.6% 33% (I) 37.5% (O)	21.9% 100% (I) 12.5% (O)	18.8% 66% (I) 25 % (O)	9.4% 16.6% (I) 25% (O)	Ave 2.5

I - Inner Thames Marshes O - Outer Thames Marshes

Fragmentation due to industrial development has occurred on all the Inner Thames Marshes and only one of the Outer Thames Marshes and overall is responsible for 21.9% of fragmenting events. Agriculture (15.6%), urbanisation (15.6%) and mineral extraction (9.4%) have all become agents of fragmentation during the twentieth century, affecting 75% of the outer marshes and 66% of the inner marshes. The construction of Utilities, i.e. power stations, sewage works etc, became a more influential fragmenting agent post 1897 being responsible for 18.8% of fragmentation and affecting six marshes, with four (66.6%) in the Inner Thames Marshes and two (22.2%) of the Outer Thames Marshes. Road construction (15.6%) has remained an important fragmenting agent affecting seven marshes (50%), but the percentage of fragmentation resulting from road building has decreased because of the increase in fragmenting events from 24 pre 1897 to 35 after 1897.

6.3.2 Fragmenting agents post 1897 – Discussion.

Fragmentation of the North Kent Marshes in the twentieth century has been far more extensive than in earlier periods, as the number of fragmenting agents and events has increased, the number of fragments created has increased and the overall loss of grazing marsh has increased. The nature of the fragmenting agents has changed as the needs of the region and economic and defensive needs of the country. For example, canal construction was an important fragmenting agent in the nineteenth century, whereas in the twentieth century there have been no new canals built.

Roads have continued to be one of the more important factors in the fragmentation of the Inner North Kent Marshes. Continued development throughout the Thames Gateway has required new roads to link development sites, resulting in the further fragmentation of Erith, Crayford, Dartford and Stone Marshes. Of the Outer Thames Marshes, Denton and Great Clane have been further fragmented by roads, which have been associated with urbanisation; only Crayford Marsh of the inner marshes has been directly affected by roads linked to urban development.

Fragmentation arising from the construction of railways fell from 13% of fragmentation events prior to 1897 to 3.2% after1897. Fragmentation in the early period reflects the railway boom of the nineteenth century. The subsequent decline in the status of railways has meant that since 1897 little railway construction occurred. There were however, two new lines built after 1897, which fragmented Allhallows and Higham Marshes and are examples of how two fragmenting agents are often complimentary and reflective of economic and population needs. The branch line, which fragmented Allhallows Marsh, was opened in 1932 to provide access to the new holiday resort of Allhallows-on-sea (White 1976). The closure in 1961 reflects the change in people's holiday requirements and growing importance of road transport (White 1976) and has now allowed grazing marsh vegetation to be re-established. Higham Marsh fragment 1c was created by the construction of a railway line to transport sand from the mineral workings between Cliffe and Higham Marshes (Fig 6.3.1), and is an example of two fragmenting agents acting in tandem, i.e. the occurrence of one agent results in the need for the other. In the future rail construction will cause further grazing marsh fragmentation as the anticipated route for the Channel Tunnel Rail Link crosses Swanscombe Marsh.

Fig 6.3.1: Divisive fragmentation of Higham Marsh by mineral railway.

Mineral extraction acting as a fragmenting agent has affected three marshes. On Stone Marsh the extraction of sand between the wars resulted in the loss of 90% of fragment 1 through intrusive fragmentation, (see Fig 6.3.2). The effect of mineral extraction on Cliffe and Higham Marshes has been to create a barrier between the two marshes as well as causing fragmentation.

Fig 6.3.2: Intrusive fragmentation of Stone Marsh by sand extraction.

Industrialisation, urbanisation and changes in agricultural practices were identified by Thornton and Kite (1990) as having been responsible for not only fragmentation but also loss of marshlands throughout the Inner Thames region. This study recognises that these factors have been of importance, but also highlights that the agents can produce different fragmenting processes (Sections 6.4.1 and 6.4.2) and the role that roads etc., play in the initial stages of fragmentation, i.e. divisive fragmentation creating smaller units that are less viable for grazing and subsequently developed. Changes in agricultural practice (15.6%), industrialisation, utilities and mineral extraction (50.1%), are in this study identified as important agents of fragmentation on the Outer Thames Marshes, whereas Thornton and Kite (1990) identified agricultural conversion as the most important factor, accounting for 65% of changes for all sites. Fragmentation and loss of grazing marsh to industrial use, has occurred on Erith Marsh, Crayford Marsh, Stone Marsh and Grain Marsh but was not considered by Thornton and Kite within either the Inner or Outer Thames Marshes, and therefore direct comparisons are difficult to interpret.

Fig 6.3.3: Intrusive fragmentation of Grain Marsh by oil refineries.

Urbanisation according to Thornton and Kite (1990) has been relatively unimportant on the Outer Thames Marshes compared to the Inner Thames Marshes. The results of this study however, show that Denton, Great Clane and Grain Marshes, of the outer marshes, all incurred fragmentation through urban development. Grain Marsh in particular has been affected by urbanisation as the oil refinery and terminal have grown in importance and new housing has been provided (Fig 6.3.3). Denton and Great Clane Marshes have become surrounded by the urban growth of Gravesend and periodically suffered losses to new housing. On the Inner Thames Marshes, Thornton and Kite (1990) recorded 68% of grazing marsh losses to urbanisation. In this study, only Erith and Crayford Marshes of the Inner Thames Marshes recorded urbanisation as a fragmenting agent, accounting for 59% of the overall loss of grazing marsh area The majority of this loss is on Erith Marsh where urbanisation through the development of Thamesmead Town on fragment 1 (Fig 6.2.5), and along the southern edge where Abbey Wood has regressively fragmented Erith Marsh, the overall loss of area is 88%. The lower figure in this study for urbanisation may result from Thornton and Kite including commercial and industrial development under the category of urbanisation.

Green (1971) identified agricultural intensification as the main threat to the grazing marshes of North Kent, whereas in this study only 25% of the sites studied recorded changes in agricultural practice as a fragmenting agent. This study highlights that other factors, such as road construction, industrialisation and urbanisation have been just as important, particularly when considering the North Kent Marshes as a whole, i.e. from Erith to Grain, and not just those areas to the east of Gravesend.

6.4.1 Fragmenting processes pre 1897 – Results.

The method of fragmentation of the North Kent Marshes was recorded using the typology proposed by Harris et al (1992). Table 6.3 shows that divisive fragmentation has been the major fragmenting process throughout the North Kent Marshes affecting 93.75% of the marshes surveyed, with all of the Inner Thames Marshes being affected and only Chetney Marsh unaffected.

Intrusive and regressive fragmentations have also been important processes affecting 62.5% and 37.5% of the marshes surveyed respectively. For both intrusive and regressive fragmentation, 71.4% of the Inner Thames Marshes and 33.3% of the Outer Marshes were affected. Of the fragmentation processes only encroaching fragmentation has not had an effect on the North Kent Marshes prior to 1897. All the processes occurred more frequently on the Inner Thames Marshes than on the Outer Thames Marshes.

Table 6.3 Fragmentation processes occurring before 1897

Site		Regressive	Enveloping	Divisive	Intrusive	Encroaching	No. of processes
Erith	I	*		*	*		3
Crayford	I	*		*	*		3
Dartford	I			*			1
Stone	I	*	*	*	*		4
Swanscombe	I	*		*	*		3
Botany	I	*		*			2
Northfleet	I			*	*		2
Denton	O		*	*	*		3
Great Clane	O	*		*			2
Filborough	O			*			1
Shorne	O			*			1
Higham	O	*		*			2
Cliffe	O	*		*	*		3
Allhallows	O			*			1
Grain	O			*	*		2
Chetney	O						0
Percentage of marshes affected by each process		37.5 (71.4 I) (33.3 O)	12.5 (14.3 I) (11.1 O)	93.75 (100 I) (88.9 O)	62.5 (71.4 I) (33.3 O)	0.0	Ave 2.06

I – Inner Thames Marshes   O – Outer Thames Marshes

The number of processes affecting each individual marsh shows that generally there were more processes affecting the Inner Thames Marshes (mean 2.6), where four marshes Erith, Crayford, Stone and Swanscombe were fragmented by three or more processes. The Outer Thames Marshes averaged 1.7 processes per marsh with only Denton and Cliffe Marshes affected by three or more processes. Chetney Marsh was unaffected by fragmentation prior to 1897. The results reflect that prior to 1897 the inner marshes underwent more fragmentation than did the outer marshes.

6.4.2 Fragmentation processes prior to 1897 – Discussion.

Divisive fragmentation usually leads to intrusive, regressive and encroaching fragmentation as division improves access and opens up new areas for development (Forman 2000). The need to improve transport connections to intrusive fragmenting agents however may also result in divisive fragmentation. The Inner Thames Marshes provide many good examples of both processes, and a basis for English Nature's comment on the loss of the North Kent Marshes as 'death by a 1000 cuts'.

The ammunition works (intrusive fragmentation) on Crayford Marsh was originally served by the River Thames (Thomas 2001). As road transport grew in importance there was a need to connect the site to the road network so leading to the construction of a new road built along the line of the cart track recorded by Hasted (1797), and so divisively fragmenting Crayford Marsh. Fragmentation of Erith Marsh arose from upgrading the tracks recorded by Hasted (1797) into new roads, which led to the industrial and urban development (regressive and intrusive fragmentation) on the newly created fragments. The River Thames always provided good communications links, and the many landing sites, which could be found along the Erith river frontage, were exploited, resulting in the loss of the surrounding marshes. Construction of access roads such as Crabtree Manorway, Church Manorway, Cross Manorway and Harrow Manorway prior to 1897, initiated the fragmentation process by linking the riverside piers and wharves to the main North Kent Railway line and road system on the southern edge of the marshes.

Regressive fragmentation affected Crayford Marsh fragment 2 where further development associated with the North Kent Railway Line notably brickworks and the railway engine yards began to extend on to the marshland. The additional fragmentation, therefore again came about after the marshes had been divisively fragmented by improvements in transport and communication links.

Evidence for fragmentation of Dartford Marsh prior to 1897 is inconclusive. The maps show a road leading to the Longreach Tavern on the banks of the River Thames, although it is unclear as to the width of the road. As the barrier extends completely across the marsh, it has been taken to be a divisive fragmenting agent. Similar roads shown across Stone Marsh of the same era however, do not completely cross the marsh, although they were later upgraded to provide access to the cement works (intrusive fragmentation), and subsequently further divide the marshes into smaller fragments. Stone Marsh was also subject to regressive and enveloping fragmentation prior to 1897, all-resulting from the development of the cement industry. Regressive fragmentation occurred with the construction of housing along the access roads and with the cement works began to envelop the marshes.

Regressive fragmentation initially began to affect the marshes of the Swanscombe Peninsula, when industrial development along the southern boundary became more extensive. The resulting improvement in the road system led to divisive fragmentation, which allowed further intrusive development on Botany and Northfleet Marshes, and the ultimate loss of all of the latter marsh.

The marshes to the east of Gravesend (Fig 6.4.1) initially were divisively fragmented by canal construction (see Section 6.2.1). Although Denton, Great Clane and Higham

Marsh became subject to other processes that did not result directly from the divisive fragmentation by the canal, but resulted from divisive fragmentation by roads and subsequent regressive fragmentation (Higham Marsh), intrusive fragmentation (Great Clane Marsh), or enveloping fragmentation (Denton Marsh).

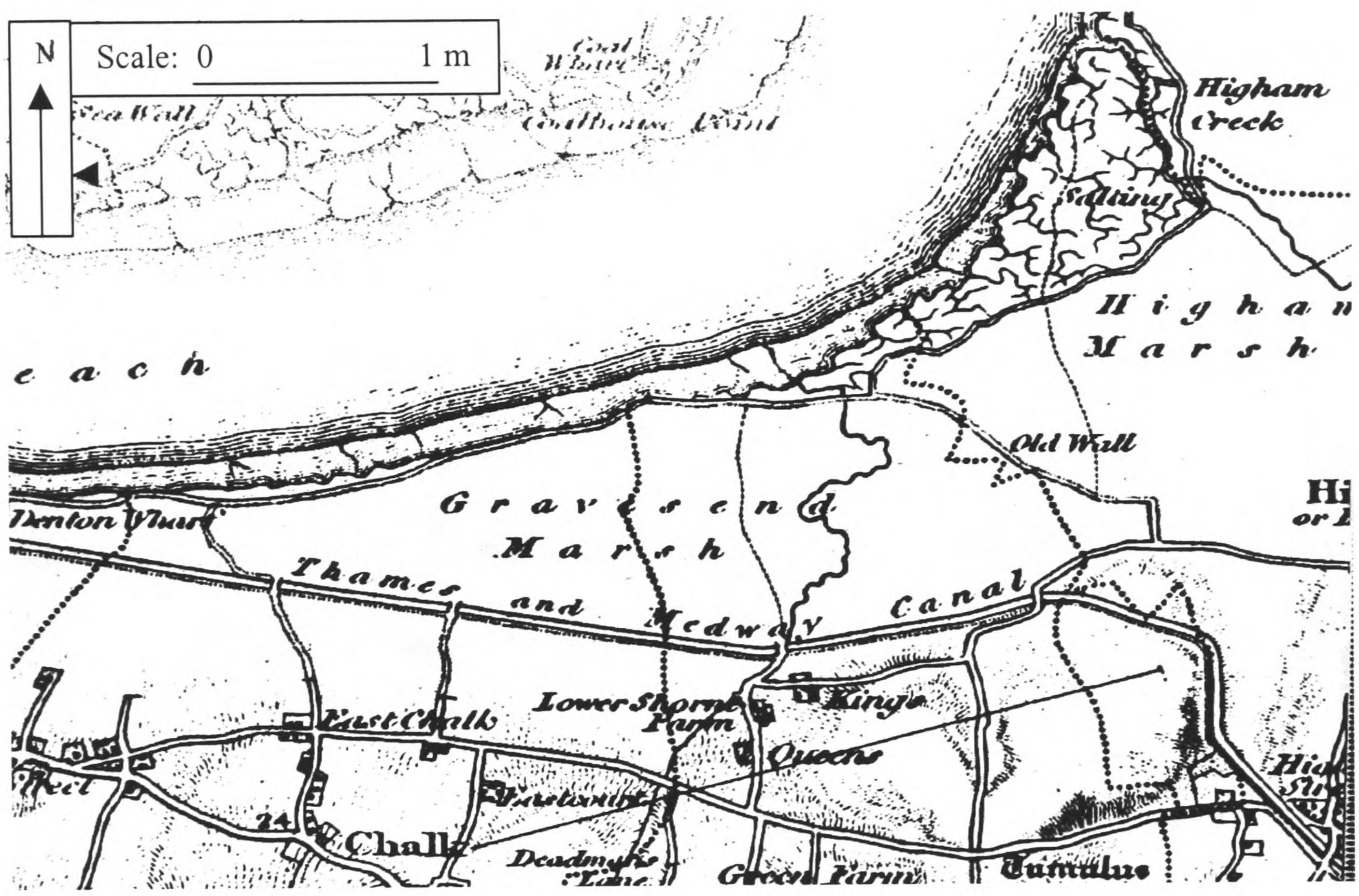


Fig 6.4.1: Gravesend Marshes showing divisive fragmentation by the Thames - Medway Canal (after Hull).

Cliffe Marsh prior to 1897 was affected by three fragmentation processes, division, regression and intrusion. Divisive and intrusive fragmentation occurred with the commencement of quarrying (intrusive fragmentation) which, led to the canal construction (divisive fragmentation). In this instance therefore, it was intrusion leading to division, rather than vice-versa, as has generally been the case throughout the North Kent Marshes. Regressive fragmentation occurred along the southern edge of the marsh resulting from developments associated with quarrying and the cement production industry (intrusive fragmentation).

Prior to 1897, Allhallows and Grain Marshes were divisively fragmented by the need to improve communications across the Hoo Peninsula. Grain Marsh was intrusively fragmented by the development of the village of Grain, which in the nineteenth century was a place of prestige and so was a desirable place to live (White 1976).

6.5.1 Fragmenting processes post 1897 – Results.

After the initial fragmenting events of the late nineteenth and early twentieth century divisive and intrusive fragmentation have remained as the primary causes of fragmentation within the North Kent Marshes responsible for 73.5% and 58.9% of the fragmentation respectively, see Table 6.4. Divisive fragmentation however, is of less importance affecting 73.5% of marshes compared to 93.75% prior to 1897. The totals for intrusive fragmentation (58.9%), regressive fragmentation (38.2%) and enveloping fragmentation (16.6%) have remained similar to those prior to 1897 (62.5%, 37.5% and 12.5% respectively). Encroaching fragmentation was not a factor prior to 1897 but has become responsible for 11.8% of fragmentation during the twentieth century.

The role of fragmentation in reducing the North Kent Marshes to smaller remnant fragments is most noticeable in the Inner Thames Marshes where the number of fragments has increased from seven to twenty three, whereas, the number of fragments in the Outer Thames Marshes increased from nine to eleven fragments. Only Filborough Marsh was unaffected by fragmentation. The number of fragmenting processes acting on the fragments also shows that the Inner Thames Marshes have been affected more by fragmentation (2.13 agents per marsh) than the Outer Thames Marshes (1.63 agents per marsh). The average number of processes per fragment overall has fallen from 2.06 pre 1897 to 1.97 post 1897.

Table 6.4 Fragmenting process affecting the individual fragments post 1897

Site		Regressive	Enveloping	Divisive	Intrusive	Encroaching	No.of processes
Erith 1	I			*	*		2
Erith 2a	I	*		*			2
Erith 2b	I	*	*	*	*		4
Erith 2c	I		*	*			2
Erith 2d	I			*			1
Erith 2e	I			*	*		2
Erith 3	I			*	*	*	3
Crayford 1	I	*					1
Crayford 2a	I	*	*		*		3
Crayford 2b	I			*			1
Crayford 3a	I	*		*			2
Crayford 3b	I	*		*	*		3
Barnes Cray	I						0
Dartford 1	I			*	*		2
Dartford – Fresh marsh	I	*		*			2
Stone 2a	I			*	*		2
Stone 2b	I			*	*		2
Stone 2c	I			*	*	*	3
Stone 2d	I	*	*	*	*		4
Stone 2e	I			*	*	*	3
Swanscombe	I	*			*		2
Botany	I	*			*		2
Denton	O	*	*	*	*		4
Great Clane	O	*		*	*		3
Filborough	O						0
Shorne	O				*		1
Higham 1a	O			*			1
Higham 1b	O	*		*			2
Higham 1c	O			*			1
Cliffe	O				*		1
Allhallows	O			*			1
Grain 1	O			*	*	*	3
Chetney	O				*		1
Percentage of marshes affected by each process		38.2 (43.5 I) (27.2 O)	14.7 (16.6 I) (9.1 O)	73.5 (78.3 I) (63.4 O)	58.9 (65.2 I) (45.5 O)	11.8 (13.0 I) (9.1 O)	Ave 1.99

I – Inner Thames Marshes O – Outer Thames Marshes

The recording of fragmenting process in Tables 6.3 and 6.4 however; does not always reflect the level of fragmentation that has occurred. For example, intrusive fragmentation has been recorded on Dartford Marsh, but there has been more than one intrusive fragmenting event, resulting from the construction of two hospitals, Littlebrook Power Station, a sewage works and the Astra fireworks factory. The effects of the additional fragmenting events have been to reduce the total area of the individual marshes. These losses are discussed in Sections 6.6 and 6.7.

6.5.2 Fragmentation processes post 1897 – Discussion.

Early divisive fragmentation prior to 1897 improved access and allowed marshes to later be reclaimed for light industrial use, utilities and office building. From the commencement of the study period in 1897 Erith Marsh fragment 3 (Fig 6.2.5), the most easterly of the marshes, was affected by regressive fragmentation as Erith town expanded and from intrusive fragmentation linked to the development of oil and bitumen works along the riverside. The process of further divisive fragmentation to fragment 3 was also beginning to become apparent, as access roads to these works and subsidiary developments were commenced at the end of the nineteenth century.

Transport links i.e. divisive fragmentation, acts as corridors and traffic acts as a medium for seed movement so a great number of opportunities are created for the dispersal of ruderal competitors. Divisive fragmenting agents and in particular roadside verges have become important footholds for many of the competitive species that have become a feature of many of the small and highly fragmented marshes (see Section 8.4).

Landscapes that are fragmented by processes involving construction, i.e. roads, house building etc; (intrusive or regressive fragmentation), will be influenced by different edge effects during the construction phase and the operational phase. Disturbance however, is key to both phases and will be instrumental to the changes that occur. During both phases of an operation, noise will be a continual disturbance factor, though the level and temporal span will differ. The size of a project will ultimately determine the area over which disturbance and edge effects will act, as will the location, i.e. whether the project is intrusive, divisive or regressive. The increased amount of disturbed ground created during construction increases the number of sites where competitive plant species can occur (Section 8.4).

Intrusive or regressive fragmentation in the majority of instances then occurred as the result of additional building works, either as an extension to an existing development, e.g. Erith Marsh fragment 3 or as totally, new developments e.g. Stone Marsh. The largest example of intrusive fragmentation has been caused by urbanisation and the development of Thamesmead Town, which has since 1960 accounted for the whole of Erith Marsh fragment 3, through progressive fragmentation. Divisive fragmentation however, again has been the catalyst to further fragmentation, as the construction, usually of a new road provides the access from which further development can take place. Although, on Erith and Stone Marshes for example, where this type of intrusive and regressive fragmentation has continued, it has led to further new roads and therefore additional divisive fragmentation. Subsequently both Erith and Stone Marshes have been further divisively fragmented in 1996 by the construction of new roads and creating further fragments Erith 2d, 2e (Fig 4.3) and Stone 2e (Fig 4.15).

Fig 6.5.1: Regressive fragmentation of Crayford Marsh from industrial expansion.

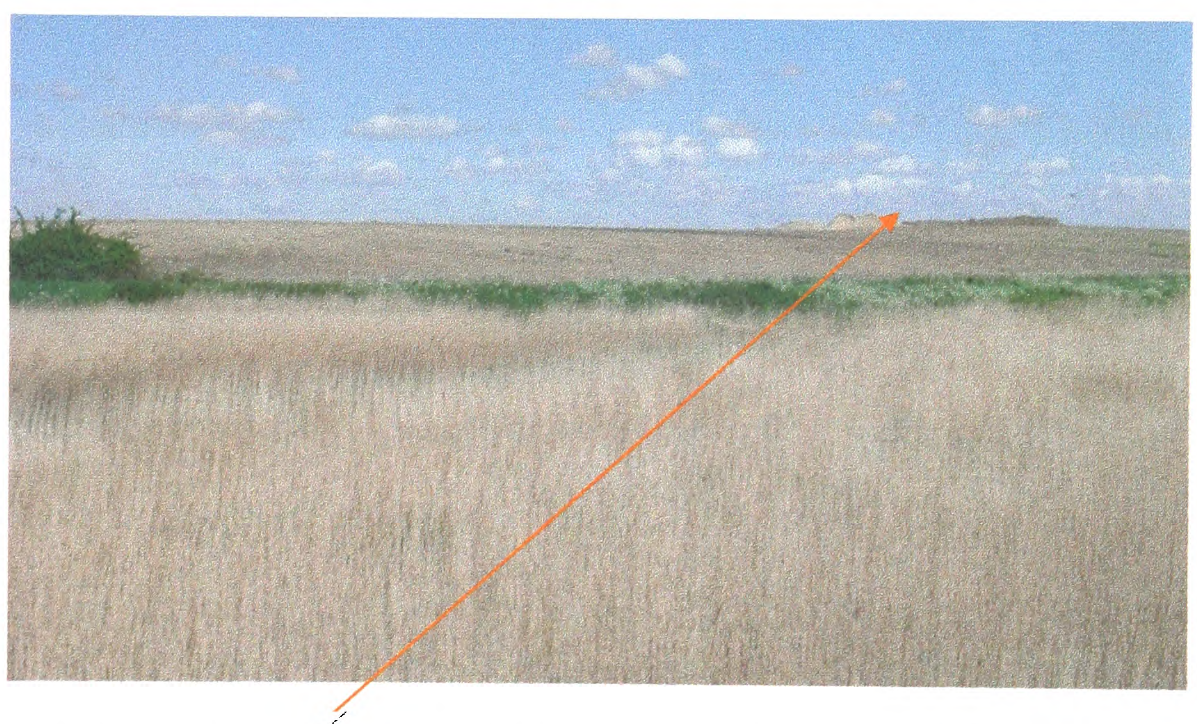


Fig 6.5.2: Intrusive fragmentation on Crayford Marsh from landfill operations.

During the course of the twentieth century, the land on Crayford Marsh occupied by the ammunition works has been taken over by industrial units, and have gradually increased in size, increasing the effects of intrusive fragmentation in particular fragments 1 and 2 (Fig 6.5.1). Expansion of Erith as an urban centre during the early twentieth century caused further regressive fragmentation along the western edge of Crayford Marsh fragment 1. Intrusive fragmentation on Crayford Marsh has also been extensive and has resulted from a landfill site opened in the 1960's and the landfill, which has caused the loss of the southern extension of Crayford Marsh fragment 2 (Fig 6.5.2).

Fig 6.5.3: Divisive fragmentation of Crayford Marsh by road construction.

Between 1960 and the present time development of new housing in Slade Green has further regressively fragmented Crayford Marsh along their western edge and resulted in further losses to both fragments 1 and 2. The construction of a new road along the western flank of fragment 1 (Fig 6.5.3) completed in 1997 has resulted in an additional loss of area (5ha), which has been reclaimed for housing and together with the industrial units has had the effect of reducing the marsh area to a third of that covered in 1897. The extension to the industrial estate has increased the intrusive fragmentation and has resulted in the creation of fragment 2a, which is subject to further enveloping fragmentation. Fragment 3 (Fig 4.6) was divisively fragmented in 1992 with the opening of a new road across the marshes, creating fragments 3a and 3b. Whilst 3a has remained unaffected by fragmentation, fragment 3b has been intrusively fragmented by the construction of a maintenance plant for Thames water and maintenance of the North Kent sewer, reducing the overall area by 0.23ha (5%).

Utilities have been responsible for the major intrusive fragmentation that has occurred on Dartford Marsh. The construction of the sewage works and Littlebrook Power Station not only intrusively fragmented the marshes but also increased the isolation of Stone Marsh from the formerly large marsh area that existed at the end of the nineteenth century (Section 6.6).

During much of the post World War II period, the value of the marshes as areas of ecological importance was unrecognised and they were perceived as good sites for the development of utilities or 'dirty industries' (Thomas 2001). This attitude led to further intrusive fragmentation on Crayford, Dartford, Swanscombe and Denton Marshes with the construction of sewage plants, (Dartford and Denton), or use as landfill sites (Crayford and Swanscombe).

Divisive fragmentation of Allhallows Marsh from the construction of a railway line occurred much later during the twentieth century when a branch line to Allhallows on Sea opened in 1932 (White 1976). During the same period the new road system linking Allhallows to the main Hoo Peninsula road isolated Allhallows Marsh from the adjacent St. Mary's Marsh. Conversion to arable production in the post World War II period resulted in increased fragmentation and isolation between the two marsh systems. The branch line closure in 1961 (White 1976), has subsequently allowed the grazing marsh vegetation to re-establish itself.

In the post World War II period, agriculture became an important fragmenting agent as areas were turned from grazing to arable production. This resulted in two fragmenting events; the intrusion of the North Kent Agricultural Belt across the Hoo Peninsula, separating Allhallows and Grain Marshes from those in the west, and the conversion of Great Clane Marsh, which further isolated Denton Marsh from the remaining marshes to the south of the North Kent Railway. Agricultural intensification and the change to arable production have been responsible for the fragmentation of Botany and Great Clane Marsh. In both instances, the whole area of grazing marsh has been converted and can therefore be regarded as habitat loss rather than habitat fragmentation. To a lesser extent, Dartford Marsh and Allhallows Marsh have areas given over to arable production; in both cases, they form intrusions into the grazing marsh without completely fragmenting them.

Regressive fragmentation has been a factor on twelve fragments (35.4%), and has arisen from either development along a divisive fragmentation e.g. office development on Stone Marsh or as an extension to an existing development, e.g. the extension to the Glaxo-Smith-Klein pharmaceutical works on Dartford Fresh Marsh.

Enveloping fragmentation occurs when a fragment becomes surrounded by the agents of fragmentation, creating a barrier to movement. In the case of the North Kent Marshes, enveloping fragmentation seldom becomes a factor, as many of the marshes still front the River Thames. Once a fragment becomes isolated from the river e.g. Erith Marsh fragments 2b, 2c, 2d and 2e, Barnes Cray, Dartford Fresh Marsh, Denton Marsh and Great Clane Marsh then envelopment can become a fragmenting factor. Currently enveloping fragmentation can be seen to be acting on Denton Marsh, although individual fragments of Erith and Stone Marshes (Fig 4.4 & 4.16) are subject to pressures on all edges, which are resulting from further road building. The envelopment of Denton Marsh has resulted from the post World War II spread of industrialisation and urbanisation (Fig 6.5.4). In the future, as climate change and sea level rise gain in significance and as a result increase the pressures on the North Kent Marshes from the river frontage many more fragments may well begin to experience enveloping and regressive fragmentation but from differing agents.

Fig 6.5.4: Enveloping fragmentation of Denton Marsh.

Encroaching fragmentation, whereby the process occurs along either side of a linear incursion has had little impact on the North Kent Grazing Marshes. Where development has occurred in conjunction with divisive fragmentation, usually a new road, it has tended to occur as an intrusive element on the interior of the fragment isolated by the new roads. It may be argued however, that in the case of Stone Marsh, the secondary development in subsequent years could be interpreted as encroaching fragmentation on the former marshland. The one major example of encroaching fragmentation has occurred on Grain Marsh (Figs 4.28a/b) where the expansion of the oil refinery can be seen to have expanded out from the original divisive fragmentation caused by the road and rail links.

6.5.3 Conclusion.

Divisive fragmenting events were most important in the initial fragmentation of the marshes and created the conditions for habitat losses and further fragmentation that occurred as regressive, intrusive and encroaching fragmentation events invaded the marshes. It is evident however, that there remains a severe pressure on many of the North Kent Marshes and that fragmentation, primarily divisive and intrusive, and the agents that are responsible for the processes are still operating and that further fragmentation and complete habitat loss are likely to occur in the foreseeable future.

Particularly since the Second World War, the construction of more roads has created many smaller fragments, which have lost their value as grazing areas, and are viewed as prime areas for redevelopment and despite protection losses are still occurring. Erith and Stone Marshes exemplify this process, as during the preparation of this thesis Erith Marsh fragment 2d is to become the site of a new hotel, and 50% of Stone Marsh fragments 2c and 2e have been lost to further office development.

Divisive fragmentation can be likened to the 'death by a 1000 cuts' referred to by English Nature, but it is evident that once a marsh has become divisively fragmented, the process of fragmentation continues through intrusion, regression etc. 'Mortal wounding by a 1000 cuts' may therefore be a better description of the initial fragmentation processes, and that 'death' results from the subsequent fragmentation events.

6.6 The changes in sizes and extent of the North Kent Marshes.

The following sections compare the areas and perimeters of the individual marshes and the marsh fragments and the changes that have resulted from fragmentation from 1897 to the present day. The changes have been examined through reference to the Ordnance Survey maps of 1897 (2nd edition) and 1955/60 (4th edition), and cover period 1897 – 1945, i.e. post World War II changes. Figures 6.6.1 – 6.6.2 illustrate the extent to which the North Kent Grazing Marshes have become fragmented during this period.

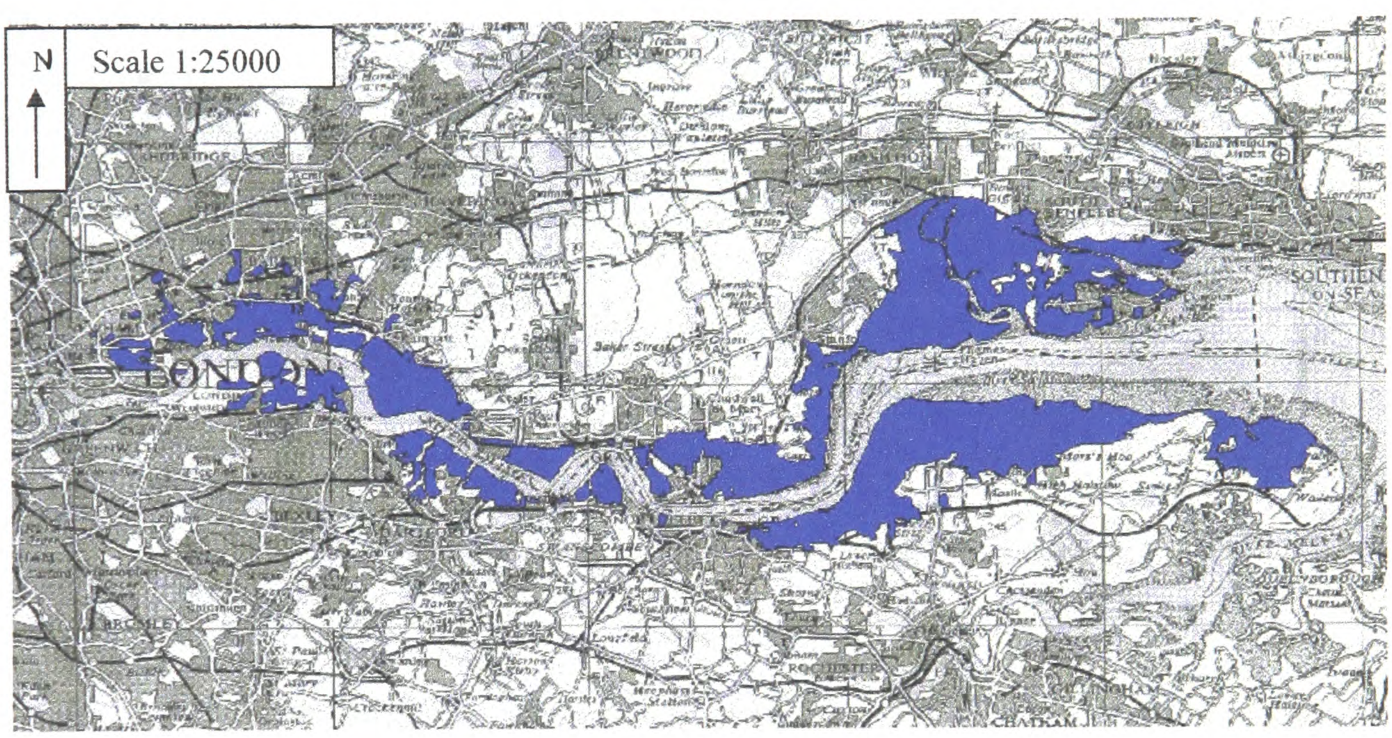


Fig 6.6.1: The extent of grazing marshes in the Thames Estuary 1935 (GIS).

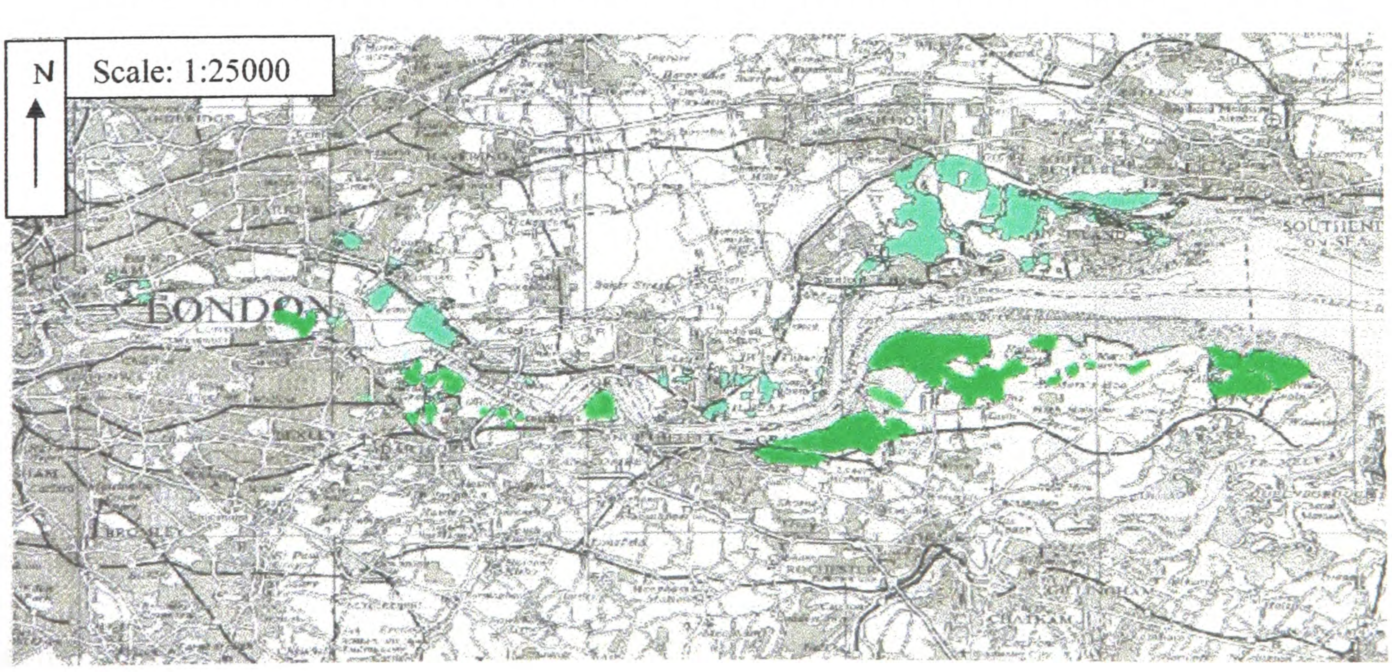


Fig 6.6.2: The extent of grazing marshes in the Thames estuary 1989 (GIS).

6.6.1 1897-1950 – Results.

Table 6.5 Quantitative data for individual marshes recorded from the Second Series Ordnance Survey Maps 1897

Marsh	Location	No. of fragments	Area (ha)	Edge (m)	Edge/area ratio	CPA	Proximity (m) intra
Erith	I	3	2159.98	12621	5.84	0.76	1685
Crayford	I	3	315.51	13977	44.30	2.20	25
Barnes Cray	I	1	39.72	2905	73.14	1.29	205
Dartford	I	1	508.64	1595	3.37	0.21	-
Stone	I	3	118.37	8182	69.12	2.12	-
Swanscombe	I	1	73.60	4100	55.71	1.35	5
Botany	I	1	39.24	3300	84.10	1.49	5
Northfleet	I	1	7.80	1400	179.49	1.41	10
Denton	O	1	30.68	1700	55.41	0.87	25
Great Clane	O	1	69.22	2600	37.56	0.88	25
Filborough	O	1	60.00	4750	79.17	1.73	45
Shorne	O	1	248.09	7215	29.08	1.29	-
Higham	O	1	496.40	11440	23.05	1.45	-
Cliffe	O	1	745.53	7935	10.64	0.82	160
Allhallows	O	1	549.58	15995	29.10	1.92	-
Grain	O	2	1175.00	24560	20.90	2.02	-
TOTAL		23	6637.36	124275	18.72 (ave)	1.34 (ave)	

I – Inner Thames Marshes O – Outer Thames Marshes

Tables 6.5 and 6.6 record the data for the areas, perimeters, edge/area ratios and proximity to the nearest marsh at the start of the study period, i.e. 1897. The data for the individual marshes is shown in Table 6.5, whereas Table 6.6 records the data for the individual fragments recorded in 1897. The marshes to the east of Gravesend, i.e. Denton – Higham are considered individually, although at this time they comprised two larger areas of marshland to the north and south of the Thames – Medway Canal, (see Section 6.2.1). Similarly, the three marshes that comprised the Swanscombe Peninsula and Dartford/Stone Marshes, which were contiguous in 1897, have all been considered individually for historic reasons (see Section 4).

The greatest changes in area have occurred amongst the Inner Thames Marshes with Erith, Crayford and Stone Marshes having been the most severely affected by fragmentation from increasing urbanisation, industrialisation and road building from 1897 to the present day. These three grazing marshes now comprise of five, six and six fragments respectively. The remaining marshes, although all showing evidence of fragmentation in terms of area loss, have remained as single areas of marshland, with the notable exceptions of Northfleet and Great Clane Marshes, which can no longer be classified as grazing marsh and can be regarded as a total loss of the resource.

Table 6.6 Quantitative data for individual Grazing Marsh fragments recorded from the Second Series Ordnance Survey Maps 1897

Marsh	Location	Area (ha)	Edge (m) external	Edge (m) internal	Edge/area ratio	CPA	Proximity (m) inter
Erith 1	I	178.54	2269	-	12.71	0.48	30
Erith 2	I	996.27	5186	366	5.57	0.50	20
Erith 3	I	984.99	4800	1500	6.40	0.57	20
Crayford 1	I	134.74	4140	-	30.73	1.01	25
Crayford 2	I	138.95	6737	-	48.49	1.61	25
Crayford 3	I	41.82	3100	-	74.13	1.35	100
Barnes Cray	I	39.72	2905	-	73.14	1.30	80
Dartford	I	473.97	1595	-	3.37	0.21	-
Dartford Fr.	I	34.67	4125	960	146.67	2.42	-
Stone 1	I	26.20	2774	447	122.94	1.77	220
Stone 2	I	76.96	2588	-	33.63	0.83	120
Stone 3	I	15.21	2149	224	156.02	1.72	-
Swanscombe	I	73.60	4100	-	55.71	1.35	5
Botany	I	39.24	3300	-	84.10	1.49	5
Northfleet	I	7.80	1400	-	179.49	1.41	10
Denton	O	30.68	1700	-	55.41	0.87	25
Great Clane	O	69.22	2600	-	37.56	0.88	25
Filborough	O	60.00	4750	-	79.17	1.73	45
Shorne	O	248.09	7215	-	29.08	1.29	-
Higham	O	496.40	11440	-	23.05	1.45	-
Cliffe	O	745.53	7935	-	10.64	0.82	-
Allhallows	O	549.58	15995	-	29.10	1.92	-
Grain 1	O	600.00	12410	-	20.68	1.43	-
Grain 2	O	575.00	12150	-	21.13	1.43	-

I – Inner Thames Marshes   O – Outer Thames Marshes

Comparison of tables 6.5 and 6.7 shows that there was a small increase in the number of fragments across the study sites, with 23 recorded in 1897 to 25 in 1960. The small increase in the number of fragments however is unreflective of the overall loss of grazing marsh area throughout the period, with a loss of 38% (2533.95ha) between 1897 and 1960; Sections 6.2.1 and 6.4.1 discuss the reasons for the loss of grazing marsh.

Table 6.7 Quantitative data for individual marshes recorded the from Ordnance Survey maps 1960

Marsh	Location	No. of fragments	Area (ha)	Edge (m)	Edge/area ratio	CPA	Proximity (m) intra
Erith	I	3	830.72	16535	19.90	1.61	3050
Crayford	I	3	145.76	12021	82.47	2.79	20
Barnes Cray	I	1	28.46	2340	88.22	1.23	205
Dartford	I	1	436.77	18334	23.82	0.78	20
Stone	I	3	75.76	5562	73.41	1.80	1440
Swanscombe	I	1	37.27	2702	72.50	1.24	-
Botany	I	1	28.20	2080	73.76	1.10	-
Northfleet	I	-	-	-	-	-	-
Denton	O	1	17.71	1645	92.88	1.09	650
Great Clane	O	1	51.87	2815	54.27	1.09	60
Filborough	O	1	60.00	4750	79.17	1.72	60
Shorne	O	1	195.48	6625	33.89	1.33	-
Higham	O	3	461.99	18990	41.10	2.49	-
Cliffe	O	1	554.69	7465	13.46	0.89	1760
Allhallows	O	2	503.73	16770	33.29	2.09	160
Grain	O	2	675.00	23490	34.80	2.53	160
TOTAL		25	4103.41	142124	34.64 (ave)	1.98 (ave)	

I – Inner Thames Marshes   O – Outer Thames Marshes

The pattern of losses on the individual marshes is again a reflection of the greater fragmentation that has occurred on the Inner Thames Marshes. At the beginning of the twentieth century Erith Marsh comprised three major fragments, two of comparable size (996 ha and 985ha) and a third to the east (179ha), see Fig 6.6.3. By 1960 in terms of remaining area (1329ha) Erith Marsh has suffered the greatest fragmentation and percentage loss (61.5%). Crayford Marsh (50.4%), Stone Marsh (36%), Swanscombe Marsh (49.4%) amongst the Inner Thames Marshes, and Denton Marsh (42.3%) and

Grain Marsh (42.6%) of the Outer Thames Marshes all lost over a third of the area to fragmentation and habitat loss during this period.

Table 6.8 Quantitative data for individual Grazing Marsh fragments recorded from the Ordnance Survey Maps 1960

Marsh	Location	Area (ha)	Edge (m) external	Edge (m) internal	Edge/area ratio	CPA	Proximity (m) (inter)
Erith 1	I	152.00	2490	-	16.38	0.57	520
Erith 2	I	627.87	8964	-	14.28	1.00	75
Erith 3	I	50.85	5081	-	99.92	2.00	75
Crayford 1	I	56.26	4637	-	82.42	1.73	25
Crayford 2	I	72.32	5081	-	70.26	1.67	25
Crayford 3	I	17.18	2303	-	134.05	1.56	1030
Barnes Cray	I	28.46	2340	-	82.22	1.24	400
Dartford 1a	I	95.68	6900	-	72.11	1.99	-
Dartford 1b	I	269.01	8440	-	31.37	1.45	-
Dartford Fr	I	33.28	4205	-	126.35	2.04	-
Dartford 1c	I	37.41	2994	-	80.03	1.38	1240
Stone 1	I	-	-	-	-	-	-
Stone 2a	I	60.55	3413	-	56.37	1.24	256
Stone 3	I	15.21	2149	-	141.29	1.55	256
Swanscombe	I	37.27	2590	-	69.49	1.20	-
Botany	I	28.20	2080	-	73.76	1.10	-
Northfleet	I	-	-	-	-	-	-
Denton	O	17.71	1645	-	92.89	1.10	650
Great Clane	O	51.87	2815	-	54.27	1.10	60
Filborough	O	60.00	4750	-	79.17	1.73	60
Shorne	O	195.48	5415	1210	33.84	1.34	-
Higham 1a	O	330.44	10420	-	31.53	1.62	-
Higham 1b	O	40.05	2530	-	63.17	1.13	320
Hihgam 1c	O	91.50	6040	-	66.01	1.78	25
Cliffe	O	554.69	7465	-	13.46	0.89	510
Allhallows 1	O	393.73	10340	-	26.26	1.47	35
Allhallows 1a	O	110.00	6430	-	58.45	1.73	35
Grain 1	O	475.00	12960	-	27.28	1.68	533
Grain 1a	O	200.00	10530	-	52.65	2.10	533

I – Inner Thames Marshes O – Outer Thames Marshes

Tables 6.5 and 6.7, show the increase in edge length and in the edge – area ratio for the individual marshes. Between 1897 and 1960, the overall length of edge, calculated for all the marshes, increased by 14.4%, and the average edge-area ratio, for all the marshes increased by 85%. The totals are indicative of a landscape that now comprises a number of smaller fragments, which include a greater proportion of edge habitat, see Section 8.7.

6.6.2 The changes in size and extent of the North Kent Grazing Marshes 1960 – 2001.

Table 6.9 Quantitative data for individual Grazing Marshes recorded from Ordnance Survey maps 2001

Marsh	Location	No. of fragments	Area (ha)	Edge (m)	Edge/area ratio	CPA	Proximity (m)
Erith	I	5	90.29	9210	102.00	2.71	3800
Crayford	I	5	95.19	8418	88.43	2.42	45
Barnes Cray	I	1	28.46	2340	82.22	1.23	400
Dartford	I	4	223.80	12370	55.27	2.33	45
Stone	I	6	23.60	4415	187.08	2.54	1470
Swanscombe	I	1	43.76	3498	79.93	1.48	-
Botany	I	1	21.42	2258	105.42	1.37	5250
Northfleet	I	-	-	-	-		-
Denton	O	1	13.43	1809	74.24	1.16	1940
Great Clane	O	1	-	-	-		-
Filborough	O	1	60.00	4750	79.17	1.72	60
Shorne	O	1	274.35	6595	24.04	1.11	-
Higham	O	3	341.72	18990	55.57	2.88	2090
Cliffe	O	2	530.00	11650	21.98	1.42	-
Allhallows	O	1	503.73	11600	23.03	1.45	250
Grain	O	2	570.00	23090	40.51	2.71	250
TOTAL		34	2819.75	120993	42.91	2.03	

I – Inner Thames Marshes   O – Outer Thames Marshes

The period between 1960 and 2001 showed a 36% increase overall in the number of fragments, with the largest increase being amongst the Inner Thames Marshes. The largest increase in the number of fragments was recorded on Stone Marsh, with an increase in the number of fragments of 100%. Erith and Crayford Marshes show a 66% increase in the number of fragments, although Erith Marsh has also recorded the total loss of fragments 1 and 3 during this period. The Outer Thames Marshes in contrast have show a reduction in area rather than an increase in the number of fragments. The

Table 6.10 Quantitative data for individual Grazing Marsh fragments recorded from the Ordnance Survey Maps (2001)

Marsh	Location	Area (ha)	Edge (m) external	Edge (m) internal	Edge/area ratio	CPA	Proximity (m)
Erith 1	I	-	-	-	-	-	
Erith 2a	I	25.83	2430	680	120.40	1.73	125
Erith 2b	I	56.88	4220	-	74.19	1.58	125
Erith 2c	I	1.43	385	-	269.23	0.91	75
Erith 2d	I	4.10	810	-	197.56	1.13	175
Erith 2e	I	2.05	685	-	334.15	1.35	75
Erith 3	I	-	-	-	-	-	-
Crayford 1	I	41.25	2660	-	75.83	1.17	25
Crayford 2a	I	37.16	3313	-	89.16	1.53	25
Crayford 2b	I	1.81	590	-	325.97	1.24	25
Crayford 3	I	14.97	1855	-	123.91	1.35	75
Crayford 3a	I	4.16	930	-	223.56	1.29	75
Barnes Cray	I	28.46	2340	-	82.22	1.24	210
Dartford 1a	I	165.30	8210	-	49.67	1.79	75
Dartford 1b	I	52.50	3100	-	59.05	1.20	325
Dartford Fresh	I	28.83	2605	-	90.36	1.37	75
Dartford 1c	I	6.00	1060	-	176.67	1.22	410
Stone 1	I	-	-	-	-	-	-
Stone 2a	I	1.44	410	-	284.72	0.96	290
Stone 2b	I	6.19	1025	-	165.59	1.16	290
Stone 2c	I	4.00	600	-	150.00	0.85	500
Stone 2d	I	9.45	1620	-	171.43	1.49	430
Stone 2e	I	2.52	760	-	301.59	1.35	430
Swanscombe	I	43.76	3498	112.00	79.93	1.48	-
Botany	I	21.42	2615	-	73.93	1.59	-
Northfleet	I	-	-	-	-	-	
Denton	O	13.43	1809	-			500
Great Clane	O	-	-	-	-	-	35
Filborough	O	60.00	4750	-	79.17	1.73	35
Shorne	O	274.35	6625	790	27.03	1.26	-
Higham 1a	O	260.65	10420	-	39.97	1.82	-
Higham 1b	O	33.74	2530	-	74.99	1.23	370
Higham 1c	O	47.33	6040	-	127.61	2.48	25
Cliffe	O	530.00	10245	3700	26.31	1.71	-
Allhallows	O	503.73	11600		23.02	1.46	470
Grain 1	O	370.00	12310	-	33.27	1.80	470
Grain 1a	O	200.00	9300	1480	52.40	2.15	680

I – Inner Thames Marshes O – Outer Thames Marshes

greater impact of fragmentation on the Inner Thames Marshes however, is highlighted increase in the number of fragments, increasing by 66% between 1897 and 2001. In contrast, the number of fragments in the Outer Thames Marshes has only increased by 1%.

Between 1897 and 1960, further industrial expansion and infrastructure construction caused major regressive and divisive fragmentation of Erith Marsh fragment 3, reducing the overall area by 15%. Fragment 2 was reduced in area by 37% as urbanisation, roads and industry regressed, intruded and further divided the marshland. Ninety-five per-cent of fragment 3 was lost in this period with the development of the Woolwich Arsenal and the commencement of development at Thamesmead, whilst the remainder of fragment 1 was lost during the period 1960 to the present day. The development of Thamesmead has also accounted for the loss of the majority of fragment 2 (75%), although roads and industrial units have also taken (25%) over the past forty years.

The average corrected perimeter (edge) – area (see Section 5.3.1) has increased from 1.34 to 2.03 indicating that overall the shape of grazing marsh fragments has tended to become less circular and more elongated. As the index can vary between 0 (perfect circle) and infinity (infinitely long) (Farina 1998), the overall CPA indices, which are at the lower end of the scale (i.e. all are below 3), for this study they have been assumed to be of little ecological value and therefore no further discussion has been included. The changes in the edge – area ratio, which are indicative of the changes in edge and core habitat and as such have implications for the vegetation ecology (Section 8), are of greater importance to the themes of this study and are discussed more fully in Section 6.8.

6.6.3 Discussion of individual sites.

Fragmentation and habitat loss have been ongoing problems affecting the North Kent Marshes since the mid nineteenth century. Throughout the North Kent Grazing Marshes fragmentation, processes have preceded habitat loss through reclamation, drainage and construction. The greatest reduction in the area of marshland, through both fragmentation and habitat loss has occurred across the Inner Thames Marshes. These losses reflect the changing nature of land use and the post war growth in population and the subsequent requirement for new housing and jobs as London expanded out into the suburbs. During the eighteenth, nineteenth and early twentieth centuries, the Inner Thames Marshes would have been seen as large unattractive areas of land that served little purpose and therefore ripe for exploitation and development.

1) Erith Marsh

Only 9% of the original area of Erith Marsh from 1897 now remains. With further development proposed, throughout the original marshland the overall effect has been to surround the remaining fragments of Erith Marsh with divisive, intrusive and regressive fragmenting agents, e.g. proposed future hotel and warehousing development further threatens the survival of two of the remaining fragments (2a and 2d), see Fig 4.3.

2) Crayford Marsh

In 1897, Crayford Marsh comprised two major fragments of comparable size (134.74ha and 138.95ha). Crayford Marsh (Fig 4.5) now covers only 25% of the area that was recorded in 1897. Losses in the period between the start of the twentieth century and 1960 resulted from the development of new light industrial centres (intrusive fragmentation), land take for use as landfill (intrusive fragmentation) and urbanisation (regressive fragmentation).

Increased isolation, see Tables 6.5 and 6.10, of the Barnes Cray fragment during the study period has resulted from improvements and widening to Thames Road, and the construction of the Crayside industrial estate. Since the process of divisive fragmentation isolated Barnes Cray, it has suffered a relatively small decrease (14%) in the overall area. Although a small branch railway line was constructed further divisively fragmenting Barnes Cray, its abandonment however, has allowed most of the natural vegetation to re-establish itself, although successional trends on the higher ground has led to the establishment of tress and scrub. Further widening of Thames Road now threatens the future of the Barnes Cray fragment.

3) Dartford Marsh.

Dartford and Stone Marshes at the end of the nineteenth century formed one contiguous marshland area comprising some 700ha (Fig 4.7b), but has been considered here as two separate marshes for historical and landscape reasons. The position of the actual boundary between the two is not clearly identified on the maps, but for the purpose of this thesis has been taken as being along the line, which now forms the Dartford crossing approach. From the ecological viewpoint, there would have been no barrier to movement between the two marshes, but as the two marshes are referred to separately in the literature and on the maps, there is an historical significance at the regional and landscape level.

During the study period of 1897 – 2001 Dartford Marsh has been reduced in size by 56%, mainly through intrusive fragmentation. Although many of these intrusive fragmenting agents have since been abandoned and closed, their effects on the overall area of Dartford Marsh are still evident, e.g. scrub invasion across one former hospital site has effectively maintained the fragmented state of the marsh.

During the period 1897 - 2001 losses to Dartford Fresh Marsh occurred through encroaching fragmentation as the Burroughs – Wellcome pharmaceutical works increased in size, reducing the marsh area by 20%. Dartford Fresh Marsh has not undergone further fragmentation since the construction of University Way in 1992, which separated the saline grazing marshes and the fresh marsh. No further recent losses have been recorded to the fresh marsh; current planning applications however, threaten further intrusive and regressive fragmentation.

4) Stone Marsh

Stone Marsh has suffered the second highest percentage loss of any of the remaining North Kent Marshes surveyed. Since 1897, 80% of Stone Marsh has been lost to new industrial and office development and road construction, surviving as six small isolated fragments under continued threat of further development, (see Fig 6.6.3). Fragmentation has therefore reduced the marshes from three fragments to six smaller ones together with a number of small remnant features, e.g. isolated ditches and open grassland/degraded sites.

Fig 6.6.3: Hotel development on Stone Marsh

The construction and opening of the Dartford tunnel and approach roads in 1963 saw the final separation of Dartford and Stone Marshes, although the river wall still maintains a degree of connectivity between the two. These fragmenting events resulted in the loss of 25% of fragment 2 by 1963. The construction of the approach road to the Dartford tunnel provided better access to Stone Marsh and allowed the development of further infrastructure and offices causing a further loss of 28ha (36%) of fragments 2 and 3. Amongst the first was a container berth, which caused the direct loss of (38%) of fragment 2, and creating a further three fragments (Fig 4.15). Road construction since 1995 resulted in the creation of a further 2 fragments, whilst office building has now accounted for the whole of fragment 3, and encroached into much of the remains of fragment 2. Further developments are occurring on the remnant fragments of Stone Marsh, so that only fragments 2a, 2c and 2e remain as tabulated, together with four-isolated drainage ditches.

5) Swanscombe/ Botany Marshes

Botany and Swanscombe Marshes in 1897 formed a contiguous marshland area on the Swanscombe Peninsula (Fig 4.17). Historically the boundary between the two marshes followed the line of the local parish boundaries, and therefore the two marshes have been considered separately for these historical reasons. From an ecological viewpoint however, there is no barrier to movement between the two marshes, but the boundary does have importance at the landscape level.

Since 1897 Swanscombe Marsh has lost 45% of their area, primarily to landfill operations (intrusive fragmentation), and encroachment of light industrial units along the southern edge of the marsh (regressive fragmentation), see Fig 6.6.4.

During the study period, Botany Marsh has lost some 45% of their original area to the encroachment of industry and landfill operations. After the Second World War Botany Marsh was converted for use as arable production, and therefore the loss of grazing marsh could be considered to be higher than the 45% loss of open land and may be as high as 75%. Crop production has since ceased and Botany Marsh is now under a set-aside scheme, and rank grasses and scrub are now reclaiming the former marshland. The degraded nature, rank vegetation and scrub that now dominate Botany Marsh suggest that what now remains should no longer be regarded as grazing marsh.

7) Northfleet Marsh

Northfleet Marsh covered an area of 10ha to the east of Botany Marsh and was totally reclaimed during the inter-war period and is now the site of the Britannia Metal Works.

Fig 6.6.4: Regressive fragmentation of Swanscombe Marsh by industry.

8) Denton Marsh

The major loss of Denton Marsh occurred in the period from 1897 - 1960, when 50% of the original marshland was lost. Enveloping fragmentation from the urban expansion of Gravesend throughout the post war period was the primary cause of the loss. A further small loss occurred during the 1930's with the development of the sewage plant (intrusive fragmentation). Since 1960, further warehousing construction has resulted in further regressive fragmentation and a loss of 18% of the marsh. These latter developments now completely envelop the original marsh isolating it from the remaining components of the once continuous marshland. Post World War II expansion of the Gravesend suburbs has led to greater isolation of Denton Marsh as urbanisation created a new barrier between Denton Marsh and the adjacent Great Clane and Westcourt Marshes.

9) Great Clane Marsh (incorporating Westcourt Marsh)

The study period has witnessed the total loss of these marshes for grazing purposes. In the period between 1897 and 1960 a loss of 25% of the area occurred, due to regressive fragmentation caused by urbanisation. Between 1960 and the present day the remaining 60 ha of the grazing marsh has been lost due to a change in land use from grazing to arable production.

10) Filborough Marsh

Filborough Marsh was initially isolated from the main body of the grazing marshes of Shorne and Higham Marshes by the construction of the Thames – Medway canal in 1824. Since this time they have not suffered any further fragmentation.

11) Shorne Marsh (incorporating Eastcourt Marsh)

Between 1897 and 1960, Shorne Marsh lost 21% of the total area from regressive fragmentation as urbanisation regressed along on the western edges and the intrusion of the army firing ranges, an area formerly known as Eastcourt Marsh.

A potential increase in the area of grazing marsh has resulted from the purchase of the firing ranges by the RSPB and the proposed reclamation as grazing marshes (RSPB 2000). Restoration work is ongoing and currently water levels are being restored and the area returned to grazing.

12) Higham Marsh

Higham Marsh is the western most section of the North Kent Marshes Environmentally Sensitive Area (Fig 3.1). In the period between 1897 and 1960, 16% of Higham Marsh was lost to mineral extraction. Quarrying and associated infrastructure works divisively fragmented and isolated Higham Marsh from Cliffe Marsh resulting in an overall loss of grazing marsh of 370ha (103ha from Higham Marsh). Divisive fragmentation of Higham Marsh due to the construction of a rail link from the main North Kent line to the mineral workings has resulted in three fragments (1a, 1b and 1c), with the barrier between the respective fragments being subsequently increased by the improvement in road communications.

Regressive fragmentation along the line of the railway has accounted for part of the 48% loss in the area suffered by fragment 1b, with the remaining loss attributable to a lack of management, scrub development and conversion to orchards.

13) Cliffe Marsh

Cliffe Marsh comprises the western marshes of the Hoo Peninsula and is part of the North Kent Marshes Environmentally Sensitive Area see Fig 3.1. The one major fragmenting episode that has affected Cliffe Marsh resulted in the loss of 26% of the grazing marsh to the exploitation of the local mineral deposits and quarrying. This intrusive fragmenting event also created a barrier between Cliffe Marsh and Higham Marsh. The development of munitions works in 1907 over an area of 60ha, created the opportunity for further intrusive fragmentation to occur. Closure of the works has allowed the area to return to grazing marsh, although the presence of the derelict buildings maintains a visual intrusion into the marshland landscape and is visually but not ecologically distinct.

Since 1960 only minor losses, amounting to 4%, of the marshes have occurred due to the development of new housing along the southern edge and linked regressive fragmentation.

14) Allhallows Marsh

Losses to Allhallows Marsh throughout the study period of 1897 to the present time have been small only 6% of the marsh has been lost to the intrusion of arable production into the grazing marshes. In the early years of the twentieth century, the marshes did experience a divisive fragmentation event with the construction of a branch line rail line to the village of Allhallows. The publication of the Beeching report (1963) recommended that the branch line be closed (White 1976) and in the subsequent years, the line of the railway has gradually been subsumed back into the marshland.

15) Grain Marsh

Despite the fact that the rail link did not survive long into the twentieth century, closing in 1931, it was followed by a new road, which further divisively fragmented the marsh. The immediate post World War II period saw the construction of the BP oil refinery and terminal, which has led to encroaching fragmentation, and a loss of 51% of the grazing marsh present in 1897.

6.8.1 Edge effects and edge/area ratios – results.

Table 6.11 Summary of changes in the edge - area ratio between 1897 and 2001.

Marsh	1897 ratio	No. of fragment	1960 ratio	No. of fragment	% change 1897-1960	2001 ratio	No. of fragment	% change 1960-2001
Erith	5.84	3	19.90	3	240.00	102.00	5	412.00
Crayford	44.30	3	82.47	3	86.00	88.43	5	7.00
Barnes Cray	73.14	2	88.22	2	21.00	88.22	2	-
Dartford	3.37	1	42.06	4	114.00	51.93	4	23.00
D. Fresh marsh	146.67	1	126.35	1	13.85	90.36	1	28.47
Stone	69.12	3	73.41	3	6.00	187.08	6	155.00
Swanscombe	55.71	1	72.50	2	30.13	79.93	2	10.00
Botany	84.10	1	73.76	1	12.00	105.42	1	43.00
Denton	55.41	1	92.88	1	68.00	92.44	1	-
Great Clane	37.56	1	54.27	1	44.00	-	1	-
Filborough	79,17	1	79.17	1	-	79.17	1	-
Shorne	29.08	1	33.89	1	17.00	24.04	1	29.00
Higham	23.05	1	41.10	3	78.31	55.57	3	35.20
Cliffe	10.64	1	13.46	1	27.00	21.98	1	63.00
Allhallows	29.10	1	33.29	2	14.00	23.03	1	38.00
Grain	20.90	2	34.80	2	67.00	40.51	2	16.00

Table 6.11 records the changes to the edge/area ratios that occurred during the study period. As fragmentation occurs and the overall area of the individual marshes becomes smaller, the perimeter of the fragments also declines, see Tables 6.5 and 6.7. There are however, exceptions as occurred on Erith Marsh, in the period between 1897 and 1960 where the perimeter length increased by 31% and Cliffe Marsh between 1960 and 2001 with an increase of 56% in the perimeter length.

The majority of the grazing marshes (81%) show an increase, in the perimeter – area ratios between 1897 and 2001, indicating that fragmentation has led to an increase in the edge component of the habitat. The greatest changes in edge to area ratio occurred during the period 1897 - 1960 and occurred where fragmentation has been accompanied by a large decrease in the area of habitat, e.g. Erith with a percentage change of 240%

and Dartford with a percentage change of 114%. Swanscombe Marsh had the smallest increase in edge – area ratio of 3% and Filborough Marsh remained the same throughout the whole period. In the period between 1960 and 2001 when fragmentation was more extensive Erith and Stone Marshes were both further fragmented and there was a proportionately large increase in the edge/area ratio of 412% and 155% respectively. Three marshes, Denton, Filborough and Barnes Cray showed no change to the edge/area ratio. Both Barnes Cray and Filborough Marsh were unaffected by fragmentation during this period. Denton Marsh however, was reduced by 24.1% in area, due primarily to envelopment by new housing, and this result may suggest therefore that enveloping fragmentation has no influence on the edge/area ratio. Thus, where fragmentation becomes more extensive and more fragments are created the edge – area ratio becomes greater, increasing by a factor of at least 20%, see Table 6.11.

In two instances, Allhallows and Shorne Marshes the edge area ratio has decreased in the period between 1960 and 2000. This is a result of a loss of a fragmenting agent. Closure of the branch railway line that formerly fragmented Allhallows Marsh has allowed the former marshland vegetation to re-establish itself and on Shorne Marsh the acquisition of the former artillery range by the RSPB has resulted in increases in marsh area and a decrease in the edge – area ratio.

Although the number of fragments is highly influential in determining the edge – area ratio, the method of fragmentation is also an important factor. Marshes that have been intrusively fragmented e.g. Erith and Stone Marshes are showing much larger increases in the edge – area ratio than those that have just suffered divisive fragmentation, e.g.

Allhallows Marsh, which showed a decrease in the edge/area ratio. Similarly, marshes that have been affected by several fragmenting agents also show a large increase in the edge – area ratio.

6.8.2 Edge effects and edge/area ratios – discussion.

One of the major effects of fragmentation is to increase the length of edge of a habitat and consequently increase edge effects, as discussed in Section 2.5.6. If there is an increase in edge length, a fragment with the greatest increase in both length and edge – area ratio should contain more generalist species, have a greater modified matrix habitat and suffer increased disturbance, see Sections 7.9 and 8.5.

Edges are defined as the part of an ecosystem near its perimeter, which is influenced by its surroundings, and may be seen as a zone of influence (Murcia 1995) that varies in width depending on the fragmenting factor. The majority of fragmentation across the North Kent Marshes has been either divisive or intrusive, which have introduced what are termed hard edges between the grazing marsh and the surrounding fragmenting element. Hard edges are associated with human activities e.g. roads, (Forman 1997), and produce a marked contrast between the habitat and the fragmenting element and are well illustrated by fragmentation of the North Kent Marshes, particularly in the Inner Thames region, e.g. Erith and Stone Marshes. Because of these hard edges, abrupt structural changes are created between ecosystems, landscape components and the fragmenting agent, which create more intense edge effects (Noss and Csuti 1997). The intensity of the edge effect will however, vary with the nature of the fragmenting agent, e.g. divisive fragmentation by road creates a different effect to intrusive fragmentation by an office building or a factory, see Sections 7 and 8.

The creation of edge and associated edge effects are a particular feature of divisive fragmentation and these have been considered to have major influences on the changes that occur to fragmented landscapes and habitats (Laurence 1991, Forman 1997). Road construction (divisive fragmentation) has been the major cause of fragmentation across the North Kent Marshes and has therefore created the most edges. Schonewald-Cox and Buechner (1990) regarded roads as features that sub-divide landscape, remove habitat, inhibit species dispersal and migration and facilitate movement of disturbances (e.g. pollutants and exotic species). As well as the range of effects on landscape (Section 7) and the ecology (Section 8), ecological processes may be affected, by changes to microclimates, increased disturbance and differing management regimes to road verges. As edge length and width increases immigration and emigration to the remnant fragments are influenced by the fragmenting agent's ability to act as a corridor, and the nature of the species that use the corridor, which will ultimately affect the matrix habitat and species composition of the matrix and conservation value.

Regressive, encroaching and enveloping fragmentation can all be linked with the construction of roads, and therefore many of the edge effects that are associated with roads are enhanced by the additional fragmentation. In particular, barriers to movement will be increased as the fragmenting element increases in width. Urbanisation and industrialisation acting as regressive fragmenting agents increase the influence and amount of disturbance associated with edges and again influence the microclimate that occurs at the perimeter of a fragmented habitat.

The nature of the fragmenting agent can also produce soft edges, i.e. the gradation between grazing marsh and its surrounds are less marked. Arable production and gardens within urban areas are examples of soft edges, which may however, be more susceptible to the movement of species between the habitats and result in the more competitive and generalist species influencing the vegetation composition of the grazing marshes see Section 8. Fragmentation through urbanisation, particularly in the Inner Thames Marshes, is therefore increasing the amount of soft edges, as is the landscaping of new office developments, e.g. Stone Marsh.

A comparison of the edge - area ratios however, gives a more accurate picture of how the nature of the individual marshes has been affected by fragmentation. The ratio indicates an increase in the edge effects, a decrease in core area and an increase in edge habitat (Andren 1994), (see section 2.4.5 for a discussion on edge effects). Increases in edge habitat may lead to an increase in the range of species adapted to edges (Planty-Tabacchi et al 1996), and a subsequent decline in conditions that support the matrix communities of a grazing marsh (see Section 8.7). The area to edge ratio may therefore be important in determining the minimum size of grazing marsh (see Section 9).

Edge – area ratios, although not showing a correlation with the presence of invasive species (Section 8.3.3), will undoubtedly influence the nature of a fragment. Whether through the introduction of pollutants or the increase in the occurrence of disturbance events, there will be an influence on the status of a fragment, although quantifying that change and determining at what point that influence begins to take effect will depend on several factors: e.g. isolation, length of time fragment has been isolated, and management.

Mader (1984) regarded sites of less than 0.5ha being composed entirely of edge. Grazing marshes however, show no discernible edge, unlike woodland habitats, and therefore edges often only become defined once fragmentation has occurred. Increased and changing edges and edge dimensions will therefore have a crucial influence on the landscape characteristics and features and affect the immigration and emigration of species into the fragment. The latter also being an important influence on species composition within the vegetation communities that make up the grazing marsh mosaic. No sites studied within the North Kent Marshes fell below this size, but with the level of road construction that has occurred within the Inner Thames Marshes, in particular, fragments greater than 0.5ha show indications of comprising all edge, e.g. Stone Marshes 2a.

6.9 Conclusion: Historical fragmentation of the North Kent Marshes.

Development and the need for land have been the key factors that have led to the fragmentation of the North Kent Marshes. From the Industrial Revolution (1850) to the present day, the typical pattern of fragmentation of the North Kent Marshes in most instances has been firstly through improvements in the transport network via improved road and rail connections. The result of such infrastructure projects was the divisive fragmentation of 74% of the marshes studied. With improved transport, access to the more remote areas of the marshes became easier, which in turn led to the reclamation, drainage and changed land use for agriculture, industry and housing on 95% of the marshes studied, as the needs of the population grew and changed. The construction of infrastructure, since the Second World War, primarily more road building has created many smaller fragments, which then lose their value as grazing areas, and is viewed as prime areas for redevelopment and despite protection losses are still occurring. Erith and Stone Marshes exemplify this process, as during the preparation of this thesis Erith Marsh fragment 2d is to become the site of a new hotel, and 50% of Stone Marsh fragments 2c and 2e have been lost to further office development.

Industrialisation, urbanisation and changes in agricultural practices as discussed by Thornton and Kite (1990) have been responsible for not only fragmentation but also loss of marshlands throughout the Inner Thames region, whilst those on the edges of suburban areas have subsequently become enveloped in the urban sprawl of Gravesend and the Medway towns. In this study, the effects of industrialisation and urbanisation have been shown to be the most important factors in the loss of grazing marsh and that roads, rail etc, improvements have been the catalyst for these increases. Thornton and Kite's study does not reflect the influence that infrastructure change has had on the North Kent Marshes.

In their report of 1990, Thornton and Kite stated that there had been a 65% reduction in grazing marsh areas in the Thames Estuary between 1935 and 1990. The Kent Biodiversity Action Plan (1997) recorded a 54.8% reduction in grazing marsh between 1961 and 1990 within the Thames Gateway area of Kent. Figures from this study show similar results with an overall reduction of 57% of grazing marsh between 1897 and 2000 in the selected marshes studied. Proportionately the Inner Thames Marshes have suffered greater losses than the Outer Thames Marshes having lost 87% of the area recorded in 1897. This figure is again very similar to the 85% loss recorded by Thornton and Kite (1990) for the Inner Thames Marshes. Over the same period, the Outer Thames Marshes have lost 32% of the grazing marshes from the 1897 totals. This figure differs from the 48% recorded for the Kent grazing marshes recorded by Thornton and Kite (1990). The difference in values may be accounted for in the large losses of grazing marsh that occurred on the Hoo Peninsula and Isle of Sheppey, which were not included in this study and the increase in grazing marsh on Shorne Marsh, which has occurred since 1990.

The impact of fragmentation on the Inner Thames Marshes is highlighted by the increase in the number of fragments, increasing by 66% between 1897 and 2001, whereas the Outer Thames Marshes saw an increase of just 1% the number of fragments. These results reflect the varying perceived importance of the inner and outer marshes throughout the study period. During the eighteenth, nineteenth and early twentieth centuries, the Inner Thames Marshes would have been seen as large unattractive areas of land that served little purpose and therefore ripe for exploitation and development Garrad (1954), Pritchard (1976), Baldwin (1984) and Thomas (2000), whereas the Outer Thames Marshes have been regarded as best suited to grazing. In turn, the usage of the marshes is related to the remaining areas, with the larger unfragmented outer marshes deemed more suitable for agricultural production. Fragmentation in turn has reduced the inner marshes to areas that would be unproductive and unsustainable for agriculture, but suitable for further development.

Any process of fragmentation will lead to an initial habitat loss through the action of land take for the development concerned (Harris et al 1991). The quantity of habitat loss and fragmentation effects will however differ with the different types of fragmentation. Intrusive fragmentation has a greater effect on the matrix of the habitat than divisive, regressive or enveloping fragmentation, which have greater influence on the edge of the habitat. Intrusive fragmentation acting on the matrix of the habitat will directly impact on the landscape features as well as being responsible for habitat loss and intuitively will alter the micro scale homogeneous – heterogeneous structure of the grazing marsh.

Fragmentation may well also record a range of effects that will influence the immediate habitat surrounds, i.e. neighbourhood effects. In particular, where industrial complexes have been constructed, e.g. Erith Marsh, airborne pollutants will have greater effects on surrounding fragments rather than the fragment on which it is situated.

Of the fragmentation processes, enveloping fragmentation is anticipated as having the most severe effects as the fragment is surrounded and isolated by a completely different habitat and environment, which will act to influence immigration and emigration as predicted by MacArthur and Wilson (1967). The effects of divisive fragment, which occurs by bisecting a habitat, are believed to be proportional to the magnitude of the divisive force (Harris et al 1992). Regressive fragmentation, where the process is acting as a force in a single direction is seen as enhancing the effects of divisive fragmentation as development from the initial divisive incursion proceeds across a fragment. Under these circumstances, the edge between the fragment and surrounding land use is increased and hence edge effects are of greater importance in determining the viability of the grazing marsh fragment.

The effects of the fragmenting events and their agents have produced a marked divergence between the Inner Thames Marshes and those of the Outer Thames in the characteristics and features (see Section 7.2 and 7.6) and vegetation communities (see Section 8.4). In all cases, these result from the extensive development and pressures that have been placed on the Inner Marshes by fragmentation. Each agent and type of fragmentation will result in different effects on the characteristics, features and vegetation communities (see Sections 7.10 and 8.4).

Fragmentation leads to a loss of habitat area and therefore as suggested by Preston (1962) and Williams (1964) the number of species that can be supported by the habitat as reduced. MacArthur and Wilson (1967) presented the theory that these effects are manifested in the ability of species to disperse from the habitat to a similar habitat or in the rate of immigration into the habitat and that an equilibrium species number occurs for given areas.

Fragmentation by regression, envelopment, encroachment and division will also all act to affect immigration and migration to and from a habitat fragment and so modify the species – area relationship described by MacArthur and Wilson (1967). The fragmenting agents will act as barriers to movement and may influence the time that species take to move between fragments, with enveloping agents being the most disruptive as they provide a barrier that surrounds the habitat fragment. Throughout the

North Kent Marshes, fragmentation has been caused by human created structures, all of which generally inhibit movement and dispersal of species (Noss and Csuti 1997). Thus, species composition through fragmentation becomes vulnerable to the reduced area available to them and by increased isolation created by the barrier effect of the fragmenting agent. Discussion of the effects of reduced area on species composition will be considered in Section 8.4 and Section 9.

Few fragmentation studies have attempted to answer the question as to at what point does a habitat fragment become so small that it is no longer a viable example of the habitat in question. In the SSSI Guidelines (NCC 1989) 0.5 ha is recorded as the minimum area that should be selected when considering grassland interest features. Whereas, Robertson and Jefferson (2000) regard areas of less than 0.25 ha as 'invariably having insufficient species, and being too small to support viable populations of vascular plant species'. To fully answer this question however, the effect of fragmentation on the landscape characteristics, features and vegetation communities has to be established and then to see if there comes a point where the size of a fragment is influencing the make up of the grazing marshes, or if other factors are at work. There is also the case where some of the landscape features e.g. wet flushes may well fall below the 0.25ha limit, and therefore assessment of the viability of these features will need to be on an individual site basis.

Chapter 7 Landscape Characteristics and Features.

7.1 Introduction.

The landscape characteristics and features of the North Kent Grazing Marshes are the elements of the homogeneous - heterogeneous structure that forms the matrix of grazing marshes, as defined in Section 5.2.2. Section 5.3.4 explained how the scores for the landscape characteristics and features were assessed and scored. The grazing marsh landscape characteristics surveyed were: -

- homogeneity;
- the external landscape influences, e.g. urban and industrial;
- the nature of the ditches;
- embankments and counter walls.

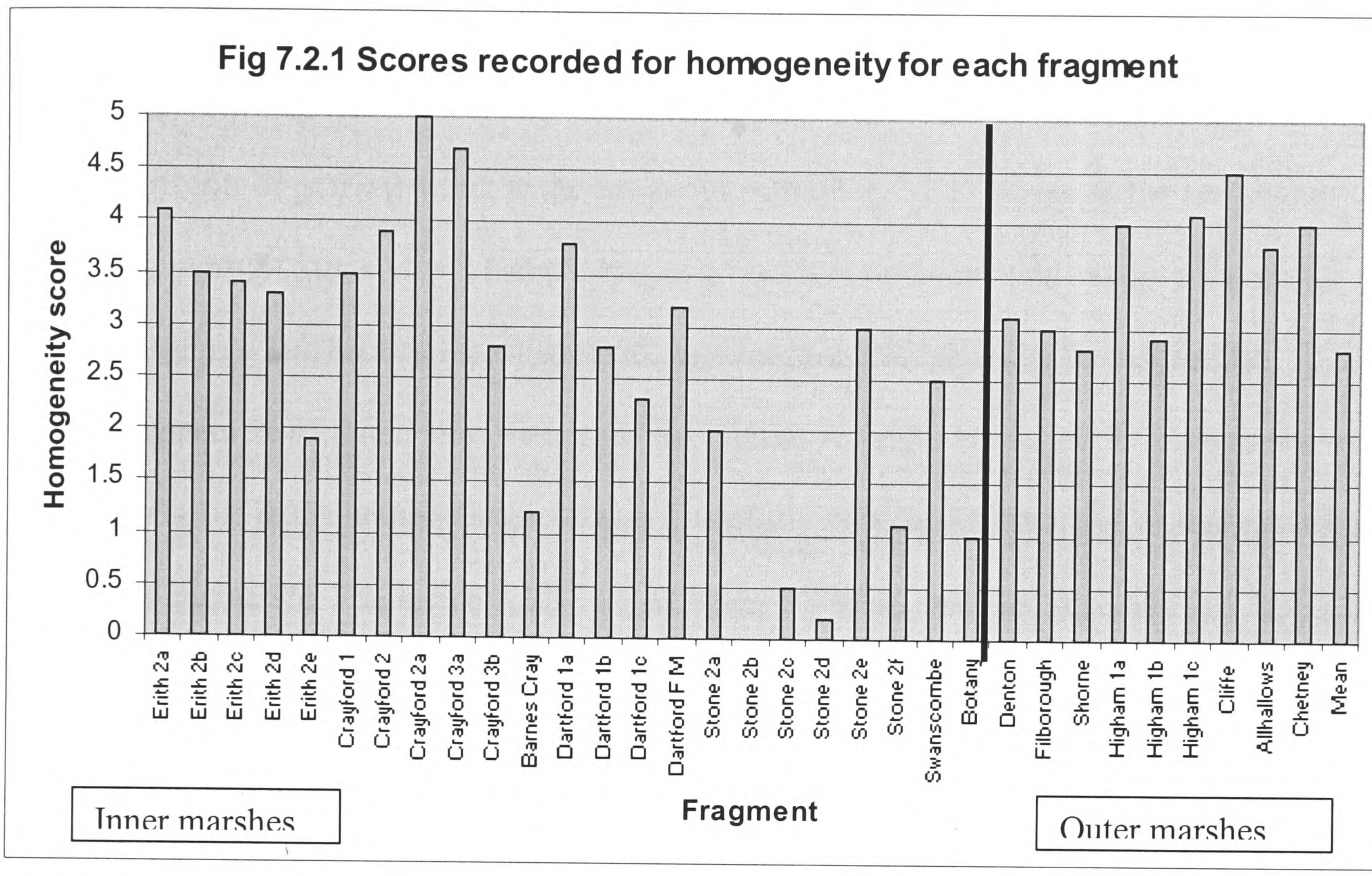
The grazing marsh landscape features surveyed were: -

- sward height
- tussocky grassland
- rills and wet flushes.

The criteria used to assess the characteristics and features were adapted from English Nature survey protocols (2000), limits of acceptable change criteria (Stankey et al 1985), habitat restoration criteria (2000), habitat inventories (Kent and Smart 1981) and the priorities for habitat conservation in England (Moffat 1999). The criteria were discussed in detail in Sections 5.1, 5.2 and 5.3.4.

7.2.1 Homogeneity – Results.

Homogeneity was assessed from a landscape perspective i.e. the overall marshland appearance at the landscape scale. Grazing marshes at this scale should present a homogeneous appearance of lowland wet grassland interspersed with drainage ditches as shown in Fig 5.2. Habitat heterogeneity only becomes apparent at the micro scale. A low score for homogeneity therefore represents the furthest departure from homogeneity, i.e. there is a lack of uniformity within the fragment (see Fig 5.3.1 for scoring). Figure 7.2.1 shows the score for homogeneity for all the fragments surveyed.



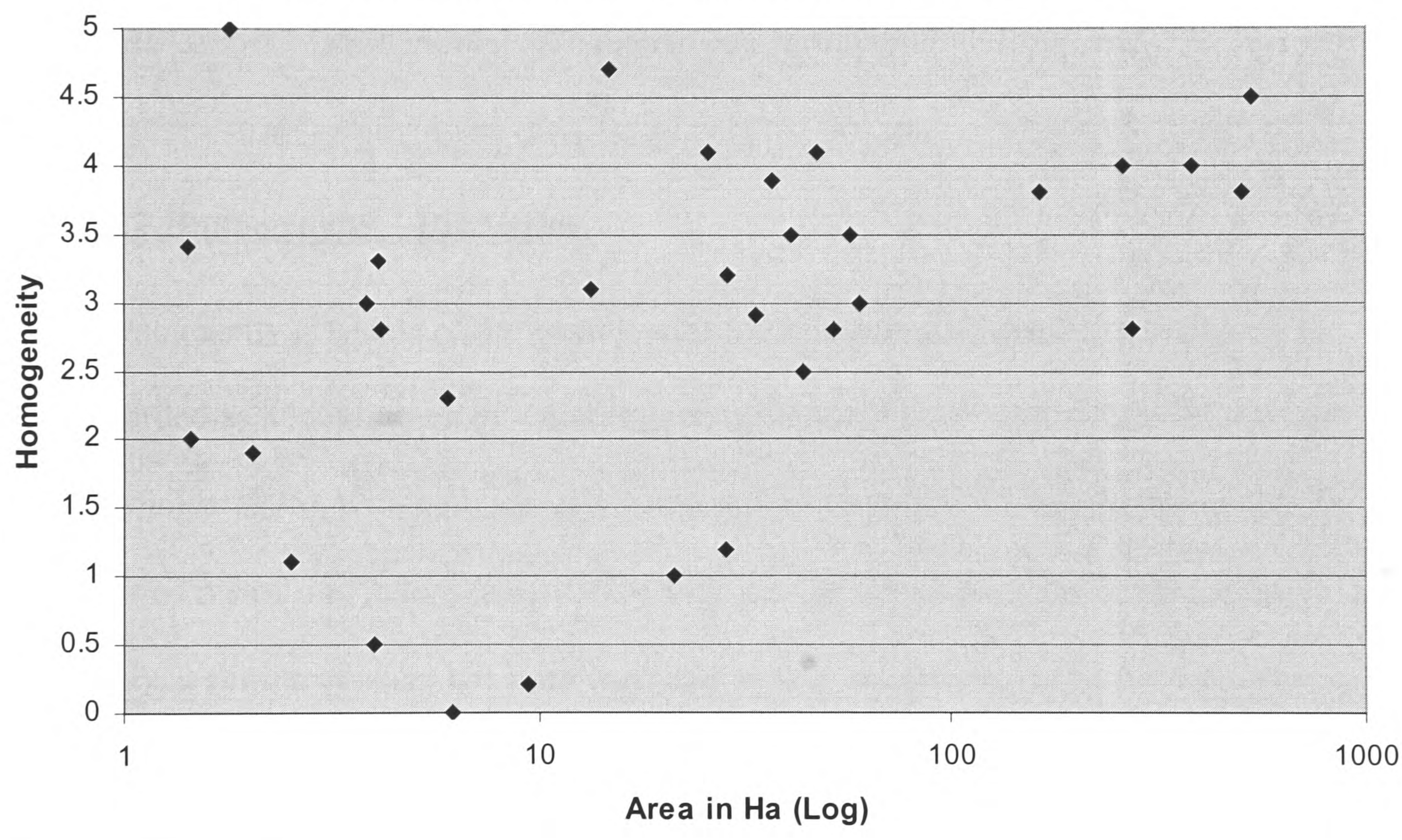
The mean score for homogeneity for all of the fragments surveyed was 2.8, and 44.1% of the fragments surveyed, recorded a score below the mean. In the Inner Thames Marshes 54.2% of the surveyed fragments and in the Outer Thames Marshes 20% recorded homogeneity below the mean value of 2.8. As discussed in Section 5.3.4 a score of four and above was regarded as being the standard condition of homogeneity for this thesis, only 23.5% of the fragments had a value higher than 4.0. 8.3% of the Inner Thames Marshes and 60% of the Outer Thames Marshes can therefore be regarded as having an ideal level of homogeneity at the landscape level. Over half (52.9%) of the fragments surveyed had a value for homogeneity of three or above indicating that the fragment showed homogeneity over half of the fragment area. Homogeneity occurred on less than 25% of a fragment on 26.4% of fragments surveyed, i.e. the value of homogeneity was below two. All values of less than two were recorded on the Inner Thames Marshes.

Stone Marsh, the most severely fragmented in terms of the number of fragments of the original marshlands, had a low value for homogeneity on five of the remaining seven fragments of grazing marsh at the landscape scale (Fig 7.2.1). Overall, the remaining fragments of Stone Marsh had the lowest scores for homogeneity (average 0.9), which indicates a link between the degree of fragmentation and landscape homogeneity. Fragment 2e of Stone Marsh recorded the highest value for homogeneity (3.0); however this is due to the homogeneous sewing of amenity grassland swards rather than remnant grazing marsh. Fragments 1, 2b – 2d of Stone Marsh all recorded scores of less than 1.0, for homogeneity, i.e. the fragments were highly heterogeneous at the landscape level (see Fig 5.3). Lack of management and subsequent landscaping and management of remnant marsh around newly constructed offices and industrial units have resulted in the heterogeneity of these fragments.

Swanscombe Marsh with a homogeneity score of 2.0 and Botany Marsh with a score of 1.0 both scored below the mean, indicating that landscape heterogeneity is the predominant character of the fragments, rather than homogeneity. Alternative land uses such as landfill and set-aside on these fragments have created a heterogeneous landscape with homogeneity only a minor component of the overall landscape.

The highest scores for homogeneity were recorded on Crayford Marsh fragment 2b and on Great Clane Marsh both with scores of 4.8. Crayford 2b was the smallest fragment surveyed at 1.81ha and retained homogeneity through regular mowing. Great Clane Marsh is now used for arable production, and homogeneity arises from the uniformity of the crop. Similarly, Barnes Cray also recorded a high score for homogeneity (3.0). The score in this instance reflects that homogeneity arises from uniform stands of individual species, great willow-herb, (*Epilobium hirsutum*) and redshank (*Polygonum persicaria*). The high scores for homogeneity on small fragments such as Crayford 2b and 3a indicates that size of fragment may not always be an indicator of homogeneity, Fig 7.2.2 shows the relationship between area and homogeneity.

Fig 7.2.2 Graph plotting homogeneity against area



The highest scores for landscape homogeneity occurred on the Outer Thames Marshes with 80% recording scores above the mean (2.8), (see Fig 7.2.1). In the Outer Thames Marshes, Shorne Marsh and Higham Marsh fragment 1b recorded scores below the mean, due largely to the effect of scrub development across at least 50% of the fragments. The marshes within the ESA scheme, Higham – Chetney all recorded homogeneity of at least 80%, which should be regarded as a guide to the level of homogeneity that well managed grazing marshes can exhibit.

To test the hypothesis that a positive relationship exists between fragment size and marsh homogeneity Spearman's coefficient of rank correlation was calculated. The resultant coefficient of 0.508 suggests that there is a positive relationship at the 95% confidence level between the two variables, and the hypothesis is not rejected. From this evidence, it suggests that the size of a fragment does affect site homogeneity although other factors may also be influential in determining this characteristic of grazing marshes.

7.2.2.Homogeneity – Discussion.

Homogeneity is a state of uniformity within a landscape, whereas heterogeneity is regarded as a 'continuum of variability and complexity – from low to high,' (Li and Reynolds 1995), with homogeneity being at the low point. Li and Reynolds (1995) viewed measuring heterogeneity indirectly, i.e. the departure from homogeneity. In this study, a similar concept has been used, but with homogeneity being the high point of the scale (Section 5.3.4). Vegetative and landscape homogeneity are determining characteristics of grazing marshes, Fig. 5.2 illustrates the overall appearance of grazing marshes as homogeneous landscape of flat grassland divided only by drainage ditches. Homogeneity of grazing marshes is therefore primarily due to vegetative homogeneity, i.e. grassland vegetation is the dominant characteristic within the landscape.

Heterogeneity results from the landscape homogeneity of a grazing marsh integrating with the characteristics and features to create homogeneous-heterogeneity of the landscape. Section 7.3 discusses the surrounding influences of urbanisation and industry that will increase landscape heterogeneity or landscape diversity (Forman 1997). From a visual perspective homogeneity is therefore, an essential defining feature of grazing marshes, which enhance the 'big skies' and gives the appearance of openness, which was typical of grazing marshes in the past, e.g. Dickens (1861).

Divisive fragmenting agents (roads etc.) act as corridors, which in turn open up opportunities for new species to move into the fragmented marshes (Findlay and Houlahan 1997). The introduction of new species changes the vegetative homogeneity of grazing marshes fragments by creating vegetative stands that are of visually different composition to the ideal grazing marsh (see 8.4.2), e.g. Stone Marsh 2c, although examples such as Barnes Cray (Fig 7.2.3) show how invasive species can create a vegetative homogeneous fragment that is not dominated by grassland.

Fig 7.2.3 Homogeneity Barnes Cray

As divisive fragmentation increases the amount of edge (Soule et al 1992), the influence of disturbance on a remnant fragment increases and therefore the degree of homogeneity will change, i.e. increased fragmentation will cause a decrease in homogeneity and an increase in heterogeneity, unless human intervention in the form of management is practiced.

Roads, railways etc. which cause divisive fragmentation also act as corridors, which in turn are a source of invasion of weeds (Simberloff and Cox 1987, Noss 1987) see Section 8 for further discussion of invasive species. The high constancy at which a range of competitive – ruderal species, such as mugwort (*Artemesia vulgare*), ragwort (*Senecio jacobaea*), barren broom (*Bromus sterilis*) and cow parsley (*Anthriscus sylvestris*) were found on the North Kent Marshes has led to an increase in the habitat heterogeneity, and altered the composition of the grazing marsh matrix vegetation communities (see Section 8.3). Edges created by fragmentation therefore induce the changes in features and species content, which can increase the degree of heterogeneity of the remnant grazing marsh fragments.

Homogeneity of the grazing marsh matrix will also be affected by waterlogging, for example Dartford Fresh Marsh (Fig 7.2.4), where stress tolerant competitors such as soft rush (*Juncus effusus*) has formed stands that dominate the wetter areas, and create heterogeneity at the landscape scale. These patterns occur either through under grazing or a lack of water management, which in these cases are the result of fragmentation. Similarly, the wetter rills may become dominated by competitive species that will form large homogeneous stands e.g. Barnes Cray (Fig 7.2.3), which creates both micro scale heterogeneity and landscape homogeneity, although the species content does not conform to the lowland grassland matrix of grazing marsh.

Fig 7.2.4 *Juncus effusus* Dartford Fresh Marsh

The homogeneous – heterogeneity of a fragment created by the landscape characteristics and features will be influenced by regressive, divisive and enveloping fragmentation, where the fragmenting agent destroys or causes direct disturbance to the characteristic or feature. Their effects will be more influential on how the fragment changes because of the reduction in area and through the introduction of external pressures i.e. edge effects, which will vary depending on the nature of the fragmenting agent (Harris et al 1991, Forman 1997). Over and above losses to the landscape features and characteristics, fragmentation may lead to damage and a lowering of the value and quantity of the individual feature or characteristic, e.g. silting of ditches (see Section 7.4.2). The increased edge effects (see Chapter 6) and the distance over which additional disturbance occurs can lead to further degradation and reduction in the homogeneity of the fragment as a whole.

Extensive development and associated infrastructure works across the majority of the former grazing marshes, i.e. intrusive fragmentation have altered or destroyed the micro scale landscape features and therefore the homogeneous – heterogeneous structure and result in low scores for homogeneity, e.g. Stone Marsh. In such an example, not only is internal homogeneity decreased but also the landscape diversity and heterogeneity are increased. Such developments act either directly, i.e. habitat loss, or indirectly through edge effects and through disturbance. Wetland sites, such as grazing marshes when intrusively fragmented are going to be adversely affected by changes to the hydrology (Andrews 1990, Forman and Deblinger 2000), which will affect the ability of wetland plant species to survive and therefore alter the community structure (Section 8.3), which will alter the internal homogeneous- heterogeneous structure of a remnant grazing marsh fragment.

Of the edge effects produced by intrusive fragmentation, changes to microclimates are expected to have the greatest effect (Hobbs 1993). Grazing marshes are open habitats, intrusive fragmenting agents will introduce areas of shade and changes to wind flows, which can bring about changes to vegetation structure and decrease habitat homogeneity, i.e. the landscape character of grazing marshes.

Fragmentation creates smaller units of grazing marsh; Small et al (1999) found that sites under 10ha were often considered too small to be of value for grazing, i.e. less management occurs on smaller sites. A change in or lack of management allows the invasion of scrub and trees, which will also lead to a loss of vegetative homogeneity, Fig 7.2.5 shows Stone Marsh 2f where homogeneity has been lost through scrub invasion. Similarly on larger fragments changes in land use where management has not returned to grazing vegetative homogeneity has also been lost, Fig 7.2.6 shows Dartford Marsh, where hospital closure has allowed succession to occur and again there has been an increase in heterogeneity.

Fig 7.2.5 Scrub development Stone Marsh

Fig 7.2.6 Succession on Dartford Marsh

The result of the test for rank correlation shows that at the 95% significance level correlation existed between the remaining area of a fragment and the homogeneity of that fragment. Stone Marsh fragment 2e however showed a high degree of homogeneity, primarily because of landscaping, and therefore the overall results for a relationship between homogeneity and area are not always easy to interpret. The typical grazing marsh should show homogeneity (Fig 5.2) at the landscape scale. As fragmentation occurs, landscape homogeneity is disrupted by the fragmenting agent, which increases landscape heterogeneity. Management may however, restore a degree of homogeneity, as Stone Marsh fragment 2e, but with no micro scale heterogeneity. It is not therefore, homogeneity per se, which is important in grazing marshes, but homogeneity at the landscape visual aspect, which defines grazing marshes in a landscape context. To assess grazing marsh therefore, homogeneity needs to be considered as a component and not the whole.

Openness and big skies are descriptions of the North Kent Grazing Marshes introduced by Dickens (1861) and more recently by Cobham (1995). To evaluate the openness of remaining fragments, as decreasing homogeneity, (or increasing heterogeneity) alone does not necessarily determine the openness of grazing marshes, e.g. Shorne Marsh (2.8), homogeneity and surrounding land use (Section 7.3) should be considered together. A high score for homogeneity, Crayford Marsh fragment 2a (4.8) for example, does not always create the openness as the influence of the surroundings dominate the fragment scoring five, and therefore the grazing marsh has lost the traditional openness. The relationship between the landscape elements has to therefore be considered holistically and not individually when assessing the effects of fragmentation.

7.3.1 The urban and industrial influence on grazing marshes – Results.

The assessment of the urban and industrial influence on the grazing marsh fragments was undertaken using Cobham (1995) categories of urban/industrial influence or dominance. Where the marshland character has been affected by peripheral industry or urbanisation or by the presence within the marsh of urban/industrial features, e.g. power lines; the classification is deemed influential as shown in Fig 5.4. When the marshland character is overwhelmed by the urban/industrial features, the effect is classified as being dominant as shown in Fig 5.5. Classification of the influences was based on the scoring system explained in Section 5.3.4, and the assessment of the influence on the landscape was taken from a minimum of three points across every fragment. Different viewpoints were taken to ensure that the influence at one specific part of the marsh was no more important than any other point. For example, parts of Dartford Marsh are dominated by the Littlebrook Power Station, whereas other areas are quite remote with little external influence, therefore the results reflect an average influence over the whole fragment (Fig 7.3.1). A high score indicates that the marsh or fragment is highly influenced or dominated by the urban/industrial surroundings including the fragmenting agent.

Figs 7.3.1 and 7.3.2 record the scores for the urban/industrial influence or dominance on the grazing marshes studied, 52.9% of the fragments surveyed were recorded as having urban/industrial influence, whereas the remaining 47.1% of the fragments had urban/industrial dominance. The mean score for marsh fragments influenced by urbanisation or industrialisation was 2.56, 61% of fragments recorded a score greater than this value. The mean score for urban/industrial dominance was 4.16 and 56.25% of fragments in this category had a score exceeding the mean. Sixteen marsh fragments (45.1%) recorded urban/industrial dominance, fifteen of which were in the Inner Thames Marshes. Overall, 62.5% of the Inner Thames Marshes are categorised as having urban/industrial dominance, against 10% of the Outer Thames Marshes, with only

Denton Marsh of the Outer Thames Marshes being recorded as having urban/industrial dominance.

Fig 7.3.1 Scores recorded for urban/industrial dominance for each fragment

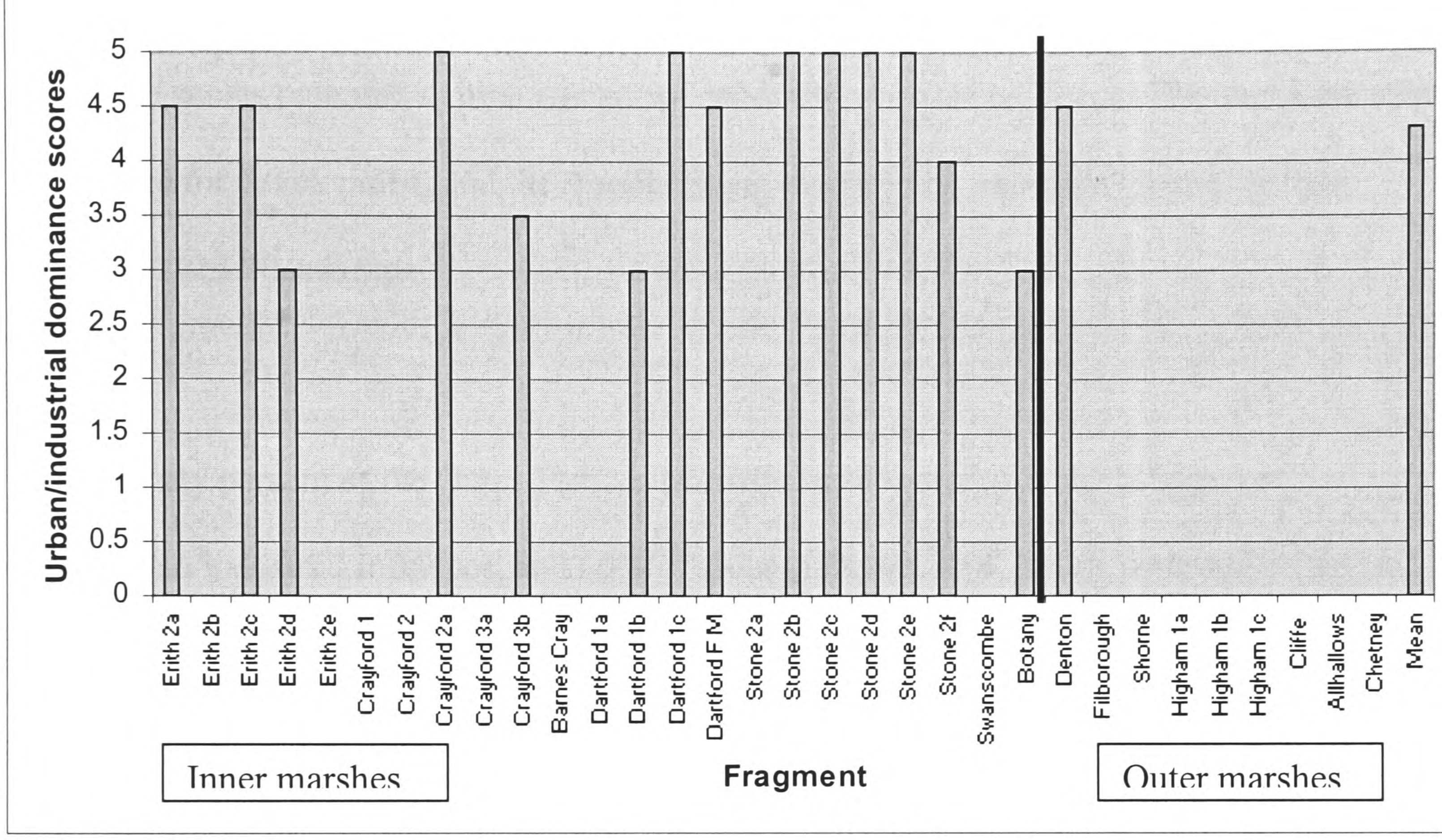
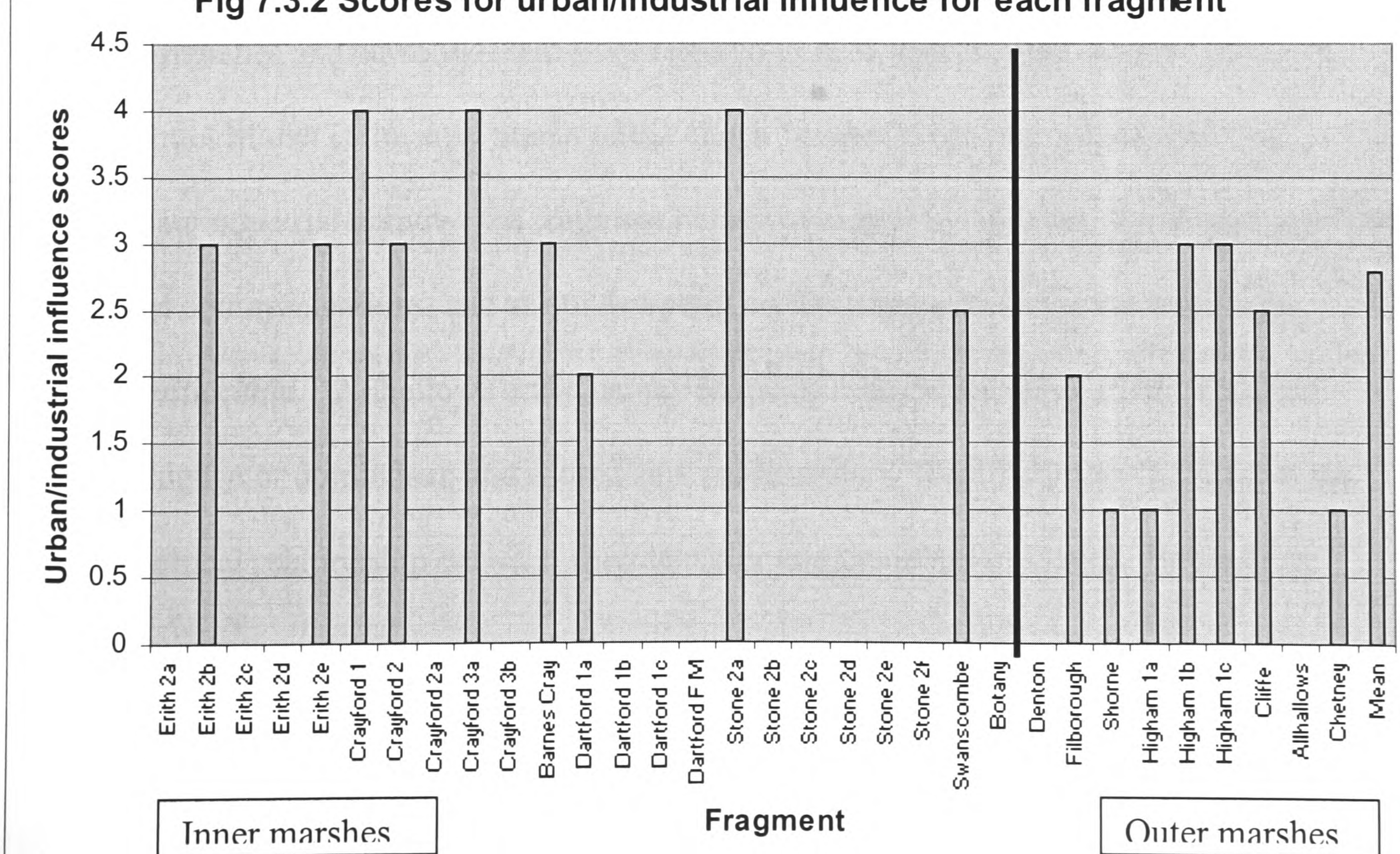
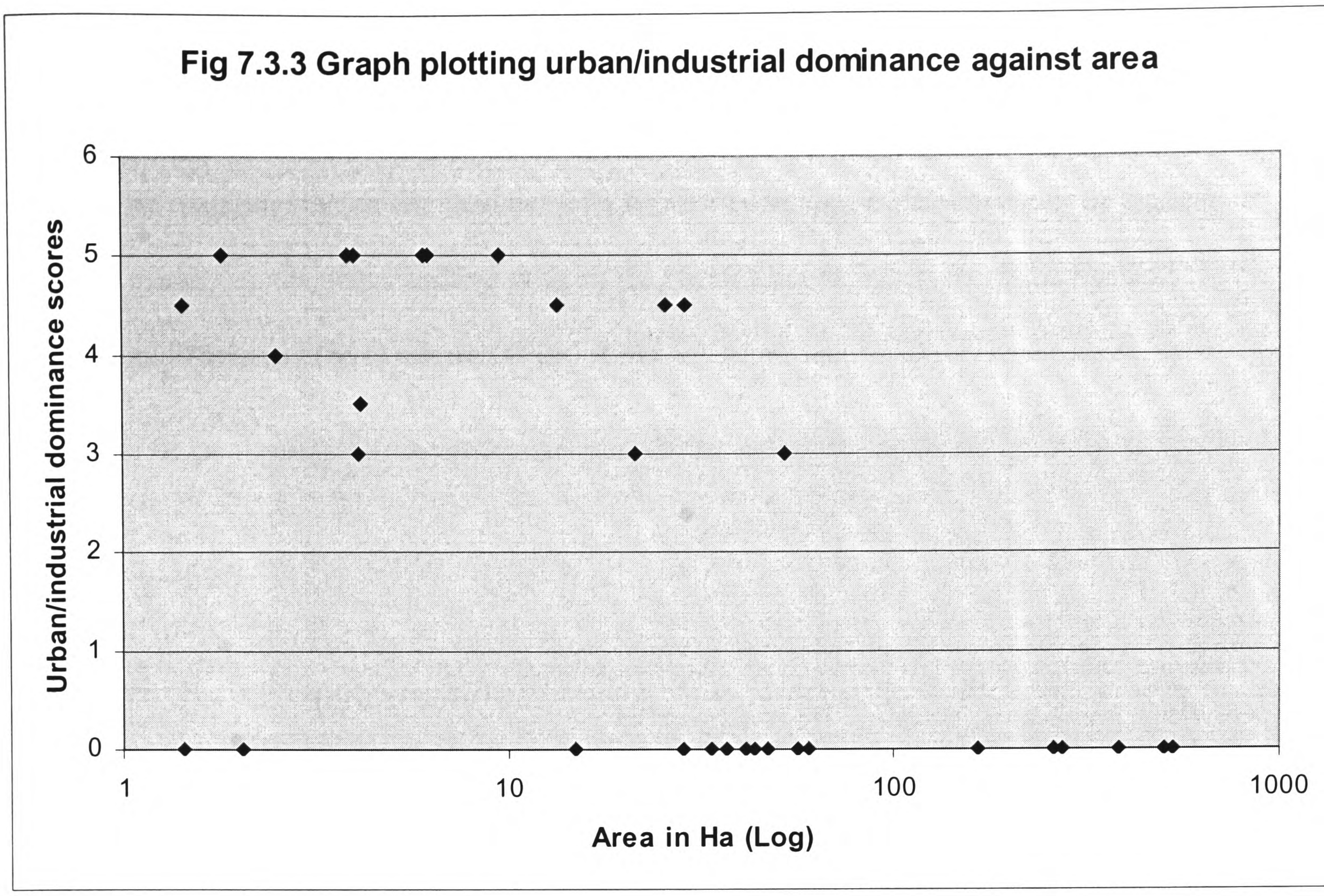


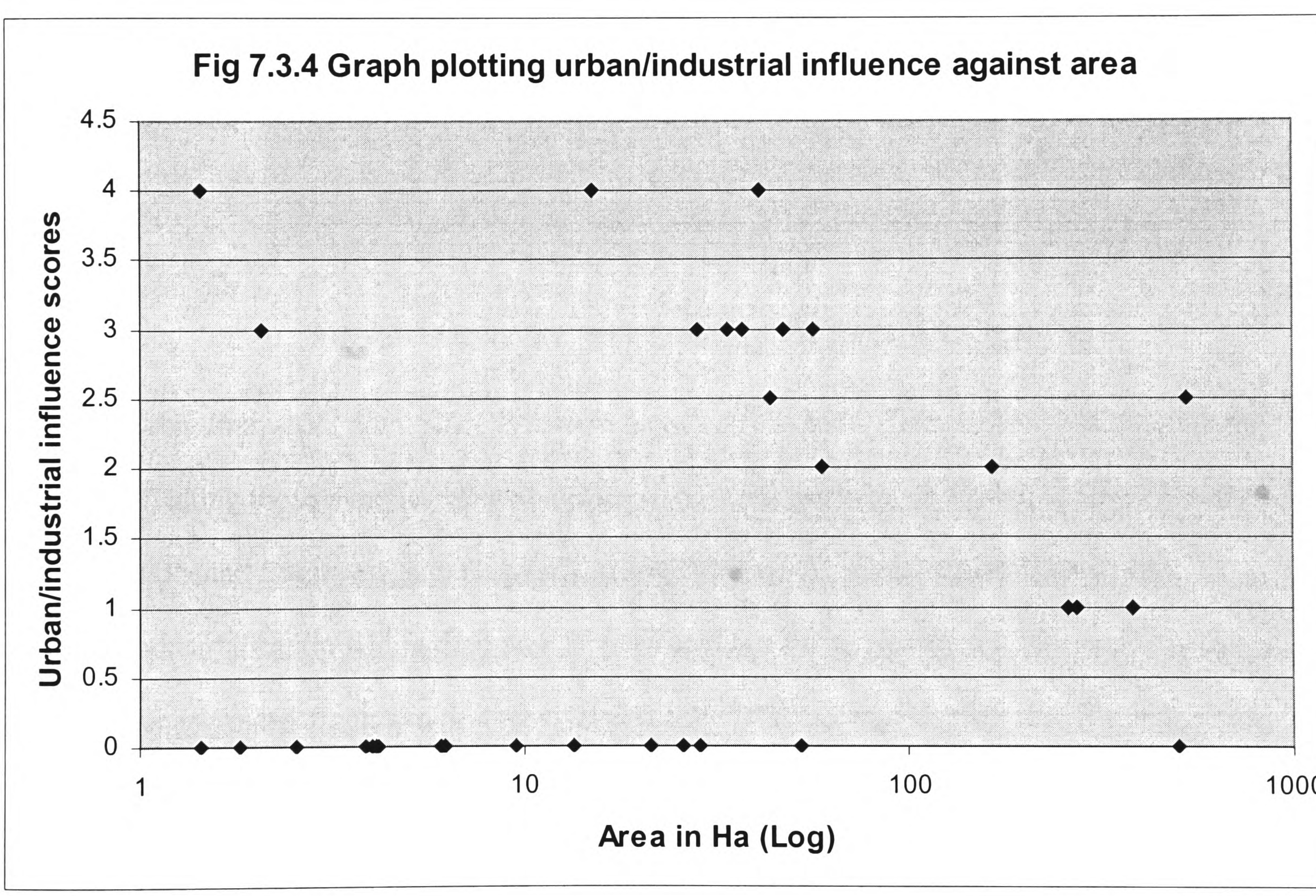
Fig 7.3.2 Scores for urban/industrial influence for each fragment



Scoring for industrial/urban influence or dominance was overall greater for the Inner Thames Marsh than the Outer Thames Marsh fragments. Inner marsh fragments subject to urban/industrial dominance recorded a mean score of 4.64, with 81% of the fragments scoring more than the mean. The inner marshes with urban/industrial influence have a mean score of 3.2, and 77.8% of the fragments in this category scored over the mean. The scores recorded in both categories reflect how the Inner Thames Marshes have been used for development and the smaller fragments become integrated into the urban /industrial landscape.

Ninety percent of the Outer Thames Marshes were recorded in the category of urban/industrial influence, and 60% of those outer marshes, which recorded influence, had scores below the overall mean influence value (2.62). The low scores for the outer marshes indicate that they retain the open character of the North Kent Marshes written about by Dickens and discussed by Cobham (1995) (see Fig 7.3.5). The higher scores for urban/industrial influence recorded on the following outer marshes, Great Clane (3.0), Higham 1b (3.0) and 1c (3.0) and Cliffe (2.5) reflect both past and current usage of the marshes and surrounds that have resulted in the fragmentation to these marshes. Denton Marsh is the only marsh of the Outer Thames recording a dominance of urban/industrial activity, the fragment being enveloped by housing, warehousing rail and road communications, and at no viewpoint on the fragment are the surroundings unnoticeable. Allhallows and Chetney Marshes both recorded no urban/industrial influence or dominance and scored zero in the survey. Figs 7.3.3 and 7.3.4 show the graphical relationship between fragment size and the urban/industrial influence or dominance.





7.3.2 Surrounding land uses and influences – Discussion.

Cobham (1995) characterised the North Kent Marshes in terms of the influences imposed upon their landscapes by on site and surrounding land usages, using the terms urban/industrial influence or urban/industrial dominance. Both classes of surrounding and on site land use will affect the landscape characteristics of grazing marsh, i.e. openness and big skies of the North Kent Marshes, to which Hasted (1797) and Dickens (1861) referred (Fig 7.3.5).

Fig 7.3.5 Openness and big skies of the North Kent Marshes

Urban/industrial dominance is more a feature of the Inner Thames Marshes particularly affecting those marshes which have been most fragmented, i.e. Erith and Stone Marshes, and small fragments, e.g. Crayford 2a and Dartford 1c. Greater urbanisation and industrialisation within the Inner Thames area has led to greater pressure on the land and hence greater fragmentation (see Section 6.3). The increase in the number of fragments between 1897 and the present time has resulted in the increasing influence and dominance that new developments exert on the smaller remnant grazing marsh fragments found in the Inner Thames Marshes.

Fragmentation of grazing marsh can often increase urban/industrial dominance, usually through intrusive or enveloping agents. The agents responsible for divisive, regressive and encroaching fragmentation create the changes that occur at the periphery and along edges of a fragment (Harris et al 1991), and therefore producing urban/industrial influences. For example, roads and rail traffic along divisive fragmenting agents will exert an influence on the fragment, but will not dominate the marsh. Divisive fragmentation however provides the opportunity for urban and industrial expansion, the intensity of which will determine whether remnant fragments become influenced or dominated by their surrounds. For example, the most highly fragmented of the North Kent Marshes; Stone Marsh, has been progressively fragmented by roads, creating smaller fragments, which have been subject to further development subsequently becoming dominated by the external and/or internal influences of the fragmenting agents, (Fig 7.3.6).

Fig 7.3.6 Stone Marsh development

Intrusive fragmentation has occurred on Erith Marsh and the level of fragmentation, i.e. the creation of five fragments creates urban/industrial dominance. The size of the remnant fragment is therefore a factor in determining the urban/industrial influence on the marshlands. There are however, examples where small fragments record urban/industrial influence rather than dominance, e.g. Crayford Marsh 3a, although a high score (4.0) was recorded, but there were no small fragments which recorded no influence or dominance. Overall, the higher scores recorded in the Inner Thames Marshes for both urban/industrial influence or dominance reflects the greater intensity at which development has occurred around these sites, when compared to the Outer Thames Marshes. Dartford Marsh however, provides an exception to the high scores for the inner marsh fragments, although the smaller fragment 1c and Dartford Fresh Marsh recorded high scores for urban/industrial dominance (Fig 7.3.1 and 2). Fragment 1a recorded the lowest score (2.0) for either category within the inner marshes, which results from there being little visual influence from many of the survey points on Dartford Marsh. As Dartford Marsh 1a is the largest remaining fragment within the Inner Thames Marshes, the results indicate that fragment size will influence the maintenance of the open grazing marsh character. Whether the openness of grazing marshes can be conserved in the Inner Thames will be discussed in Section 9.

Fig 7.3.7 Power Lines across Higham Marsh

The Outer Thames Marshes from Shorne in the west and out across the Hoo Peninsula still show the characteristic features of grazing marshes i.e. open landscape and huge skies highlighted by Dickens (1861) and more latterly Cobham (1995). A number of visual intrusions however influence the overall landscape character of each individual marsh, e.g. overhead power lines are notable examples of influences (Fig 7.3.7), which in individual places overwhelm the marshland landscape and could therefore, be said to be locally dominant, although the overall scores reflect urban/industrial influence across the marshes. Regressive fragmentation on the southern boundaries of all the Outer Thames Marshes are the areas most influenced by the surroundings, and as such has a more direct influence on the marshland character, although the development of trees and scrub and planted tree screens have softened the visual impact from the marshlands.

The processes and agents of fragmentation are responsible for the urban/industrial influence or dominance on the fragments of the North Kent Marshes. Divisive fragmentation has been identified as the prime cause of fragmentation (Section 6.3.2), but the direct effects in terms of influence on marshland character are not as extensive those of intrusive, enveloping or regressive fragmentation. Construction of industrial premises, offices and waste facilities (intrusive and regressive agents) that have arisen from the opening up of the marshlands, and the Inner Thames Marshes in particular, generally exert a far greater visual impact than roads and rail, where the influence is primarily through noise and pollution. The dominance of the Dartford Crossing on Stone Marsh, Fig 7.3.8, is an exception where roads exert a dominant visual intrusion on fragmented marshland.

Increasing heterogeneity of marshland fragments resulting from fragmentation and an increase in tree and scrub cover as succession proceeds, often acts to reduce the impacts of the surrounding land-use by screening the fragmenting agent. There are examples e.g. Cliffe Marsh where tree planting has been specifically introduced to shelter intrusive fragmenting agents (MacDougall 1980), thereby increasing heterogeneity, but reducing urban/industrial influence (Fig 7.3.9). Other examples occur on Swanscombe Marsh and on Dartford Marsh; therefore one of the more unexpected outcomes of increased heterogeneity and scrub invasion is to mitigate the effects of urban/industrial influence or dominance, although the openness of grazing marshes is still affected.

Fig 7.3.8 Dartford crossing dominating Stone Marsh 2e

Fig 7.3.9 Trees screens Cliffe Marsh

7.4.1 Drainage ditches – Results.

Ditches were scored on a basis of their condition: -

- level of maintenance and management;
- their presence on each fragment;
- the status of the emergent vegetation, e.g. was it dominating and choking the waterway, and/or whether the ditch was overgrown by bank side vegetation, both of which would result in a low score.

The status of emergent vegetation was also used as an indicator of the level of management employed on the marsh fragment. The isolation of ditches, i.e. whether the ditches are inter-connected, and the absence of water within the ditches were also considered as factors which affect the score for the drainage ditches.

Fragments were given a lower mark if they contained fewer ditches than recorded in 1897, the evidence for which could be obtained from comparing the second series Ordnance Survey with current maps. No allowance was made in the scoring for the ditches having a traditional appearance, i.e. following an irregular course. Although straightening the ditches infers human interference, grazing marshes are of anthropogenic origin in the first place and therefore further human activity in modifying the ditches in this way was not considered as a factor that would alter the character as a basic component of grazing marshes.

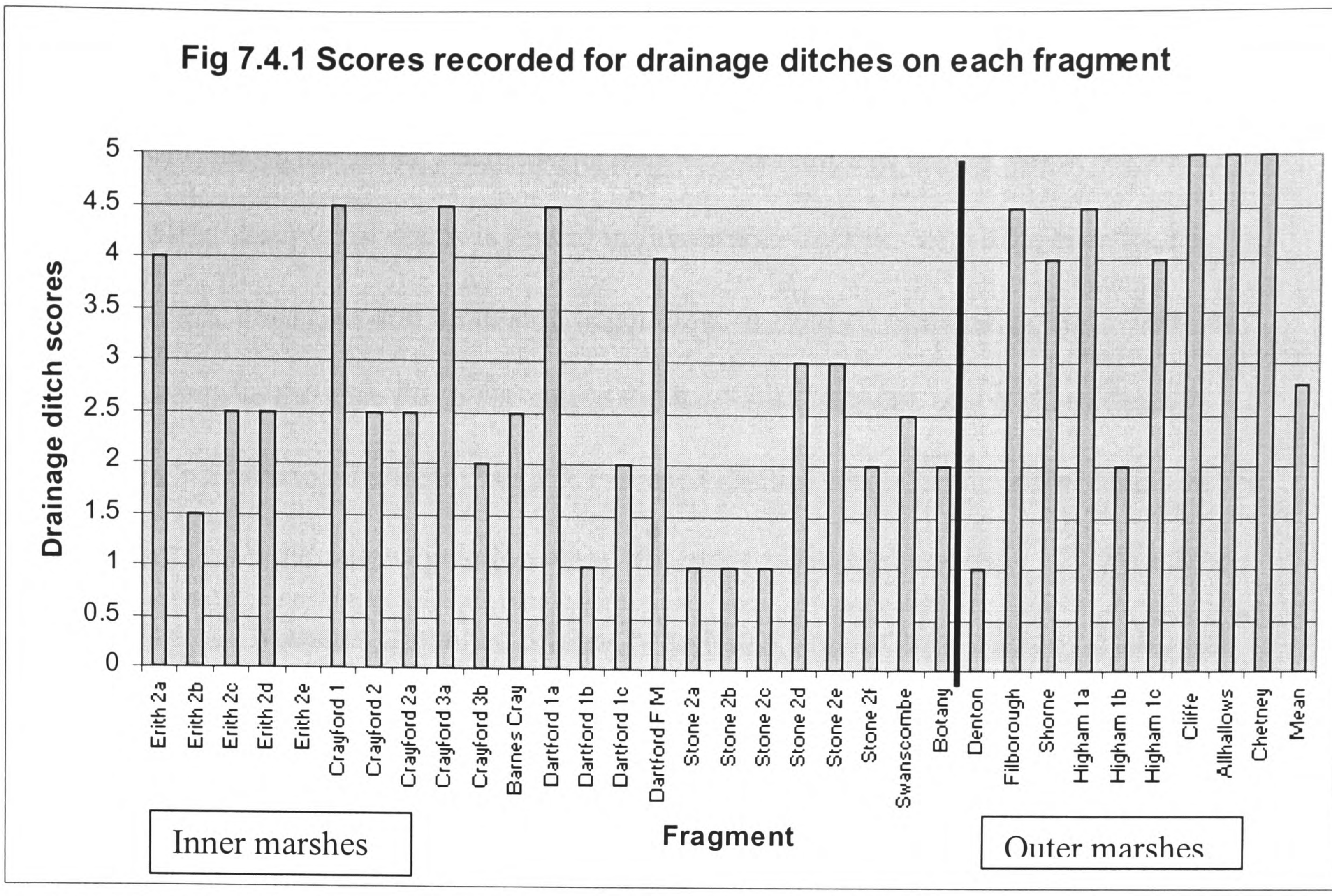
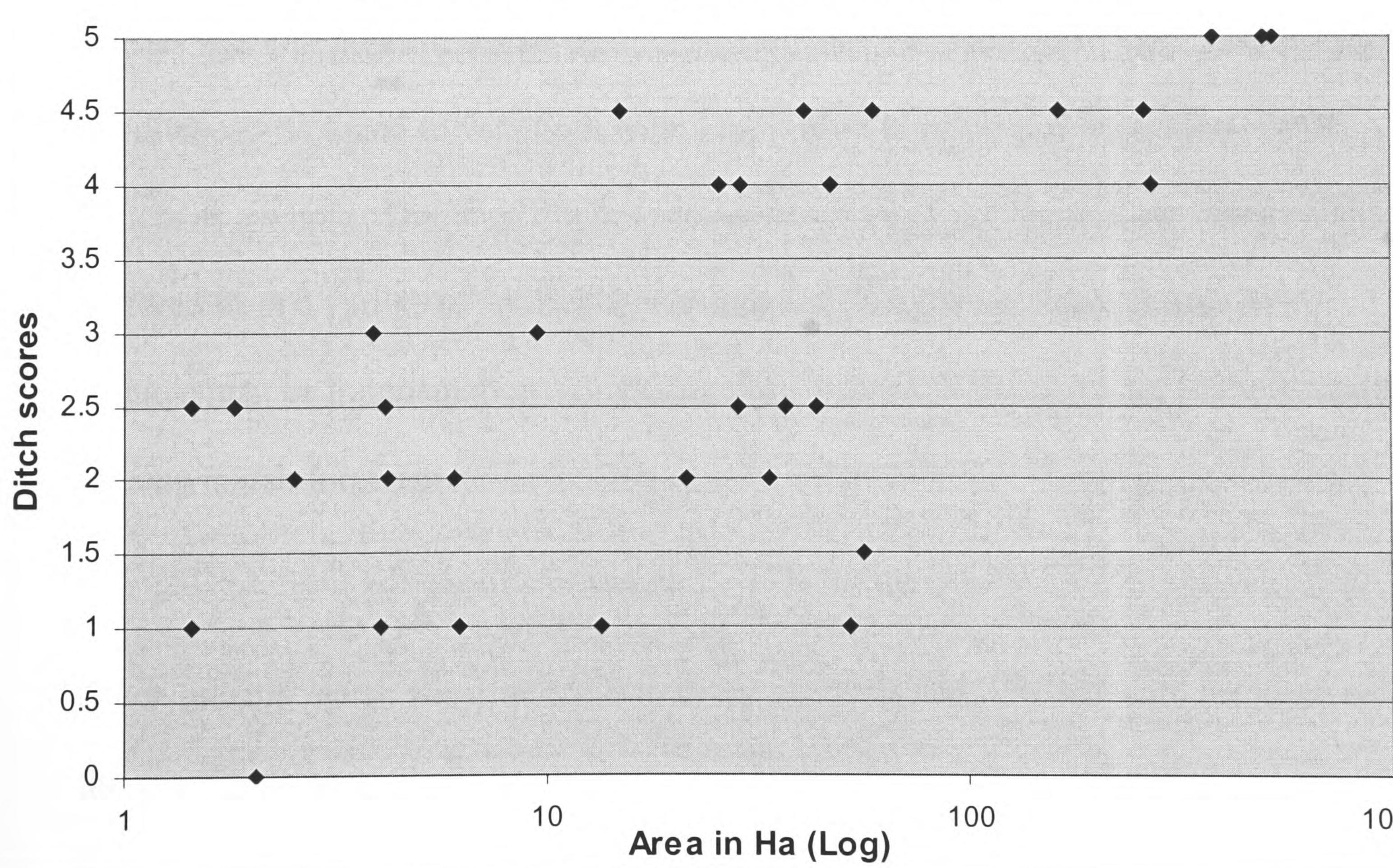


Figure 7.4.1 shows the average scores for the drainage ditches for each fragment. Only two fragments Erith Marsh 2e and Stone Marsh 1 recorded a score of zero, indicating that no evidence of a drainage ditch system remained. Forty four percent of all the marsh fragments surveyed recorded a score above the mean value of 2.8, with 80% of the Outer Thames Marshes and 29.2% of the Inner Thames Marshes recorded a score greater than the mean. In the Outer Thames Marshes only Denton Marsh scored below the mean, the ditches on this site being recorded as partially destroyed. The mean score for the Inner Thames Marshes was 2.34, i.e. ditches declining (Fig 5.8); whilst on the Outer Thames Marshes the mean score was 3.9, i.e. favourable and improving (Fig 5.10). The lower status of the ditches on the Inner Marshes is reflected by 79.2% of the fragments having drainage ditches scoring three or less indicating that the ditches are declining in condition. Three marshes Cliffe, Allhallows and Chetney all scored a maximum of five, i.e. their ditches were all managed and well maintained. There were no fragments on the inner marshes scoring a maximum five, although three fragments Crayford 1, Crayford 3a and Dartford 1 recorded a score of 4.5 with two others Erith 2a and Dartford Fresh Marsh scoring 4.0.

Of the ditches on the Inner Thames Marshes 41.6% recorded scores below the mean that indicate that the overall status is one of unfavourable decline, with all elements, i.e. water levels, emergent and bank side vegetation, in need of remedial action. This may not however be the case for every single ditch on the fragment, and 60% of these marshes, i.e. scoring between 2 and 3, recorded ditches where either water levels or the emergent and bank-side vegetation were still in a favourable condition. 29.2% of the Inner Thames Marshes contained ditches, which had been at least partially destroyed (see Fig 7.4.1), with only Denton Marsh of the outer marshes recording a similar score, the ditches being partially destroyed. The fragments included Erith Marsh 2b, Dartford Marsh 1b and Stone Marsh 2a, where emergent and bank side vegetation had choked the ditches, and Stone Marsh 2b and 2c, which have become isolated by the effects of fragmentation, and generally neglected.

Fig 7.4.2 Graph plotting ditch status against area



Spearman's coefficient of rank correlation was calculated to test the hypothesis that there is a relationship between fragment size and the status of the ditches. A coefficient of 0.612 indicates that there is a significant degree of correlation between the two variables at the 95% confidence limit, and therefore fragment size does influence the status of the ditches. Fig 7.4.2 also indicates that there is a relationship between fragment size and the status of the ditches, although this may also reflect that there are more ditches on the larger fragments.

7.4.2 Drainage ditches – Discussion.

Drainage ditches, dykes, fleets and associated wetlands are consistently recorded as being one of the most characteristic landscape features of grazing marshes (Cobham 1995, Kent BAP 1997, MAFF 1997). All the marshes in this survey showed some evidence of a drainage system, even where a marsh scored zero, the profile of individual ditches was still present, but all other characteristics had been destroyed. The quality of the ditches was found to vary both within individual marshes and across the marsh system as a whole. Drainage ditches across the whole of the North Kent Marshes have suffered from a variety of anthropogenic-induced changes via either change in management or fragmentation, which therefore influences the character of the remnant grazing marsh fragment.

When grazing marsh was first reclaimed, the channels and rills that were enclosed with the grasslands would have been sinewy and irregular in pattern. With the adoption of more intensive and managed grazing post 1897 the pattern of drainage ditches was often altered to a more regular pattern, often delineating land ownership (ADAS 1997). This involved the straightening of dykes and fleets in order to facilitate the control of water levels and periods of inundation. These functions are still of importance today, but management of the ditch systems is now also allied to defence against flooding, although this may conflict with management for fauna such as water voles (Wells *pers com.*).

Divisive fragmentation, as usually the first and most frequent process, may not appear as destructive a force on the drainage ditches as later fragmentation processes, particularly intrusive fragmentation. Drainage ditches often remain after roads have been built flowing through culverts under the construction and maintaining connectivity between two isolated fragments, for example linking Erith Marsh fragments 2a and 2b, and linking Dartford Marsh and Dartford Fresh Marsh. Divisive fragmentation for example on Erith Marsh by the construction of Bronze Age Way has left a number of drainage ditches as isolated lengths (Fig 7.4.3). A few of these ditches have been maintained as features to enhance the landscape, i.e. to improve the image of the surrounding factories, whilst others are becoming choked by the growth of *Phragmites australis*.

The effect of divisive fragmentation on the quality of drainage ditches result from indirect actions. These include changes in water quality through deposition of pollutants from road surfaces (Forman 1997), and siltation (Andrews 1990), which will affect the effective depth and quality of the water in the ditches, which in turn will affect the structure of the vegetation, both emergent and bank side. Changes to the vegetation and water quality will affect the invertebrate populations and hence the whole ecology of the ditch systems (Campbell and Doeg in Andrews 1990).

Fig 7.4.3 Isolated Ditch Erith Marsh

Forman and Deblinger (2000) recorded that the effects of roads on water quality could extend for up to 500m into a wetland habitat. Water in drainage ditches can therefore transport suspended material resulting from divisive fragmentation by roads across marsh fragments. The effects of divisive fragmentation may therefore, ultimately affect areas of the marsh that are not been directly influenced by the original fragmentation process (Forman 2000). As most of the North Kent Marsh fragments are less than 50ha, much of their area will lie within the 500m range discussed by Forman and Deblinger (2000), and therefore it is anticipated that the water quality on the majority of fragments will be affected by road construction. Effects from divisive fragmentation therefore tend to act indirectly on the ditches and water quality of the remnant fragments.

Intrusive fragmentation can cause either direct loss of ditches (Erith Marsh), or the isolation of ditches (Stone Marsh). Processes, which are acting directly, e.g. office building, not only lead to the loss of these ditches within the area of construction, but the act of construction will affect the hydrology of a wetland site (Campbell and Doeg 1989 in Andrews 1990) and will therefore affect the remaining ditches beyond the area of development. Loss of grazing marsh to arable production as an intrusive fragmenting agent may not however lead to any loss of drainage ditch features, e.g. Great Clane Marsh and Allhallows Marsh, because of the need to regulate water levels to maintain crop growth. Agricultural use may however, influence the status of the water quality in connected drainage ditches through run-off from the fields of fertilisers and herbicides, which in turn can cause the excess growth of algae i.e. eutrophication (Barendregt et al 1992 in Findlay and Houlahan 1997).

Drainage ditches can remain after grazing marsh fragments have been totally lost, if retained for landscape features and drainage for example throughout the development of Thamesmead on Erith Marsh fragment 1 (Fig 7.4.4). Drainage ditches cannot however, be considered in isolation. Their value is as a constituent of the ideal grazing marsh (Kent BAP 1997), which provides the basis of the aquatic habitats and wetland features of grazing marshes (see Section 7.7.2 and 9). Isolated drainage ditches are therefore not an indicator of grazing marshes, i.e. lowland wet grassland plus drainage ditches are an indicator of grazing marsh, lowland wet grassland minus drainage ditches and drainage ditches minus lowland wet grassland are not considered to be typical grazing marsh.

Fig 7.4.4 Canalised ditches in Thamesmead

The remaining processes of fragmentation, i.e. regressive, enveloping and encroaching, intensify the effects created by divisive fragmentation. New building will follow the patterns created by intrusive fragmentation, i.e. total loss of the characteristic (Erith Marsh), isolation of ditches (Erith Marsh) and the loss of connectivity between fragments (Denton and Great Clane Marshes) as drainage ditches are lost. Buechner (1989), and Forman and Godron (1986) in Collinge (1996), recorded that type and intensity of land use activities will markedly influence the flow of nutrients and materials in the remnant fragment. Construction work and the intensity of subsequent land use carried out on grazing marsh fragments can therefore; add to the sediment and pollution load that is transferred into the ditch system. The status and quality of the water in drainage ditches is therefore lowered by the effects of fragmentation.

Anthropogenic activity has been responsible for altering the physical characteristics of many of the drainage ditches throughout the North Kent Marshes by straightening and changing the X-sectional shape (Wade 1990). The original sinewy nature of the saltmarsh channels has been altered to accommodate intensive agriculture (Van Strien et al 1991) or to facilitate drainage (Williams et al 1983). Many of these changes have occurred because of fragmentation and have subsequently led to conflict between the needs of conservation and management. Fragmentation through intensive agriculture, which has occurred on Botany and Great Clane Marshes, should have the effect of lowering water levels, (Van Strien et al 1991). The ditch systems on these marshes were however found to be in good condition, therefore disagreeing with the comments of Van Strien at al.

Wade (1990) recorded that drainage ditches need a range of dimensions, design and water depths to maintain a diversity of flora and fauna, and fragmentation has meant that for many of the Inner Thames Marshes in particular, fragments have been left with too few ditches to achieve the range suggested by Wade. Where fragmentation has left sufficient ditches, i.e. Outer Thames Marshes, Erith 2b, Crayford 1, and Dartford Marsh 1, a balance needs to be reached between the level and type of management that keeps the channels open for drainage and the maintenance of the ecological value.

Managing the drainage ditches on the North Kent Marshes is necessary to enable the hydrological balance of the lowland wet grasslands to be maintained. Particularly within the Inner Thames Marshes a lack of management is evident, resulting in ditches, which have become choked by emergent vegetation, e.g. Stone 2a, Crayford 3b and Dartford 1b, or where management has ceased, resulting in overgrown and choked ditches. Only Denton Marsh of the outer marshes is showing a similar pattern of succession, management has only recently been abandoned, the water levels have fallen and emergent vegetation is now dominant.

Management, either through ESA proscriptions or agreements between the Environment Agency and local landowners maintains many of the ditches across the North Kent Marshes in a condition that is conducive to the plant and invertebrate communities that are reliant on them. Conflict can however, arise in the management techniques required for drainage ditches, between management for flood prevention and management for the ecological value of the ditches. To maintain the ditches for flood prevention requires keeping the emergent vegetation controlled by dredging or cutting back. The removal of the vegetation however, will reduce the value of the ditches ecology, particularly for water vole (*Arvicola terrestris*), which requires stretches of vegetated ditch banks for feeding etc. (Wells *pers com.*). Where management has ceased, ditches have become overgrown and choked, and therefore a balance needs to be maintained between too much and too little management. The Association of Drainage Authorities (1986) recorded the importance of clearing short lengths of ditch and ditch bank and leaving uncleared stretches to maintain the ecological value. Particularly therefore with the drainage ditches, management is the most important factor in their maintenance, although fragmentation can lead to the isolation of ditches e.g. Erith Marsh and then a subsequent lack of management leads to devaluing of their status. Thus fragmentation is usually the precursory event, which leads to a loss of management and ultimately the ditch flora and fauna.

There remains however, contrast in the ditch status between managed and unmanaged marshes. Although some larger fragments, e.g. Erith 2b, Shorne Marsh, exhibit examples of degraded ditches, the significant correlation between fragment size and ditch quality indicates that fragmentation is an influential factor in the maintenance of the drainage ditches. As many of the smaller fragments are also unmanaged, the implication is that divisive fragmentation creating small uneconomic units of grazing marsh, results in the loss of management, which in turn leads to a fall in ditch quality.

Fragmentation effects on the drainage ditches therefore, act to reduce the influence that the aquatic habitats have on grazing marshes, either by causing loss of the characteristic or by altering the water quality. Many ecological processes that are associated with grazing marshes, e.g. high water table, are related to the drainage ditch system and their break down will lead to the reduced value of grazing marshes as wetland sites. Hobbs (1993) suggested that ecological processes may be of greater importance than species conservation and the continued presence of ditches on grazing marshes would support this view.

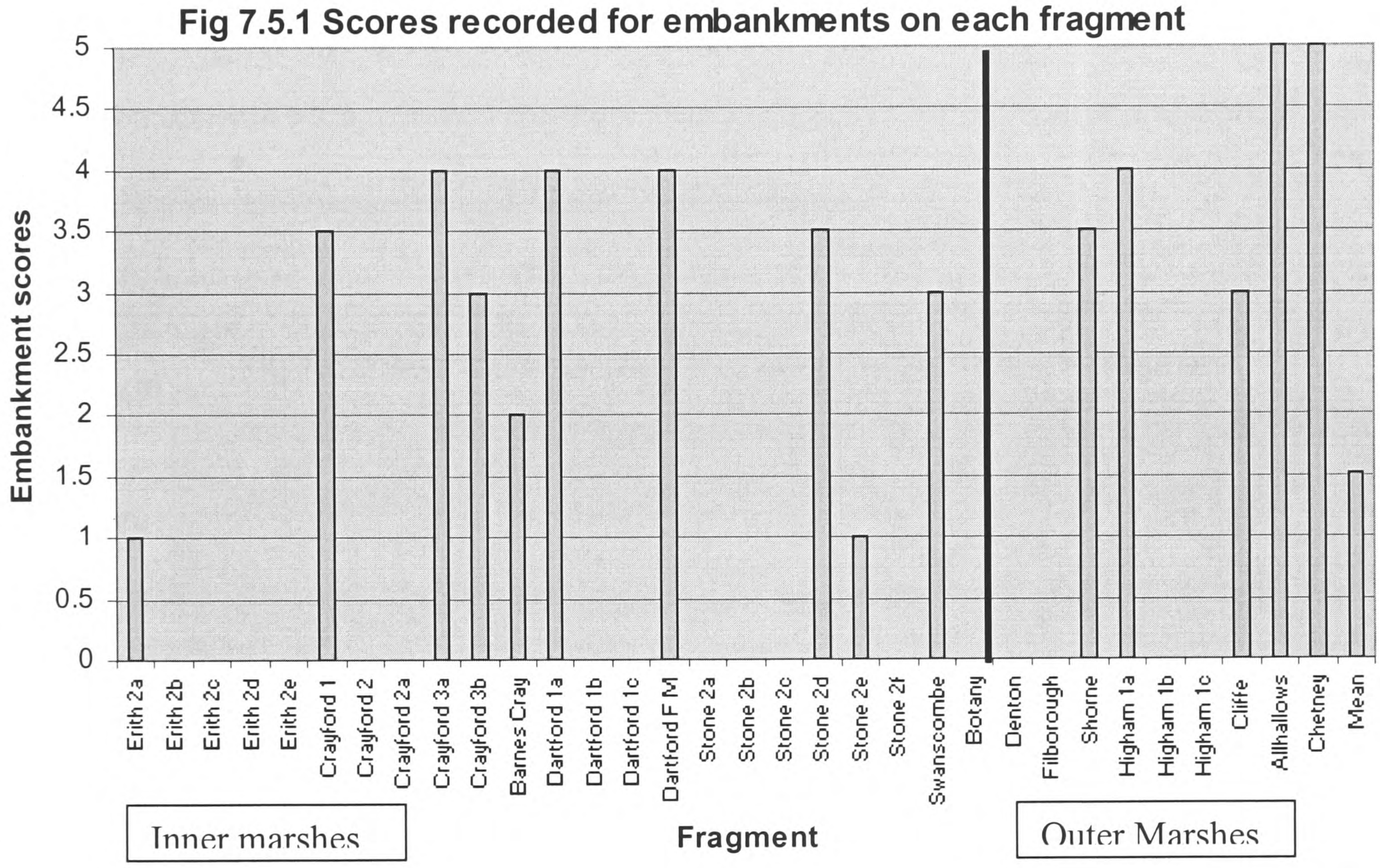
7.5.1 Embankments and counter walls – Results.

Scoring for the embankments and counter walls depended on: -

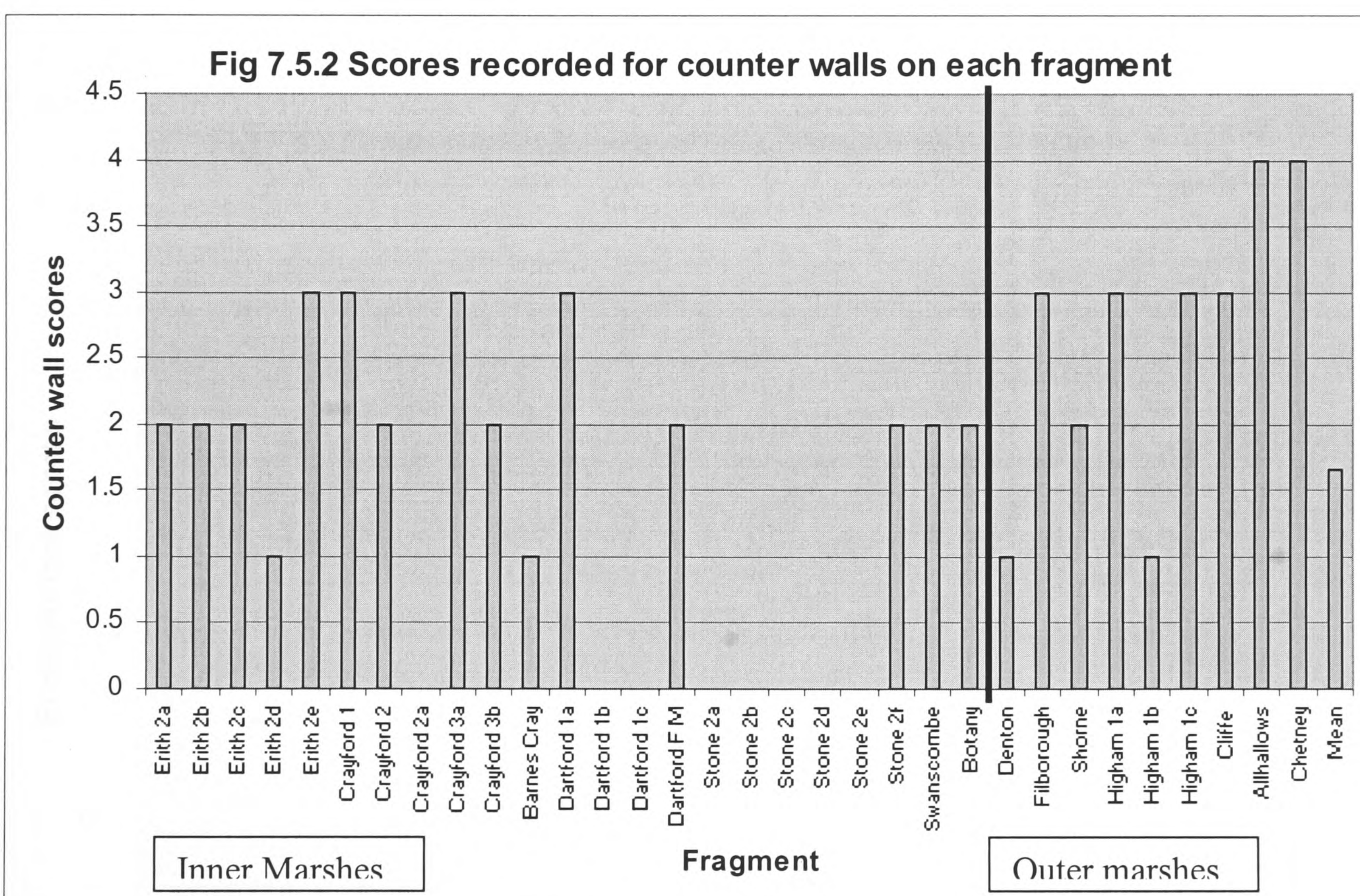
- presence or absence;
- management by either grazing or mowing;
- the nature of construction and contribution to the overall landscape.

Newer concrete sea walls/embankments were scored lower than those of the more traditional earth bund construction were. Concrete walls represent fragmentation of the embankment characteristic, which can lead to a loss of connectivity between fragments or influence the nature of the vegetation that occurs within a fragment. The composition of the vegetation on embankments and counter walls was also taken into account, i.e. the presence of species such as hemlock (*Conium maculatum*), nettle (*Urtica dioica*), bramble (*Rubus fruticosus*) and elder (*Sambucus nigra*), were recorded as signs of neglect in management, and indicative of a lack of management. The presence of upper saltmarsh species e.g. golden samphire (*Inula crithmoides*) or species such as pepper saxifrage (*Silaum silaus*) and Hog's fennel (*Peucedanum officinale*), regarded as typical of the North Kent Marshes, on the embankments were regarded as positive indicators and consequently scored higher.

Fig 7.5.1 Scores recorded for embankments on each fragment

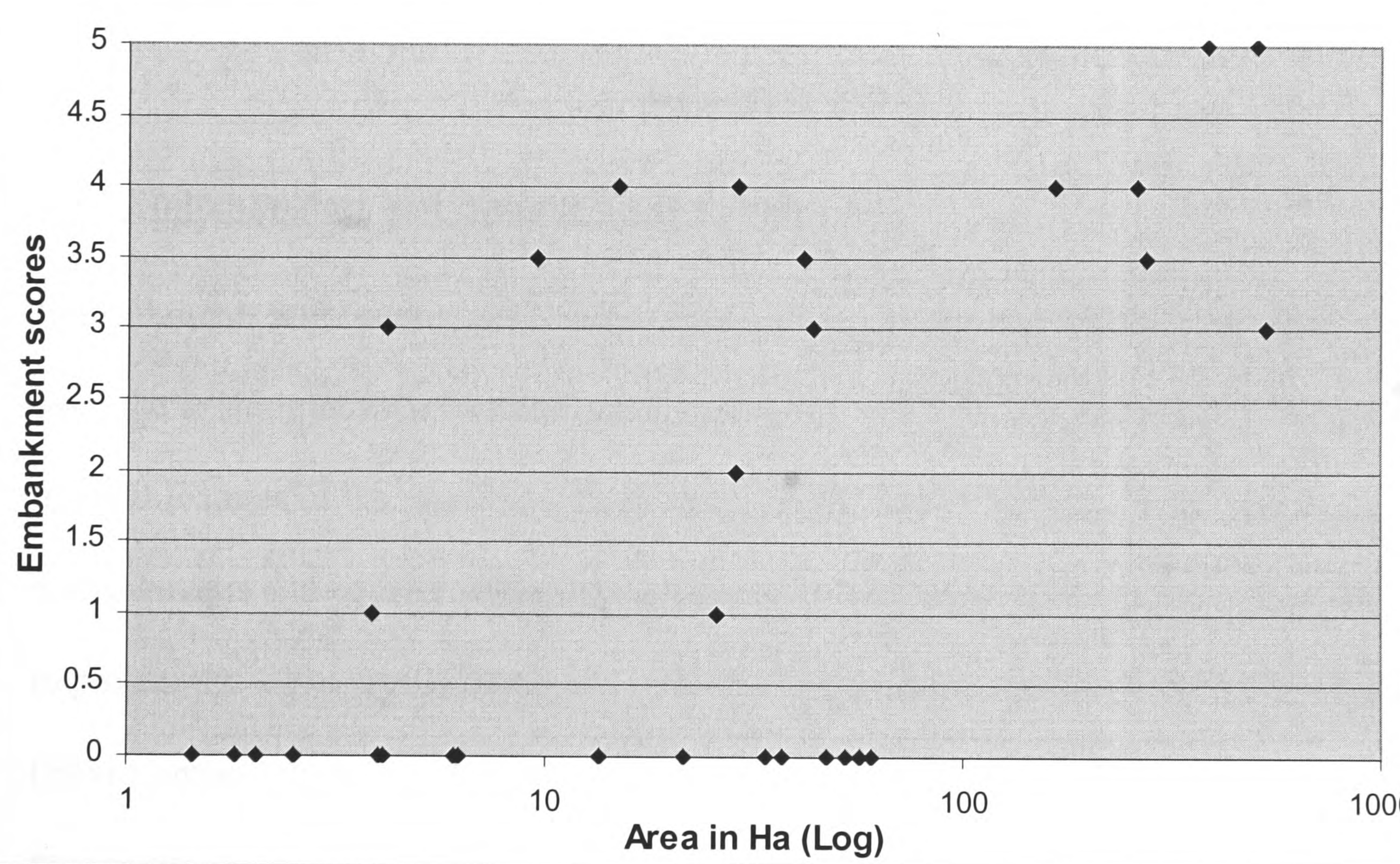


Embankments have often become lost when grazing marsh fragments are isolated from the River Thames frontage by intrusive or divisive fragmentation, e.g. Erith marsh. Fifty percent of the fragments on the Outer Thames Marshes and 54.2% of the Inner Thames Marshes recorded no embankments and therefore scored zero (Fig 7.5.1). The mean score for embankments, including those fragments scoring zero, was 1.5 only 29% of the inner marshes and 50% of the outer marshes recorded scores above this figure. The results indicate that across the North Kent Marshes on most sites the embankments are partially destroyed or declining irretrievably. Five fragments e.g. Stone Marsh 2e, on the inner marshes recorded scores showing that the condition of the embankments had deteriorated to a level below the limits of acceptable change, i.e. <2. Ignoring the scores for fragments where the embankments have been lost, the mean score becomes 3.19, i.e. the overall situation for the remaining embankments is one where decline can be reversed through management, e.g. Crayford and Dartford Marshes. Eighty percent of the outer marshes and 54.5% of the inner marshes surveyed retained embankments that recorded a score in excess of the mean of 3.19. Only two marshes, Allhallows Marsh and Chetney Marsh scored a maximum five for the embankments. Overall, where embankments were recorded the Inner Thames Marshes scored lower for the condition of their embankments than the Outer Thames Marshes.



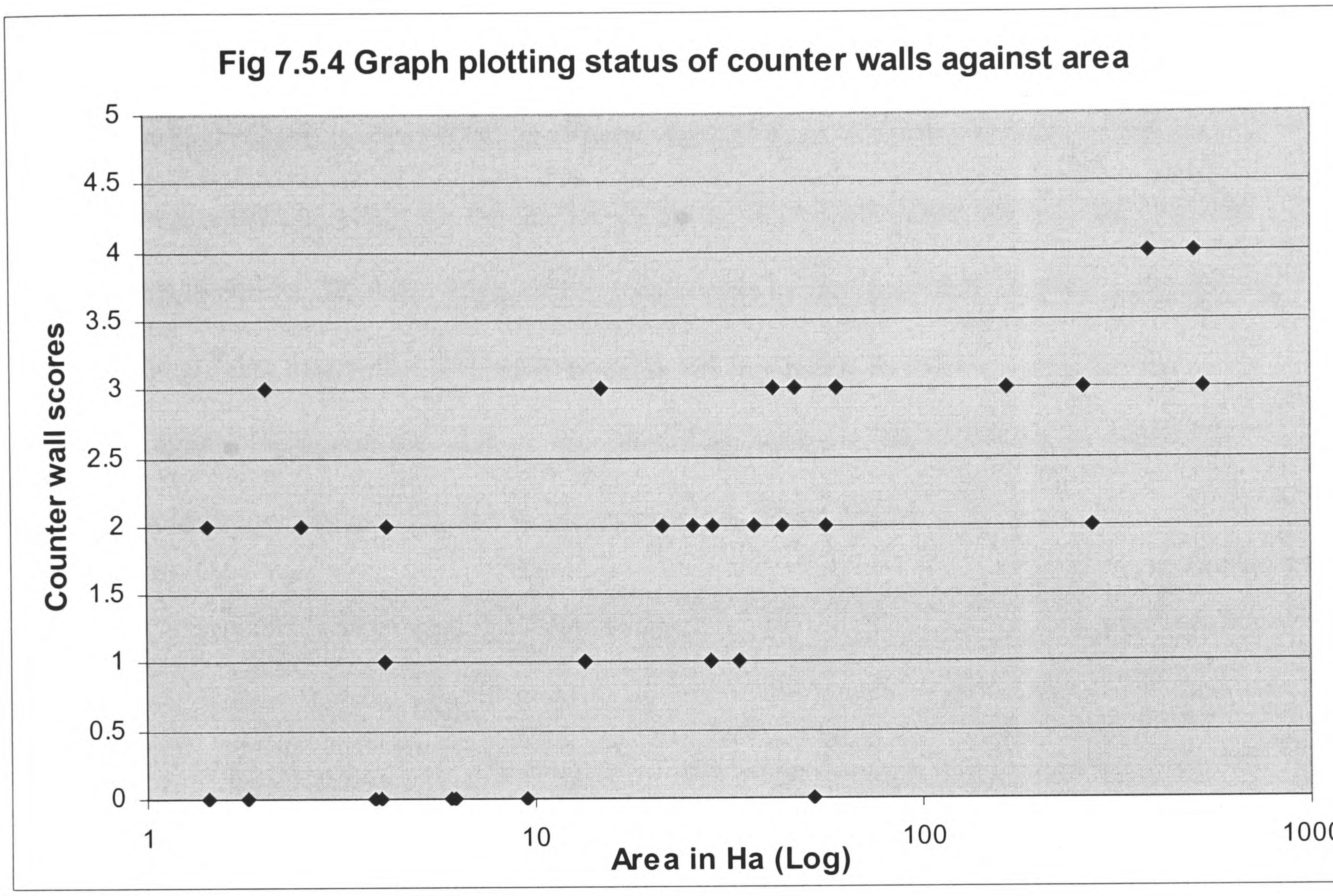
The condition of the counter walls is similar to that of the embankments; Fig 7.5.2 records the scores for the counter walls. In this case, intrusive fragmentation has effectively destroyed the counter walls and 29.4% of the fragments surveyed showed no evidence of counter walls and scoring zero for this characteristic. A further 38.2% of the fragments recorded scores for the counter walls that showed their condition was declining or irretrievably altered. Ignoring those fragments with a score of zero (29.4%), the mean score for fragments retaining counter walls is 2.3, i.e. the status of the counter walls is declining. Only 16.6% of the Inner Thames Marshes recorded a score above the mean, whereas, 66.6% of the Outer Thames Marshes scored above the mean value. Every fragment in the Inner Thames Marshes where counter walls were identified recorded them as a declining characteristic. No marsh or fragment scored a maximum five for counter walls, 26.4% of the fragments surveyed recorded the counter walls in a favourable condition and only 5.9% of fragments had counter walls that are not in decline.

Fig 7.5.3 Graph plotting status of embankments against area



Spearman's coefficient of rank correlation was calculated to test the hypothesis that there is a relationship between the area and the presence of counter walls. At the 95% significance level, the coefficient of 0.65 indicated that there is significant correlation between fragment areas and the presence and condition of the counter walls. Figs 7.5.3

and 7.5.4 indicate that a relationship exists between the area of a fragment and the status of the embankments and counter walls.



7.5.2 Embankments and counter walls – Discussion.

Embankments and counter walls were created when the grazing marshes were reclaimed from the existing saltmarshes and marshland to act as coastal sea defences. They are integral features of the marshland landscape (AERC 1992, Cobham 1995). Both embankments and counter walls are maintained as traditional features and sea defences to protect the urban, agricultural, and industrial developments of the Thames floodplain (Environment Agency 1997). The counter walls provide changes in the surface topography, which creates some of the drier habitats of the heterogeneous homogeneity of the grazing marsh matrix.

Embankments maintain a presence on all the marshes, which have retained a frontage on the River Thames or major rivers, e.g. Crayford fragments 3a and 3b, Barnes Cray, Dartford Marsh and Dartford Fresh Marsh which all have embankments that front the Rivers Cray or Darenth. Of the 56.2% of the fragments that recorded no score for the embankments, twelve (60%) have been isolated from the embankments by divisive fragmentation, whilst for the remainder intrusive fragmentation has been the cause of this isolation. Divisive fragmentation can cause embankments to become isolated from the grazing marsh that they were constructed to enclose as intrusive and divisive fragmenting agents are built on the marsh fragment, i.e. the embankment remains in isolation, whilst grazing marsh disappears, e.g. Stone Marsh (Fig 7.5.5).

Fig 7.5.5 Isolated embankments Stone Marsh.

Intrusive fragmentation has also been responsible for the low scores for embankments on Erith Marsh 2a and Stone Marsh 2e, where industrial development has either caused the replacement of traditional earth walls with concrete (Erith Marsh), or loss due to a decline in the level of management (Stone Marsh). Embankments can be directly affected by intrusive fragmentation. For example, construction of Crossness Sewage

Works (Erith Marsh) and Littlebrook Power Station (Dartford Marsh), (Fig 7.5.6), both required the additional building of river frontages and piers, which replaced the original earth embankments with concrete ones, so altering the nature and characteristics of the traditional embankments.

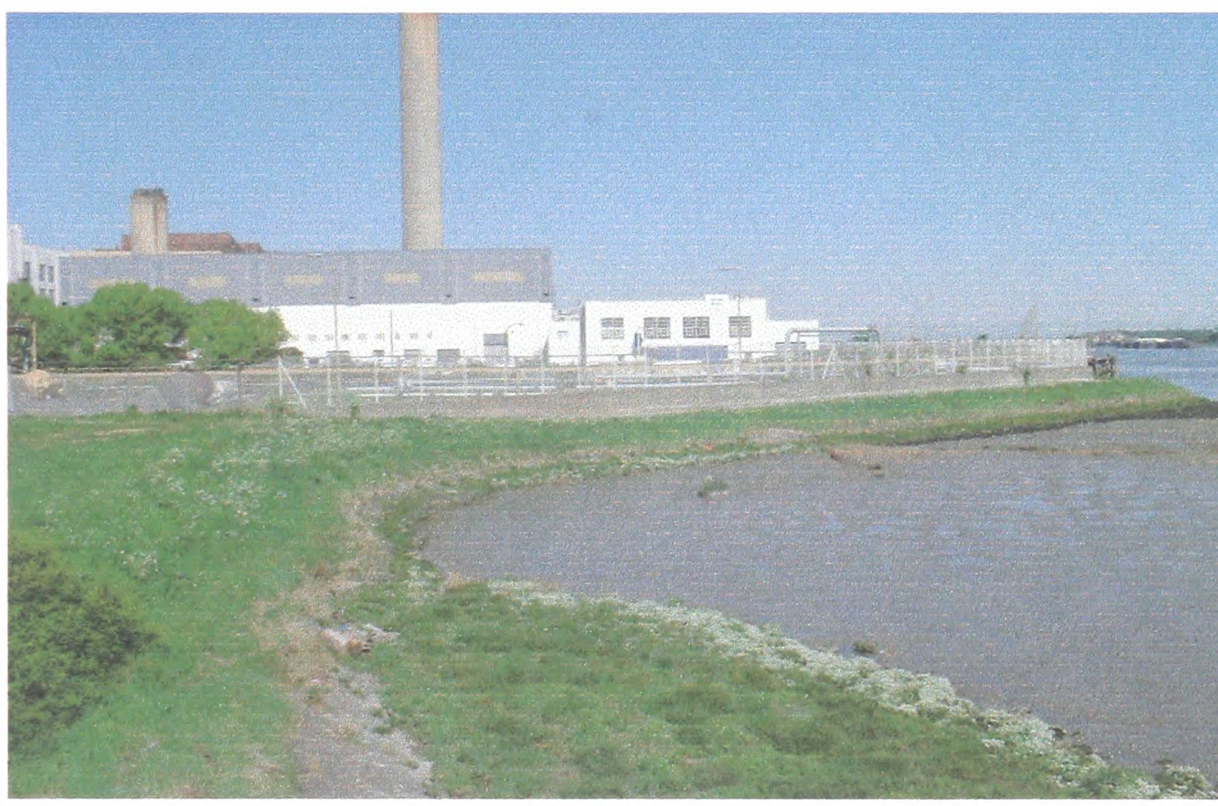


Fig 7.5.6 Embankments at Littlebrook

Embankments may also act as corridors between remnant fragments and provide connectivity along which species may disperse between isolated areas of grazing marsh. Intrusive fragmentation of embankments, which has meant reconstruction, often as concrete walkways has allowed stands of alien species to develop, e.g. buddleia (*Buddleia davidii*) and elder (*Sambucus nigra*). The presence of a corridor created by intrusive fragmentation will also allow the dispersal of these alien species to other fragmented grazing marsh. Embankments can therefore be of benefit to movement between isolates but they can increase the possibility of invasion, when acting as a corridor in the riparian zone (Planty – Tabbachi et al 1996). This point is illustrated by Fig 7.5.7, which shows the embankment between Dartford and Stone Marshes, where

Japanese knotweed (*Reynoutria japonica*), sycamore (*Acer pseudoplatanus*) and bramble (*Rubus fruticosus*) have all become established.

Fig 7.5.7 Japanese knotweed invading embankments on Stone Marsh.

The scores for the embankments (Fig 7.5.1) show that generally the embankments of the Inner Thames Marshes have been more affected by fragmentation and in a worse state of maintenance than the Outer Thames Marshes. The Inner Thames Marshes have recorded fragmentation influences to the embankments on every marsh, whereas on the Outer Thames Marshes, all embankments remain unaffected, apart from strengthening that has occurred on Cliffe Marsh. Maintenance of embankments has generally owed more to their value as flood protection (Environment Agency 1997), than as a characteristic of grazing marshes, and more recently as parts of long distance footpaths. The embankments remain as a positive indicator, which enhance the traditional visual landscape of grazing marshes; however examples of grazing marsh where no embankments remain indicate that their loss does not necessarily indicate that a fragment is no longer recognised as grazing marsh.

Counter walls, as the results in Fig 7.5.2 show, are a characteristic that is in decline and have been lost on many fragments as fragmentation and development removes much of the surface topography of the North Kent Grazing Marshes. The results indicate that there is a contrast in the occurrence of counter walls between the Inner and Outer Thames Marshes. As many of the smaller fragments lie within the Inner Thames Marshes, the significant correlation between fragment area and the presence of counter walls is indicative, that fragmentation has been a factor in their reduced presence on these marshes.

Intrusive fragmentation, i.e. alteration of the habitat from within its boundaries will cause direct loss and deterioration to counter walls as the fragmenting agent influences the grazing marsh matrix. Small remnant fragments isolated by divisive fragmentation, although retaining some physical evidence of counter walls the condition is deteriorating, usually because of a lack of management. There is therefore, a loss of the ecological features, as rank grasses and generalist vegetation dominates the traditional species of the drier conditions created by counter walls. As counter walls have been recorded as containing some of the rarer plant species of grazing marsh, e.g. saltmarsh goosefoot (*Chenopodium chenopodium*) (Gee 1998), their loss through a lack of management is one of concern.

Counter walls are now more evident on the Outer Thames Marshes, where intrusive fragmentation has not been as extensive as on the Inner Thames Marshes. Only Great Clane Marsh recorded no counter walls, which have been lost because of the conversion of the marsh to arable production and the subsequent levelling of the marsh topography. The only other Outer Thames Marsh fragment to record a low score for the counter walls was Higham Marsh 1b. The counter walls on this fragment were difficult to detect as an individual feature because of the development of scrub and tall herbs over much of the fragment.

Divisive fragmentation may introduce barriers to movement, which act to decrease dispersal between fragments, counter walls as a habitat for some of the rarer plant species of grazing marshes (Section 5.3.4), may therefore also lose their botanical interest. The fragmenting agents of divisive fragmentation however, e.g. roads, rail, etc can also act as corridors, which facilitates the dispersal of the more common species of grasslands, e.g. false oat grass (*Arrhenatherum elatius*), thistle (*Cirsium spp*) and dock (*Rumex spp.*). As rarer species tend to have poorer dispersal capabilities, the value of the corridors created by fragmentation are not as significant and therefore invasive species tend to become more prominent, thus reducing the value of the counter walls as an ecological feature. The other processes of fragmentation will act to enhance the effects that intrusion and division have created, i.e. they will increase the habitat loss and reinforce the barriers that divisive fragmentation has introduced.

7.6 Landscape Features.

The landscape features are the basis of the micro scale heterogeneity of grazing marshes and include the features which comprise the lowland grassland habitat mosaic e.g. tussocks, rills, wet flushes, and sward height as discussed by Milsom et al (2000). The combination of above-mentioned features together with the lowland grassland matrix establishes the 'appropriate mosaic of communities' discussed by Delaney (1991), and is further discussed in Section 8.3 vegetation communities. Landscape features are found mainly across the interior of the grazing marsh they will probably be more susceptible initially to intrusive fragmentation creating disturbance across the interior areas of grazing marshes where the microtopography occurs The following sections consider the status of the individual features on the North Kent Marshes and discuss the effects of the fragmentation processes on each feature.

7.7.1 Sward height – Results.

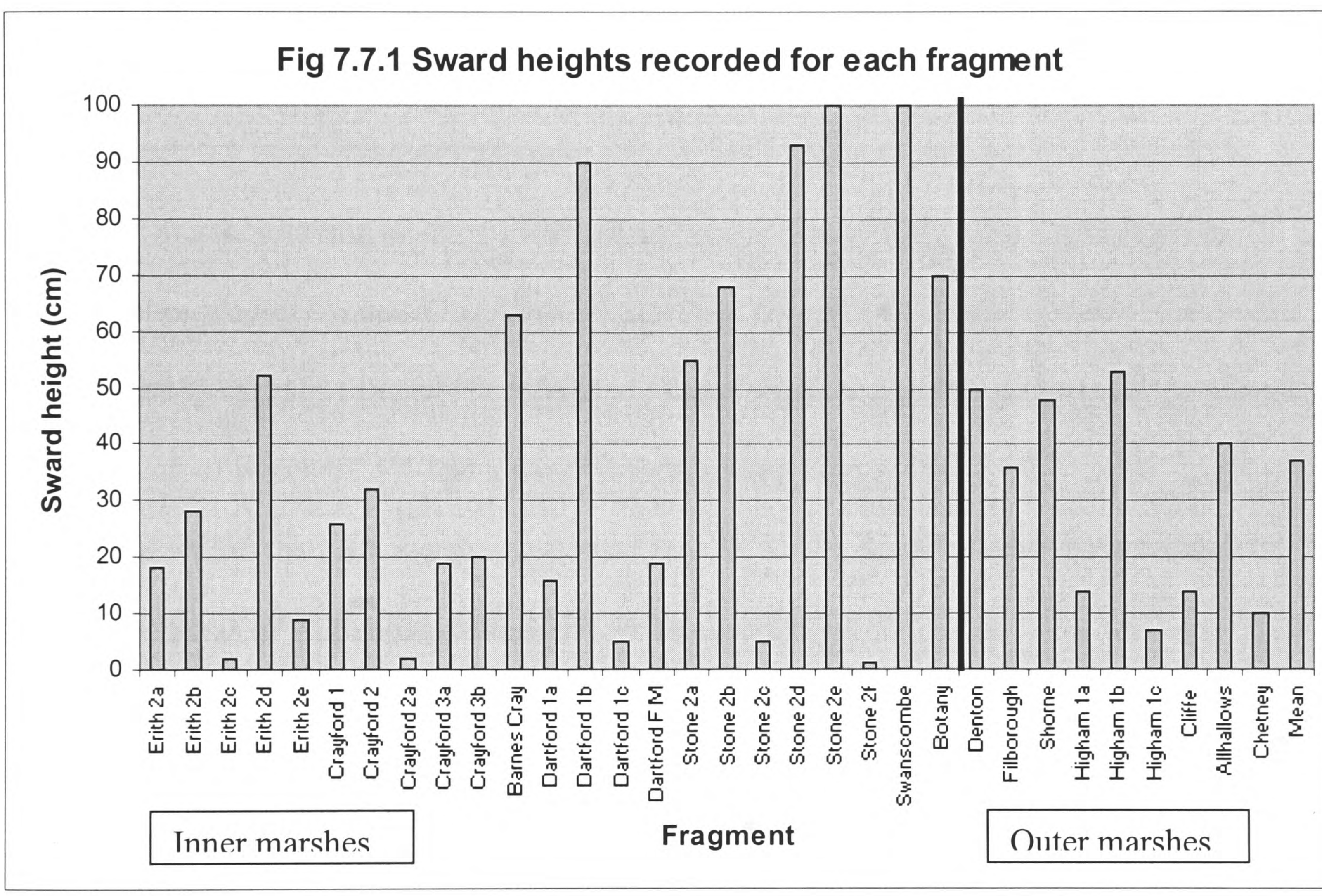


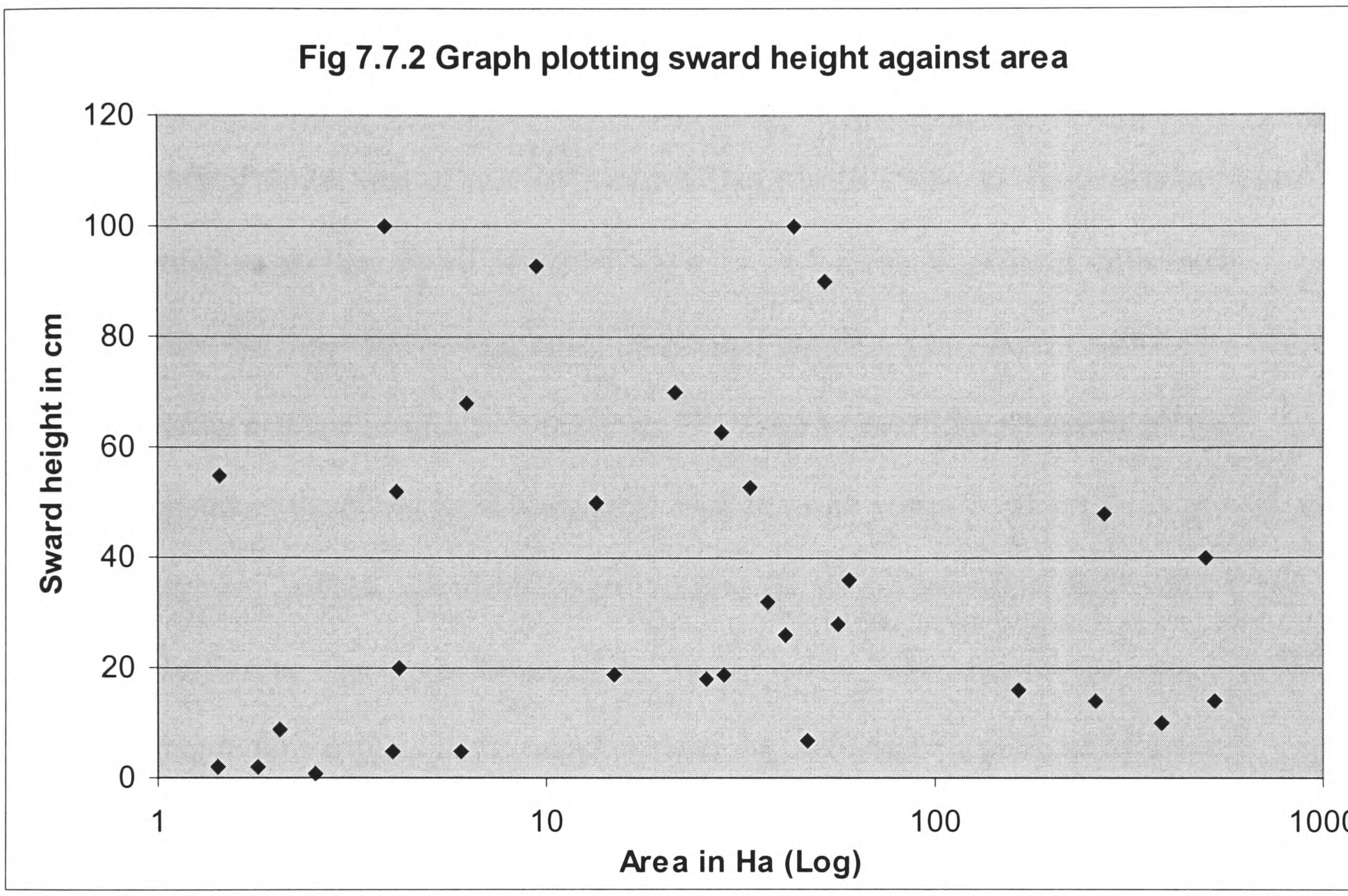
Fig 7.7.1 shows the average heights for the individual fragments. Overall, the sward heights across the North Kent Marshes varied from a height of 1cm on the amenity grasslands of Stone Marshes fragment 2e to 100cm plus on unmanaged sites where taller rank grasses e.g. false oat grass (*Arrhenatherum elatius*), herbs *Rumex spp, Cirsium spp* etc or common reed (*Phragmites australis*) come to dominate. The overall variation in height is greater within the Inner Thames Marshes, where both the tallest swards of 100cm were recorded (Stone Marsh 2f and Swanscombe Marsh) and the shortest sward

of 1cm (Stone Marsh 2e) occurred. The range in height of the Outer Thames Marshes was 46cm between 7cm on Higham Marsh fragment 1c and 53cm on Higham Marsh fragment 1b, which reflects the lack of management over 50% of Higham 1b. The recorded heights are for grass and herbs. Scrub and tree heights were not included within the sward height in this survey.

Sixty three percent of the sites surveyed had a sward height lower than the mean height of 36.97cm. No clear pattern however, emerges from a study of the sward heights between the inner and outer marshes, with 44% of the outer marshes and 42% of the inner marshes having an average height above the mean height. The Inner Thames Marshes recorded a mean height of 39.5cm, and overall 41.6% of fragments had sward heights in excess of the mean. Whilst the Outer Thames Marshes had a mean height of 30.2cm, of which 55.5% had a sward height greater than the mean. The mean height of sward within the ESA marshes surveyed was 22.4cm, a figure that has been influenced by the areas of Allhallows Marsh left for hay production.

Fig 7.7.2 indicates that there is no clear relationship between the sward height and the fragment area. Spearman's coefficient of rank correlation was calculated to test the hypothesis that there is a relationship between sward height and fragment size. A coefficient of 0.04 is too low to suggest that there is any relationship between sward height and the size of grazing marsh fragment. Evidence of the poor correlation is highlighted by Stone Marsh 2e, which recorded the lowest sward height and was one of the smallest sites at 2.52ha, whereas two other small fragments Stone 2c (4.0ha) and Stone 2a (1.44ha) recorded some of the tallest vegetation of 93cm and 68cm respectively. In contrast, larger fragments such as Dartford 1b (ranked 9th in size) and

Swanscombe (ranked 11th in size) also recorded some of the tallest swards (90cm and 100cm) respectively. Tall swards were recorded on sites with a lack of management, whereas many short swards were on managed sites, therefore management as opposed to area and hence fragmentation is of greater importance in determining sward height.



7.7.2 Sward height – Discussion.

Sward height together with tussocks (Section 7.8) are the features of the landscape that adds structure to the homogeneous – heterogeneity of the North Kent Marshes. The importance of sward height has been recorded by ADAS (1997), Benstead et al (1997), Milsom et al (1998, 2000) and Vickery et al (2001) as determining the presence of a range of bird species, associated with grazing marshes, e.g. lapwing (*Vanellus vanellus*) and redshank (*Tringa totanus*). Milsom et al (2000) however, regarded heterogeneity of sward height as being more important than the mean height, and Vickery et al (2001) recorded that short uniform swards afforded poor shelter for birds. Variation in sward height therefore, across the marshes as a whole and across individual marsh sites is one of the requirements of grazing marshes if they are to remain viable as important bird habitats.

Robertson and Jefferson (2000), recommend the typically average height of the sward to be 15cm but due to the management by grazing and mowing average heights will vary depending on the time of year (ADAS 1997). Only 24.2% of the fragments surveyed recorded an average sward height of below 15cm, with no significant differences between the inner and outer marshes, and all of the ESA sites, except Allhallows Marsh recording average heights below 15cm. The average sward height across all the fragments of the North Kent Marshes is 36.97cm, and across those regularly grazed, the average is 22.60cm, and therefore greater than the height recommended by Robertson and Jefferson. The sward height of the Outer Thames Marshes does correlate with the grazing regime applied to the marsh, but the average height is affected by areas of farmland being used for hay production and as a result, areas of grazing marsh will have fields where the sward height is greater than the average.

Milsom et al (2000) also regarded 15cm as a height at which the sward could be regarded as containing tussocks (Section 7.8) and that heterogeneity of height was a key element in establishing grazing marsh importance. The variation in height is therefore, of greater importance than the overall height. With the exception of Great Clane Marsh and fragments of Stone Marsh, heterogeneity of sward height occurs consistently across the North Kent Marshes.

Divisive fragmentation is in most cases initially responsible for the dividing of grazing marsh into smaller fragments. As no relationship has been shown to occur between sward height and fragment area, therefore fragmentation by roads etc. will not be directly responsible for increased height but agents e.g. roads, acting as corridors will influence species content (Andrews 1990, Forman and Deblinger 2000). The taller herbs and rank grasses e.g. *Senecio spp, Cirsium spp.* and *Arrhenatherum elatius,* that cause the height differentiation may well therefore, be dispersing along road corridors (Fig 7.7.3), from where they can disperse onto grazing marsh fragments.

Fig 7.7.3 Road verges with invasive species

The remaining fragmenting agents influence the internal landscape features, which create the micro-heterogeneity of grazing marshes, usually by destroying the features, although amenity planting (Stone Marsh 2e) or garden escapees (see Section 8.3.3) from urban developments can also influence sward height. Intrusive fragmentation resulting in new developments can lead to the grazing marsh fragments having manicured landscaped grounds (Stone Marsh 2e) or areas left wild and unmanaged (Stone Marsh 2c), and therefore there is no definitive guide as to what the effects of fragmentation may be. Creation of small uneconomical fragments by regressive or enveloping fragmentation, does not appear to have been a factor in the development of different sward heights across the North Kent Marshes, as many of the smaller fragments, e.g. Erith Marsh 2e, Crayford Marsh 2a, Stone Marsh 2e, have a below average sward height.

Sward height is regarded as an early warning signal of conditions that may be deleterious to the plant assemblage (Robertson and Jefferson 2000). Across the study sites of the North Kent Marshes sward height is variable and shows no consistent relationship with either grazing or mowing management nor was there any correlation with fragment size. The marshes that are regularly grazed through a formal management system generally have a lower sward height than those that are randomly managed through grazing. Hay production is another variable that is adding to the average height of a fragment, primarily where grazing is still the preferred method of management, e.g. Dartford Marsh, Filborough Marsh, and Allhallows Marsh. Fragmentation and changes to the patterns of management that occur as a result of fragmentation contribute to the variations in sward height, e.g. Dartford Marsh 1b, which is currently managed under a set-aside scheme. The fragment recorded one of the highest sward heights (90cm), which has resulted from the lack of management and not linked to fragmentation. Undergrazing on a fragment can also lead to changes in the overall and average sward height. On Dartford Fresh Marsh, under grazing has led to the development of taller tussocks of *Juncus spp.,* which have developed in the remnant rills and wet hollows found across the marsh (Fig 7.7.4). Although, the overall average sward height (19cm) is below the overall mean height, the development of these taller tussocks (average 75cm) could be interpreted as evidence of the deterioration in the overall sward as suggested by Robertson and Jefferson (2000).

Fig 7.7.4 *Juncus* tussocks Dartford Fresh Marsh

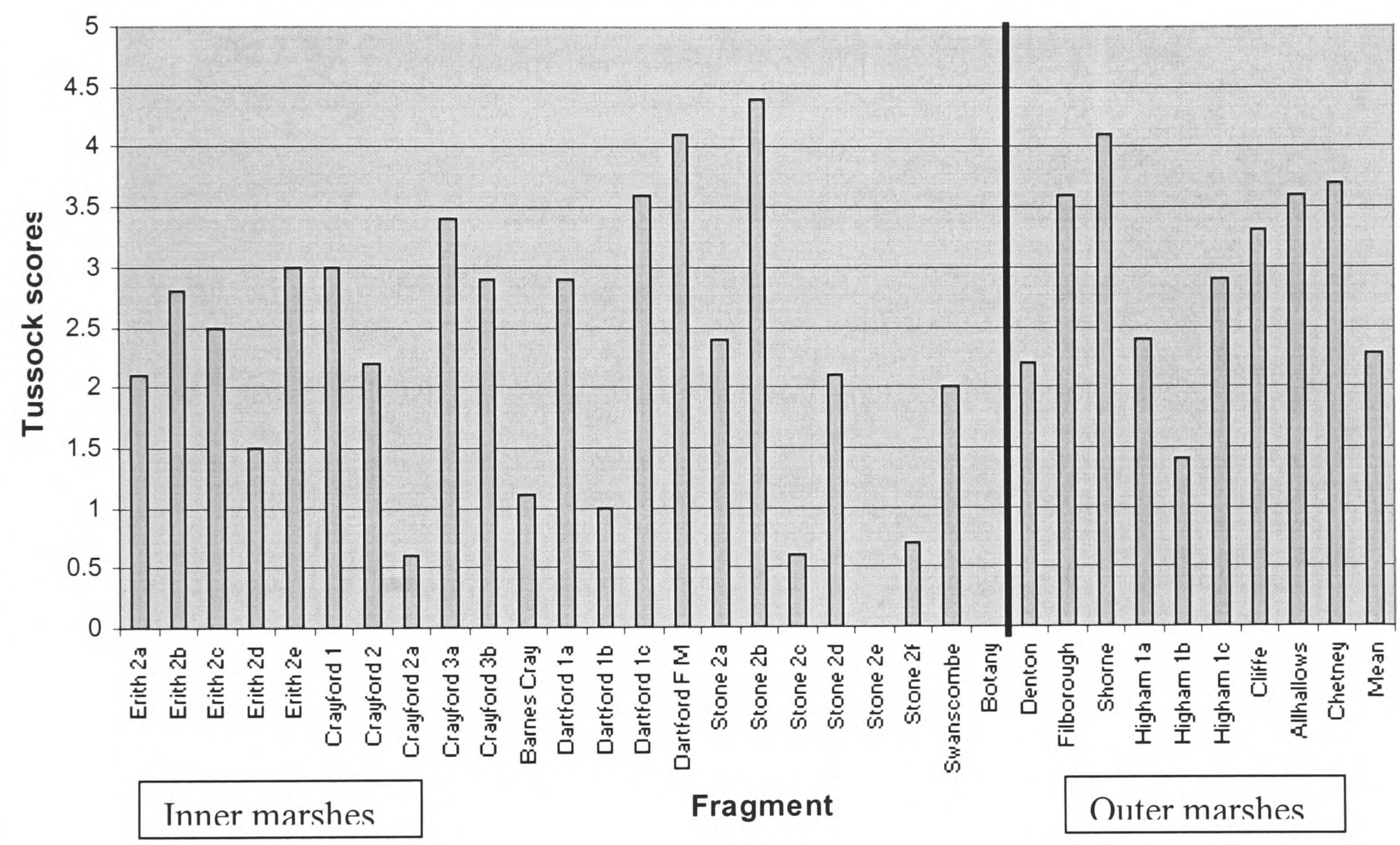
The importance of the sward height as a landscape feature is therefore, not the mean height, but the range of heights, i.e. heterogeneity of height. As a guide therefore, a range of heights between 5cm – 30cm should be considered acceptable for the ideal grazing marsh. Where the overall height begins to exceed 30cm and rank grasses and ruderal herb species become part of the sward, then as Robertson and Jefferson (2000) suggest the height of the sward can be used as an early warning of deterioration in the condition of the grazing marsh. The overall result therefore may be to alter the nature of the vegetation communities that comprise the grazing marsh matrix as the low growing constituents become shaded out (see Section 8.3.2).

7.8.1 Tussocky grassland – Results.

Tussocky grassland in this thesis is viewed as being grassland containing numerous patches of taller grassland, which form a patch of heterogeneous height 10cm above the surrounding sward (see Section 3.1.1). A high score for tussockiness indicates that a fragment contains a high proportion of tall grasses and a heterogeneity that would suit the requirements of species that respond to these factors e.g. Lapwing (*Vanellus vanellus*) and redshank (*Tringa totanus*). A level of tussockiness that promotes the presence of these species is therefore a positive indicator of grazing marsh quality.

The mean score of 2.14 for tussocky grassland as shown in Fig 7.8.1 falls within the categories of occasional to frequent, i.e. tussocky grassland is found to cover 15 – 50% of the typical grazing marsh.

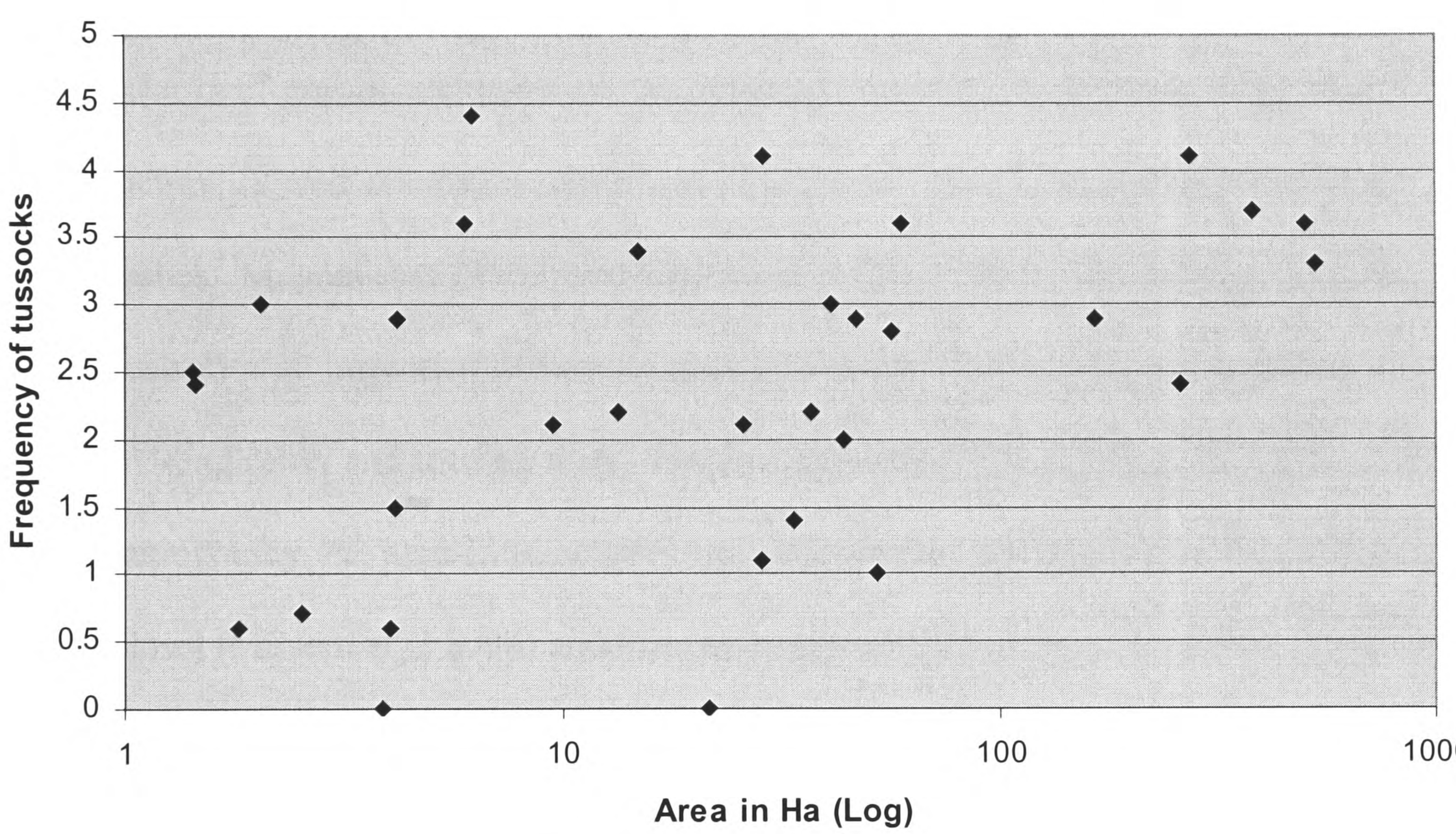
Fig 7.8.1 Scores recorded for tussocks on each fragment



Fifty five point nine per cent of the fragments scored higher than the mean, with 45.8% of the inner marshes and 80% of the outer marshes above the mean value. There were 23.5% of the fragments surveyed, which scored 1.0 or less, i.e. tussocks were sparsely distributed or absent, all of which, except Great Clane Marsh, were Inner Thames Marshes. All of these fragments, except Crayford 2a, where random horse grazing occurs, are fragments where the land use has changed, either from grazing marsh to agriculture, e.g. Botany and Great Clane Marshes or to office development e.g. Stone

Marsh. Three marshes, Dartford Fresh Marsh and Stone 2b in the inner marshes and Shorne Marsh, in the outer marshes, all scored over four, indicating tussocks were dominant, although for Stone Marsh 2b tussocks were composed of a range of herb species not associated with grazing marshes, e.g. lucerne (*Medicago sativa*) and white melilot (*Melilotus alba*). Tussocks on Dartford Fresh Marsh and Shorne Marsh comprised species such as hard rush (*Juncus inflexus*), soft rush (*J. effusus*) and cock's-foot (*Dactylis glomerata*) indicating a degree of under grazing.

Fig 7.8.2 Graph plotting frequency of tussocks against area



The majority of fragments (67.6%) recorded scores in the categories of occasional (2), 32.4% or frequent (3), 35.3%, with 80% of the Outer Thames Marshes and 62.5% of the Inner Thames Marshes falling into these two classes. As discussed in sections 5.2.1 and 5.2.2 the Outer Marshes have been regarded as approximating to the typical conditions of grazing marsh where the mean score for tussocks 3.06, i.e. tussocks occur frequently and therefore the optimum occurrence of tussocks should be in this range.

Fig 7.8.2 shows that there is a relationship between the occurrence of tussocks and the area of a fragment does occur. The hypothesis that fragment size and the grassland feature are correlated and that size influences the occurrence of grassland tussocks was tested. By calculating Spearman's coefficient of rank correlation, the measure of the relationship can be examined. The resultant coefficient of correlation of 0.52 is significant at the 95% confidence level and indicates that there is a relationship between fragment size and the occurrence of tussocky grassland.

7.8.2 Tussocky grassland – Discussion.

Tussocks of grasses and herbs are the landscape feature, which provides the sward structure, as well as being a constituent of the micro scale heterogeneity of grazing marshes. Milsom et al (2000) and Vickery et al (2001) both recorded that tussocky grassland is an important feature for bird species such, as lapwing and redshank, providing cover and feeding sites. The development of tussocks can arise from changes in topography, i.e. anthills (Gee 1997), around dunging areas (Vickery et al 2001), in hollows (Milsom et al 2000) and from management (Benstead et al 1997). A high score for tussocks however is an indication that fragments may be undergrazed and that there is a build up of unpalatable species, e.g. false oat grass (*Arrhenatherum elatius*) on drier areas, cocksfoot (*Dactylis glomerata*) around dunged areas, soft rush (*Juncus effusus*) in wet hollows. An abundance of tussocks as suggested by Gieckie (*pers com*) therefore, maybe the first indications of deterioration in site conditions (Robertson and Jefferson 2000), (see Section 7.7.3). Milsom et al (2000) stated that there were optimal frequencies for tussocks depending on the species concerned, but that 'marshes containing an extensive cover of tussocks were more likely to be occupied by different bird species than those with localised tussocks'.

The occurrence of tussocks relies equally on the topography of the individual marshes and the past management. The importance of tussocks lies in the varying habitats and vegetation heights that are provided by tussocky grassland across the grazing marshes, which provide cover and nesting sites for the assemblage of breeding and over wintering birds that are attracted to the North Kent Marshes. Gieckie (*pers com.*) suggested a target of 70% cover of tussocks for a typical grazing marsh, which would indicate that tussocks were the dominant feature of grazing marshes. Only two fragments recorded scores within this range. Milsom et al (2000) recorded the optimal frequency for tussocks as being >35% cover. In assessing the scores therefore a fragment with a dominant cover, of tussocks, i.e. 4/5 was regarded as being undesirable and that a range of scores between occasional (2) and frequent (3) is optimum.

Intrusive fragmentation is the process, which will have the greatest effect on tussocky grassland simply by destroying the grassland matrix. Where grazing marsh remains around the intrusive agent, disturbance during the construction phase of the operation will alter the topography and conditions that give rise to the development of tussocks, e.g. anthills. The remainder of the fragment then becomes uneconomic for grazing and is therefore unmanaged, allowing the introduction of invasive species (see Sections 7.7.3 and 8.3.2). Fig 7.8.3 shows intrusive fragmentation on Swanscombe Marsh and the change in landform that has resulted from the landfill operations and the loss of tussocky grassland.

The effects of divisive fragmentation as discussed in Section 7.2.2 will also apply to tussocky grassland, i.e. increased edges, corridor effects and increased isolation, will allow alien species to establish (Andrews 1990, Smallwood 1994), which may cause changes to the species composition or the occurrence of tussocks. Invasive species will tend to increase the amount of tussockiness, initially through the invasion of grasses such as false oat grass (*Arrhenatherum elatius*) and herbs such as curled dock (*Rumex crispus*) and ragworts (*Senecio spp.*), which are unpalatable to stock (Grime et al 1988, Small et al 1999, Robertson and Jefferson 2000). With an increased number of invasive species creating the taller and tussocky elements of a grazing marsh, and an increase above the optimum level of tussocks, i.e. they become a dominant feature, the value as a breeding site for target bird species may also be reduced. Lapwing (*Vanellus vanellus*), redshank (*Tringa totanus*) and snipe (*Gallinago gallinago*) preferring grass and sedge tussocks for breeding and feeding as opposed to tussocks comprising herbs (Benstead et al 1997).

Fig 7.8.3 Swanscombe Marsh – no tussocks due to change in landform.

Encroaching, enveloping and regressive fragmentation by gradually reducing the area of grazing marsh enhance edges by increasing the width of edge and thereby reduce the quantity of core habitat on a fragment, which is where grassy tussocks will be most effective in providing the required bird habitat, (see Section 9). The three processes will therefore, each increase the barrier effect (Mader 1984, Merriam et al 1989, Forman

1997); and as the amount of core habitat is reduced then encroaching, enveloping and regressive fragmentation will cause increased loss to landscape features, thereby reinforcing the initial effects of intrusive fragmentation as shown on Erith 2d, Stone 2c and Denton Marsh.

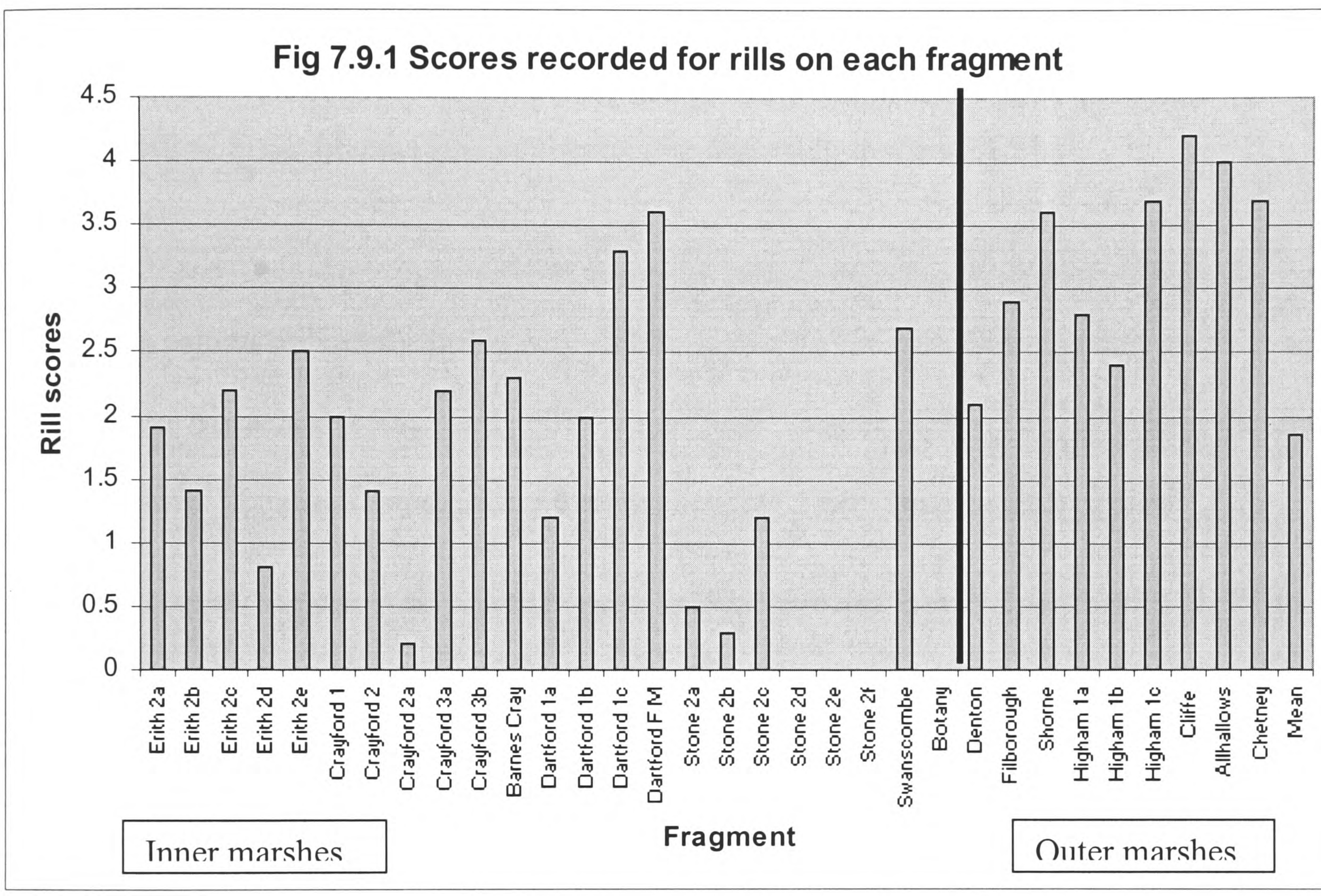
The level of management can affect the occurrence of tussocky grassland, i.e. grazing and mowing, will tend to reduce the presence of tussocky grassland, although grazing effects will depend on the level of grazing and the grazer used on the fragment, e.g. cattle and sheep will improve and maintain the vegetation structure (Small et al 1999). Tussocky grassland occurring on the marshes managed under the ESA scheme recorded a mean score for tussocks of 3.14, i.e. tussocks occur frequently, (whereas the mean for non ESA sites was 2.10). Their presence occurring at a frequency, which has been determined to be the optimum level undoubtedly, results from management techniques, even though the ESA monitoring report (ADAS 1997) does not include tussockiness within their management proscriptions.

Under grazing will produce a mosaic where the tussocks come to dominate the grazing marsh (Rodwell 1992), (Fig 7.8.4). Cattle grazed grasslands produce a sward with a structure of taller and shorter areas, caused by the rejection of less palatable grass species or of areas around dung (Vickery et al 2001). The patches of tussocky grassland comprise therefore, some of the more unpalatable and undergrazed species e.g. sedges (*Carex spp.*) and coarse grasses e.g. couch grass *Elytgia repens* and cocksfoot (*Dactylis glomerata*) (Grime 1988, Small et al 1999). The presence or absence of this characteristic feature may not however reflect the management regime that is practiced on the particular sites i.e. different grazers will produce different sward characteristics, but may equally be due to the nature of the plants and grasses present and their growth characteristics. The contribution that fragment size may make to the level of grazing on a particular site relies on economics, with graziers finding it unattractive to graze cattle and sheep on sites of under 10ha (Small et al 1999).

Fig 7.8.4 Marsh where tussocks have become dominant due to undergrazing.

Rather than fragmentation, being the main factor in determining the presence and frequency of tussocks, other factors such as management will influence the quality of grassland. Comparison of the fragments studied show that where the fragment has been heavily influenced by taller vegetation i.e. trees, tussocky grassland occurs sparsely. Results may therefore be influenced by the height of the surrounding sward, which makes individual tussocks difficult to detect. On sites such as Erith Marsh, fragment 2c and Barnes Cray, where the height of the sward exceeds heights at which tussocks begin to lose their value, i.e. 30cm (Benstead et al 1997, Vickery et al 2001), and therefore low scores have been recorded. There may be better correlation therefore between low sward heights and the presence of tussocks, which in turn would relate to management levels and the perceived value of remnant fragments of grazing marsh. Results in this study showing that the level of tussockiness decreases with fragment size and that many of these smaller fragments are ungrazed therefore supports the hypothesis that economics and management are more instrumental in the decline of grazing marsh than fragmentation.

7.9.1 Rills and wet flushes – Results.



Rills are the remnants of smaller saltmarsh channels and constitute the wetter areas of the grazing marsh matrix, and were measured as described in Section 5.3.4. The overall mean score across all the fragments surveyed is low at 1.82, (Fig 7.9.1), which on the scoring system (Table 5.11) means sparse to occasional. With the exception of Great Clane Marsh, which recorded no rills, all the marshes of the Outer Thames recorded a score greater than the mean of 1.82. In the Inner Thames Marshes 29.4% of fragments surveyed exceeding the mean value (1.82), with 32.3% of the fragments having no or sparsely distributed rills, with the lowest scores being recorded on the most fragmented sites, e.g. Stone Marsh and the smallest fragments, e.g. Crayford Marsh 2a.

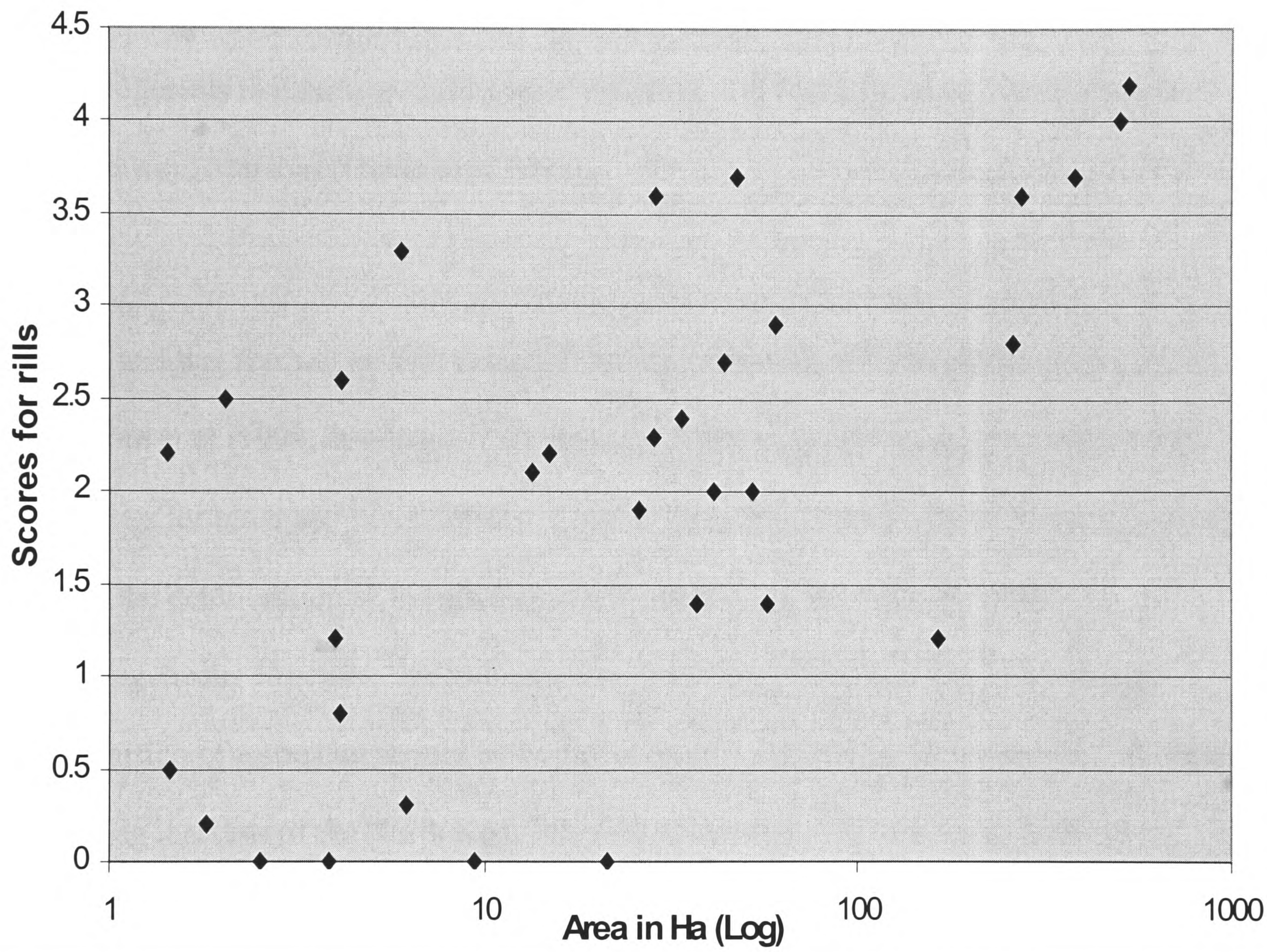
The overall mean value for the occurrence of rills on the marshes within the ESA is 3.68, i.e. rills occurring frequently or abundantly across the whole marsh. On non-ESA marshes, the mean for rills etc was 1.55, i.e. sparse to occasional. As the ESA marshes are regarded as being a guide to the typical grazing marsh condition, this score is therefore regarded as the optimum, (see Section 5.3.4). There were no fragments surveyed in the Inner Thames Marshes recording a score over this figure for rills, with Dartford Fresh Marsh (3.6), containing the highest proportion of rills.

The pattern for wet flushes is very similar to that for the rills, although they occur at a lower frequency (1.66). Only 60% of the Outer Thames Marshes and 37.5% of the Inner Thames Marshes scored greater than the mean of 1.66. There is also a greater number of fragments recording none or sparsely distributed wet flushes with 45.8% of the Inner Thames Marshes and only Great Clane Marsh in the Outer Thames recorded in this category. The lowest scores have again been recorded primarily on the most fragmented marshes, e.g. Erith and Stone Marshes.

The ESA marshes are being used as a guide to the typicalness of grazing marshes (see Section 5.2.1) and therefore the scores for wet flushes are compared against the mean for these marshes of 2.96, i.e. wet flushes occurring frequently (Section 5.3.4). There were 26.5% of the fragments surveyed exceeding this figure, which comprised 25% of the Inner Thames Marshes and 33.3% of the Outer Thames Marshes.

Fig 7.9.2 shows that there is a relationship between the occurrence of rills and the area of a fragment. Spearman's coefficient of rank correlation was calculated to test the hypothesis that there was a relationship between the area of a fragment and the occurrence of rills. A correlation coefficient of 0.655 indicates that at the 95% confidence level there is significant correlation and that the size of a fragment is a factor in the occurrence of rills.

Fig 7.9.2 Graph plotting frequency of rills against area



<u>7.9.2 Rills and wet flushes – Discussion.</u>

Rills are the remains of some of the smaller drainage channels that were present on the original saltmarsh. Over time, the hollows and rills gradually become filled and become shallower and colonised by plant species that are less tolerant of waterlogged conditions, although they may retain an element of the original species composition e.g. marsh foxtail (*Alopecurus geniculatus*), and floating sweet grass (*Glyceria fluitans*). These species are typical of MG13 inundation grassland communities, one of the RSPB targets for grazing marshes (Benstead et al 1997). Wet flushes occur where drainage becomes impeded or is influenced by the surface topography (ibid), and are characterised by species tolerant of wetter and waterlogged conditions e.g. common reed (*Phragmites australis*), rushes (*Juncus spp*) and sedges (*Carex spp.*), which may be positive or negative indicator species, depending on the abundance (see Section 8.4). These species are all found on grazing marshes in ditchside communities, marshes that are ombrogenous in nature or undergrazed marshes, all of which can be found across the North Kent Marshes (Hollis et al 1993).

Rills and wet flushes, as with tussocks, have been recorded by Benstead et al (1997), Milsom et al (1998, 2000) and Vickery et al (2000) as important features on grazing marshes for birds and invertebrates. Loss of these features will therefore be an indicator as to the deterioration of the grazing marsh mosaic and the homogeneous – heterogeneous structure. No indication is given in the literature however, as to the proportion of a site that should be occupied by rills etc, but the occurrence of rills on the grazing marshes of the North Kent Marshes ESA were used as a guide to the ideal frequency.

The North Kent Marshes recorded a range of conditions for the rills and hollows in the surface topography, from marshes with abundant rill features, e.g. Cliffe Marsh, to the drier conditions of the Inner Thames Marshes e.g. Erith Marsh fragment 2b. The Inner Thames Marshes recorded fewer rills and wet flushes (45.8%) than the Outer Thames Marshes (90% and 60%), (Fig 7.9.1). Notable exceptions occurred on Barnes Cray, Crayford Marsh fragments 3a and 3b, Dartford Fresh Marsh and Dartford Marsh fragment 1c, which are ombrogenous in nature, i.e. they are dependent on rainfall to maintain their water levels. All these fragments recorded areas of waterlogged ground, which are not related to any site management, but in the case of Barnes Cray, Crayford Marsh and Dartford Marsh 1c may be influenced by the additional run off of surface water from the new roads which have divisively fragmented the marshes. The waterlogged areas of Dartford Fresh Marsh appear to be related more to impeded drainage of the settling ponds within the GlaxoSmithKlein pharmaceutical works (personal observation). On Dartford Fresh Marsh, the waterlogging has resulted in the development of swamp communities S22 and MG13 (see Section 8.3), whereas on the other examples there is no evidence of the site conditions influencing the vegetation structure (personal observation). A high water table and surface water are however, characteristics of these fragments particularly after periods of heavy rain (personal observation).

Swanscombe Marsh in the Inner Thames Marsh also retains large areas of waterlogged marsh, dominated by stands of reeds (*Phragmites australis*), reed mace (*Typha latifolia*), hard rush (*Juncus inflexus*) and jointed rush (*J. articulatus*). The development of these waterlogged and swamp communities have been caused by the development of the landfill, which intrusively fragmented Swanscombe Marsh and has subsequently impeded the natural drainage pattern of the peninsula.

The second series Ordnance Survey maps of Erith Marsh indicates that wetland features such as rills and wet hollows were previously more extensive than currently recorded (Fig 7.9.1). As Erith Marsh has become fragmented, divisively by roads and intrusively by industrial development, the resulting small fragments have received less management of the water levels and as a result indications are that the marshes are drying out. Intrusive fragmentation has directly led to the loss of changes in the surface topography, which result in the wetter hollows and rills, e.g. Erith Marsh. Further landscaping to intrusively fragmenting agents further adds to the losses as well as impacting on the hydrology of a fragment, by diverting water through storm drains, rather than on to the marshland surface where the topography causes the creation of wet hollows etc.

Divisive fragmentation by roads as discussed in Section 7.4.2 can introduce increased run-off, which transports silt and other material into the drainage ditch system of the grazing marsh. As discussed by Andrews (1990), these changes can lead to the silting up of ditches and rills again changing the hydrology of a fragment. The extensive fragmentation of the Inner Thames Marshes by division can be identified as one of the main reasons for the difference in the frequency of rills etc with the Outer Thames Marshes.

The Outer Thames Marshes from Shorne to Allhallows all have abundant rills and small channels (mean score 3.4), although as in the inner marshes Shorne Marsh and parts of Higham Marsh fragments 1a and b the rills are beginning to be lost under the growth of rank and tall grasses. The development of the sward is resulting from a degree of undergrazing, which although not destroying the feature, is causing them to dry out. Thus, management rather than fragmentation is the underlying reason for changes that are occurring to these features.

Rills and wet hollows were more frequent within the marshes managed under ESA proscriptions, where they provide an important habitat for some of the rarer plant species of the North Kent Marshes, e.g. annual beard grass (*Polypogon monspeliensis*), which can be found on Cliffe and Allhallows Marshes. The Outer Thames Marshes show a varying level in the occurrence of wet flushes for reasons that are not immediately apparent. There is a possibility that at the time of surveying the rainfall totals have been lower and the build up of surface water is no longer occurring during the summer periods. The maintenance of rills and hollows is an aim of ESA management (ADAS 1997), and therefore their greater frequency across these areas of the North Kent Marshes is a reflection of positive management practices.

The loss of rills and hollows particularly on the Inner Thames Marshes is a result of a combination of both size and management. On fragments where these features have become abundant or dominant with swamp and mire species beginning to dominate the sward, the matrix would tend towards a condition of permanent waterlogging and not periodic inundation, as the definition of grazing marshes (Section 3.1.1.), implies, i.e. grazing marsh is replaced by permanent wetland. The retention of traditional grazing marsh features therefore relies more on climatic factors and impeded drainage than management techniques and their maintenance is probably a result of site conditions that arise from fragmentation rather than being lost or disturbed by fragmentation.

The presence of rills and evidence of smaller drainage channels are often difficult to observe. On the under grazed marshes where the sward consists of tall grasses, rills etc. become obscured and overgrown and as such can no longer be considered as a constituting a major element of the grazing marsh. Water management is also a crucial factor in the maintenance of rills, on marshes where water levels and flooding is controlled, e.g. Cliffe, Chetney the rills are better preserved than on the inner marshes where no water management plans are currently in operation. A factor that is particularly evident on the Inner Thames Marshes, although Dartford Marsh fragment 1c and Dartford Fresh Marsh exhibit frequent to abundant rills, there is no consistency as to the water level in these rills, i.e. the water levels are dependent on precipitation rather than management. Under the ESA scheme however, maintenance of ditch water levels and retention of reedbeds is a tier 1 proscription and under tier 1a water levels shall be such as to create shallow pools (ADAS 1997). Action is also undertaken by some landowners, e.g. RSPB, and with proposed water plans for both Crayford and Dartford Marshes (Gieckie *pers com.*) the features of rills etc. will become a more easily distinguishable feature as water levels are raised. The result of raising the water levels will influence the vegetation community structure (see Section 8.4) and provide a variety of habitats, which is more attractive to the bird species dependent on coastal grazing marshes (see Section 9).

As rills are a positive indicator as to the status and quality of a grazing marsh, as discussed by Milsom et al (2000) and Vickery et al (2001), their loss as a landscape feature on the Inner Marshes detracts from the overall status of a fragment of grazing marsh and reduces the value as a grazing marsh remnant. The level to which fragmentation has resulted in the loss of rills etc. is discussed in Section 7.10.

7.10 Conclusion.

The individual landscape characteristics and features identified and defined in Section 3.1.1 are regarded as being the typical landscape elements of grazing marshes, which together produce the landscape mosaic of homogeneous lowland wet grassland and drainage ditches enclosed by embankments and with a micro scale heterogeneity of features: - a homogeneous – heterogeneous complex (Section 5.2.2). In addition to these characteristics and features, grazing marshes have as described by Dickens (1861) and Cobham (1995), been landscapes of openness and big skies.

Fragmentation has impacted on all of the landscape characteristics and features of the North Kent Grazing Marshes. The landscape features of the Outer Thames Marshes, with the exception of Great Clane Marsh, have been in all cases less affected by fragmentation and retained all of the landscape features. Of the landscape characteristics only the embankments are absent from five fragments (Fig 7.5.1), resulting from their isolation from the River Thames Embankment by the construction of the Thames – Medway canal. Where fragmentation has been more extensive in the Inner Thames Marshes the landscape characteristics and features have either been lost, damaged or retained at a lower than acceptable quality.

Hasted (1797), Dickens (1861) and Cobham (1995) all described the openness and big skies that characterise the North Kent Marshes, and together with the homogeneous – heterogeneity of the grazing marsh matrix place grazing marshes within a landscape context. Fragmentation and the increasing development of remnant fragments within the Inner Thames Marshes has replaced the openness with marshland increasingly influenced and dominated by their surroundings. Although the ideal grazing marsh should exhibit the open character, as an indicator of typical grazing marsh openness is a characteristic that cannot be recreated and therefore may be of lesser importance than the maintenance of other characteristics and features, e.g. Erith Marsh and the recently established Crossness Nature Reserve.

The landscape characteristics and features surveyed in this study were chosen to encompass those included within previous definitions of grazing marsh e.g. Delaney 1991, Kent BAP 1997, and with regard to the requirements of species associated with grazing marshes, e.g. birds and sward height and described by Milsom et al (1998, 2000). Landscape features of the grazing marsh habitat form the basis of a mosaic of vegetation communities within the lowland wet grassland matrix, therefore the effects of fragmentation on these elements will impact on the typical grazing marsh structure and vegetation communities (see Section 8). The effects of fragmentation on the landscape characteristics will alter the macro habitats and influence the visual quality of the grazing marsh.

The presence, absence and occurrence of the landscape characteristics and features can be used as positive or negative indicators of the quality and to the extent to which fragmentation has influenced the grazing marsh fragments. Not all of the characteristics and features need necessarily be present however, to constitute the presence of grazing marsh, as discussed within the individual sections, i.e. fragments have become isolated from embankments. Pickett et al (1989) regarded ecological units, i.e. grazing marsh consisting of several subunits, i.e. landscape characteristics and features, which belong to lower hierarchical levels. There is a hierarchy therefore, in which the individual characteristics and features are linked to create the grazing marsh habitat and their value as indicators is dependent on their position in the hierarchy. Pickett et al (1989) referred to these units as the minimal and configurational structure of habitat, with components of the minimal structure being necessary for the habitat to persist. The configurational structure is the 'second order structure', and may vary without causing change to the minimal structure (ibid). Landscape characteristics and features therefore comprise part of the minimal and configurational structure of the grazing marsh habitat, and their position in one level of the units determines the importance as an indicator of fragmentation effects.

In grazing marshes, the minimal structure elements will be those, which comprise the homogeneous – heterogeneous matrix, i.e. drainage ditches, rills and hollows, tussocky grassland and counter walls. The second level, configurational structural elements will include openness, homogeneity, embankments and sward height. The effects of fragmentation on the hierarchical habitat structure will depend on the type of fragmentation and the fragmenting agent. Individual effects on the characteristics and features were discussed in the appropriate section.

Drainage ditches are considered one of the key characteristics of grazing marshes (Delaney 1991, Kent BAP 1997). They are the basis of the aquatic habitats and are a main component of the landscape character. Drainage ditches also support a range of plants, mammals and invertebrates, which are dependent on the aquatic habitat. Their importance within the grazing marshes identifies drainage ditches as part of the minimal structure, without which the grazing marsh system would disappear.

Homogeneity is a visual characteristic of grazing marshes at the landscape level. The influence of surrounding features, as discussed in 7.2.2 can give rise to the loss of homogeneity, as can the breakdown of the landscape features, which creates the homogeneous – heterogeneity of the grazing marsh matrix. Loss of homogeneity is therefore related to changes in other factors and as a result, homogeneity is considered part of the configurational structure.

Similarly, embankments are not present on all fragments, and although they are considered a landscape characteristic (Cobham 1995), their presence or absence does not influence the survival of features such as rills and tussocky grassland. Embankments are therefore considered as a sub-unit of the configurational structure, and although they may support the presence of some rarer species, e.g. least lettuce (*Lactuca saligna*), their absence from a grazing marsh will not lead to a breakdown of the habitat. Counter walls in contrast, add to the variations in surface topography of the grazing marsh, therefore contributing to the homogeneous-heterogeneous matrix, and are therefore to be regarded as part of the minimal structure.

Intrusive fragmentation causes the loss of landscape features, such as rills, hollows and tussocky grassland, over the area of the intrusive agent. Thus, part of the minimal structure of a fragment will either be totally lost or compromised, as some of the feature may still be represented on the fragment. For example, fragments such as Erith 2c and Stone 2c both recorded low scores for rills indicating that the feature has not been totally lost and that part of the minimum structure remains. For example, fragments such as Stone 2d and Botany Marsh, recorded zero for the rills and hollows and therefore as this element of the minimal structure has been lost and therefore as one of the key elements has been destroyed so the overall system will disappear (Sennhauser (1991).

Divisive fragmentation creates smaller fragments and introduces barriers between fragments or creates corridors between remnant fragments and marshes. The effects can include loss of the features directly affected by the construction or increased connectivity, which can introduce invasive species and alter the vegetative homogeneity and community structure (Section 8.4), or prevent the movement of species between fragments, again affecting the vegetative structure. Sections 7.4.2, 7.5.2, 7.8.2 and 7.9.2 discussed the effects of divisive fragmentation on the minimal structure elements of a grazing marsh. The effects of divisive fragmentation tend to influence changes within the minimal structure rather than causing complete loss, i.e. siltation within drainage ditches can alter the ecology or water levels without destroying the characteristic.

The remaining methods of fragmentation, i.e. encroaching, enveloping and regressive, will affect the landscape characteristics and features in a similar manner to intrusive and divisive fragmentation. Where fragmenting agents are constructed within a remnant fragment, they cause losses to the minimal and configurational structural elements. Developments along the edge of a fragment will influence the structure without always causing total loss and therefore the breakdown of the minimal structure will occur over a period of time. For example, within the Inner Thames Marshes, many fragments, which have been divisively fragmented, retain many of the minimal structure features, but at lesser quality than the larger fragments of the Outer Thanes Marshes.

Landscape characteristics and features therefore constitute the configurational and minimal structures of grazing marshes and the loss or decline of one characteristic or feature is therefore, indicative of an overall decline in the grazing marsh status, and that habitat stability is being compromised. The effects of fragmentation on the landscape characteristics and features therefore, need to be considered, in terms of their relationship to each other, because they all contribute equally to the overall landscape and conservation value of grazing marshes, by providing the matrix for the typical grazing marsh vegetation communities.

Grazing marshes were created by anthropogenic action (Section 3.2.1) and they have been maintained by grazing and water level management. Where fragmentation has occurred and created smaller uneconomical areas of grazing marsh, formal management has ceased. The lack of management has often led to the decline in quality of many of the landscape characteristics and features, which comprise the minimal and configurational structure of grazing marshes. Management of grazing marshes is therefore a key component in maintaining the sward and tussocky grassland, controlling the water levels in the ditches and in managing the ditches and emergent vegetation, which influences the surface water levels (rills and hollows). Evidence from many of the Inner Thames Marshes, where many of the key landscape features and characteristics are at below optimum level, indicates that management should also be considered as part of the minimal structure of grazing marshes. The level of grazing and how it affects the surrounding sward through intensity, poaching, dunging and disturbance, may be considered part of the configurational structure, but the other factors such as control of water levels and the use and amount of fertilisers etc. will rely on human intervention to maintain the grazing marsh.

Are then the effects of fragmentation related to the size of the remnant fragment per se or are other factors involved? Fragmentation effects on the landscape characteristics and features have shown a consistent pattern of creating smaller fragments within the Inner

Thames Marshes that record scores below the mean for all the characteristics and features studied. As the smaller fragments generally recorded scores that indicated a lower overall value for the landscape characteristics and features, there is evidence to suggest that size is a factor.

The results of the tests of correlation are unclear as to the exact relationship between area of a fragment and the individual landscape characteristics and features, although most show a degree of significant correlation between area and the quality of the characteristic or feature. It is apparent from the surveys however, that particularly in the Inner Thames Marshes fragmentation has led to degradation and a lack of appreciation as to the value and character of grazing marsh as a distinct habitat. Remnant fragments therefore become prime targets for developers, with the result that the remaining grazing marsh takes on additional negative influences that affect the open character that is still present in the Outer Thames Marshes and create the marked difference that can be observed in the landscape characteristics of the two areas.

Area, however, has not always appeared to be a factor in determining for example, the hydrology and water table levels. Small fragments, e.g. Crayford Marsh 3a and 3b and Erith Marsh 2c all have areas that retain water and closely relate to the term lowland wet grassland in structure. The question of how large an area needs to be in order to retain the core features is harder to assess. From the examples of the fragmented North Kent Grazing Marshes, fragments of 2 – 3ha are still large enough to maintain the range of characteristics and features, but this is considerably larger than the 0.5ha regarded by Mader (1984) as being the minimum size for a fragment to contain core habitat. Similarly, Crofts and Jefferson (1989) in the SSSI guidelines stated that 0.5ha is the minimum size for selecting sites containing grassland features of interest. There were examples of fragments e.g. Crayford Marsh fragment 1 and Dartford Marsh fragment 1b, that were of greater area than suggested by Mader (1984), where landscape features such as rills and wet flushes were not such prominent factors, but also a range of smaller sites, e.g. Erith Marsh 2c and Crayford Marsh 3a that retained such features. It is difficult to determine at what point a fragment loses all the qualities of grazing marsh and what area can be regarded as being minimally viable. Size therefore, is probably not the principal deciding factor, and that management and other external influences that have been instigated by fragmentation are the significant causes of the decline and breakdown of the minimal structure leading to further losses of the grazing marsh resource.

Fragmentation can be regarded as an act of disturbance (Forman 1997) and changes to grazing marsh landscape characteristics and features occur as a response to these acts of disturbance as discussed in section 2.2. Fragmenting events e.g. divisive fragmentation by road construction, are acts of disturbance that often act as the precursor for further disturbance and habitat loss, e.g. industrial development and intrusive fragmentation. Together with the other major pressures and problems that affect grazing marshes, e.g. hydrological change, overgrazing, eutrophication and lack of management, fragmentation becomes responsible for deterioration of the whole marshland system. The responses by the individual marshes and the individual marsh characteristics however are related to the type of disturbance and the agent that is causing the fragmentation, i.e. intrusive fragmentation resulting in the loss of all interior features, or road construction influencing ditch water levels. Impacts of fragmenting events have been considered as to how they affect the minimal and configurational structure of grazing marshes and whether fragmentation, area or management has been the crucial factor in the status of grazing marshes.

The agents of fragmentation across the North Kent Marshes at the landscape scale have had a major effect on the characteristics from a visual and aesthetic view. The effects at the micro scale of the landscape features are more difficult to discern because particularly with the smaller fragments, there is difficulty in establishing what effects may be due to fragmentation and what are a result of poor or a lack of management. It may be that fragmentation is the overall cause of the decline in management levels, in which case any change in the status of the landscape features does ultimately result from fragmentation. Evidence from the Inner Thames Marshes however, would indicate that as grazing marsh fragments have become uneconomical for grazing; their value has increased in terms of development land. As traditional grazing management has ceased so, the hierarchical structure has broken down, and the result is vacant land exhibiting few grazing marsh characteristics. Fragmentation therefore becomes the agent by which grazing marsh management ceases and the combined effect of these two processes is the loss and erosion of the traditional grazing marsh characteristics and features and the enclosure of many fragments to the detriment of the openness and big skies.

Chapter 8 The Vegetation Ecology of the North Kent Grazing Marshes

8.1 Introduction.

Chapter 8 evaluates the effects of fragmentation on the ecological features of the North Kent Marshes. The ecological features of grazing marshes derive from firstly, the landscape characteristics and features, which are considered to form the habitat matrix (as defined by Foreman 1997), and secondly, the management regime and thirdly, external influences e.g. disturbance. Comparison of the vegetation communities present on the studied fragments has been carried out using MATCH analysis (Section 5.3.3). Using the grazing marsh communities identified by ADAS (1997) and Benstead et al (1997) as a guide, the mosaic of the communities that comprise grazing marshes is proposed.

Analysis of habitat change can be linked with the effects of fragmentation on the landscape characteristics and features, which comprise the template of the mosaic of habitats, discussed in Section 7.3. Each habitat type resulting from the mosaic of landscape features and the matrix of lowland wet grassland will consist of different NVC communities. By comparing the presence and absence of individual indicator species to the NVC, and whether these species have been over or under recorded in the site surveys, a grazing marsh mosaic of communities for the North Kent Marshes can be identified, which can be used to monitor fragmentation and its effects on the make up of the communities.

Section 8.2 analyses the effects of fragmentation on the North Kent Marsh habitats identified in Chapter 1.5, whereas Section 8.3 analyses the results of the MATCH process (Chapter 5.4.3) and how the individual and invasive species influence the community structure. In Section 8.4 the mosaic of plant communities that comprise a good quality grazing marsh are identified. The variations that occur within a grazing marsh and the species indicating the differing sub-communities that make up the regional variation that is the North Kent Marshes are also described. The effects of fragmentation can be determined by analysing the range of different community types that can now be found across the fragmented North Kent Marshes against the ideal community types.

Where invasive species occur in greater or lesser constancies than those indicated by Rodwell (1992, 2000) they are used as indicators of the impact of fragmentation or other factors, e.g. management on the individual fragments. The influence on the communities by invasive species has been recognised as a major factor in determining the direction of change in community structure. The effect of these species has been considered separately in Section 8.4.1.

8.2.1 Grazing Marsh habitats - Analysis.

The range of habitats that are believed to occur on the North Kent Grazing Marshes was discussed in Section 1.5. Lowland wet grassland is regarded as the main habitat type in the North Kent Grazing Marshes and forms the 'matrix or background ecosystem of the grazing marsh mosaic. Maintaining lowland wet grassland communities amongst the mosaic of habitats that characterise the region is therefore, a primary indicator of the status of the marsh condition. The range of habitats found across the North Kent Marshes includes improved and unimproved grasslands (Kent Habitat survey 1991).

The associated habitat component communities include the aquatic habitats of the ditches, bankside riparian habitats, embankments and counter walls, tussocky grassland, anthills, rills and wet flushes. The occurrence of these habitats is influenced by management or lack of, periods of inundation, aspect and the surrounding land use. Grazing marsh habitats have evolved therefore, as a product of both management, i.e. grazing and agricultural improvement and from the landscape characteristics and features, which have been defined Section 3.1.1. A discussion on the vegetation communities and their component species that occur on the North Kent Marshes follows in section 8.3.

In Sections 7.2, 7.4, 7.5 and 7.7 to 7.9, the effects of fragmentation on the landscape characteristics and features of grazing marshes, were discussed. The processes that have led to losses, degradation and changes to the landscape characteristics and features will in turn have effects, on the composition of the habitats, e.g. siltation of ditches will cause the effective depth of water to change and influence changes to the species content of the aquatic systems (Andrews 1990). Similarly, intrusive fragmentation, which causes losses to landscape features, such as rills and tussocky grassland, will be directly responsible for the loss of the habitats associated with these features. Fragmentation effects can therefore, range from total loss of the habitat to changes in the species content, through edge effects, the introduction of barriers between habitat types or indirectly e.g. changing the chemical nature of the soil or water (Laurence and Yensen 1991, Andren 1994, Forman 1997).

8.2.2 Grazing Marsh Habitats - Discussion.

The landscape characteristics discussed in Section 7.2 – 7.5 are primarily of anthropogenic origin e.g. embankments, or have been strongly influenced by anthropogenic activities, e.g. drainage ditch management. Landscape features result from topographical changes in the surface of the grazing marshes e.g. hollows and anthills, but may also be associated with anthropogenic influences, e.g. management regimes, or the remnants of saltmarsh (Delaney 1991). Each of the individual landscape characteristics and features give rise to a range of different habitats depending on the nature of the particular characteristic or feature. For example, aquatic habitats, both brackish and fresh water, bankside and riparian habitats derive from the characteristics of the drainage ditch system. Rills and anthills provide contrasting habitat types ranging from swamp communities to drier grassland communities associated with the higher topography found on anthills (Gee 1997). Embankment habitats are influenced by aspect, management, and their frontage, where the vegetation will be influenced by the saline nature of the River Thames or inland where salinity is less of a factor. Surrounding land uses influence the nature of the edge. The resulting edge effects (Section 6.8.2), may then determine the invasive species content of the habitat through the introduction of corridors to facilitate movement between fragments, i.e. the type of fragmentation influences changes to the habitats and species content.

Fragmentation is a form of disturbance to a habitat and therefore affects the status and organisation of the habitat in terms of its spatial arrangement of features and species content. In Sections 7.6 and 7.10 the effects of fragmentation on the landscape characteristics and features was discussed. As the landscape characteristics and features determine the habitats found in the North Kent Marshes, the effects of fragmentation will therefore be expected to have similar impact on the composition of the habitats associated with these characteristics and features.

Divisive fragmentation was typically the first type of fragmentation occurring on a grazing marsh, initially creating smaller fragments, and reducing the overall area available for each habitat. Encroachment, envelopment, intrusion or regressive fragmentation occurring after a divisive fragmenting event can destroy or modify existing landscape characteristics and features therefore destroying or modifying the associated habitat. Road, rail and canal construction have been the most important agents of divisive fragmentation in the North Kent Marshes. Direct loss of habitat due to divisive fragmentation by these agents is considerable, but is less than the loss to major intrusive developments, e.g. Thamesmead. As a precursor to all other means of fragmentation however, the effects of division is the most influential in altering the habitats of the North Kent Marshes.

By dividing habitats, divisive fragmentation produces the conditions that lead to change in the grazing marsh composition. The introduction of corridors across the grazing marshes, are influential in opening up grazing marsh to species with good dispersal characteristics. Divisive fragmentation also creates barriers which reduce the ability of less mobile grazing marsh species to move between fragments creating totally isolated fragments (Stone Marsh fragment 2a), or fragments with totally isolated characteristics, e.g. drainage ditches on Erith and Stone Marshes. Once a ditch has become isolated from other ditches, management tends to decrease or cease and eventually through hydroseral succession the ditch will dry out, with related effects on the fragments water table. Of the fragments studied, 20% had evidence of ditches that have now dried out and become colonised by grasses. There is however, no relationship between size and drying up of ditches (Personal Observation), some small fragments (e.g. Crayford fragment 2b) retain ditches, whilst some larger fragments (e.g. Dartford fragment 1b) have a ditch system, which is overgrown and choked. Lack of management, therefore appears to be more important than fragmentation in determining ditch characteristics. For example, Dartford 1b is currently under set-aside, and so management is in this instance a greater factor. Small isolated fragments are however, less likely to be actively managed because their size makes it economically unviable. Fragmentation in all forms therefore, tends to lead to a lowering in the value of aquatic habitats particularly on the smaller fragments where absence of management has failed to maintain the drainage ditches and their loss may be an indirect result of fragmentation.

The greatest loss of habitat arises from intrusive fragmentation, which directly destroys the landscape characteristics and features and the associated habitats. Urbanisation, industrialisation and office building have all caused loss of grazing marsh by intrusive fragmentation. As discussed in Section 6.2.1 urbanisation has been responsible for the greatest loss in terms of area, although only three marshes Erith, Crayford and Denton have suffered losses in this respect.

Change of land-use, through intrusive fragmentation not only causes losses to the matrix habitats, but also to the habitats of ditches, and counter walls. Where fragmentation has been most extensive, e.g. Erith and Stone Marshes counter wall habitats have been completely lost, but ditches have remained, in a modified state. As recorded in Section

7.3, on the above two marshes the ditches have been incorporated into the landscaping, which although maintaining a level of management has resulted in a loss of traditional communities of bankside vegetation, i.e. ditches have become canalised (Erith Marsh), Fig 8.2.1, or the emergent vegetation is lost (Stone Marsh).

Fig 8.2.1: Canalised ditch Erith Marsh.

Fragmentation increases the risk to drainage ditches of the effects of industry and road run-off in the form of pollutants and silt. Increased run-off can lead to the drainage ditches becoming shallower, making it easier for emergent vegetation to choke the system. Infiltration of contaminants into the ditch network may have serious consequences for the ditch flora and fauna. Pollution of ditches can remain a problem even on unfragmented and larger marsh fragments. Regular dredging of ditches as part of their management can remobilise pollutants that have been trapped in the sediment at the bottom of the ditch. Episodic pollution events may therefore become a feature of grazing marshes, (Holts et al 1993).

Lowland wet grasslands of the North Kent Marshes may be affected by any factor, which alters its hydrology, e.g. road building can alter hard surfacing causing a change in the balance of water supply and the level of the grazing marsh water table (Holts et al 1993). Hydrological changes will be particularly damaging to those grazing marsh fragments that are ombrogenous in nature (ibid). Fragments such as those of Stone Marsh (2a, 2b, 2c and 2e) all scored low in terms of rills and wet flushes, between 0 and 0.9, i.e. either absent or sparse. The loss of these landscape features due to fragmentation is directly responsible for the loss of the wet/aquatic habitats associated with them.

The construction of utilities, i.e. power stations, sewage works etc., have intrusively fragmented embankment habitats on Erith, Dartford and Grain Marshes. Stone and Swanscombe Marsh have had their embankments fragmented by construction of piers and jetties. In all cases, the outcome has been to replace the original earth bund with a concrete embankment, which therefore causes the direct loss of the embankment habitat, and reduces the effectiveness of the embankment to act as a corridor between marsh fragments. A further example of divisive fragmentation of an embankment has occurred on Dartford Marsh, where road construction has separated the saline grazing marsh from Dartford Fresh Marsh. Efforts were made to maintain the embankment under the bridge, but the provision of an earth bund has failed to induce any vegetative growth. The road is therefore acting as a barrier that is effectively fragmenting the embankment. Typically, concrete embankments are depauperate in terms of flora (personal observation), although species such as buddleia (*Buddleia davidii*) and rosebay willow-herb (*Chamaeniron angustifolium*) have established themselves along these embankments from Erith to Cliffe (personal observation).

Edge effects are mostly associated with effects from divisive fragmentation, i.e. arising from road and rail construction. Fragmentation therefore induces an increase in the level of disturbance to a fragment and access for species with good dispersal characteristics (Planty-Tabacchi 1996). For the embankments and counter wall habitats, this will inevitably mean that a suite of more competitive and ruderal plant species will eventually begin to colonise. Buddleia (*Buddleia davidii*), prickly lettuce (*Lactuca serriola*), coltsfoot (*Tussilago farfara*), rosebay willow-herb (*Chamaenerion angustifolium*) and Japanese Knotweed (*Reynoutria japonica*) are examples of species that can now be found along embankments of the North Kent Marshes (personal observation). The appearance of invasive species is associated with the loss of some of the more traditional and rarer embankment species associated with the area, e.g. least lettuce (*Lactuca saligna*), a Red Data Book species no longer found on the North Kent Marshes (Gee 1997). Typical species such as hog's fennel (*Peucedanum officinale*) and pepper saxifrage (*Silaum silaus*) are finding their habitat squeezed as embankments are lost to fragmentation.

The surrounding land use can also influence changes in habitat type, e.g. the mineral extraction works adjacent to Stone Marsh fragment 2b have in fact influenced the grazing marsh soils, which now have a loosely compacted sandy constituency. This is a major factor accounting for the different vegetation communities found on this fragment (Table 8.3.8, Appendix 4). With the change in the soil construction the fragment begins to lose the characteristics of a lowland wet grassland habitat type to be replaced by species that tolerate the drier conditions and amenity grasslands, and therefore the loss of lowland wet grassland.

Fragmentation can therefore affect the composition of grazing marsh communities in a variety of ways both directly and indirectly. The effects may be due to alterations to:

- hydrology;
- creating barriers;
- isolation of marsh fragments;
- by influencing soil composition;
- structure of the characteristics and features.

Such changes can be indicated by an increase in the presence of ruderal plant species and communities, scrub communities and amenity grasslands, and the loss of landscape features and typical plant communities. The direction of change resulting from fragmentation of grazing marshes therefore tends to be from one of wetland communities to dry grassland communities; and scrub and woodland as succession proceeds. The type and intensity of management can be critical in maintaining the landscape characteristics and features, which are the basis of the vegetation communities, see Section 8.4.

Direct results of fragmentation therefore lead to the destruction of the landscape characteristics and features, and therefore the habitats. The indirect effects of fragmentation may be to induce changes to the habitats, vegetation communities and aid the introduction of alien species, through edge effects and increases in the edge/core ratio, but actual impacts on species composition have not previously been investigated. This study therefore in Sections 8.3 and 8.4 evaluates the vegetation communities of the North Kent Marshes against the proposed communities suggested by MAFF (1997) i.e. MG6, MG7 and MG11 and RSPB (1997), i.e. MG6, MG7, MG11 and MG13, and considers how changes in the community composition may be influenced by fragmentation.

8.3.1 Vegetation Community Characteristics – Results.

Table 8.1 identifies the best match to the NVC vegetation communities defined by Rodwell (1992), recorded for each fragment using the Czekanowski coefficient of similarity, i.e. the communities ranked first in similarity to the site data sets. The best matches, 62.5% were with open vegetation communities with 54.2% of the best matches recorded with OV23 *Lolium perenne – Dactylis glomerata* community, i.e. thirteen of the twenty-four sites surveyed shared a first match with this community.

Table 8.1 Summary of Match Analysis showing NVC communities with the highest coefficient of similarity for all fragments.

Fragment	MG6	MG7A	MG7B	MG10	MG11	OV10	OV21	OV23
Erith 2a								***
Erith 2b								***
Erith 2e	**							
Crayford 1								****
Crayford 2a								****
Cayford 3a								***
Crayford 3b								****
Barnes Cray					**			
Dartford								**
Dartford Fresh				**				
Stone 2a							**	
Stone 2b						*		
Stone 2c		***						
Stone 2d								**
Swanscombe								*
Botany								**
Denton								****
Shorne								**
Filborough								**
Higham 1a		**						
Higham 1c	**							
Cliffe					**			
Allhallows	**							
Chetney			***					
Totals	3	2	1	1	2	1	1	13

* Highest match under 40%
** Highest match 41-50%
*** Highest match 51-60%
**** Highest match over 60%

Of the NVC communities predicted for grazing marshes by ADAS (1997), and Benstead et al (1997), i.e. MG6, MG7, MG11 and MG13; MG6 recorded the highest match on three marshes, whilst MG7 and MG11, recorded the highest match on two marshes, and MG13 did not appear as a first matched community.

On each fragment where OV23 ranked first, with the exception of Swanscombe Marsh, the coefficient of similarity was over 40%. Generally, it can be seen that community

OV23 recorded a higher coefficient of similarity on the inner marshes, where 6 of 15 sites recorded a coefficient of similarity of over 50% than the outer marshes. Stone Marsh fragment 2c is the exception to the rule in the Inner Thames Marshes, where MG7a *Lolium perenne – Trifolium repens* was the highest ranked community. The Outer Thames Marshes, with the exception of Shorne Marsh (OV23) and Filborough Marsh (OV23) all recorded mesotrophic grassland communities (MG6, MG7a, MG7b and MG11) as the best match.

Of the fragments, surveyed only Stone Marsh fragment 2b (37.7%) and Swanscombe Marsh (39.4%) had a first match coefficient of similarity below 40%. The best matches, i.e. over 60%, were found on the inner marshes of Crayford 1, 2a and 3b and on Denton Marshes, where OV23 was the best matched community in each sample.

Table 8.2 shows the overall top ten matches for each fragment using Czekanowski coefficient of similarity. The table shows matches with a range of mesotrophic and open vegetation communities across the North Kent Marsh fragments. Mesotrophic grassland communities occur as the most consistent vegetation groups appearing as top ten matches in 55.4% of the fragments, open vegetation communities appear as top ten matches in 41.7% of samples and saltmarsh and swamp vegetation communities in just 2.6% of samples. Four communities MG6, MG7a, MG11 and OV23 were recorded on all of the Outer Thames Marshes, whereas only one community OV21 was recorded on all of the Inner Thames Marsh fragments.

Table 8.2 Top Ten NVC Matches for the individual fragments showing the coefficients of similarity.

	E2a	E2b	E2e	C1	C2a	C3a	C3b	Bc	D	Dfr	S2a	S2b	S2c	S2d	Sw	Bo	De	F	Sh	H1a	H1c	Cl	A	Ch
MG1												30.3		36.3		43.5								
MG6	46.6	41.6	46.9	49.8	53.3								41.6				42.6	46.6	37.8	40.5	43.9	44.5	50.2	43.8
MG7A	48.5	42.9	41.0	59.1	57.8	44.0			45.6		36.3		56.4				40.7	44.2	43.1	47.1	43.0	43.1	43.4	42.4
MG7B	43.4	35.3	45.5	53.3	50.0								45.7					45.3		41.9	43.6	45.8	43.4	51.3
MG7C	39.2		37.6	51.4	49.6								37.3					41.4			35.6	39.9		41.2
MG7D	38.4	36.7	38.2	49.1	48.7			36.4				30.1	47.4						37.0	38.1	36.3		42.7	43.9
MG7E	40.7	37.9	36,8	53.8	49.2	40.3	39.0		44.2		35.3		48.1					41.5					41.3	41.8
MG7F	39.9	38.5	38.9	54.9	52.8	39.7	38.2		48.0				49.6	35.9			40.6	44.1		36.3	35.7	38.9	44.1	
MG9								39.9		47.2						39.2		41.5			35.1	43.9		39.5
MG10								38.0		48.6												39.0		
MG11	46.3		43.6	50.2	56.8	45.9	38.4	47.4	54.1	44.5	40.4	30.4		37.5	38.7	43.4	47.6	46.7	40.4	42.4	41.7	48.4	46.0	42.0
MG12														37.5									38.4	
MG13								36.0		45.2														
OV10							41.5		49.9		39.5	37.7		37.8	36.9	38.5	41.5		35.4	36.9				
OV18							42.6						39.5		34.0									
OV19		36.1				40.5	44.9		50.2		36.8	32.7		38.9	35.4	43.8	42.3		37.9					
OV20						41.0					42.9	29.2												
OV21	47.0	44.3	42.8	50.7	52.3	49.3	44.8	37.0	55.4	41.3	45.9	37.5	40.4	35.5	39.3	44.4	55.6	45.9	42.4	39.6	41.4	41.4	44.3	
OV22		37.4					40.5		46.8		36.1					38.4	41.4		35.6					
OV23	51.0	53.7	44.5	62.5	60.3	55.0	61.0		59.9	40.7	45.8	35.7	52.6	48.7	39.4	45.8	61.1	49.1	50.1	46.5	39.6	44.7	46.1	38.5
OV24						38.2						31.9				38.3								
OV25							43.6		47.5		38.4			36.7	33.9	43.1	41.0		35.5	36.3				
OV26								42.0		48.5														
OV28						42.3		46.5		40.6					31.1									38.5
S4															31.1									
S18															33.1									
S26								37.7		40.5														
SM28														36.2										

The range of communities represented is indication of the mosaic of communities which occurs across the study fragments that are indicative of the presence of a group of site conditions that include lowland wet grassland, amenity grasslands, wet flushes, relict saltmarsh and associated species.

MG11 *Festuca rubra – Agrostis stolonifera – Potentilla anserina* was the most consistently occurring match to a mesotrophic grassland community occurring on 91.7% of the fragments surveyed i.e. all the sites except Erith 2b and Stone 2c. OV21 *Poa annua – Plantago major* and OV23 *Lolium perenne – Dactylis glomerata* were the most frequently occurring matches to open vegetation communities being present on 95.8% of the fragments surveyed, i.e. all sites except Chetney Marsh (OV21) and Barnes Cray (OV23). Where mesotrophic grassland (MG) community matches were recorded in the top ten, 59.2% of matches were MG7 *Lolium perenne* leys, and of these communities MG7a *Lolium perenne – Trifolium repens*, was the most common match occurring on 70.8% of the fragments at a constancy of over 40% except for Stone Marsh 2a. On nine fragments (37.5%) MG7a *Lolium perenne – Trifolium repens* had the highest occurrence of first ranked mesotrophic grassland communities and overall appeared as the best matched community in at least one quadrat on seventeen (70.8%) of the fragments (Table 8.8). MG7f *Lolium perenne – Poa pratensis* occurred on 66.6% of fragments, with a similar distribution to MG7a, but with a lower matching coefficient. Although similar in species content to MG7a, MG7f comprises a higher constancy of ruderals and grasses such as *Dactylis glomerata, Holcus lanatus* and *Agrostis capillaris.* The remaining MG7 communities MG7d *Lolium perenne – Alopecurus pratensis* and MG7e *Lolium perenne – Plantago lanceolota* communities were both recorded on 54.2% of the fragments surveyed, whereas MG7c *Lolium perenne – Alopecurus pratensis – Festuca* *pratensis* occurred as a match on 37.5% of the fragments. MG7e is identified by the high constancy of *Plantago spp* and *Taraxacum spp*. The community was recorded on 66.7% of the Inner Thames Marshes, i.e. those that are smaller and have a lower level of management and grazing than the Outer Thames Marshes, where MG 7e was recorded on 30% of the sites.

MG7b *Lolium perenne – Poa trivialis* recorded top ten matches on 50.0% of the fragments surveyed, although only Crayford Marsh fragment 2a recorded a coefficient of similarity of 50% or above. The level of the matches in this instance relying on a high constancy of secondary community species, e.g. *Dactylis glomerata, Trifolium repens, Holcus lanatus, Agrostis capillaris* and *Cerastium fontanum*.

OV23 *Lolium perenne – Dactylis glomerata* was recorded as a top ten match on 95.8% of the fragments surveyed, with only Crayford Marsh fragment 3a not recording a presence of this community. The Czekanowski coefficient of similarity with OV23 was higher on the Inner Thames Marshes (mean 50.44%), than on the Outer Thames Marshes (mean 46.96%), whereas, the coefficient of similarity was higher for MG communities for the Outer Thames Marshes than the Inner Marshes.

Fragment 2b of Stone Marsh (mean 32.7) and Swanscombe Marsh (mean 35.3) recorded the lowest matches, all ten matches having a coefficient of below 40%, and these two fragments accounted for the total number of matches recorded below 35%. Erith Marsh 2b (60%), Barnes Cray (70%), Stone Marsh 2a (60%), Stone Marsh 2d (90%), and

Filborough Marsh (60%) all recorded more matches with coefficients below 40% than above 40%.

Table 8.3 Mesotrophic grassland communities' percentage of first matches for all individual quadrats

Fragment name	MG1	MG6	MG7a	MG7b	MG7d	MG7e	MG7f	MG10	MG11	MG13
Erith 2a	-	12.0	12.0	28.0	28.0	8.0	-	-	-	-
Erith 2b	-	12.0	64.0	-	-	8.0	-	-	-	-
Erith 2e	-	40.0	10.0	30.0	-	-	-	-	-	-
Crayford 1	-	4.1	12.5	33.3	4.1	16.6	-	-	-	4.1
Crayford 2a	-	8.3	16.6	8.3	4.1	8.3	-	-	12.5	8.3
Crayford 3a	-	-	21.4	-	-	7.1	-	-	-	7.1
Crayford 3b	-	-	-	-	-	-	-	-	-	-
Barnes Cray	-	-	-	-	-	-	-	-	-	-
Dartford	-	2.8	27.1	1.4	1.4	2.8	-	2.8	2.8	1.4
Dartford Fr	1.7	-	-	8.7	-	0.9	-	2.6	-	44.3
Stone 2a	-	-	20.0	-	-	-	-	-	-	-
Stone 2b	-	-	-	-	-	20.0	10.0	-	-	-
Stone 2c	-	-	-	-	-	-	-	-	-	-
Stone 2d	6.3	-	-	-	6.3	-	6.3	-	-	-
Swanscombe	-	-	19.2	-	-	-	-	-	19.2	-
Botany	6.5	3.3	3.3	-	-	-	-	-	-	6.5
Denton	-	7.1	28.6	-	-	7.1	-	-	-	-
Filborough	-	8.3	29.2	12.5	12.5	4.2	-	-	-	-
Shorne	-	10.8	30.4	27.5	-	1.0	3.9	1.0	-	-
Higham 1a	-	19.2	26.9	26.9	-	-	-	-	-	3.8
Higham 1c	-	31.3	31.3	18.8	-	-	-	-	-	-
Cliffe	-	24.1	19.0	31.6	-	-	-	1.3	3.8	5.1
Allhallows	-	50.0	6.7	23.3	3.3	-	3.3	-	3.3	-
Chetney	-	8.3	16.7	58.3	-	-	-	-	-	12.5
Percentage of sites where MG placed 1st	12.5	62.5	75.0	54.2	29.2	41.7	16.7	16.7	20.8	37.5

Tables' 8.3, 8.4 and 8.5 show the percentage of the top matches of the individual communities in the individual quadrats for all the study fragments.

Twenty-four fragments were surveyed, (Table 8.3), of which fourteen (58.3%) had mesotrophic grassland communities occurring as the first ranked community, whilst open vegetation communities had the highest number of first places on eight fragments

(33.3%). The four fragments of Stone Marsh surveyed produced the most mixed results with fragment 2a having three communities appearing with equal first place ranking, MG 7a *Lolium perenne – Trifolium repens,* OV 20 *Poa annua – Sagina procumbens* and S4 *Phragmites australis* with 20% each. Stone Marsh fragment 2b produced an unexpected result with scrub community W23 *Ulex europaeus – Rubus fruticosus* being the most commonly matched first place community.

Mesotrophic grasslands produced the highest percentage of first placed matches (61.3%) primarily on the Outer Thames Marshes where 78.9% of the first placed matches were mesotrophic grasslands. On the Inner Thames Marshes 41.6% of the first placed matches were mesotrophic grasslands, whereas Open Vegetation communities were first placed matches in 39.6% of the samples. There were 7.2% of the first placed matches, which were neither mesotrophic grasslands nor open vegetation communities, all but five of which were on the Inner Thames Marshes and comprised saltmarsh, sand dune or swamp communities (Table 8.5). The smaller fragments occurred within the Inner Thames Marshes and the results showed that open vegetation communities were more prevalent than mesotrophic communities within the Inner Thames Marshes, the hypothesis was therefore proposed that fragment size affected the community type. To test for a correlation between the area of fragment and the occurrence of mesotrophic grassland communities, Spearman's coefficient of rank correlation was calculated at 0.77. The result indicates a significant correlation between the area of a fragment and the occurrence of mesotrophic grassland communities, i.e. there is a tendency for mesotrophic communities to occur more frequently on larger fragments of grazing marsh.

Table 8.4 Open vegetation communities percentage of first matches for all individual quadrats

Fragment name	OV 8	OV 9	OV 10	OV 18	OV 19	OV20	OV 21	OV 23	OV 24	OV25	OV 26	OV 28
Erith 2a	-	-	-	-	-	4.0	8.0	-	-	-	-	-
Erith 2b	-	-	-	-	-	-	8.0	8.0	-	-	-	-
Erith 2e	-	-	-	-	-	-	-	20.0	-	-	-	
Crayford 1	-	-	-	-	-	-	-	12.5	-	-	-	12.5
Crayford 2a	-	-	-	-	-	-	8.3	20.8	-	-	-	4.1
Crayford 3a	-	-	-	-	-	14.3	28.5	-	7.1	-	-	14.3
Crayford 3b	-	-	-	-	-	14.3	7.1	78.6	-	-	-	-
Barnes Cray	-	-	-	-	-	-	-	-	30.0		-	60.0
Dartford	-	-	-	-	1.4	11.4	5.7	12.9	-	2.8	-	17.1
Dartford Fr	-	-	-	-	-	-	-	-	1.7	5.2	0.9	10.4
Stone 2a	-	-	-	-	10.0	20.0	-	10.0	-	-	-	-
Stone 2b	-	-	-	-	-	-	-	-	-	-	-	-
Stone 2c	-	-	-	-	-	-	-	-	30.0	-	-	70.0
Stone 2d	-	-	-	-	12.5	6.3	-	31.3	-	-	-	-
Swanscombe	-	-	-	15.4	-	-	7.7	11.5	-	3.8	-	15.4
Botany	3.2	6.5	3.2	-	3.2	-	3.2	25.8	9.7	-	9.7	3.2
Denton	-	-	-	-	-	-	21.4	35.7	-	-	-	-
Filborough	-	-	-	-	-	-	8.3	8.3	-	-	-	16.7
Shorne	-	-	-	-	-	6.9	5.9	-	-	1.0	-	8.8
Higham 1a	-	-	-	-	-	1.9	3.8	-	-	-	-	15.4
Higham 1c	-	-	-	-	-	-	-	6.3	-	-	-	6.3
Cliffe	-	-	-	-	-	1.3	-	-	-	-	-	13.9
Allhallows	-	-	-	-	-	3.3	-	-	-	-	-	-
Chetney	-	-	4.2	-	-	-	-	-	-	-	-	-
Percentage of sites where OV placed 1st	4.2	4.2	8.3	4.2	16.7	41.7	50.0	54.2	20.8	16.7	8.3	58.3

Of the MG communities proposed by ADAS (1997) and Benstead et al (1997), MG6 *Lolium perenne - Cynosurus cristatus* and MG7b *Lolium perenne – Poa trivialis* communities occurred in first place in at least one quadrat on 62.5% and 50.0% of the sites sampled respectively. MG6, MG7a and MG7b occur as a first match in at least one quadrat on 100% of the Outer Thames Marshes, with the exception of Denton Marsh, where MG7b was not recorded as a first match in any sample. MG7a *Lolium perenne – Trifolium repens* leys was the most frequently appearing first matched community occurring in first place in 19.5% of the samples matched. The Inner Thames Marshes generally showed closer matches with the Open vegetation communities (Table 8.4). OV21 *Poa annua – Plantago major,* OV23 *Lolium perenne – Dactylis glomerata* and OV28 *Agrostis stolonifera – Ranunculus repens* occurring as a first placed community in 52.2%, 52.2% and 60.4% of the individual quadrats respectively in the Inner Thames Marshes.

Table 8.5 records a range of other NVC communities that occurred as the first match in the individual quadrat survey. Swamp (S), Sand Dune (SD) and Saltmarsh (SM) communities occurred less frequently than mesotrophic grassland and open vegetation communities as a top matched community, with only SM28 *Elymus repens* saltmarsh, S4 *Phragmites australis* and S21 recorded as a first match community in over 10% of site samples. The results indicate that although the presence of these communities within the fragments is less dominant, they play an important role in determining the grazing marsh mosaic.

Saltmarsh communities were only found to occur in over 2% of the quadrats on 56.5% of the fragments surveyed. Although not representing a high constancy of occurrence the communities represented SM16, SM20 and SM28 are all upper saltmarsh communities (Rodwell 2000), and may reasonably be expected to occur as relict communities within a grazing marsh mosaic, and therefore a positive indicator of grazing marsh. From the tables of the MATCH analysis SM20 *Eleocharis uniglumis* and SM28 *Elymus repens* occur on nineteen (71%) and sixteen (66.6%) of the grazing marsh fragments respectively surveyed. Swamp communities (S) indicate the occurrence of areas of waterlogged ground, e.g. Dartford Fresh Marsh and Swanscombe

Marsh, or samples dominated by *Phragmites australis*, e,g, Stone Marsh 2a. The presence of these communities may also be indicative of the wetter areas that form the grazing marsh mosaic. Sand Dune communities (SD) were recorded on Stone Marsh 2b and Botany Marsh, both of which exhibited drier conditions than the other fragments surveyed.

Table 8.5 Other vegetation communities percentage first match for all individual quadrats

Fragment name	SM 16	SM 20	SM 28	SD 1	SD 3	SD 6	SD 7	SD 9	S4	S5	S 12	S 21	S22	W23
Erith 2a	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erith 2b	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erith 2e	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crayford 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crayford 2a	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crayford 3a	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crayford 3b	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Barnes Cray	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-
Dartford	-	-	4.3	-	-	-	-	-	1.4	-	-	-	-	-
Dartford Fr	-	-	1.7	-	-	-	-	-	2.6	1.7	2.6	-	14.8	-
Stone 2a	-	-	-	-	10.0	-	-	-	20.0	-	-	-	-	-
Stone 2b	-	-	10.0	-	-	-	10.0	20.0	-	-	-	-	-	30.0
Stone 2c	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stone 2d	-	-	-	-	-	-	-	-	25.0	-	-	-	-	-
Swanscombe	-	-	3.8	-	-	-	-	-	3.8	-	-	-	-	-
Botany	-	-	-	6.5	-	6.5	-	-	-	-	-	-	-	-
Denton	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Filborough	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shorne	-	-	-	-	-	-	-	-	-	-	-	2.9	-	-
Higham 1a	-	-	-	-	-	-	-	-	-	-	-	1.9	-	-
Higham 1c	-	-	-	-	-	-	-	-	-	-	-	6.3	-	-
Cliffe	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Allhallows	3.3	3.3	-	-	-	-	-	-	-	-	-	-	-	-
Chetney														
Percentage of sites where placed 1st	4.2	4.2	16.7	4.2	4.2	4.2	4.2	4.2	20.8	4.2	8.3	12.5	4.2	4.2

Table 8.6, records the overall occurrence of mesotrophic grassland communities and indicates that MG11 *Festuca rubra – Agrostis stolonifera – Potentilla anserina* is a key community of the North Kent Grazing Marshes occurring as a top ten match on 95.8%

Table 8.6 Match analysis of mesotrophic grassland communities showing coefficients of similarity.

	MG1	MG6	MG7a	MG7b	MG7c	MG7d	MG7e	MG7f	MG9	MG10	MG11	MG12	MG13
Erith 2a		46.6	48.5	43.4	39.2	38.4	40.7	39.9			46.3		
Erith 2b		41.6	42.9	35.3		36.7	37.9	38.5					
Erith 2e		46.9	41.0	45.5	37.6	38.2	36.8	38.9			43.6		
Crayford 1		49.8	59.1	53.3	51.4	49.1	53.8	54.9			50.2		
Crayford 2a		53.3	57.8	50.0	49.6	48.7	49.2	52.8			56.8		
Crayford 3a			44.0				40.3	39.7			45.9		
Crayford 3b							39.0	38.2			38.4		
Barnes Cray						36.4			39.9	38.0	47.4		36.0
Dartford			45.6				44.2	48.0			54.1		
Dartford Fresh									47.2	48.5	44.5		45.2
Stone 2a			36.3				35.3				40.4		
Stone 2b	30.3					30.1					30.4		
Stone 2c		41.6	56.4	45.7	37.3	47.4	48.1	49.6					
Stone 2d	36.3							35.9			37.5	37.5	
Swanscombe											38.7		
Botany	43.5								39.2		43.4		
Denton		42.6	40.7					40.6			47.6		
Shorne		46.6	44.2	45.3	41.4		41.5	44.1	41.5		46.7		
Filborough		37.8	43.1			37.0					40.4		
Higham 1a		40.5	47.1	41.9		38.1		36.3			42.4		
Higham 1c		43.9	43.0	43.6	35.6	36.3		35.7	35.1		41.7		
Cliffe		44.5	43.1	45.8	39.9			38.9	43.9	39.0	48.4		
Allhallows		50.2	43.4	43.4		42.7	41.3	44.1			46.0	38.4	
Chetney		43.8	42.4	51.3	41.2	43.9	41.8		39.5		42.0		
% of sites	12.5	58.3	70.8	50.0	37.5	54.2	54.2	66.6	29.2	12.5	95.8	8.3	8.3

Table 8.7 Match Analysis of Open Vegetation Communities showing coefficients of similarity.

	OV10	0V18	OV19	OV20	OV21	OV22	OV23	OV24	OV25	OV26	OV27	OV28
Erith 2a					47.0		51.0					
Erith 2b			36.1		44.3	37.4	53.7					
Erith 2e					42.8		44.5					
Crayford 1					50.7		62.5					
Crayford 2					52.3		60.3					
Crayford 3a			40.5	41.0	49.3		55.0	38.2				42.3
Crayford 3b	41.5	42.6	44.9		44.8	40.5	61.0		43.6			
Barnes Cray					37.0					42.0	35.3	46.5
Dartford	49.9		50.2		55.4	46.8	59.9		47.5			
Dartford Fresh					41.3		40.7			48.6		40.6
Stone 2a	39.5		36.8	42.9	45.9	36.1	45.8		38.4			
Stone 2b	37.7		32.7	29.2	37.5		35.7	31.9				
Stone 2c		39.5			40.4		52.6					
Stone 2d	37.8		38.9		35.5		48.7		36.7			
Swanscombe	36.9	34.0	35.4		39.3		39.4		33.9			31.1
Botany	38.5		43.8		44.4	38.4	45.8	38.3	43.1			
Denton	41.5		42.3		55.6	41.4	61.1		41.0			
Shorne					45.9		49.1					
Filborough	35.4		37.9		42.4	35.6	50.1		35.5			
Higham 1a	36.9				39.6		46.5		36.5			
Higham 1c					41.4		39.6					
Cliffe					41.4		44.7					
Allhallows					44.3		46.1					
Chetney							38.5					39.4
Percentage of sites	41.7	12.5	45.8	12.5	95.8	25.0	95.8	12.5	37.5	8.3	4.2	20.8

of the fragments surveyed, although only occurring as a first match in 1.9% of the samples. MG11 was not recorded on Erith Marsh 2b and Stone Marsh 2c.

MG6, MG7a, and MG11 are found consistently on the Outer Thames Marshes and at a coefficient of over 40% in all cases except for MG6 on Filborough Marsh (coefficient 37.8). Where MG6, MG7a and MG11 occur on the Inner Thames Marshes however, they appear at higher coefficients of similarity than on the outer marshes. MG7b *Lolium perenne – Poa trivialis* and MG7f *Lolium perenne – Poa pratensis* were both found on 75% of the Outer Thames Marshes, whereas they occurred on only 37.5% and 64.7% of the Inner Thames Marshes respectively. MG7e *Lolium perenne – Plantago lanceolota* was however more common on the Inner Thames Marshes occurring on 62.5% of the fragments, compared to just 37.5% of the Outer Marshes.

Table 8.7 highlights the community matches produced by the Czekanowski coefficient of similarity for the open vegetation communities. OV21 *Poa annua – Plantago major* and OV23 *Lolium perenne – Dactylis glomerata* were the most frequent, both occurring on 95.8% of the fragments surveyed, and being absent only from Chetney Marsh and Barnes Cray respectively. In situations where open vegetation communities matched 73.5% were within the Inner Thames Marshes area. Where open vegetation communities occurred on the Outer Thames Marshes the coefficients of match were lower than for the Inner Thames Marshes, and apart from OV21 and OV23 all coefficients for the Outer Marshes were below 40%.

Table 8.8 (Appendix 4) the individual quadrat analysis, shows that mesotrophic grassland communities account for 57% of the top ten matches produced by the MATCH programme, i.e. for every ten matches 5.7 were a mesotrophic grassland community. In the top ten matches for all of the individual fragments, 78.3% comprised mesotrophic grassland and open vegetation communities, with 60.9% of fragments having a greater number of mesotrophic grassland matches than open vegetation. Of the fragments surveyed 79.2% recorded more mesotrophic grassland communities in the top ten matches than any other community type. For the Outer Thames Marshes 100% of fragments recorded more mesotrophic grassland matches than open vegetation, whereas on the Inner Thames Marshes only 50% of fragments recorded more mesotrophic grassland communities than open vegetation..

Of the individual quadrat matches MG7B *Lolium perenne – Poa trivialis*, MG7A *Lolium perenne – Trifolium repens* and MG11 *Festuca rubra – Agrostis stolonifera – Potentilla reptans* were the most common occurring in 72.7%, 71.1% and 63.6% of samples respectively. Open vegetation communities occurred in 32.4% of the quadrats sampled, with OV23 (58.9%), OV21 (57.7%) and OV28 (54.2%) the most commonly occurring.

Of the other major NVC communities swamp (S) communities occurred in only 3.9% of samples, saltmarsh (SM) in 2.9% and sand dune (SD) in 1.5% of samples taken. Saltmarsh communities were however, recorded on 79.2% of the fragments surveyed, with SM 20 (12.6%) *Eleocharis uniglumis* and SM28 (12.5%) *Elymus repens* occurring in the most samples and saltmarsh communities are therefore considered a minor element of the grazing marsh mosaic. Sand dune communities were represented on

66.7% of the fragments surveyed and swamp communities occurred on 54.2% of fragments surveyed. With the exception of Stone Marsh fragment 2b, sand dune communities overall occurred in less than 5% of the samples taken for each fragment, and therefore these communities were not regarded as constant constituents of the grazing marsh mosaic.

Table 8.5 recorded the occurrence of W23 *Ulex europaeis – Rubus fruticosus* on Stone Marsh 2b as a first matched community. The result is reflective of the changing nature of a fragment where no recognisable grazing marsh management is currently being practiced and scrub woodland is developing through succession. The result is disregarded in terms of grazing marsh structure but is indicative of the changes that can occur to unmanaged fragmented grazing marshes.

8.3.2 Individual species Analysis.

The species composition of the vegetation communities recorded in the site surveys was compared to the diagnostic tables produced in Rodwell (1992 and 2000). For the purposes of comparison, it was decided that as grazing marshes are primarily lowland wet grassland (see Section 3.1), and community matches were more consistent with mesotrophic grassland communities, MG6, MG7a, MG7b and MG11, communities would be compared to the survey data in Tables 8.9 – 13. The results are then compared with the constancies recorded by the MATCH programme and the diagnostic community tables in Rodwell (1992, 2000). These four communities were recorded in over 55% of the matches (Table 8.6). The diagnostic tables used for comparison are derived from Rodwell (1992), and the tables record where the discrepancy between the constancy of species in the NVC and North Kent Marsh data, was two classes or more (Malloch 1999). The non-recording of species however, does not mean that the particular species is not present on the site, just that it did not occur within the samples, and therefore absence within the sample data should not be considered a reason for not including a community within the grazing marsh mosaic. The presence, absence under or over recording of species may be reflective of local conditions (Rodwell 1992).

Table 8.9 records those species that occur at a constancy of IV or V within the sample data, and are therefore, considered the major components of grazing marsh communities. Rye grass (*Lolium perenne*) and creeping bent (*Agrostis stolonifera*) are recorded at a high constancy (IV or V) across the whole of the North Kent Marshes, regardless of fragment size. Crested dogstail (*Cynosurus cristatus*), meadow barley (*Hordeum secalinum*) and timothy (*Phleum pratense*) are found at higher constancies across the Outer Thames Marshes (III or above), and are present on every fragment of the outer marshes studied, but occurring on 40%, 53.3% and 53.3% of the inner marshes respectively, (see Table 8.9 for constancy values). White clover (*Trifolium repens*) and divided sedge (*Carex divisa*) are also recorded on every outer marsh fragment studied. Divided sedge was however, not recorded on any of the inner marshes, and white clover was recorded on 75% of the Inner Thames Marshes fragments. *Festuca rubra* was recorded in sample data on 50% of the Outer Thames Marshes, but only 6.6% of the Inner Thames Marshes at a constancy of I, although the species surveys recorded *F. rubra* on a further 25% of the outer marshes.

Perennial rye grass (*Lolium perenne*) was recorded as the most consistent species occurring across the North Kent Marshes, present on every fragment surveyed and occurring at a maximum constancy (V) on 73.9% of the fragments. Any community that is representative of the North Kent Grazing Marshes should therefore be inclusive of improved grassland leys, e.g. MG6 *Lolium perenne – Cynosurus cristatus* and MG7 *Lolium perenne* leys, which both include rye grass as a dominant species. Creeping bent (*Agrostis stolonifera*) is recorded at a maximum constancy (V) on 43.4% of all fragments studied, and on 75% on the Outer Thames Marshes. The high constancy of *A. stolonifera* on the outer marshes therefore suggests that MG11is also an important grazing marsh community and along with MG6 and MG7 these communities should be considered as the basis for the matrix homogeneity of the grazing marsh structure.

Meadow barley (*Hordeum secalinum*) occurs on all of the Outer Thames Marshes at a constancy of at least 21-40% (II), and on 87.5% of the fragments, the constancy is at either IV (61-80%) or V (81-100%), indicating that *H. secalinum* should be considered as a grazing marsh community constant. On the Inner Thames Marshes, *H. secalinum* is present on 50% of the fragments surveyed, albeit at a lower constancy (see Table 8.9), and is absent from Stone, Swanscombe, Botany and Dartford Fresh Marsh. There is currently no community specified in Rodwell (1992) that includes *H. secalinum* at any level of constancy. The implication is therefore that, as *H. secalinum* occurs consistently across the North Kent Marshes, being absent only from the wetter sites (Dartford Fresh Marsh) and the most fragmented and developed (Stone Marsh), the species should be considered as a major component of any grazing marsh community.

Tables 8.10 – 8.13 highlight the species, which are over or under recorded in the site surveys as compared to Rodwell's diagnostic tables, along with those species, which do not appear in the site surveys. The tables for MG6, MG7a and 7b highlight that creeping bent (*Agrostis stolonifera*) was over recorded in the site surveys when compared to the NVC, on 82.6% (MG6), 95.6% (MG7a) and 83.3% (MG7b) of the sites respectively, whereas MG11 is under-recorded on 17.4% on the surveyed fragments. In contrast, rye grass (*Lolium perenne*) is over recorded for MG11 on 73.9% of the fragments surveyed, but under-recorded at an average of 13% of fragments for communities MG6, MG7a and MG7b on the North Kent Marshes.

MG6 *Lolium perenne – Cynosurus cristatus*, (Table 8.10), shows that the community constant for *Cynosurus cristatus* is under-recorded on 52.2% of the fragments and was not recorded on 43.4% of fragments. It was present at a higher constancy on the Outer Thames Marshes (III) than the Inner Marshes (I). *Trifolium repens* was under-recorded on 73.4% and unrecorded on 13.0% of fragments. Both species were however, recorded on 56.5% and 82.6% of all fragments studied. *Festuca rubra* was unrecorded in 73.9% of the samples and under-recorded on the remainder. On the Inner Thames Marshes, *F. rubra* was unrecorded in the quadrat data, although separate species surveys recorded a presence on 71% of the fragments surveyed. As *F. rubra* is expected to occur in 61-80% of the samples (Rodwell 1992), the low-recording in the samples indicates that on the Inner Thames Marshes, unfavourable site conditions due to fragmentation, have resulted in *F. rubra* occurring less frequently. The presence of *F. rubra* at a constancy of III or above should however, be regarded as a positive indicator of grazing marsh condition.

Table 8.9 Constancy values for the main species recorded in the site surveys

	E2a	E2b	E2e	C1	C2	C3a	C3b	D	Dfm	S2a	S2b	S2c	S2d	Sw	B	De	F	Sh	H1a	H1c	Cl	A	Ch
Agrostis stoloinefera	IV	II	V	IV	V	V	V	IV	II	III	II	I	V	III	III	III	V	V	V	III	V	V	V
Hordeum secalinum	III	I	V	I	II	I	I	I	-	-	-	-	-	-	-	II	V	IV	V	V	IV	IV	IV
Cynosurus cristatus	I	I	II	I	I	-	-	-	-	-	-	-	-	-	I	II	I	III	III	IV	III	III	III
Phleum pratense	II	-	IV	III	II	I	I	I	-	-	-	-	-	-	I	III	IV	V	III	IV	IV	IV	IV
Dactylis glomerata	I	-	I	III	II	-	-	-	I	-	-	V	II	-	I	I	II	II	I	I	I	I	-
Lolium perenne	V	V	V	V	V	V	V	V	II	III	-	V	-	V	II	V	V	V	V	V	V	V	V
Trifolium repens	III	IV	IV	III	II	II	II	II	I	I	-	IV	-	-	I	III	II	I	II	II	I	II	II
Carex divisa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I	II	III	II	I	II	II
Holcus lanatus	I	-	-	III	II	II	I	I	III	I	-	-	II	-	I	-	I	I	I	-	I	I	III
Festuca rubra	-	-	-	-	-	-	-	-	I	-	-	-	-	-	-	-	-	-	-	I	I	I	I

Constancy values are as defined by Rodwell (1992):

V	a species present in 81-100% of samples:	IV	a species present in 61-80% of samples
III	a species present in 41-60% of samples:	II	a species present in 21-40% of samples
I	a species present in 1-20% of samples	-	species not recorded in quadrat surveys

Table 8.10 Comparison of the species constants of NVC community MG6 with their occurrence in the site survey records.

	E2a	E2b	E2e	C1	C2	C3a	C3b	Bc	D	Dfr	S2a	S2b	S2c	S2d	Sw	Bo	De	F	Sh	H1a	H1c	Cl	A	Ch
Lolium perenne (V)								**		**		*		*										
Cynosurus cristatus (V)	**	**	**	**	**	*	*	*	*	*	*	*	*	*	*	**	**	**	**	**		**	**	**
Trifolium repens (V)	**			**	**	**	**	**		**	**	*		*	*	**	**	**	**	**	**	**	**	**
Holcus lanatus (IV)	**	*	**			**	**	**	**		**	*	*	**	*	**	*	**	**	**	*	**	**	
Cerastium fontanum (IV)	*	*	**	**	**	*	*	*	**	*	*	*	*	*	*	**	**	*	**	**	**	**	**	**
Festuca rubra (IV)	*	*	*	*	*	*	*	*	**	**	*	*	*	*	*	*	*	*	*	**	*	**	**	**
Dactylis glomerata (III)	**	**	**			*	**	*		**	*	*	++		*					**	**	**	**	*
Poa pratensis (III)		*	**	*	*	*			**			**			*	*	**	*						
Agrostis stolonifera (I)	++		++	++	++	++	++	++	++		++			++	++	++	++	++	++	++	++	++	++	++
A. capillaris (III)		**		**	**	*	**		**	**			*		**	*	*							
Phleum pratense (I)		*	++	++		*	*	*			*	*	*	*	*			++	++	++	++	++	++	++
Hordeum secalinum (0)	++		++														++	++	++	++	++	++	++	++

Figures in brackets represent constancy classes (Rodwell 1992)

* Species not recorded on site ** Species under recorded by two constancies or more less

++ Species over recorded by two constancies or more blank indicates species recorded at NVC constancy

Table 8.11 Comparison of the species constants of NVC community MG7a with their occurrence in the site survey records.

	E2a	E2b	E2e	C1	C2	C3a	C3b	Bc	D	Dfr	S2a	S2b	S2c	S2d	Sw	Bo	De	F	Sh	H1a	H1c	Cl	A	Ch
Lolium multiflorum (II)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
L. perenne (V)								**		**	**	*		*		**								
Agrostis stolonifera (0)	++	++	++	++	++	++	++	++	++	++	++	++		++	++	++	++	++	++	++	++	++	++	++
Agrostis capillaris (I)	++		++			*		++			++	++	*			*	*	++		*	*		++	
Dactylis glomerata (III)	**	*	**			*	**	*		**	*	*	++		*	**				**	**	*	**	**
Phleum pratense (II)		*	++			*	*	*			*	*	*	*	*				++		++		++	
Trifolium repens (III)		++						**			**	*		*	*	**			**			**		
T. pratense (II)	*					*		*			**	*					*	*						*
Hordeum secalinum (0)	++		++														++	++	++	++	++	++	++	++

Figures in brackets represent constancy classes (Rodwell 1992)

++ Species over recorded by at least two constancies

** Species under recorded by at least two constancies

* Species not recorded on site

blank indicates species recorded at NVC constancy

Table 8.12 Comparison of the species constants of NVC community MG7b with their occurrence in the site survey records.

	E2a	E2b	E2e	C1	C2	C3a	C3b	Bc	D	Dfr	S2a	S2b	S2c	S2d	Sw	Bo	De	F	Sh	H1a	H1 c	Cl	A	Ch
Lolium perenne (V)								**		**		*		*		**								
Holcus lanatus (III)		*	*				**		**		**	*	*		*	**	*	**		**	*	**	**	
Festuca rubra (I)	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*						
Dactylis glomerata (IV)	**	**	**		**	*	**	**	**	**	*	*			*	**	**		**	**	**	**	**	*
Poa pratensis (I)	*	*		*			*				*			*	*									*
P. trivialis (V)	*	*	*	**	*	*	*	**	**		*	**	**	*	*	**	*	*	**	**	**	**		*
Agrostis stolonifera (I)	++		++	++	++	++	++	++	++		++			++	++	++	++	++	++	++	++	++	++	++
A. capillaris (III)		**		**						*			*		**	**								
Phleum pratense (IV)	**	**			++	**	*	**	**	**	**	*	*	*	**	**	*							
Hordeum secalinum (0)	++	++	++				*	*		*		*	*	*	*	*	++	++	++	++	++	++	++	++
Plantago lanceolota (I)							++	*				++	++	++			++							
Taraxacum spp. (II)		++						*					**	**										
Trifolium repens (V)				**	**	**		**		**	**	**		**	**	**	**	**	**	**		**		

Figures in brackets represent constancy classes (Rodwell 1992)
* Species not recorded on site ** Species under recorded by two constancies or more less
++ Species over recorded by two constancies or more blank indicates species recorded at NVC constancy

Table 8.13 Comparison of the species constants of NVC community MG11 with their occurrence in the site survey records.

	E2a	E2b	E2e	C1	C2a	C3a	C3b	Bc	D	Dfr	S2a	S2b	S2c	S2d	Sw	Bo	De	F	Sh	H1a	H1c	Cl	A	Ch
Festuca rubra (IV)	*	*	*	*	*	*	*	*	**	**	*	*	*	*	*	*	*	*	*	**	*	**	**	**
Agrostis stolonifera (V)										**		**	**		**									
Agrostis capillaris (I)	++		++			*		++			++	++	*			*	*	++					++	
Potentilla reptans (I)																								
Lolium perenne (III)	++	++	++	++	++	++	++	**	++	**		**	++	**	++		++	++	++	++	++	++	++	++
Trifolium repens (III)		++						**			**	*		*	*	**			**			**		
Holcus lanatus (II)	*	*	*			*		*				*	*		*		*				*			
Poa pratensis (II)	*	*		*	*	*	*				*			*	*	*	*	*						**
Phleum pratense (I)		*	++	++		*	*	*			*	*	*	*	*			++	++	++	++	++	++	++
Hordeum secalinum (0)	++		++														++	++	++	++	++	++	++	++

Figures in brackets represent constancy classes (Rodwell 1992)

++ Species over recorded by two or more constancies
** Species under recorded by two or more constancies
* Species not recorded on site blank indicates species recorded at NVC constancy

MG7a *Lolium perenne- Trifolium repens* leys (Table 8.11) is a relatively species poor community (Rodwell 1992), with only *L. perenne* present at a constancy level of 81-100% (V). In the survey, *L. perenne* was under-recorded on 17.4% and unrecorded on 8.7% of fragments, these sites were degraded marsh as Stone Marsh 2a, 2b, and Botany Marsh or contained waterlogged areas, e.g. Barnes Cray, Dartford Fresh Marsh and Stone 2d. Cocks'foot (*Dactylis glomerata*) and white clover (*Trifolium repens*), both occur at a constancy of 41-60% (III) in the diagnostic tables but were under-recorded on 34.8% and 21.7% of fragments respectively and unrecorded on 30.4% and 13% of fragments respectively

Creeping bent (*Agrostis stolonifera*), meadow barley (*Hordeum secalinum*) and common bent (*A. capillaris*) were generally over recorded (Table 8.11) in the surveys. The two former species are not recognised as components of the MG7a community by the NVC, and are therefore over recorded on whichever fragment they occur. *A. capillaris* was recorded as having a constancy of I (present in 1-20%) on all of the sites surveyed and is therefore only a minor component and therefore any variation in its occurrence is not very significant. This can be seen in Table 8.11, where *A. capillaris* is over recorded there is no pattern or similarity between the fragments.

MG7b *Lolium perenne – Poa trivialis* occurred in 72.8% of the matches for mesotrophic grasslands, and although the Czekanowski coefficient of similarity was below 50 in 87% of matches, the consistency of occurrence across both the Inner and Outer Thames Marshes indicate that MG7b as a potential component of the grazing marsh matrix. Table 8.12 records the species constants in the site surveys and again indicates the high constancy of *L. perenne* and *A. stolonifera* on all the fragments. The over recording of both meadow barley (*Hordeum secalinum*) and timothy (*Phleum pratense*), particularly on the Outer Thames Marshes and the under-recording or absence of Yorkshire fog (*Holcus lanatus*), smooth meadow grass (*P. pratensis*) and cock'sfoot (*D. glomerata*) have resulted in the lower level of match with MG7b. The consistent presence of *L. perenne* and close similarity in the constancies of some of the lesser community components red clover (*T. repens*), and common bent (*A. capillaris*) and the overall presence of timothy (*P. pratense*) are reasons for the consistent occurrence of the community in the matches. *Poa trivialis* a species constant was under recorded on 41.6% and not recorded on 50% of the fragments surveyed. Only Dartford Fresh Marsh and Allhallows Marsh recorded *P. trivialis* at a constancy of III or greater.

MG 11 *Festuca rubra - Agrostis stolonifera – Potentilla reptans* (Table 8.13) was the most consistently recorded mesotrophic grassland community recorded in the matching process. On an individual species basis, Table 8.13 shows a greater level of consistency in the species constants than the MG6 and MG7 communities do. The major exceptions are the absence and under-recording of *F. rubra*, and the over recording of rye grass (*L. perenne*). Additionally meadow barley (*H. secalinum*) and timothy (*P. pratense*) were both consistently over recorded on the Outer Thames Marshes in terms of MG11 species.

8.3.3 Invasive Species – Analysis

Invasive plant species are defined as those species, which have a high reproductive output, are easily dispersed, have a fast growth rate and have a wide tolerance, (generalist/ruderal species) (Grime et al 1988). On grazing marshes, they include dock (*Rumex spp.*), thistle (*Cirsium spp.*), ragworts (*Senecio spp.*) and nettle (*Urtica dioica*), and they are regarded as negative indicators of grazing marsh status (Robertson and Jefferson 2000). There are however, some invasive species e.g. dandelion (*Taraxacum spp*), autumn hawkbit (*Leontodon autumnalis*), which are recorded in the community diagnostic tables of Rodwell (1992, 2000) as being associated with communities albeit at a low constancy of I or II and should therefore, occur only occasionally in the samples. Where these species begin to occur at a higher constancy in the North Kent Marshes then they again may be regarded as indicating a change to the described community.

Table 8.2 shows the MATCH correlation coefficients for all fragments and the vegetation communities associated with the fragments. Open vegetation communities (OV) recorded a high number (41.7%) of matches in the sampling data, and these communities can be regarded as indicating the occurrence of a greater number of invasive species on the respective fragments.

Figure 8.3.1 shows the occurrence and cover of invasive species on the individual fragments studied. No score was recorded for Great Clane Marsh as having been converted to arable production; technically this marsh has 100% cover of alien species, when compared to typical grazing marsh conditions.

On the Inner Thames Marshes 50% of the fragments surveyed, recorded a score over the mean value of 2.24 for invasive species (Fig 8.3.1), whereas 77.8% of the Outer Thames Marshes were below the mean value for invasive species. The Inner Thames Marshes when analysed separately had a mean score of 2.54 for invasive species, and although only 37.5% of the fragments studied scored greater than this value, overall 69.5% of the fragments recorded a cover of invasive species of at least 25% (i.e. a score of 2 or more). The Outer Thames Marshes scored much lower for invasive species with 33% of fragments surveyed recording a cover of invasive species of less than 10%.

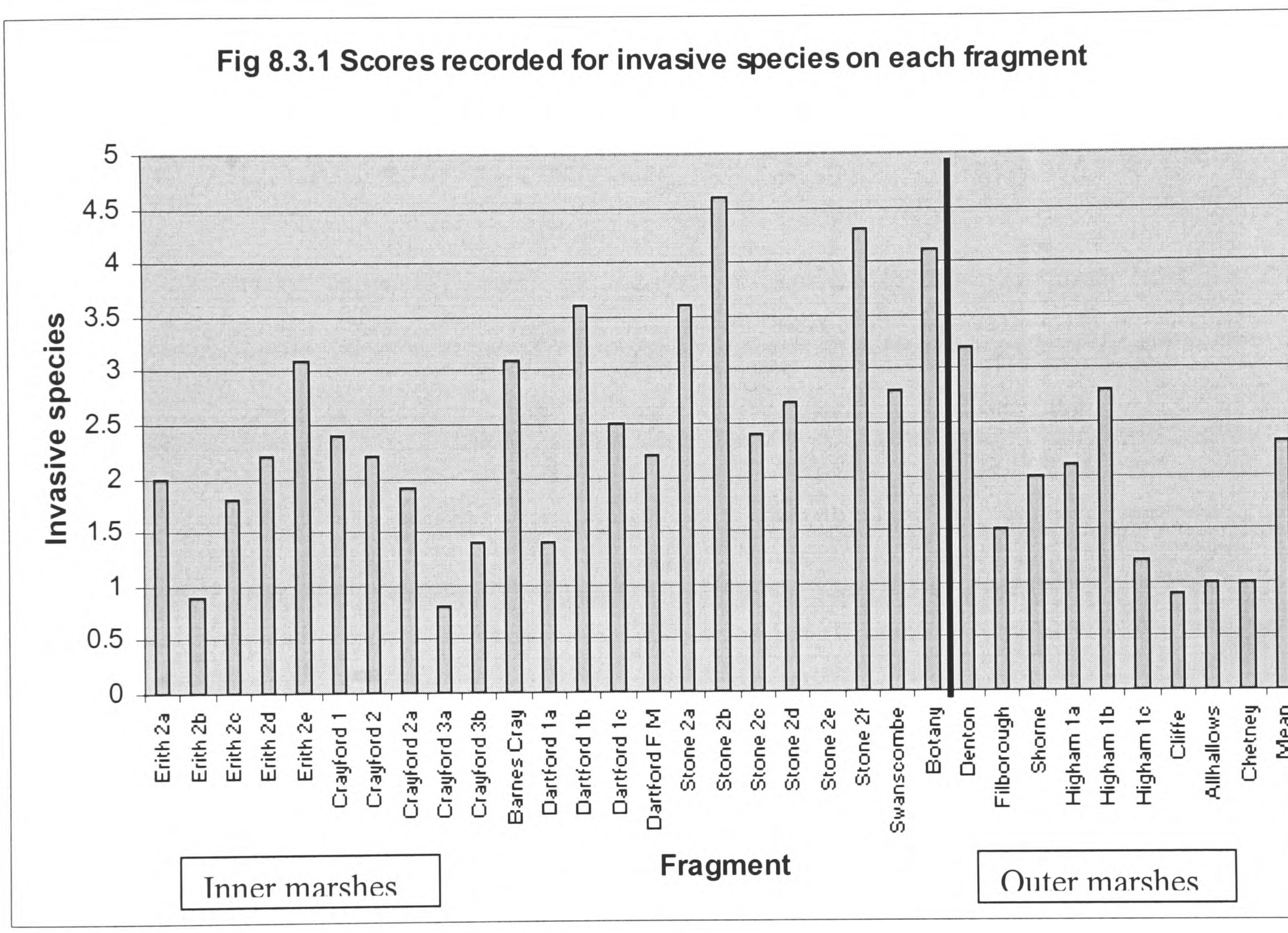
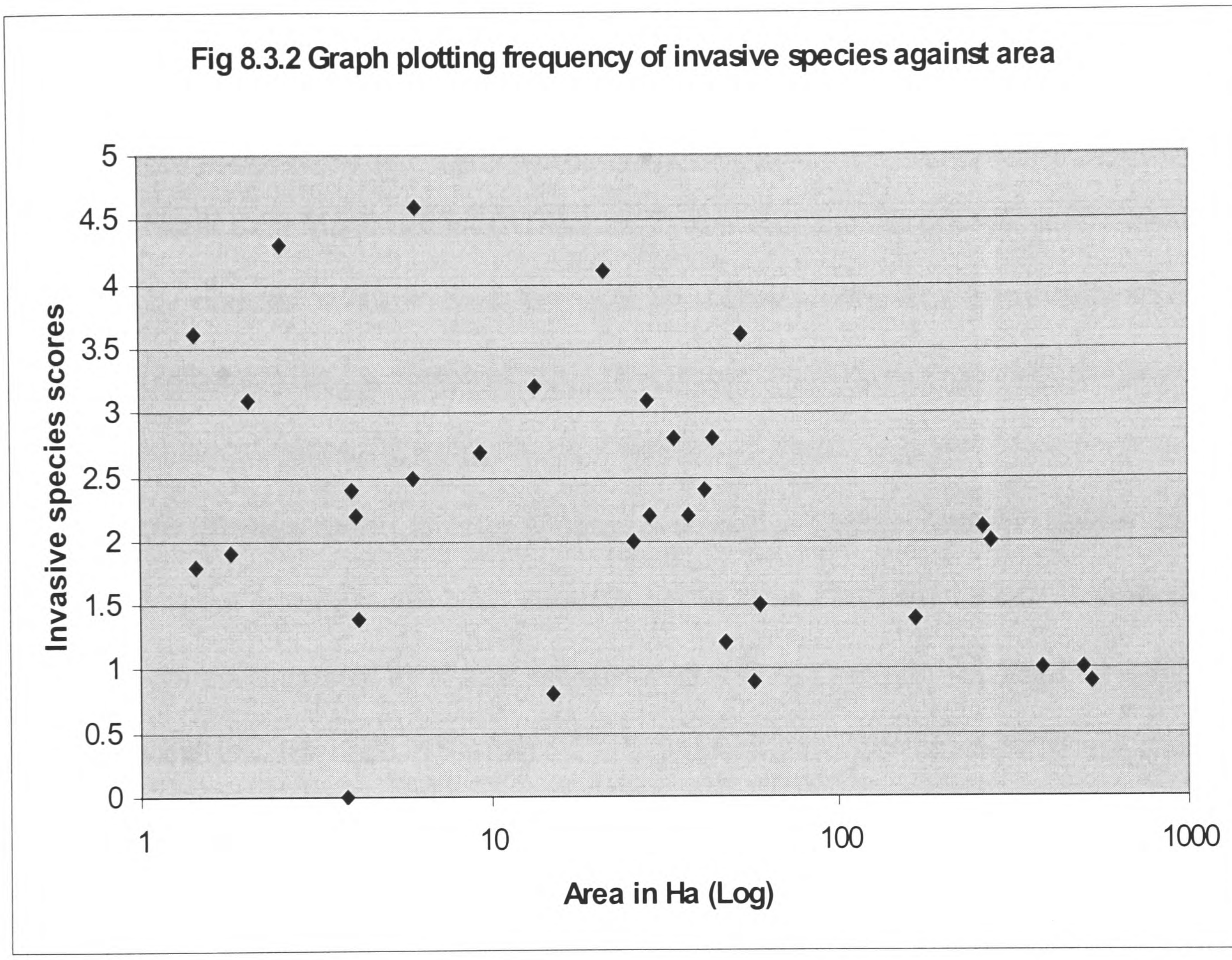


Fig 8.3.1 Scores recorded for invasive species on each fragment

To test the hypothesis that there is a relationship between the cover of invasive species and the area of fragment Spearman's coefficient of rank correlation was calculated. The coefficient of correlation 0.269 was too low, showing that there is no significant correlation between the two variables at the 95% level. This is illustrated by Stone Marsh fragment 2e, one of the smaller fragments (2.52ha), having no cover of invasive species, although this results more from management and amenity planting than an affinity to grazing marsh. Similarly, large fragments e.g. Swanscombe Marsh (43.76ha) a larger fragment recorded over 50% cover of invasive species. Fig 8.3.2 shows that there is no definitive relationship between the frequency of invasive species and the area of a fragment.



To test the hypothesis that there is a relationship between the cover of invasive species and the edge/area ratio of a fragment Spearman's coefficient of rank correlation was calculated. A low coefficient of correlation 0.211 was recorded between edge/area ratio and invasive species, indicating that there is no relationship between the two variables. The results were influenced by fragments like Stone Marsh 2e, which has an area/edge ratio that ranked as the second highest (301.19), but as above no invasive species cover. The occurrence of invasive species on grazing marsh fragments is therefore not directly related to area or area/edge ratio, but must be symptomatic of other factors such as management and edge effects (Section 8.4).

8.4 Vegetation Communities and species – Discussion.

The difficulty in determining which communities are considered as positive indicators of grazing marshes was highlighted in Section 3.1.1. Problems arise because grazing marshes have not having been regarded as separate vegetation units in previous plant community studies e.g. Tansley (1939) and Rodwell (1992). The monitoring report for the North Kent Marshes ESA (ADAS 1997) indicated a group of communities, which can be expected to occur across the North Kent Grazing Marshes, specifically MG6, MG7a/b and MG11a. Benstead et al (1997) however, devised a specification for seeding marshland to recreate grazing marsh, which incorporated rye grass (*Lolium perenne*), red fescue (*Festuca rubra*), timothy (*Phleum pratense*) and white clover (*Trifolium repens*), with target grazing marsh NVC communities of MG6, MG7 and MG13. This thesis uses the criteria suggested by MAFF and Benstead et al and from the results of the sampling and analysis described in Section 5.2.2, to propose the key communities which make up the grazing marsh habitat mosaic, i.e. the communities of the lowland grassland matrix and the communities that arise from the landscape features described in Sections 7.6 – 7.9. The aim is to identify and describe the 'appropriate mosaic of communities' that makes up the North Kent Grazing Marshes as referred to by Delaney (1991).

Results indicated a wide range of community matches occurring as top NVC matches on the surveyed fragments. The degree of similarity varied from 33.1% on Swanscombe Marsh (OV28, S4, S18) to 62.5% on Crayford Marsh fragment 1 (OV23). Sanderson et al (1995) considered a match coefficient of over 60% to be relatively high and therefore a good match, because of the relative number of factors, e.g. soil, management, which influence the presence and absence of plant species (ibid). As only 2% of the matches in this study had a coefficient of similarity over 60%, a coefficient of similarity below 40%

whilst indicating a poor match overall, in the context of grazing marshes, communities with low coefficients of similarity may be of importance, because the nature of the grazing marsh habitat is to produce a habitat mosaic with a variety of communities comprising that mosaic. Half of all the matches (50.4%) produced a coefficient of similarity between 40 – 50%, and in this study are considered to be good matches.

Results of the MATCH analysis for the fragments surveyed record a mix of best-fit communities for the North Kent Grazing Marshes, primarily grouped within either mesotrophic grasslands or open vegetation communities. The tables in Section 8.3.2 show that the most commonly occurring mesotrophic grassland communities found on grazing marshes were: -

MG6 *Lolium perenne – Cynosurus cristatus* 53.9% of fragments;

MG7a *Lolium perenne – Trifolium repens* leys 71.1% of fragments;

MG7b *Lolium perenne – Poa trivialis* 72.8% of fragments;

MG11 *Festuca rubra – Agrostis stolonifera – Potentilla reptans* 63.6% of fragments;

OV20 *Poa annua – Sagina procumbens*, OV21 *Poa annua – Plantago major* and OV23 *Lolium perenne – Dactylis glomerata* were the most commonly occurring open vegetation communities on the North Kent Marshes. These provide evidence that communities regarded by Rodwell (2000) as 'weedy communities' may either form part of the traditional grazing marsh mosaic or have become common as the result of fragmentation. Evidence from the Outer Thames Marshes and those marshes managed under the ESA scheme, where MG communities are dominant indicate that they are more common within the grazing marsh mosaic, and that OV communities do not constitute a part of the mosaic.

The variation in community matches overall supports Delaney's (1991) definition that grazing marshes comprise an 'appropriate mosaic of communities', and the implication that several communities are involved in comprising the matrix of the grazing marsh and that different communities will arise from the landscape features that comprise the homogeneous-heterogeneous mosaic. It is anticipated therefore that a series of community matches with lower coefficients of similarity will arise from samples taken for a grazing marsh fragment as a whole, reflecting the micro scale heterogeneity of grazing marshes (Section 7.6). As a result, low coefficients of similarity may be just as important as high coefficients as indicators of the grazing marsh mosaic. The 'appropriate mosaic' for grazing marsh should therefore comprise a range of communities found consistently within the coefficients of similarity and which occur frequently within individual quadrat samples.

MG6, MG7a/b and MG11 were all target communities for grazing marsh described by ADAS (1997) and Benstead et al (1997). The frequency with which these mesotrophic grassland communities occur in the individual samples provides evidence to support the recommendations and criteria produced by ADAS (1997) and Benstead et al (1997). Both ADAS (1997) and Benstead et al (1997) indicate that MG11 *Festuca rubra – Agrostis stolonifera – Potentilla reptans* is the dominant community and with MG11 occurring on 95.8% of the fragments surveyed and within 63.6% of the individual samples, there is evidence to suggest that this community will constitute the grazing marsh matrix. Benstead et al (1997) describe MG6 and MG7 communities occurring within areas that have been improved and intensively managed, and ADAS (1997) recorded the two community groups as occurring in 35% of the stands surveyed. MG6 and MG7 communities can therefore also be considered to comprise part of the grazing marsh matrix, but at a lesser frequency than MG11. Results from the surveyed fragments again provide evidence that MG6 and MG7 communities will comprise areas within the matrix that represent the more intensively managed grazing marsh remnants.

Although the coefficients of matching may not be regarded as being high, i.e. falling between 40-50%, low coefficients do not necessarily mean that these vegetation communities do not represent the North Kent Grazing Marshes as, the low coefficient may result from the communities represent intermediary sub-communities or that the sampling is over emphasising locally occurring species (Malloch 1999). In the North Kent Marshes, the high occurrence of local species, *H. secalinum* and *C. divisa* are affecting the coefficients of similarity produced by the MATCH analysis, and therefore indicating that modifications to the existing NVC communities are required to fully describe the grazing marsh mosaic of the North Kent Marshes.

MG13 *Agrostis stolonifera – Alopecurus geniculatus,* a target community of the RSPB occurred in 39.6% of the individual samples, with the highest representation on those fragments with a high score for rills, e.g. Dartford Fresh Marsh, Cliffe Marsh. These results indicate therefore that MG13 appears to best represent the grazing marsh that occupies areas around the rills and drainage ditches.

For grazing marshes to retain the homogeneous-heterogeneous structure, they need to exhibit the full range of landscape characteristics and features discussed in Section 7 if they are to encompass the range of community types that comprise the mosaic. The results of the MATCH analysis reflected a difference between the Inner Thames Marshes (Erith – Botany Marshes) where open vegetation communities are predominant and the Outer Marshes (Denton – Chetney Marshes) where the mesotrophic grasslands were more common. Although there was a significant correlation at the 95% significance level between fragment size and the occurrence of mesotrophic grasslands, maintaining the landscape features which are responsible for the mosaic of communities would appear to be a much more crucial factor in the occurrence of the different community groupings. Fragmentation however, creates the conditions through which the eventual loss of these features occurs.

The differences between the inner and outer marshes may also reflect an historical difference in the vegetation of the two regions. Garrad (1954) for example, recorded a distinction between the inner and outer marshes based on soil type, although an earlier study by Stapledon and Davies (1940) singled out Cliffe Marsh as being different from the other marshes of North Kent, based on the quality of the improved rye grass (*Lolium perenne*) pastures. Historical evidence is therefore not completely conclusive in drawing a distinction between the inner and outer marshes. It is evident however, that the whole of the North Kent Marshes over the past sixty years have been dominated by a mix of bent grasses (*Agrostis spp.*) and rye grass (*L. perenne*), the main constants of mesotrophic grassland communities. It has been assumed therefore, that communities such as MG6, MG7 and MG11, where *L. perenne* and *Agrostis spp* are the dominant species, form the basis of the grazing marsh mosaic.

The high occurrence of the bent grasses and in particular creeping bent (*Agrostis stolonifera*) (Table 8.9) is consistent with past records (Garrad 1954). Historically all the sites in this survey, with the exception of Swanscombe Marsh, were described by Stapledon and Davies (1940) as *Agrostis* with ryegrass pastures. Creeping bent (*Agrostis stolonifera*) does not occur at a constancy of greater than II in any MG6 or MG7 sub-community (Rodwell 1992), whereas across the North Kent Marshes *A. stolonifera* occurs with constancy of III or above on every fragment except Stone Marsh 2a and 2b (Table 8.9). In establishing the community mosaic for the North Kent Marshes therefore, *Agrostis spp.* will need to be considered as one of the main component species of the grazing marsh mosaic occurring with a constancy of III or greater (Table 8.9), and therefore, a proposed modification to communities MG6 and MG7 to fit grazing marshes is required.

Rye grass (*Lolium perenne*) occurs as a constant species across all of the fragments sampled, and is recorded at a constancy of III or above on 75% of the fragments surveyed (Table 8.9). The presence of rye grass (*L. perenne*) at these levels of constancy is probably the reason for the high number of matches with communities MG6, MG7 and OV23, where *L. perenne* is the predominant species (Rodwell 1992, 2000). Comparison with the diagnostic tables for mesotrophic grasslands shows that the lower constancy values (I – III) are being influenced by the presence or absence of a few species in the site surveys. Communities MG7a/f and MG11 in the site surveys show a higher than expected occurrence of two species, crested dogstail (*Cynosurus cristatus*), and meadow barley (*Hordeum secalinum*) which are not listed in the MG7a/f and MG11 NVC diagnostic (Tables 8.11 and 13). These species occurred at a high constancy of III or IV on the Outer Thames Marshes from Denton to Allhallows (Table 8.9). These species may therefore be components of the ideal North Kent Grazing Marshes plant communities and not invasive species. Divided sedge (*Carex divisa*), was recorded in the survey data on 85.7% of the Outer Thames Marshes, but on none of the Inner Thames Marshes. On 62.5% of marshes *C. divisa* occurred at constancy of II or above, however *C. divisa* is not recorded in the NVC. *C. divisa* is regarded as a species, characteristic of the North Kent Marshes (Kent BAP 1997), as well as being nationally scarce (Davidson 1991, Gee 1998), divided sedge should therefore be regarded as a community associate in the grazing marsh mosaic at constancy of II, and as a regional variation of a mesotrophic grassland community. The inclusion of *C. divisa*, in these grasslands therefore requires the modification of the typical NVC MG7 or MG11 community.

Species included in the constancy tables, but either under recorded or unrecorded in the site surveys includes false oat grass (*Arrhenatherum elatius*), the presence of which may be indicative of lower levels of management. Italian rye grass (*Lolium multiflorum*), is recorded with a constancy value of II in MG7 communities (Rodwell 1992), but is not recorded on any of the study site. The result supports the comments of Garrad (1954) who stated that Kentish rye grass was more favoured in seed mixes and could better withstand the close grazing that had been practised in the past. A further suite of species associated with MG7 communities; which occur regularly in the diagnostic tables for mesotrophic grasslands Rodwell (1992), were not recorded in the site surveys. Of these species common sorrel (*Rumex acetosa*) and soft broom (*Bromus hordeaceus*) are not typical of wetland sites (Grime et al 1988). Whereas, sweet vernal grass (*Anthoxanthum odoratum*) prefers the more acidic soils found in upland areas rather than lowland wet grassland (ibid), and is unpalatable to stock (Hubbard1992) and is therefore unlikely to occur in improved or semi-improved grasslands. The absence of these species from the fragment surveys is therefore to be expected and although this may influence the coefficient of similarity, their absence is not regarded as being of importance when determining the grazing marsh mosaic.

The high occurrence of *H. secalinum, Cynosurus cristatus* and *Carex divisa* across the North Kent Marshes indicates as shown in Table 8.9 that they should therefore be considered as the key indicators of the grassland communities typical of North Kent. Creeping bent (*Agrostis stolonifera*) occurs as a major constant of MG11 and MG13 communities, both of which are found consistently across the North Kent Marshes. MG13 *Agrostis stolonifera – Alopecurus geniculatus* is an inundation community (Rodwell 1992) that would be appropriate for the rills that form part of the micro scale heterogeneous homogeneity of a grazing marsh. The absence of marsh foxtail (*Alopecurus geniculatus*) in the samples taken on the inner marshes where many of the rills are drier and colonised by competitors, e.g. Erith Marsh 2b and 2e, may explain the reduced number of matches that the community achieved. *A. geniculatus* should be regarded as a positive indicator of grazing marsh condition, typical of areas where surface water is retained. Where drainage has been impeded and wet flushes are more extensive, hard rush (*Juncus inflexus*) and soft rush (*J. effusus*) become more extensive (Milsom et al 2000), as on Dartford Fresh Marsh and Chetney Marsh, a change towards an MG10 *Holcus lanatus – Juncus effusus* rush pasture is indicated (Rodwell 1992). The occurrence of *Juncus spp* at a constancy of >III may however, be regarded as negative indicators of grazing marsh condition, as they arise not only from waterlogging, but also from undergrazing (Benstead et al 1997), (see Page 420, for model of grazing marsh and implications of fragmentation).

Rodwell (1992) describing the physiognomy of MG6 *Lolium perenne – Cynosurus cristatus* states that *C. cristatus* can be rarer in pastures with a high level of management, and remains a "subsidiary species". Results in this study tend to support Rodwell's premise, with *C. cristatus* occurring less frequently in the managed pastures of the ESA. Yorkshire fog (*Holcus lanatus*) and cock's-foot (*Dactylis glomerata*) can become more "prominent in coarse tussocks where pasture is undergrazed" and *H. lanatus* can be abundant around areas of dunging (Norris et al 1998). Erith Marsh fragment 2b and Shorne Marsh both recorded conditions, which support the community descriptions of Rodwell. Red fescue (*F. rubra*) and common bent (*Agrostis capillaris*) according to Rodwell (1992) are frequent in long established pastures, both species are under recorded in the surveys but maintain a presence on the outer marshes. *F. rubra* however, is infrequent or absent from the majority of the inner marshes, which indicates that fragmentation has brought about disturbance to the long established pastures causing the decline in value of *F. rubra* as an indicator of grazing marsh within the inner marshes.

MG7 *Lolium perenne* leys are generally improved grasslands treated to produce a range of species-poor swards that are highly productive and used for grazing (Rodwell 1992). Improvement of the North Kent Grazing Marshes through drainage, and increased use of fertilisers and herbicides (Williams et al 1983, Williams and Hall 1987) resulted in swards, with high similarity to the community descriptions of MG7. Differences to MG7 arise because of the variety of habitats that occur across grazing marshes, i.e. wet hollows and drier counter walls. The sub-community MG7a occurs on 70.8% of all the sites and 100% of the Outer Thames Marshes and thus gives support to the specification produced by the RSPB (1997) for recreating grazing marshes (Section 5.2.1). *Lolium* *perenne – Trifolium repens* leys MG7a however, should include cock's-foot (*D. glomerata*) at a constancy of III. The RSPB specification excludes *D. glomerata*, which may indicate that their ideal grazing marsh condition precludes the occurrence of *Dactylis glomerata,* probably because the moisture content is too great for this species.

Shorne and Filborough Marshes recorded *D. glomerata* at a constancy of II (present in 21-40% of samples), indicating therefore that these sites maybe under grazed and drier than other grazing marsh sites and therefore undergoing a change in vegetation structure. These conditions and the presence of *D. glomerata* have therefore affected the MATCH results for these samples leading to better matches with open vegetation communities rather than the mesotrophic grasslands, OV23 occurring as the best match on Filborough and Shorne Marshes. The occurrence of *D. glomerata* at a constancy of greater than II should be regarded as a negative grazing marsh indicator. Overall, the high constancy of community MG7a throughout the North Kent Marshes surveyed indicates that it should be one of the positive indicators of a grazing marsh community, although modifications to the constancy of secondary species, such as *D. glomerata,* will need to be included.

MG7b *Lolium perenne – Poa trivialis* leys are according to Rodwell (1992) more species rich, and along with timothy (*Phleum pratense*) are often used in seed mixes for moister soils, and found mainly in the north of England. The high constancy of *Dactylis glomerata* and *Holcus lanatus* has influenced the similarity of match for this community, both species which indicate drier conditions (Grime et al 1988). *P. pratense* is included in the Benstead et al (1997) grazing marsh specification, at a constancy of I. Results in this study indicate a much higher constancy of IV (Table 8.9), i.e. in closer accordance with the diagnostic of Rodwell (1992). The MG7b community was included by ADAS (1997) in the North Kent Marshes ESA monitoring report, but was found only in one sample area. Low recording of community constants *Poa trivialis, Alopecurus pratensis* and *Festuca pratensis* on all the fragments surveyed therefore, indicates that this community should not considered as part of the grazing marsh mosaic.

MG7c/d are described by Rodwell (1992) as being found on seasonally flooded lowland river valleys and may equate to the 'drowning fields' described by Harvey (2001). Rodwell (1992) describes MG7d as a 'community commonly used as hay meadow. It is most characteristic of moist and fertile alluvial soils in lowland river valleys'. The low constancy of meadow foxtail (*A. pratensis*), which occurred across the study fragments at a constancy of I, whereas Rodwell (1992) included *A. pratensis* as a community constant (i.e. constancy V), probably accounts for a lower match than the may be expected to this community. MG7c/d are therefore not considered as part of the North Kent Grazing Marshes mosaic.

MG7e *Lolium perenne – Plantago lanceolata* grasslands in a more mature stage finds *L. perenne* becoming replaced by Yorkshire fog (*H. lanatus*) and cock's-foot (*D. glomerata*), (Rodwell 1992), again common across the North Kent Marshes. The main herbs of this community i.e. greater plantain (*Plantago major*), dandelion (*Taraxacum agg.*), common mouse-ear (*Cerastium fontanum*), daisy (*Bellis perennis*) and creeping buttercup (*Ranunculus repens*) however, all occur at lower constancies than in the diagnostic tables. The presence of rosette forming species, e.g. Ribbed plantain (*P. lanceolota*) and greater plantain (*P. major*), indicate that this community is likely to occur in areas where trampling occurs, and as such is likely to be present across the North Kent Marshes around gateways and feeding sites, and the low recording of the appropriate species results from fewer samples being taken within these areas. MG7e is therefore likely to be a peripheral community of grazing marshes, occurring around gateways and drinking areas, and is therefore not considered as part of the overall matrix because many of the constant species for the community are indicators of drier conditions than would be expected to occur on the ideal grazing marsh. A high occurrence of community MG7e is therefore regarded as a negative indicator of grazing marsh, but one which may indicate a direction of change in the community structure resulting from over grazing and trampling.

MG7c *Lolium perenne – Alopecurus pratensis* occurs at a lower frequency in the MATCH tables than the other MG7 communities and therefore is not considered to be a suitable community for the North Kent Grazing Marshes.

The tendency to improve the swards of the North Kent Grazing Marshes in the post World War II period with rye grasses (Garrad 1954) reinforces the argument for MG7 communities to be included within the typical communities of the area. In the community physiognomic descriptions of Rodwell (1992), all MG7 communities are referred to as having an association with or easily converted to MG6 *Lolium perenne – Cynosurus cristatus* communities. The high constancy of *C. cristatus* (III or above) across all the marshes and the usage in sown agricultural grasslands (Grime et al 1988) indicates that communities and sub-communities of MG6 may be more appropriate than MG7 in describing the ideal vegetation of the North Kent Grazing Marshes. Although

MG7a (70.8%) was recorded on more fragments than MG6 (58.3%), MG6 recorded a higher coefficient of similarity on all the outer marshes, with the exception of Filborough Marsh and Higham 1a, and lower coefficients of similarity on the inner marshes.

Rodwell (1992) stated that less intense management would cause MG7 communities to revert to MG6. Under ESA management agreements, the proscribed level of management may encourage *C. cristatus* to become more frequent within the sward and indicate a reversion from MG7 to MG6. Results for the ESA fragments surveyed generally recorded higher matches for MG6 than MG7, which indicates that MG6 should be considered as one of the main constituents of the grazing marsh mosaic. Grasslands of the North Kent Marshes may then be referred to as semi-improved grasslands, which would be a more indicative description of their ideal condition.

Table 8.9 highlighted species that have been commonly found across the North Kent Marshes at higher constancies than recorded by Rodwell (1998). Any definitive North Kent Marsh community structure therefore needs to take account of the higher than expected occurrence of these species. Key indicative communities that are appropriate to the North Kent Marshes should therefore include sub-communities of both MG6 and MG7. Creeping bent (*Agrostis stolonifera*) does not occur at a constancy of greater than II in any MG6 or MG7 sub-community discussed by Rodwell (1992), whereas across the North Kent Marshes *A. stolonifera* occurs with constancy of III or above on 82.6% of fragments studied, (Table 8.9). Meadow barley (*Hordeum secalinum*) does not appear in any sub-community diagnostic (Rodwell 1992), whereas it occurs with a constancy of at least III on 87.5% of the Outer Thames Marshes fragments. Timothy (*Phleum pratense*) occurs at a higher constancy on a majority of sites than recorded in the NVC diagnostic tables, with the exception of MG7b *Lolium perenne – Poa trivialis* leys. These three species were found to be the main constant species within the vegetation communities, particularly on the larger fragments of the ESA managed North Kent Marshes, and therefore should be considered as either community constants (*A. stolonifera, H. secalinum*) or associates (*P. pratense*).

MG11 *Festuca rubra - Agrostis stoloifera – Potentilla reptans* is a community that occurs where a wide range of moist, free-draining circumneutral soils are frequently inundated by fresh or brackish water (Rodwell 1992). All three species occur in the NVC at a constancy of III or more, but only *A. stolonifera* occurred at a constancy of III or greater on 79.2% of the sites surveyed. *F. rubra* and *P. anserina*, although recorded throughout the North Kent Marshes, primarily on the outer marshes, occur within the quadrat survey at a constancy of I or II. The associate MG11 species such as rye grass (*Lolium perenne*), white clover (*Trifolium repens*) and yorkshire fog (*Holcus lanatus*), appear at a constancy of III or above, which indicates a closer match to sub-community MG11a *Lolium perenne* than MG11. The *Lolium perenne* sub-community is described by Rodwell (1992) as 'including stands inundated by fresh or brackish water and have been improved by artificial fertiliser', therefore the community would be appropriate for inclusion as a matrix community for the North Kent Marshes.

The constancy with which the remaining associate species e.g. *Dactylis glomerata* (II), *Ranunculus repens* (II), and *Agrostis capillaris* (II) occur on all of the fragments surveyed, is also indicative of an MG11a sub-community. Meadow barley (*Hordeum secalinum*), timothy (*Phleum pratense*), crested dog's-tail (*Cynosurus cristatus*) and divided sedge (*Carex divisa*) are not recorded in the NVC as occurring in MG11 or any of its sub-communities. MG11 was the most frequently matched community within the study sites (95.8%), which indicates that the community is one of the constituent communities of the North Kent Marshes. The inclusion of a range of species not deemed characteristic of MG11 however, is indicative that a variant of MG11 or MG11a is considered as an important constituent of the North Kent Grazing Marsh mosaic, i.e. MG11d *Lolium perenne – Carex divisa* sub-community.

The fragments managed under the Environmentally Sensitive Areas scheme have been assumed to provide the clearest indication as to the ideal grazing marsh in terms of ecology, vegetation composition and landscape characteristics and features. Rye grass (*Lolium perenne*), creeping bent (*A. stolonifera*), common bent (*A. capillaris*), meadow barley (*H. secalinum*), crested dogstail (*Cynosurus cristatus*), timothy (*Phleum pratense*), divided sedge (*C. divisia*) and white clover (*Trifolium repens*) were found to occur at the highest constancies (III – V) across all the Outer Thames Marshes including the ESA. *Lolium perenne, Agrostis stolonifera* and *Hordeum secalinum* were all recorded at constancy IV or V (except for *A. stoloifera* on Higham Marsh 1c), on the ESA managed marshes and as these marshes are regarded as being typical of the ideal grazing marsh condition, these species are recorded as community constants. *Cynosurus cristatus, Phleum pratense* and *Trifolium repens* are community associates.

The inclusion of the additional constant species, i.e. *Hordeum secalinum* and *Agrostis stolonifera* therefore, variations to the sub-communities of the NVC are proposed as North Kent Marsh community types, along with those existing ones such as MG7a *Lolium perenne – Trifolium repens* leys. In addition to MG11d, it is proposed that an additional MG6 sub-community should be introduced as MG6d *Lolium perenne – Cynosurus cristatus, Hordeum secalinum* variant. Where *C. cristatus* is less dominant in the sward then an additional MG7 sub-community MG7g *Lolium perenne – Agrostis stolonifera – Hordeum secalinum* grassland would be appropriate. Within these classifications, the diagnostic tables should reflect the frequency with which *H. secalinum* (IV), *C. cristatus* (III), *C. divisia* (II) and *Phleum pratense* (IV) occur. The proposed communities are derived by using the matched communities produced by the Czekanowski coefficient of similarity and comparing species constancies with the diagnostics in the NVC.

To establish a group of indicative communities that are representative of the North Kent Grazing Marshes therefore, the composition of the Outer Thames Marshes and the ESA need to be considered. In the survey data recorded in Tables 8.2 and 8.8 mesotrophic grassland communities predominate. These communities form the basis of key community structure as suggested by ADAS (1997) and Benstead et al (1997). MG6 *Lolium perenne – Cynosurus cristatus* was the top matched community on two sites Higham Marsh 1c and Allhallows Marsh, MG7a *Lolium perenne – Trifolium repens* leys was top ranked on Higham Marsh 1a. Chetney Marsh recorded the highest mesotrophic grassland match with MG7b *Lolium perenne – Poa annua* at 51.3%. Cliffe Marsh top matched with MG11 *Festuca rubra – Agrostis stolonifera – Potentilla reptans* at 48.4%.

The top matches with MG6, MG7a/b and MG11 indicate that these communities as suggested by ADAS and RSPB are important elements of the ideal grazing marsh structure. Surveys by ADAS (1997), recorded MG6, MG7 and MG11 communities, with one MG6 sub-community *Trisetum flavescens* (MG6c) and two MG7 sub-communities *Lolium perenne – Trifolium repens* (MG7a) and *Lolium perenne – Poa trivialis* (MG7b), the main communities described as the 'predominant vegetation types' (ibid). The ADAS survey highlights communities that comprise the grazing marsh matrix, although MG6c *Lolium perenne – Cynosurus cristatus; Trisetum flavescens* sub-community, may be indicative of drier areas. As discussed by ADAS (1997) their survey provides a baseline, although none of the communities identified in the survey however, represent the landscape features that contribute to the grazing marsh mosaic. ADAS (1997) also recognise that poor NVC matches occur due to the presence of *Carex divisa* and *Hordeum secalinum*, but no alternatives for the North Kent Marshes are proposed. For these reasons new sub-communities are added to the baseline communities to include the constant and characteristic species of the North Kent Marshes and to be more representative of the landscape features, which are part of the grazing marsh mosaic.

Coastal grazing marsh communities identified by the Benstead et al (1997) have MG11 *Festuca rubra – Agrostos stolonifera – Potentilla anserina* grasslands as the matrix plant community. Managed lowland wet grassland however, is shown as having MG7 *Lolium perenne* leys as the matrix (Benstead et al 1997). There is still therefore a conflict between the two habitats, which are often regarded as being the same, i.e. whether they are improved, semi-improved or unimproved. The RSPB guidelines (Benstead et al) do however include communities that relate to the grazing marsh landscape features, discussed in Section 3.1.1, notably MG9 *Holcus lanatus – Deschampsia cespitosa* grasslands and MG10 *Holcus lanatus – Juncus effusus* rush – pasture associated with tussocky grassland, and MG13 *Agrostis stolonifera – Alopecurus geniculatus*, or S22 *Glyceria fluitans* found in wetter hollows and rills. The results of this survey showed that MG9 would be an inappropriate community type as *H. lanatus* is never more than an associate community member and *D. cespitosa* occurs infrequently, whereas MG10 constant *J. effusus* is a common feature of tussocks on the fragments surveyed. MG10 may therefore be a good indicator of the wetter rills and hollows of the grazing marsh mosaic. Both communities MG13 and S22 (*Glyceria fluitans*), were suggested for the wetter areas by the Benstead et al (1997) and obtained good matches on the North Kent Marshes in this study, although S4 *Phragmites australis* occurred more frequently than S22 (*G. fluitans*). The preference for S22 relates more to a lack of management, which has allowed *P. australis* to become dominant on some marshes, e.g. Swanscombe Marsh.

Section 3.2.1 discussed the creation of grazing marshes by the inning of the original saltmarshes, which occurred along the Thames estuary. On several of the North Kent Marshes, saltmarsh still maintains a presence outside the embankments with the best formations at Crayford, Dartford, Swanscombe, Higham and Allhallows. There is therefore a vestige of saltmarsh communities remaining within the current vegetation of the North Kent Grazing Marshes. SM20 and SM28 communities are examples of vegetation from upper saltmarsh and their presence alludes to the past history of the North Kent Marshes as well as providing evidence of an affinity to saltmarsh as discussed by Delaney (1991) and the Kent Biodiversity Action Plan (1997). The presence of saltmarsh communities is therefore regarded as a positive indicator for the condition of grazing marsh. Neither ADAS nor Benstead et al included saltmarsh communities within their grazing marsh mosaic, although Benstead et al suggested MG12 *Festuca arundinacea* as an upper saltmarsh sward. The results of this survey do not support the inclusion of MG12 in the grazing marsh mosaic, because it appeared in less than 1% of the samples. Both SM20 *Eleocharis uniglumis* and SM28 *Elymus repens* saltmarsh communities were found in this study to occur on 79.1% of the fragments surveyed and therefore are considered to comprise part of the grazing marsh mosaic rather than MG12 as suggested by Benstead et al (1997).

The occurrence of swamp communities (S) can be expected on sites, which become heavily waterlogged, as is the case with Barnes Cray and Dartford Fresh Marsh, and therefore indicate a direction of change away from ideal grazing marsh conditions. S4 *Phragmites australis* communities are the most commonly occurring, appearing on 21.7% of the sites surveyed. The occurrence of common reed (*Phragmites australis*) across the North Kent Marshes, particularly within the drainage ditches, is very common, however where drainage has become impeded *P. australis* has come to dominate larger areas, e.g. Swanscombe Marsh and Dartford Fresh Marsh. On the two fragments of Stone Marsh, the level of *P. australis* is higher than would be expected because overflow vegetation from drainage ditches has come to dominate an area of the fragments. As the overall areas of the Stone Marsh fragments are under 10ha, a disproportionate number of quadrats become included within the survey and may have therefore influenced the overall results. Overall, the high occurrence of swamp (S) communities is indicative of a waterlogged site and a negative indicator of grazing marsh, although within the habitat mosaic, swamp communities may be found within the rills or the ditch side communities of the riparian zone.

The inclusion of sand dune communities within the matching analysis is to be expected because of the range of community constants found across the samples, e.g. *Rumex crispus* (SD1), *Arrhenatherum elatius, Poa pratensis, Dactylis glomerata* and *Cirsium arvense* (SD9), *Agrostis stolonifera, Potentilla anserina, Ranunculus repens* and *Trifolium repens* (SD17) (Section 8.3.1). As the occurrence of sand dune communities within the sample matching is generally below 1%, (Table 8.8), sand dune communities are not considered as a constituent of the grazing marsh mosaic. Community constants such as false oat grass (*Arrhenatherum elatius*) and smooth meadow grass (*Poa pratensis*) in SD9, scentless mayweed (*Tripleurospermum maritimum*) in SD3, smooth meadow grass (*P. pratensis*) and common cat's-ear (*Hypochoeris radicata*) in SD7 and curled dock *(Rumex crispus)* in SD1 were all found consistently across the sites surveyed.

Determination of the indicative key communities of the North Kent Marshes therefore requires, crested dog's tail (*C. cristatus*), meadow barley (*H. secalinum*), timothy (*P. pratense*), and creeping bent (*A. stolonifera*) to be considered as community constants along with rye grass (*L. perenne*). Divided sedge (*Carex divisa*) is a nationally scarce species and characteristic of the North Kent Marshes and should therefore, be included as a regional sub-community for grazing marshes.

It is therefore proposed that the ideal community structure for grazing marshes in North Kent should be: -

A matrix comprising: -

MG7g *Lolium perenne – Hordeum secalinum – Phleum pratense* grassland;

or

MG6d *Lolium perenne – Cynosurus cristatus;*
Hordeum secalinum – Phleum pratense sub-community

and

MG11d *Festuca rubra – Agrostis stolonifera – Potentilla reptans;*
Lolium perenne - Carex divisa sub-community.

MG7g is expected to be the predominant habitat type reflecting the fact that many of the North Kent Grazing Marshes have been improved and *L. perenne* is recorded as the dominant species in the site surveys; the major community should therefore reflect the fact. As management becomes less intensive, *C. cristatus* is expected to become more extensive (Rodwell 1992), and therefore an MG6 variant to reflect the occurrence of *H. secalinum* and *C. divisa* is proposed, i.e. MG6d. The drier areas and tussocky grassland of the mosaic should also be indicated by the MG6d variant *Lolium perenne – Cynosurus cristatus* grassland. MG11d would become more dominant where the soil retains moisture from inundation.

The areas of the mosaic, which comprise the rills and wet hollows, should be indicated by the presence of: -

MG13 *Agrostis stolonifera – Alopecurus geniculatus* inundation grassland;

MG10 *Holcus lanatus – Juncus effussus* pasture;

S4 *Phragmites australis*

S22 *Glyceria fluitans*

SM28 *Elymus repens* saltmarsh community.

The presence of the above individual communities would be dependent on the level, time and length of inundation, and to an extent situation on the marsh, i.e. S22 would be found in areas that are inundated over a longer period than MG10, but the presence of S22 on any fragment is regarded as a positive indicator of grazing marsh. Where communities such as MG10 become too prominent, i.e. over 40% cover, it may indicate that the grazing marsh is undergrazed and that rushes such as *Juncus effusus and J. inflexus* are becoming too dominant. SM28 *Elymus repens* is included as a relict saltmarsh community and is preferred to SM20 *Eleocharis uniglumis* in so far as *E. uniglumis* was not recorded on any of the fragments surveyed, whereas *E. repens* was found on 75% of the fragments. Jefferson and Grice (1998) also suggested SM28 as a community of grazing marshes and therefore further support the inclusion within the grazing marsh mosaic. The relationship between communities and changes induced by fragmentation are shown in Figure 8.4.3 on Page 429.

Survey results showed a distinction between the Inner and Outer Thames Marshes, with mesotrophic grassland (MG) communities predominant on the outer marshes and open vegetation (OV) communities occurring more frequently on the inner marshes (Table 8.8). The occurrence of open vegetation communities on a grazing marsh is an indication that vegetation indicative of weedy pastures (OV10/23), gateways (OV19/21), paths (OV21/22), abandoned intensive arable land (OV25) and urban habitats (OV23) are infiltrating the community structure. OV communities are therefore, regarded as negative indicators of grazing marsh condition.

Divisive fragmentation has led to many fragments of the North Kent Marshes being bounded by road verges (edges), recreational areas, resown sites and waste ground. Where fragmentation has been extensive therefore, e.g. on the Inner Thames Marshes, the opportunity and conditions necessary for the establishment of species common to open vegetation communities, e.g. *Poa annua, Plantago major* and *Senecio vulgaris* has occurred. OV23 *Lolium perenne – Dactylis glomerata*, which was the most commonly occurring open vegetation community, occurring on 95.6% of sample matches is described as being 'found commonly in mosaics of other grasslands and weed communities, on verges, recreation and waste ground', (Rodwell 2000).

The high occurrence of OV23 across the fragmented marshes reflects a mergence between the initially improved MG7 *Lolium perenne* leys and a more neglected state. Open vegetation communities therefore indicate a move away from lowland wet grasslands to drier and less managed conditions, and have therefore, not been included within the ideal grazing marsh mosaic. The community description of OV23 as discussed by Rodwell (2000), does not however imply that it should be included within a mosaic of lowland wet grasslands. OV23 is therefore generally a negative indicator of grazing marsh condition. This community may become prevalent around the edges of smaller fragments or where the fragment abuts a road, e.g. Filborough Marsh.

Grime et al (1988) classify the primary invasive species, as competitors to competitive – ruderal species. These strategies will undoubtedly influence the structure of the grazing marsh. Fragmentation creates smaller areas (Andren 1994), that are more disturbed and with longer edges and greater area/edge ratios (Farina 1998), which create opportunities for competitive plant species to obtain a foothold within the grazing marshes. The subsequent lack of or uncontrolled grazing management on the smaller fragments has afforded the opportunity for the competitive species to establish themselves across the remainder of the fragment. As competitive species such as plantains (*Plantago spp.*), nettle (*Urticia dioica*), thistles (*Cirsium spp.*), hawkbits (*Leontodon spp,*) and dandelion (*Taraxacum officinale*) become more prevalent, they exert greater influence on the overall community structure, and therefore there is a shift from MG to OV communities. For example, Erith Marsh fragments 2a and 2b reflect these changes in community structure, where OV23 occurred as the community with the highest coefficient of similarity, 51.0 and 53.7 respectively.

Invasive species change the composition of the community structure and these species can then be used to monitor the effects of fragmentation and how the process influences the community structure. The more commonly occurring species comprise a group of grassland weeds including dock (*Rumex spp.*), ragworts (*Senecio spp.*), cow parsley (*Anthriscus sylvestris*) and nettle (*Urtica dioica*) (Robertson and Jefferson 2000), and are regarded as negative indicators of grazing marsh. Results from this study record a consistent presence of these species on all fragments surveyed, with higher frequencies recorded on the more fragmented inner marshes, which indicates a greater degree of change. The Inner Thames Marshes also recorded a higher percentage of matched OV communities, which have been identified as negative indicators of grazing marsh, and therefore these results can be regarded as supporting Robertson and Jefferson's comments regarding evidence of change in grassland communities.

Most plant communities are susceptible to invasion (Crawley 1987) and it has been suggested by Planty – Tabacchi et al (1996) that riparian zones are more sensitive to invasion. Although grazing marshes are not totally riparian they include such habitats within their mosaic, and therefore the susceptibility of the whole grazing marsh habitat is increased. Effects of invasion are undoubtedly increased either by connectivity by drainage ditches or from fragmentation by the construction of roads and resultant disturbance, which increases the connectivity of isolated fragments.

Fragmentation has however, created an increased number of grazing marsh fragments, each with longer edges, greater edge/area ratio and more disturbed areas, therefore fragmentation has created more opportunity for invasive species to obtain a foothold within the remnant fragments. The tests for correlation between area and invasive species however, showed no significant relationship at the 95% level between the two variables, thus supporting the findings of Planty – Tabacchi et al (1996), i.e. area does not influence the presence of invasive species. There was no correlation shown between edge/area ratio and invasive species cover, which differed from the results of Planty – Tabacchi et al (1996), who found that sites with higher edge-area ratios did have a higher percentage of invasive species in the riparian zone. As this study focused on the whole grazing marsh habitat, the edge – area ratio was found to be not as influential in effecting invasibilty of the whole fragment.

Fragmentation has led to considerable disturbance, which can be related to the invasibility of fragments (Sousa 1984), and Ashton and Mitchell (1989) described disturbance and habitat alteration as a mechanism to explain why habitats become susceptible to invasion. Fragmentation within the North Kent Marshes has created extensive disturbance and therefore given the opportunity for invasive species to increase their cover as reflected by the community match results for the Inner Thames Marshes (Fig 8.4.1). The increase in invasive species in the Inner Thames Marshes is also reflected in the changes recorded in Tables 8.2, 8.3, 8.4 and 8.8, which show mesotrophic grassland communities predominant in the Outer Thames Marshes to those of open vegetation, which were described by Rodwell (2000) as 'weedy communities', recording the greater presence in the Inner Thames Marshes.

Fragments of the Inner Thames Marshes at Erith, Crayford, Dartford and Stone confirm that garden escapees, e.g. Buddleia (*Buddleia davidii*), sweet-pea (*Lathyrus odoratus*), poppy (*Papaver spp.*), and unfortunately Japanese Knotweed (*Reynoutria japonica*) influence their flora. Intrusive, regressive and enveloping fragmentation caused by urbanisation and landscaping to new developments is responsible for the escape and dispersal of these species into neighbouring grazing marsh fragments of many garden species. The presence of these non-native species is therefore a negative indicator of grazing marsh condition.

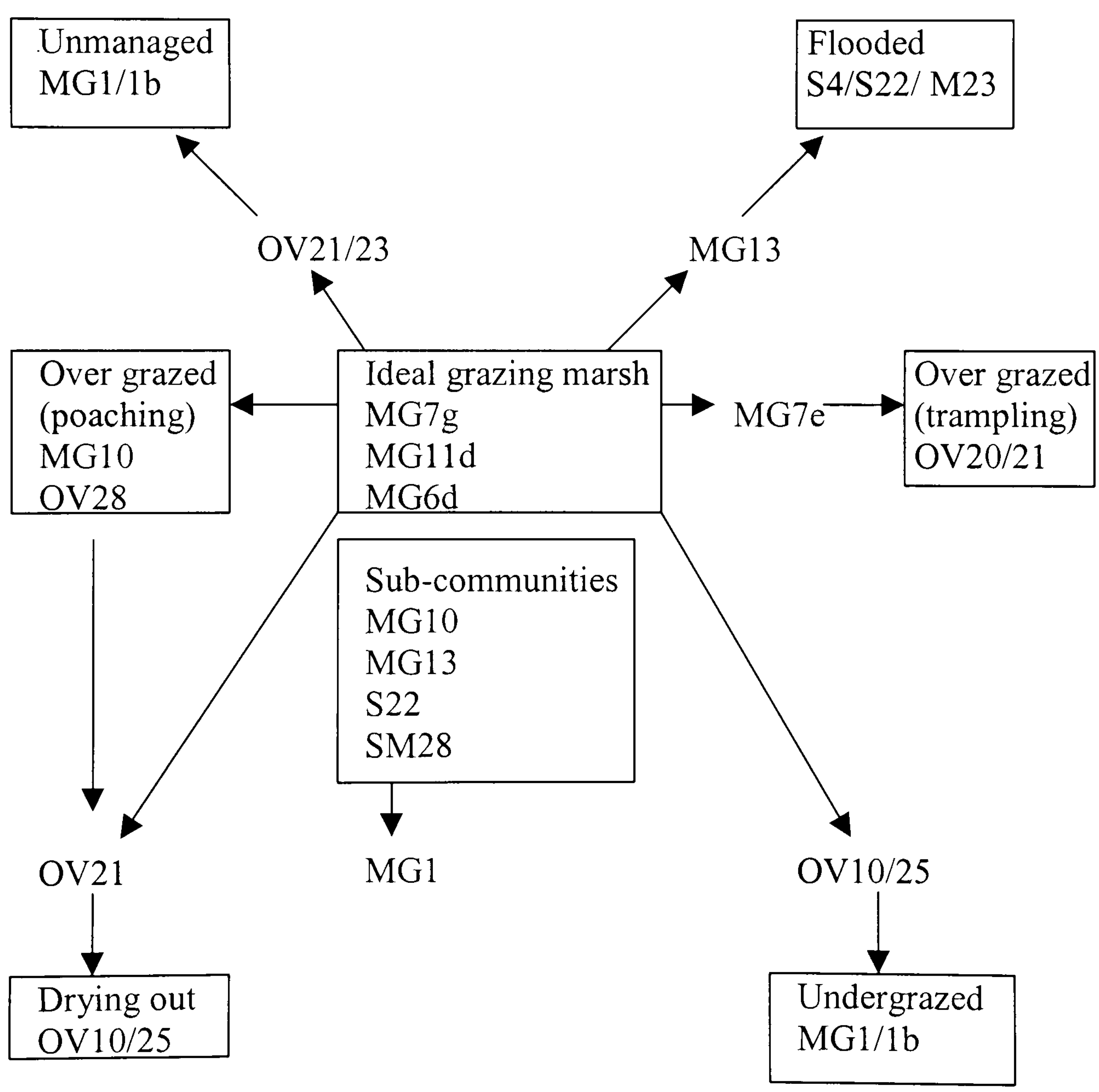
The lack of any management regime is resulting in the invasion on to many of the smaller sites e.g. Erith Marsh, from a suite of ruderal species, e.g. ragworts (*Senecio spp.*), and thistles (*Cirsium spp.*). Invasive species such as plantains (*Plantago spp.*), knotgrass (*Polygonum aviculare*) and procumbent pearlwort (*Sagina procumbens*) typify the poached areas found around water holes and walkways, colonising the many bare patches left by animal movements. Whereas, nettle (*Urticia dioica*), thistle (*Cirsium *spp.*), curled dock (*Rumex crispus*) and broad leaved dock (*R. obtusifolius*) are evident in areas that may have been over fertilised in past years, or where heavy dunging occurs (Vickery et al 2000). These above species are also commonly found establishing themselves on ditch dredging, where the depositions of silt forms a bund which when having dried out provides the opportunity for nettle, thistles etc to become established. The presence of ragworts (*Senecio spp.*) and thistle (*Cirsium spp.*) evidence selective grazing and their occurrence though not typical of grasslands (Grime et al 1988) indicate a move away from typical lowland wet grassland habitats towards the open vegetation communities that feature strongly in the community analysis (see section 8.4). The presence of the invasive species discussed above at a cover of >10% indicates the condition of a grazing marsh is in decline and are therefore negative indicator species.

Amongst the open vegetation communities discussed by Rodwell (2000) are weed assemblages and vegetation of disturbed and colonising habitats (e.g. OV10 *Poa annua – Senecio vulgaris*, OV25 *Urtica dioica – Cirsium arvense*). In many respects, an accurate description of the current condition of many of the Inner Thames Marshes is one that reflects these vegetation characteristics, i.e. abandoned fragments that are subject to colonisation by species characteristic of open vegetation communities. The presence of open vegetation communities within the Inner Thames Marshes is however, evidence to a change in the vegetation from the characteristics described by Stapledon and Davies (1940) and Garrad (1954). These changes result from fragmentation creating disturbance, which in turn creates increased edges. Disturbed edges are susceptible to colonisation from invasive species (Ashton and Mitchell 1989), which reach isolated fragments along corridors created by divisive fragmenting agents. The smaller fragments resulting from fragmentation, e.g. Erith Marsh 2e, Stone Marsh 2a, b and d and Denton Marsh, then become uneconomic to manage and so abandoned, allowing the more competitive species such as *Senecio jacobaea, Urtica dioica* and *Cirsium arvense* to become established, and therefore increasing the occurrence of open vegetation communities, and loss of mesotrophic grassland communities. This is reflected in the results where open vegetation communities were more frequently matched on the smaller and less formerly grazing managed fragments. The occurrence of OV communities at >10% on an individual fragment is therefore regarded as a negative indicator of grazing marsh.

Fragmentation of the Inner Thames Marshes, as discussed in Section 7, has been responsible for the loss and degradation of landscape features, which are responsible for the grazing marsh mosaic. The retention of the landscape features may reduce the establishment of invasive species (Planty – Tabacchi et al 1996). As the landscape features determine the vegetation communities within the grazing marsh mosaic their loss, together with changes to the hydrology, which result from fragmentation will influence the species composition of the associated communities. The pattern of change from mesotrophic grassland to open vegetation is illustrated on the Inner Thames Marshes, where a greater proportion of the communities within the surveys included invasive and ruderal species, e.g. OV10 *Poa annua – Senecio jacobaea*, OV20 *Poa annua – Sagina procumbens* and OV21 *Poa annua – Plantago lanceolota*. The increase in these communities is therefore a direct result of fragmentation. The changes in NVC communities can therefore be used to monitor grazing marsh by determining changes to the ideal community structure.

Establishment of the grazing marsh mosaic can be used to identify the changes to the community structure that have occurred both across the North Kent Marshes generally and the inner marshes in particular. Reasons for these changes and results from this study can then be examined and linked to fragmentation events, agents or other factors. Fragmentation can therefore lead to changes in the direction of community structure from the ideal grazing marsh to open vegetation 'weedy' communities, although other site conditions, e.g. soil moisture content may dictate how the progression occurs, Fig 8.4.1.

Figure 8.4.1 Possible direction of change in grazing marsh communities through changes in management.



The ideal grazing marsh matrix proposed on pages 411 – 412 comprised MG7g or MG6d and MG11d, with associate communities of MG10, MG13, S22 and SM28 linked to the specific landscape characteristics and features determined in Chapter 7. The results of this study show that many of the fragments surveyed are indicative of the direction of change that may be experienced through changes in or lack of management. The model in Figure 8.4.1 highlights the direction of change that may be experienced by grazing marshes through alterations to the management regime, e.g. change in grazing intensity or the control of water levels. As shown in the model the results may be either areas of flooded ground, poached and trampled, areas that is evidence of drier conditions and the generally unmanaged marshland. Examples of these transitions can be found amongst the remaining fragments of the North Kent Grazing Marshes.

Changes in grazing management can cause several changes from the ideal grazing marsh matrix communities (MG6d/MG7g/MG11d). Changes appear to be primarily linked to over or under grazing, hydrology, management and succession. Over grazing and associated trampling opens up the sward, leading to loss of *Carex divisa, Phleum pratense* and the increase in low growing species, e.g. *Plantago lanceolota, Sagina procumbens* and a shift in NVC community to MG7e. These features are already common around gates and drinking points, e.g. Dartford and Cliffe Marshes, where community MG7e *Lolium perenne – Plantago lanceolota* has become more frequent. Progression from MG7e to OV20/21 as shown in Figure 8.4.2 would indicate an increase in the occurrence of *Poa annua* and *Sagina procumbens* as community indicators linked to increased trampling and gateways where disturbance is combined with periodic waterlogging. Communities containing *Poa annua* can become common, *P. annua* being 'arguably the most successful ruderal species in the British flora' (Grime et al 1988). *Sagina procumbens* as described by Grime et al (1988) is found in moist disturbed, moderately fertile habitats, which is typical of North Kent Marsh habitats. Matches with OV20 *Poa annua – Sagina procumbens* was recorded on 79.2% and OV21 *Poa annua – Plantago lanceolota* was recorded on 100% of fragments surveyed, with both communities occurring in areas around gateways etc, the progression shown in Figure 8.4.1 therefore has support from the results in this study.

Table 8.15 Positive and negative indicators of grazing marsh communities with anticipated constancies

Species	MG7g	MG11d	MG6d	Positive	Negative	Comments
Lolium perenne	V	III	IV	*		
Cynosurus cristatus	III	II	IV	*		
Hordeum secalinum	V	III	IV	*		
Agrostis stolonifera	III	IV	III	*		
Phleum pratense	IV	III	II	*		
Carex divisa	II	III	II	*		
Trifolium repens	IV	III	II	*		
Festuca rubra	I	III	I	*		
Agrostis capillaris	II	II	II	*		
Holcus lanatus	III	I	II	*	*	Trampling
Potentilla reptans	I	III	I	*		
Dactylis glomerata	III	I	II	*	*	
Poa annua	I	I	I		*	Unmanaged
Trisetum flavescens	-	I	II	*		
Cerastium fontanum	II	III	II	*		
Ranunculus acris	II	II	III	*	*	Hollows/poaching
R. repens	II	I	II	*	*	Hollows/poaching
Taraxacum officinale	II	II	II	*	*	
Leontodon autumnalis	I	I	II	*		Drier areas i.e. anthills
Lotus corniculatus	I	II	I	*		Drier areas i.e. anthills
Juncus effusus	I	I	I	*	*	Hollows/undergrazing
J. geradii	I	I	I	*		Saltmarsh/rills
Cirsium arvense	I	I	II		*	Drying out/undergrazed
C. vulgare	I	I	I		*	Drying out/undergrazed
Urtica dioica	I	I	I		*	Drying out/undergrazed
Phragmites australis	II	II	II	*	*	Rills/flooded
Alopecurus geniculatus	II	II	II	*		Hollows/rills
Elymus repens	II	II	II	*		Saltmarsh
Arrhenatherum elatius	I	I	I		*	Unmanaged
Glyceria fluitans	I	I	II	*		Hollows/rills
Sagina procumbens	I	I	I		*	Poaching/trampling
Plantago lanceolota	II	II	II		*	Poaching/overgrazed
Rumex obtusifolius	II	II	II		*	Drying out
Senecio jacobaea	I	I	I		*	Undergrazed

Table 8.15 shows the indicator species for the target communities, which comprise the ideal grazing marsh, together with the anticipated constancy. Where a difference is recorded in the constancy of two or more constancy classes between the NVC and North Kent Marshes data, either with the positive indicators under recorded or the negative indicators over recorded, then a change in the community structure may be occurring as indicated in the model (Fig 8.4.1). Where a species is shown as being both a positive and negative indicator, it is anticipated that an occurrence of the species at constancy of two or more above the anticipated constancy, then it becomes a negative indicator. A difference of two categories in constancy is used in this thesis to identify changes, which follows the standard used within the MATCH programme.

Increased poaching as well as creating similar opportunities to trampling can also create areas that become waterlogged. In the model, the change in communities due to poaching may lead through MG10 *Holcus lanatus – Juncus effusus*, a typical grazing marsh community of wet rills etc, through to OV28 *Agrostos stolonifera – Ranunculus repens* community. Rodwell (2000) describes OV28 as being characteristic of waterlogged places. *J. effusus* an indicator of MG10 occurs in tussocks is a response to pasturing (Agnew 1961 in Rodwell 1992) and poaching resulting from over grazing of the sward accentuates the mosaic appearance of the vegetation (Rodwell 1992). Dartford Fresh Marsh (Fig 8.4.2) is illustrative of the above pattern where ill-drained pasture becomes waterlogged and is under-grazed, which leads to the development of large tussocks of *Juncus spp.* Many of the North Kent Marsh fragments recorded both MG10 and OV28 communities, where 60.1% of the outer marsh samples and 49.7% of inner marsh samples recorded a presence of OV28, although the greater percentage on the outer marshes is reflective of there being more rills etc on these marshes.

Fig 8.4.2 Waterlogging Dartford Fresh Marsh.

Discussing community OV28 Rodwell (2000) stated that once waterlogged areas begin to dry out a change to community OV21 *Poa annua – Plantago major* often occurs. Again, across all of the North Kent Marsh fragments matches to OV21 occurred in 57.7% of the samples and 100% of the fragments surveyed, indicating that drying out may be a problem on some or part of the marshes, e.g. Erith Marsh 2b, Crayford Marsh 1 and 3a and Dartford Marsh 1. On small fragments, i.e. under 30ha, e.g. Erith fragments 2a, 2b, and Denton Marsh, OV21 occurred in over 90% of the samples. As drying out continues OV21 may well then degrade further into communities OV10 *Poa annua – Senecio vulgaris* or OV25 *Urtica dioica – Cirsium arvense* e.g. as is occurring across Dartford Marsh. These changes have influenced the preparation of water management plans for Dartford Marsh. Two of the community constants, creeping thistle (*C. arvense*) in OV25 and groundsel (*S. vulgaris*) in OV10 are species, which are infrequent to absent on wetlands, exhibit ruderal characteristics and common on disturbed ground (Grime et al 1988). These species were recorded on 100% and 64% of fragments respectively. These two communities would therefore be characteristic of unmanaged marshes or unmanaged areas of marshes, as is the case with Dartford Marsh1b, Swanscombe Marsh and parts of Shorne Marsh. Alternately where disturbance which has led to the under grazing of a marsh fragment, e.g. Botany and Shorne Marshes, MG1b *Arrhenatherum elatius – Urtica dioica* sub-community may be an intermediary stage, in the transition to OV10/25.

After grazing marshes have been fragmented, if the remnant fragment is not then used for development, then the tendency is for the fragments to be abandoned and/or relatively unmanaged, e.g. Dartford Marsh 1b, Stone Marsh 2e, where successional trends are in evidence or they are randomly managed through occasional horse grazing. The constancy at which *Lolium perenne* occurred across all the survey sites (Table 8.9) meant that OV23 occurred as a consistently high matched community. OV 21 is described by Rodwell (2000) as being found commonly on wasteland, recreation areas and farms, descriptions that can apply to the abandoned and unmanaged fragments of the Inner Thames Marshes, therefore OV21 and OV23 are expected to represent the first community changes that occur after management becomes less intensive. Once fragments become unmanaged, succession may proceed and OV23, in particular is seen as a stage in the development of MG1 *Arrhenatherum elatius* communities (Rodwell 2000). The MG1 communities were found infrequently across the fragments of the North Kent Marshes surveyed; occurring in 13.4% of the samples, with Dartford Fresh Marsh, Botany Marsh and Shorne Marsh recorded the highest number of matches. There is evidence however from Dartford Marsh 1b, which is currently in set aside, that *Arrhenatherum elatius* is becoming more common than *Lolium perenne* (personal observation), and that the successional trends discussed by Rodwell (2000) occur on abandoned grazing marsh.

On marshes where the management of water levels is no longer practised and waterlogging occurs regularly a different progression of community change occurs (Fig 8.4.2), e.g. Dartford Fresh Marsh. The marsh is ombrogeneous and maintains a high water table, often retaining large areas of surface water. Together with an element of over grazing mesotrophic grassland community MG10 *Holcus lanatus – Juncus effusus* rush pasture has developed, which as described by Rodwell (1992), is characteristic of permanently moist soils. On sites therefore, where drainage has become impeded and with increased water levels then swamp communities, e.g. S4 *Phragmites australis* develops, as can be found on Dartford Fresh Marsh and Swanscombe Marsh. Where no management in the form of grazing or mowing occurs, fen-meadow community M23 *Juncus effusus – Juncus acutiflorus – Galium palustre* may occur (Benstead et al 1997), as shown in Fig 8.4.2.

All Inner Thames Marshes with the exception of Dartford Marsh are no longer managed as traditional grazing marsh. As shown in Fig. 8.4.1 the trend in the structure of the vegetation communities should therefore, be moving towards the open vegetation communities of OV21/23. The predominance of open vegetation communities across the Inner Thames Marshes is therefore to be anticipated, and results so far indicate this trend with OV23 being consistently matched with a coefficient of similarity of over 45% on 62.5% of the fragments surveyed. The loss of landscape features such as rills and wet hollows will lead to fragments drying out as water-retaining features disappear. Drier sites, such as Stone Marsh 2b recorded OV10 as a first matched community, which illustrates the community succession shown in the model.

Where fragments become unmanaged, the model shows a pathway from the ideal grazing marsh through OV21/23 to MG1. 75% of the Inner Thames Marshes recorded one of these communities as a first placed match, indicating that currently the unmanaged inner marshes are within the first transitional stage of the model. The consistent presence of OV28 is indicative of changes occurring to the remaining wetter hollows due to the lack of management, which is also shown in the model as a transitional stage in the drying out of fragments. There is evidence therefore that across all of the North Kent Marshes, the management of water levels needs to be improved or reinstated to maintain the ideal grazing marsh vegetation community structure.

Waterlogging and flooding can also be a problem on grazing marshes where water levels are not actively managed. From the model, (Fig 8.4.1) the change in community composition results in the ideal grazing marsh moving through MG13 to S4, S22 or M23. Barnes Cray, Dartford Fresh Marsh and Swanscombe Marsh all recorded areas where this progression is in evidence, and therefore water level management would need to be introduced here in order to retain the proposed grazing marsh community structure.

The Outer Thames Marshes generally retain the ideal grazing marsh structure and community composition, although Denton Marsh and areas of Filborough Marsh, Shorne Marsh and Higham Marsh 1b show evidence of community change shown in the model. Both Filborough and Shorne Marshes had a best match with OV23, and good matches with OV21, therefore indicating a change in community structure is occurring and that the fragments are not suitably managed and that they may be drying out. The RSPB have recorded that management of the water levels needs to be reinstated on Shorne

Marsh (RSPB *pers com.*). Predictions in the model show that OV21 is a community that occurs in the early stages of wetland sites drying out and the RSPBs' actions are evidence of changes occurring within the Outer Thames Marshes. If the plans are not implemented therefore the trends shown in Fig 8.4.1 would indicate that MG1 communities will become established leading to a loss of conservation value as the landscape features, which are important for the bird and invertebrate populations (Section 9), are subsumed within successional processes.

The remaining Outer Thames Marshes, Higham, Cliffe, Allhallows and Chetney Marshes are all managed under the North Kent Marshes ESA scheme, and therefore should retain the landscape characteristics and features, which are the template for the vegetation communities (see Section 7). Results recorded a higher number of matches with mesotrophic grassland communities on the ESA managed marshes (76%), than on the other Outer Thames Marshes (57%). Open vegetation communities were recorded in 24% of the matches for the ESA marshes and 47% of the matches for the remaining Outer Thames Marshes. Results also indicated that the marshes managed under the ESA scheme recorded higher scores for landscape characteristics and features than the remaining Outer Thames Marshes. There is therefore a contrast beginning to develop between the marshes managed as traditional grazing marsh and those managed in a less sensitive manner. Traditional management is therefore a key requisite in maintaining the landscape characteristics and features so that the ideal grazing marsh vegetation mosaic is maintained.

Fig 8.4.3 Proposed Monitoring Form for Grazing Marshes

Site Name

NVC type: Coastal Grazing Marsh – *Lolium – Hordeum – Agrostis* grassland MG11d/MG6d

Condition: Favourably maintained/ Favourably recovered/ Unfavourable improving/ Unfavourable no change/ Unfavourable declining/ Partially destroyed/ Destroyed

Recommended visiting period: April – August, with periodic visit in autumn and winter to check water levels and levels of grazing.

Recommended frequency of visits – Site-specific decision

Key management activities
Grazing period/intensity FYM inputs (no other inputs)
Scrub and weed control
Ditch management – December – April, maintain water levels no less than mean field level to create shallow pools. May- November, maintain min. 30cm water in ditches.
Maintain ditches /dykes by mechanical means.

Attributes	Target	Estimate of area	
Extent of community	No additional loss acceptable.		
Sward composition: grass/herbs	40 – 90% grasses		
Sward composition: frequency of positive indicator species. *Carex divisa ( ), Cynosurus cristatus ( ), Phleum pratense ( ), Festuca rubra ( ), Agrostis stolonifera ( ), Lolium perenne ( ) Hordeum secalinum ( ), Cerastium fontanum ( ) Potentilla reptans ( ) Trifolium repens ( )*	At least four species frequent or greater, other species occasional throughout sward		
Sward composition: frequency and % cover of negative indicator species. *Cirsium arvense ( ), C. vulgare ( ), A. elatius Rumex obtusifolius ( ), R. crispus ( ), Urtica dioica ( ) Senecio jacobaea ( )*	No species more than occasional throughout the sward or more than 5% cover.		
Sward composition: indicators of waterlogging *Juncus inflexus ( ), J. effusus ( ), Phragmires australis ( ), Epilobium hirsutum*	No species more than occasional throughout the sward.		
Sward composition: indicators of over-grazing. *Plantago lanceolota ( ), Sagina procumbens ( ),*	No species more than occasional throughout the sward or more than 5% cover		

Structured walk recording form
Frequencies: totals of 20 stops 1-4 rare, 5-8 occasional, 9-13 frequent, 14 abundant

Feature	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rills																				
Hollows																				
Ditches																				
Tussocks																				
Scrub																				
Sward height																				

Structured walk recording form – Positive indicators

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
L. perenne																				
A. stolonifera																				
H. secalinum																				
C. cristatus																				
P. pratense																				
F. rubra																				
C. divisa																				
T. repens																				
C. fontanum																				
P. reptans																				
T. flavescens																				
A. geniculatus																				
P. monspeliensis																				
L.autumnalis																				
J. geradii																				
E. repens																				
L. corniculatus																				

Structured walk recording form – Negative indicators

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
U.dioica																				
C.arvense																				
C. vulgare																				
R. crispus																				
S. jacobaea																				
J. effusus																				
J. inflexus																				
P. australis																				
P. lancelota																				
S.procumbens																				
E. hirsitum																				
A. elatius																				

Fig 8.4.3 shows a proposed monitoring form for grazing marshes and the vegetation structure of the grazing marsh habitat. The format follows the structure set out by English Nature in their Lowland Grassland SSSI condition assessment protocols, and would be carried out by means of a structured walk as discussed in Section 5.3.2. Recommended visiting times are designed to coincide with the period when the required species are present and easily recognised within the sward. As in the lowland grassland protocols, the maximum period of time is recommended in order that 'reliable assessments can be made'. Supplementary visiting should also be carried out to monitor the effects of grazing management and/or mowing that may be included within the management regime.

The positive indicator species are species characteristic of the communities shown to comprise the ideal grazing marsh mosaic in Section 8.4, and are indicative of the grassland type shown in the proposed community structure of grazing marshes. Species are also included that are indicative in showing that conditions are suitable for the maintenance of the grazing marsh grassland assemblage. There may however, be a need to tailor the form to incorporate indicator species of sub-communities, e.g. MG13 *Alopecurus geniculatus* or *Glyceria fluitans*, or for local variations. Targets for gramineae species refers to the level of occurrence or frequency where the individual species is recorded from over 40% of stops within the structured walk, and are the minimum level required to satisfy that the attribute reaches a minimum condition level of ' unfavourable improving'. The categories of frequency used in recording are based on those adopted in the NVC, and shown below:

- Species recorded from up to 20% stops – rare

- Species recorded from 21% to 40% of stops – occasional
- Species recorded from over 40% of stops – frequent.
- Species recorded from over 60% of stops – frequent + (should apply to *Lolium perenne, Agrostis stolonifera, Hordeum secalinum*).

'Unfavourable improving' means that one or more of the main attributes are outside required targets, but there is evidence of recovery. Sward structure should record the average height of the sward, and supplementary comments can be included which cover the extent of bare ground and extent of disturbed ground. The target for the sward composition is set at an upper limit of 90% for gramineae species as they form the integral part of the communities that should be represented, and therefore there is a minimum requirement for at least four of the target positive indicators to occur frequently of greater in the sward. Negative indicators should not be recorded as a greater occurrence than occasional, as this would indicate a decline in sward composition.

The status of the North Kent Marshes and the range of communities shown in Table 8.8 (Appendix 4) reflects the differing nature of the vegetation communities that occur on North Kent Grazing Marsh fragments from the larger open marshes of the Hoo Peninsula to the small fragments of Erith and Stone Marshes, and from the managed to the degraded. The results reflect a difference between the Inner Thames Marshes of Erith – Botany Marshes where open vegetation communities are predominant and the Outer Thames Marshes where mesotrophic grasslands are more common, as well as how the landscape features have influenced these communities. In Sections 7 and 8 changes to the landscape features and vegetation communities have been linked to changes in the management that have been bought about by fragmentation. Although there was a good correlation between fragment size and the occurrence of mesotrophic grasslands and landscape features such as tussocks and rills, management after fragmentation events appears to be a more crucial factor in determining the status of the landscape features and therefore the vegetation community structure.

Chapter 9 General Discussion & Conclusion

9.1 General Discussion.

Coastal grazing marshes have been recognised as a priority conservation habitat in the UK, e.g. UK Biodiversity Steering Group, 1995. Grazing marshes have however, not been fully defined in the literature, e.g. Tansley (1949), Ratcliffe (1977), Rodwell (1992) nor by other conservation bodies, e.g. Delaney (1991), Dargie (1993). Therefore, how can we conserve and monitor grazing marsh habitats if they are not fully defined? The grazing marshes of North Kent provide extensive areas of fragmented habitat the origins and status of which have arisen through both natural, e.g. geology or anthropogenic activities, e.g. reclamation of saltmarsh. The North Kent Marshes Environmentally Sensitive Area (ESA) represents the largest remaining tract of coastal grazing marsh in the UK comprising 6500 ha (ADAS 1997).

The current study has reviewed the status and effects of fragmentation on the grazing marshes within the North Kent Marshes ESA, i.e. Higham, Cliffe, Allhallows, Grain and Chetney, the adjacent non ESA Outer Thames Marshes of Shorne, Filborough and Denton and the Inner Thames Marshes of Erith, Crayford, Dartford, Stone, Swanscombe, and Botany. There has been, however, as discussed in Section 3, no definitive description as to what constitutes the typical grazing marsh; in this thesis therefore, the following issues were addressed: -

- What is a typical grazing marsh?;
- What characteristics and features define grazing marshes and how such features are affected by the processes and agents of fragmentation?;

- What are the typical vegetation communities, which comprise a grazing marsh, how these communities relate to the National Vegetation Classification, and whether fragmentation alters the composition of the vegetation communities?

In Section 8.4 the vegetation communities, which are representative of the North Kent Grazing Marshes are proposed. Condition and monitoring procedures for grazing marshes are also set out.

The range of landscape characteristics and features, which were identified in Section 3.1.1 and discussed in Section 7, are those that are representative of, and which should be present on the typical grazing marsh. Some of these landscape characteristics and features have been previously identified individually in the literature, e.g. drainage ditches (Dargie 1993, UKBAP 1995), embankments and counter walls (AERC 1992, Cobham 1995), tussocky grassland and wet hollows (Milsom et al 2000, Vickery et al 2001) and an affinity to saltmarsh (Delaney 1991). In no instance however, have they all been included together in a comprehensive definition of grazing marshes. The current thesis argues that grazing marshes are a composite unit that includes landscape characteristics and features, which form a homogeneous – heterogeneous matrix on which the typical range of vegetation communities occur (Section 8.3). The mosaic of vegetation communities, which occur on the North Kent Marshes are related to the landscape features, i.e. an affinity to saltmarsh, or with species which reflect the wetter conditions of the rills or drier conditions of counter walls etc. but also influenced by the landscape characteristics, e.g. the drainage ditches.

Some previous studies have been carried out on the vegetation and status of the drainage ditches of grazing marshes, e.g. Charman (1985), English Nature (1995, 2000). The emphasis in this study was therefore; to determine the vegetation characteristics of the matrix lowland wet grasslands, which are the dominant habitat of grazing marsh, rather than the drainage ditches, which have been considered in terms of their role as a landscape characteristic.

The landscape features of grazing marshes, e.g. tussocks and wet rills, have been recorded as being of value in supporting the presence of a range of target bird species, e.g. Vickery et al (1997 and 2001) and Milsom et al (1998 and 2000). Drake (1998) stated that the range of habitats on a grazing marsh, identified in Section 1.5 together with the drier tussocks and wetter rills, support important invertebrate communities. The conservation value of the grazing marsh habitat has arisen at least in part, from the presence of such target bird species and invertebrate communities (MAFF *pers com*, English Nature *pers com.*). The retention of the landscape features and plant communities is thus essential if grazing marshes are to maintain a conservation status. Landscape surveys carried out as part of this thesis have therefore been used to assess the effects of fragmentation on the landscape characteristics and features so that the influence of fragmentation on the conservation value of the grazing marsh habitat can be surmised.

With the lack of a defined ideal grazing marsh or typical NVC type, it has been assumed that because of the proscribed management regime, the grazing marshes within the ESA are approaching or indicative of the ideal North Kent Grazing Marsh condition. The

ESA grazing marshes communities are therefore used to represent grazing marsh typicalness as described by Ratcliffe (1977). As there is a lack of historical data regarding the status of the landscape characteristics and features and communities of the North Kent Marshes, this assumption has been adopted in order to establish a base line on which the landscape characteristics and features identified in Chapter 3 can be compared and assessed. Results from the site surveys showed that the ESA marshes did in fact retain more of the recognised characteristics and features of grazing marshes and that the vegetation was more typical and therefore they could be used as a baseline on which to adjudge the remaining marshes.

In terms of fragmentation three themes emerged when considering the fragmentation of the North Kent Marshes: -

- Does fragmentation materially alter the configurational and minimal structure of grazing marshes?
- Can fragmentation theory be used to predict or account for changes occurring on grazing marshes or are other factors involved, which occur because of fragmentation and therefore increase the effect?
- Is there thus a minimum critical size for a grazing marsh to retain the traditional grazing marsh features?

Fragmentation as the term suggests is the breaking up of large tracts of habitat (such as the North Kent Grazing Marshes) into smaller isolated terrestrial habitat islands (Wilcove et al 1986). The results of the current survey have shown no clear link between fragment size and the conservation value of the characteristics and features, although a significant correlation was found between the fragment size and the values allocated to the landscape characteristics and features. Some of the smaller fragments of the North Kent Grazing Marshes have however, retained vestiges of characteristic features, e.g. homogeneity on Crayford Marsh 2a, tussocks on Crayford Marsh 3a, and rills on Dartford Fresh Marsh. Whereas, some larger fragments have lost their landscape features, e.g. a lack of rills on Dartford Marsh 1a or absence of counter walls on Shorne Marsh. Size therefore, is not the only important factor in maintaining grazing marsh characteristics. The loss of landscape characteristics and features on some marshes however, can be directly attributed to fragmentation, e.g. loss of embankments on Erith Marsh 2b and Filborough Marsh. Fragmentation may however, be indirectly linked to the loss of features, for example, a subsequent lack of management and/or further development, which seems to commonly occur after the initial fragmentation results in the loss of features, such as rills and tussocky grassland. Such effects of post intrusive fragmentation management are responsible for losses of features on several marshes, e.g. homogeneity (Stone Marsh 2e) or rills (Stone Marsh 2b), and ditches (Erith Marsh 2e).

Openness and big skies were terms used to describe the North Kent Marshes by Dickens (1861) and Cobham (1990). Although, not directly measured in this thesis, the characteristics of urban/industrial influence or dominance also introduced by Cobham (1990) were measured, and these can be interpreted to reflect the influence of fragmentation on the openness of grazing marshes. Smaller fragments i.e. under 30ha, with the exception of Stone Marsh 2a, Erith Marsh 2e and Barnes Cray, are all dominated by their surroundings. Therefore, if the area of a fragment falls below 30ha it appears that the openness of grazing marsh is likely to be lost and such characteristics cannot easily be recreated, as in the condition of most Inner Thames Marshes. Results from this study indicate there is no minimum critical size below which grazing marshes lose all their landscape features and characteristics, with the exception of openness.

Fragmentation theory suggests that as fragments get smaller, fewer species will be present (MacArthur and Wilson 1967), edge – area ratios increase (Farina 1998), edge effects become more pronounced (Noss and Csuti 1997) and metapopulations will become more isolated (Hanski 2000). Smaller fragments, e.g. Denton Marsh, Crayford Marsh 3a and 3b, Stone Marsh 2a, 2b and 2d all recorded higher coefficients of similarity with open vegetation communities, which show greater diversity in terms of species recorded of the NVC. Rodwell (1992) refers to the mesotrophic grassland communities typically found on grazing marsh, i.e. MG6, 7 and 11, as being low in diversity when compared to open vegetation communities. The higher incidence of open vegetation communities on the smaller fragments indicates that in terms of their flora, they have a higher species richness. This result supports the findings of Quinn and Robinson (1987) who recorded that smaller sites do not necessarily have less species present than larger ones. The results are therefore contrary to the predictions of the traditional species-area relationship. Yet, although, there is increased diversity with decreasing size, the new species are non-typical grazing marsh species and there is also a loss of the typical wet grassland species, e.g. *Carex divisa* and *Cynosurus cristatus*. Therefore increasing diversity on small sites can lead to a decrease in typicalness. Such changes in diversity with fragmentation will therefore have significant impacts on bird and invertebrate species, which depend on the typical grazing marsh plants and communities and ultimately on the conservation value of grazing marshes.

Relationships between edge effects, increased edge – area ratios and fragmentation of the North Kent Marshes have been discussed in Sections 6.8.2, 8.3.3 and 8.4. Section 7 covered the influence of edges on the landscape characteristics and features. Results from the current study suggest that edge effects may have influenced the vegetation communities of the smaller fragments of the North Kent Marshes. Harris et al (1991) argues that divisive fragmentation creates corridors along which invasive alien species can obtain access to fragments. The change in the structure in vegetation communities on smaller fragments from mesotrophic grasslands to open vegetation communities indicates that generalist species from edge habitats are colonising and influencing the core of grazing marsh habitats. The findings therefore, support the prediction of fragmentation theory. Further studies on the edge – interior patterns of small and large grazing marsh fragments and the gradient of change in species content from edge to core of the grazing marsh habitat are required to determine the extent of such effects.

Edge effects may create a refuge for a range of species, which in turn may alter the vegetation communities (Collinge 1996) or increase predation (Andren and Angelstram 1988). In open grassland habitats however, many edge effects will be less marked, as edges tend to be wider, softer and less well defined (Forman 1997). Studies record that the effects of increased edges and fragmentation include the introduction of edge effects to the core area of habitats leading to habitat loss and modification, isolation, increased disturbance and changes to hydrology e.g. Andrews (1990), Findlay and Bourdages (2000). Results indicate that for small grazing marsh fragments that have become isolated by road building, the result is a change in hydrology, i.e. drying out or waterlogging. Such changes lead to a change in vegetation community structure from mesotrophic grasslands to open vegetation (drying out), e.g. Stone Marsh or swamp communities (waterlogging), e.g. Dartford Fresh Marsh.

Forman and Deblinger (2000) recorded that where new roads cross wetlands; drainage effects could extend outwards from the road for distances between 50 m and 500 m. They added however, that measuring additional attributes such as sediment run off, water table and soil measurements might possibly show the effects of roads extending further into the wetland, effects that would be of particular importance on grazing marshes. The effects of changing hydrology on the vegetation and community structure and the surface heterogeneity, should include changes in and loss of a range of habitats, e.g. dry mounds and wet hollows and will influence the presence of key bird and invertebrate species and hence the conservation value of grazing marshes. The hydrology of the North Kent Marshes has been little studied, with the exception of studies carried out by University College London, e.g. Summersgill (1990) and Hollis et al (1993). Further research is therefore, required into the hydrological patterns and the effects of hydrology on key features and species.

Section 7.10 categorised the landscape characteristics and features, which constitute the configurational and minimal structure of the grazing marsh habitat. The retention of landscape characteristics and features on small fragments, e.g. Dartford Marsh 1c would indicate that the minimal structure of grazing marshes may not always be lost as a result of fragmentation. If minimal structures such as rills and tussocky grassland remain then the bird and invertebrate species that rely on these features may also be retained. Although, it could be argued that as the conservation value of grazing marshes often relies on the presence of bird and invertebrate communities (Benstead et al 1997, English Nature *pers com.*), they would also constitute part of the minimal structure. Milsom et al (1998, 2000 and 2002) has established a link between a range of landscape features and the presence of target bird species on grazing marshes. It would therefore, be appropriate to include target bird species, e.g. lapwing, redshank etc., within the configurational structure. Further studies, however are needed to establish relationships between the landscape features and invertebrate populations, within the North Kent Grazing Marshes.

The core of the grazing marsh habitat is composed of the landscape features (Section 3.1.1), which create the micro scale heterogeneity. It is expected that fragmentation effects, i.e. edge effects on landscape features would be lessened closer to the habitat core. That is not to say that edge effects will not influence the character of landscape. If so fragmentation and the introduction of edge effects will begin to change the fine scale heterogeneity of the interior of the grazing marsh. The relationship however, between fragmentation and the landscape characteristics and features of grazing marshes is not straightforward. The results in Section 7 and 8 indicate that the presence of landscape characteristics and features may therefore be of more importance than species – area relationships in determining the conservation value of grazing marshes, i.e. the presence of target species of birds and invertebrates.

Results from the vegetation study recorded a range of open vegetation and mesotrophic grassland matched communities, with few exceeding a Czekanowski coefficient of similarity of 60% and with a majority recording a similarity of below 40%. Mesotrophic grasslands on the North Kent Marshes were shown to comprise the greater number of matches (58.5%), particularly for the outer marshes within the ESA (78.9% of matches). Open vegetation communities predominated in the Inner Thames Marshes, although the community constants for the two groups (MG and OV) were often similar. It would be easy to say that the differences between the two-marshland groupings resulted directly from fragmentation, as the inner marshes show a higher degree of fragmentation than the outer marshes. A more cogent reason than fragmentation for the differences is due to the low level or lack of management of the individual fragments and the greater core – edge ratios on the Inner Thames Marshes. The latter permits the colonisation by some of the ruderal species associated with the open vegetation communities. In practice, the differences between marshes are probably due to a combination of both factors with the agents of fragmentation playing a major role in creating the conditions, which allows the introduction of alien species, and the reduction of marsh to areas that are uneconomical to graze. Fragmentation may therefore be the underlying cause, if not the direct cause, of such changes, i.e. a death indirectly by a thousand cuts.

The matrix mesotrophic grassland communities for grazing marshes were defined in Section 8.4 as MG6d, MG7g and MG11d, with MG10, MG13, S4, S22 and SM28 occurring in the rills and hollows and MG6d and MG11d, also occurring as tussocks and on the drier areas. The communities result from the surface heterogeneity, which in turn arises from the influence of the landscape characteristics and features. The survey results indicate however, that the continuing survival of the landscape features does not always appear to be influenced directly by fragmentation, i.e. many small isolated fragments retain vestiges of the landscape features albeit in a degraded form. The effects of a fragmentation event, the nature of the fragmenting agent and the resultant disturbance are of importance in that many fragmenting events have ultimately led to a total loss of habitat through further building or change in land use to arable crop production. What has probably been of greater consequence than fragmentation is the creation of many smaller fragments, which are seen as being unproductive and of little value in terms of grazing or conservation. Such small fragments, e.g. Erith Marsh 2c and 2e and Denton Marsh have therefore been left unmanaged or grazed, primarily by differing numbers of horses at random intervals.

Fragmentation of the grazing marsh habitat may be inducing further pressure on the grazing marsh matrix through the creation of edges and increased edge effects, which in turn affect both the minimal and configurational structure of the marsh. The minimal structure of a grazing marsh as discussed in Section 7.10 may be affected by the introduction of new habitat conditions, e.g. road verges or from agriculture that may offer the opportunity for stress tolerating and competitive species to enter and change the balance of species within the community composition, and so weakening the links between structural elements. Results of the MATCH analysis record differences between large and small fragments with the best matches to mesotrophic grassland on large fragments and the best matches to open vegetation communities on the more fragmented marshes of Stone Marsh and Crayford Marsh 3a and 3b. The influence of fragmentation on the minimal structure of grazing marshes, i.e. ditches, tussocks, rills and homogeneity, will increase the pressures on their survival. Results from the landscape surveys show that the more fragmented and smaller marshes of Erith, Stone and Denton have lost some minimal structural components, e.g. rills on Stone Marsh or ditches on Erith Marsh 2e and Denton Marsh, and therefore the configurational elements are being influenced. For example, Erith Marsh 2e and Stone Marsh 2a and 2b recorded no inundation vegetation communities (MG10 or 13) or open vegetation communities associated with damp areas in pastures (OV28), indicating that the loss of ditches and rills is causing change to part of its configurational structure, i.e. vegetation communities. Fragmentation in therefore a force, which is causing change both directly and indirectly to structural elements of the grazing marsh habitat.

Other processes introduced by fragmentation may well affect the configurational and minimal structure. Increased disturbance resulting from increased traffic movements, either human or vehicular, as the infrastructure of the Thames Gateway is improved has been a major factor influencing the decline in importance of the Inner Thames Grazing Marshes. For example, the increase in road building has led to new developments, which have intrusively fragmented much of both Erith and Stone Marshes.

Divisive agents such as roads are responsible for noise and light pollution (Forman 2000), altering the hydrology of the habitat (Forman and Deblinger 2000) and act as a source of pollutants entering the system through surface water run off (Andrews 1990). Urbanisation can cause noise and light pollution and industry adds a range of chemical pollutants, which can enter the system through the atmosphere, soil or water. In this thesis, the process of fragmentation and how it has affected the physical structure of grazing marshes has been discussed. Other factors such as increases in pollutants, chemical, noise and light pollution, which all influence grazing marsh systems, are introduced to an ecosystem because of fragmentation are not covered in this thesis, but they may have affected the results. For example, the influence of sand extraction adjacent to Stone Marsh fragment 2b has altered the soil structure and communities present in the match analysis.

It would appear therefore, that a range of factors are interacting within a grazing marsh ecosystem and are responsible for determining their suitability for the large-scale presence of waders and wildfowl, invertebrates and in maintaining the vegetation communities. Size and fragmentation are not the only determinants of grazing marsh characteristics. Studies by Van der Zande et al (1980), Brown and Dinsmore (1986) recorded effects on bird populations that can be attributed to fragmentation, either by reducing the area (Brown and Dinsmore) or by fragmenting agents, e.g. roads (Van der Zande et al). Both studies suggested that reduced areas or disturbance from roads etc would influence bird populations on affected sites. Small fragments however, may be just as important for maintaining the overall conservation value of the North Kent Marshes as large fragments. For example, suitable management can make small fragments into important breeding sites, e.g. a small fragment of less than 2 ha Diggs Marsh has the highest density of redshank in the North Kent Marshes (Kent Ornithological Trust 1996).

The continued management of the North Kent Grazing Marshes and remnant fragments is therefore a major issue in ensuring that the landscape characteristics and features not only survive but also remain in a condition that retains their conservation value. ESA management proscribes the periods of grazing and the level of grazing, cutting periods, maintaining water levels through ditch management and the retention of ponds and reedbeds (ADAS 1997). Results from this study indicate that the management regimes that are currently practised on the ESA marshes are appropriate for the retention of ideal grazing marsh conditions. There are however, no monitoring reports of the North Kent Marshes ESA post 1996 (DEFRA *pers com.*). Where management targets need to be amended is in the use and disposal of spoil material from ditches and dykes. The practice of spreading spoil adjacent to the ditch or dyke is leading to raised bunds, which have become susceptible to invasion by species such as *Cirsium spp.* and *Urtica dioica.* Similarly, on Crayford and Dartford Marshes, where ditch management is carried out, the practice of creating raised bunds from dredged spoil is also carried out. These two marshes also record higher levels of ruderal species along ditch embankments. Spoil therefore needs to be either removed from site. Grazing and ditch management should therefore be regarded as key configurational structural elements of the grazing marsh habitat without which the grazing marsh habitat declines and becomes unviable, although the method of disposing of dredged soil needs to be amended.

9.2 The Ideal Grazing Marsh.

In Section 5 the anticipated scores for the landscape characteristics and features, which comprise the minimal structure, were outlined. These were: -

- Homogeneity 4/5 Homogeneity over 65% of fragment;
- Ditches 4/5 All ditches favourably managed;
- Tussocks 3 Frequent 25 – 50% coverage;
- Rills and wet hollows 3 Frequent 25 – 50% coverage;

Drainage ditches are recorded by Cobham (1990) and UKBAP (1997) as one of the key grazing marsh characteristics and therefore should record scores that indicate that all the ditches on a fragment are managed. Emergent vegetation should not be allowed to become too extensive that it begins to restrict water movement within the ditches and allow the build up of silt, thereby reducing the effective water levels. Bankside vegetation should show variation in height, with mown areas that allows the movement of ditch fauna (Wells *pers com*).

Fig 9.1 Allhallows Marsh, a typical ideal grazing marsh.

As a result of fragmentation, there are examples where embankments are no longer present as part of the grazing marsh landscape, e.g. Erith Marsh 2b and 2e, Denton Marsh, Filborough Marsh. Therefore, it is not possible to include embankments as minimal structural elements, but they should be included as important configurational elements within the ideal grazing marsh, as there absence does not lead to a loss of the overall grazing marsh structure. Embankments have been engineered as flood defences and therefore need to be maintained in a condition that will not endanger this function, i.e. erosional effects of recreational activities need to be curtailed as well as maximising their contribution to the grassland habitat of the marshes (Geikie 1999). The sward should therefore be mown or grazed to control the development of scrub, maintain habitat for ground nesting birds and invertebrates and the seed bank. Ideally, the embankments should therefore show a heterogeneous sward height with little scrub development and damage from inappropriate uses. Further research is however required to establish a range of typical vegetation communities, which would typify the embankments of the North Kent Marshes.

The landscape features, i.e. rills, wet hollows and tussocky grassland are recognised as minimal structural elements of the grazing marsh mosaic giving rise to many of the vegetation communities identified in Section 8.4 as being typical of the North Kent Grazing Marshes, i.e. MG6d (tussocks), MG13 (rills). Tussocky grassland is a description of vegetation structure, identified by Milsom et al (1998, 2000) and Vickery et al (2000) as being of importance for ground nesting and feeding birds. Too many tussocks may offer poor foraging habitat for chicks and poor visibility for nest defence (Vickery et al 2001), whereas a lack of tussocks will reduce the amount of cover and could lead to an increase in predation (ibid). Tussocks therefore, should not be a dominant feature and ideally will occur at a lower limit of 30% cover and an upper limit of 60% cover.

Rills and wet hollows were also identified by Milsom et al (2000, 2002) as important feeding areas for waders and wildfowl. As with tussocks ideally they will not be dominant features and should occur at a lower limit of 25% cover and an upper limit of

50% cover. A greater frequency of rills and wet hollows is likely to lead to waterlogging in areas, which would become unsuitable for grazing as species such as hard rush (*Juncus inflexus*) become dominant. This species has become more prominent on sites such as Dartford Fresh Marsh.

The combination of grazing, tussocky grassland, rills and wet hollows will give rise to a heterogeneous sward height on grazing marshes. Such heterogeneous sward height has been recorded by Milsom et al (1998) as being important for the maintenance of bird populations. Further discussion of the sward heights was included in Section 7.7.2, which stated that heights should ideally vary from 5 – 30cm. Sward height and structure requirements also influences the bird species potentially using grazing marsh, e.g. snipe (*Gallinago gallinago*) prefer swards with tall vegetation and lapwing (*Vanellus vanellus*), which prefer short grazed swards (Benstead et al 1997). It is not proposed however; to make firm proposals as to the percentage of a fragment for any particular sward height should cover, as this would depend on the level of grazing, season, the proscribed periods of cutting and the target bird species.

9.3 Current status of the North Kent Marshes.

Table 1.1.recorded the conservation designations, which have been granted to the North Kent Marshes. The designations reflect the landscape value of the region (AERC 1992) and the conservation value of the North Kent Marshes. The ESA designation is aimed at ensuring that the North Kent Grazing Marshes are managed and maintained in a manner that helps 'safeguard areas of the countryside, where landscape, wildlife and historic interest are of national importance and is dependent on the use of beneficial farming

practices,' (ADAS 1997). The remaining designations are aimed at protecting the North Kent Marshes at international, national, regional and local level. Recognition of the conservation value for the Outer Thames Marshes is due to the numbers of waders and overwintering wildfowl, whereas in the case of Crayford and Dartford Marshes, the proposed SSSI designation is in recognition of the invertebrate populations present (English Nature *pers com.*).

In the absence of a clearly defined grazing marsh type, the grazing marshes included within the North Kent Marshes ESA have been regarded in this thesis as the ideal grazing marsh. These grazing marshes have been maintained by proscribed management techniques, as, discussed by ADAS (1997). The retention of grazing marsh in an ideal condition, including the range of landscape characteristics and features definitive of grazing marsh (Section 3.1.1 and 7) therefore requires management. The grazing marshes of the North Kent Marshes ESA are therefore regarded as being in a good condition, which is reflected by the overall higher scores, obtained in the landscape surveys. The remaining Outer Thames Marshes of Filborough and Shorne are managed independently by farm management and the RSPB respectively. Shorne Marsh is benefiting from a change in the management regime. Since the site was surveyed, scrub has been cleared and management of the water levels has been introduced (personal observation). The status of Shorne Marsh grazing marsh landscape characteristics and features is therefore improving. Filborough Marsh is independently managed by grazing cattle and production of hay. There is evidence of scrub invasion that is probably resulting from a degree of undergrazing, but the overall condition is good. Denton Marsh, the remaining Outer Thames Marsh surveyed is deteriorating, and recent local development has resulted in further loss and it seems probable that the remainder of the marsh will be lost in the future.

The Inner Thames Marshes, with the exception of Dartford and Dartford Fresh Marsh, have no formal management. Ditch management however, is carried out by the Environment Agency on Crayford Marsh (Personal Observation). Erith Marsh 2a, 2b, and Crayford Marsh are still grazed under licence, with horses the sole grazer (Giekie *pers com*, Long *pers com*). The status of the individual Inner Thames Marshes and the varying states of management have therefore resulted in a wide range of conditions, which when compared and assessed with the ideal grazing marsh condition record a variety of differences, in vegetation community, community structure and number and condition of the landscape characteristics and features. The varying conditions of the North Kent Marsh fragments therefore show a range of states that can be used to establish a progression of changes that may or may not be attributable to fragmentation. Without formal management that maintains grazing, the correct vegetation structure, and water level management the Inner Thames Marshes are likely to become more degraded and to incur further losses in the future.

The importance and condition of the landscape characteristics and features has been considered by others, e.g. AERC (1992), Benstead et al (1997), Milsom et al (1998, 2000, 2002), and Vickery et al (2000), to be of importance in maintaining populations of key bird species, which add to the conservation value of the North Kent Marshes. Although the presence of target bird species, such as lapwing (*Vanellus vanellus*), redshank (*Tringa totanus*) and snipe (*Gallinago gallinago*) (Morris and Wright undated, Personal Observation), there have been no studies relating the numbers of birds to fragmentation on the Inner Thames Marshes. By highlighting the status of the landscape characteristics and features, this study has shown that many small fragments have maintained a range of characteristics and features that would indicate that they remain viable as sites for the key bird species, and so of value as conservation sites.

Further research is required to establish whether the numbers of target bird species on the Inner Thames Marshes is influenced by the areas of the smaller fragments and disturbance from fragmenting agents as well as linking NVC communities to the presence of the individual target species. The indications from this research show that if the landscape characteristics and features, i.e. minimal structure, are retained, then the small fragments should support the key bird species, although species specific requirements, such as size of territory, may be influential. Further research on the effects of fragmentation this aspect of behaviour is required.

9.4 Future threats to the North Kent Marshes.

Further losses within the North Kent Grazing Marshes and particularly in the Inner Thames Marshes are inevitable. The Thames Gateway has been highlighted as an area available for future development (Thames Gateway 2002). Housing and industrial development will increase the pressure for land. The smaller fragments of the Inner Thames Marshes will become susceptible to the demand for land, as their value is now regarded in their availability for development. Erith Marsh 2b and Stone Marsh 2b are currently subject to proposals for development (Bexley Environmental Forum *pers com.*). As the pressure to develop the Inner Thames Marshes grows, so the threats to the remaining fragments will increase, threats that include increased disturbance from traffic, noise and light pollution as well as direct habitat loss.

Within the Thames Gateway, grazing marsh has already been designated for development. For example, the development of the new high-speed rail link to the continent will affect the Swanscombe Peninsula (Kent Thames–side 1995). Swanscombe and Botany Marshes are designated areas for the disposal of material excavated from the proposed tunnel beneath the River Thames (Kent Thames-side 1995). On completion of tunnel construction the Swanscombe Peninsula is then to be developed into an urban village, with completion anticipated by 2011 (ibid).

The North Kent Grazing Marshes are however, regarded as important areas for birds (ADAS 1997) and invertebrate populations (Plant 1992), and this has resulted in the many conservation designations that have been granted, (Table 1.1). The future of the North Kent Marshes, and particularly the inner marshes, may therefore lie in the introduction of additional conservation designations, as has been implemented within the North Kent Marshes ESA. An example of this approach is on Crayford and Dartford Marshes, which are to receive SSSI status (EN *pers com.*), because of their invertebrate populations, yet, some sites, e.g. Diggs Marsh, which achieves SSSI status (English Nature 1989), have not been designated. However, the inclusion of Cliffe Marsh as a possible site for a new London airport has bought into question how much protection these conservation designations can provide.

Funding and finance are also important issues in maintaining the grazing management of the North Kent Marshes. The BSE dilemma and foot and mouth outbreaks have both reduced the value of grazing and resulted in a reduction in the number of cattle in particular (Elliot *pers com.*). There has also been a recent loss of farms and hence grazing management on Grain Marsh because of a reduction in funding (Carey *pers com*). The role of central government, the levels of funding provided to the ESA and conservation organisations and general economic conditions will therefore be crucial in maintaining the grazing marshes of North Kent.

Coastal grazing marsh habitat will also in the future become susceptible to changing sea levels, particularly in the southeast where a rise in sea levels is projected (Thames Estuary Partnership 2002). Estimates by Carter (1989) indicate that sea levels in the Thames basin region are rising by 1.4 to 1.5 mm/yr. Isostatic readjustment in the southeast is reinforcing the effects of sea level rise and is resulting in the overall rates of rise being higher than can be attributed to sea level rise alone. In North Kent, it is estimated that the overall rise is approximately 3 mm per annum (Long and Mason 1983).

With the world's climate currently undergoing changes (IPCC1990), mainly because of human activity (ibid), i.e. the burning of fossil fuels, it is difficult to predict how future trends of sea level rise will occur (ibid). The Intergovernmental Panel on Climate Change (IPCC) (1990) has predicted an overall rise of 65cm by 2100. If these figures prove to be accurate then the North Kent Marshes are going to become increasingly vulnerable to the effects of sea level rise, either through direct loss or through increases in coastal defences, which will reduce the saline influence and therefore change the distinct nature of the North Kent Grazing Marshes. Should the predicted isostatic rise in sea level occur in conjunction with an overall warming of the climate generally, the next century could see a marked change in both the extent of the North Kent Marshes and changes in the bird species composition and vegetation communities associated with the area. The implications for the future of estuarine wildlife including grazing marsh are of great consequence. With increased flooding the water and substrate will become more saline in influence thereby changing the nature of the vegetation, both terrestrial and aquatic. The change in salinity of the water and longer periods of inundation will affect the vegetation and lead to a shift in the dominance of community types back to saltmarsh communities. It is difficult to anticipate the effects on the bird populations of North Kent as although inundation will still be a factor in the habitat make up, the change in condition of the vegetation may make grazing marshes unsuitable as breeding sites for many species e.g. lapwing (*Vanellus vanellus*). A reduction in the number and diversity of species using the North Kent Marshes would depreciate the conservation value of the area.

Increasing the coastal defences to control flooding will also have implications for the remaining grazing marsh. As defences are increased in size, so the area of the grazing marsh habitat will be reduced, as will the estuarine and saline influences. Together with the increased pressure for development, the effects of construction of new defences will ultimately cause loss to the grazing marsh habitat through coastal squeeze, i.e. the area between the defences and developments is reduced.

In the future global climate change and sea level rise may well produce further natural fragmentation of the North Kent Grazing Marshes. The continued threat of global climate change and resulting sea level changes as the oceans warm and expand and the possible melting of the polar ice-caps pose a renewed question, which may ultimately see the North Kent grazing marshes return to saltmarsh. Currently therefore anthropogenic activity is the most serious cause of fragmentation on the North Kent Grazing Marshes, whereas natural fragmentation is a past and future concern.

9.5 Conclusion.

Fragmentation of the North Kent Grazing Marshes has resulted in the once extensive saltmarshes and lowland grasslands of the Thames Estuary being reduced to a series of remnant fragments of varying size and quality. The remaining fragments of the grazing marsh habitat can be regarded as isolated islands managed within the North Kent Grazing Marshes ESA and/or protected by conservation designations or if not neither managed nor protected are regarded as areas for development. All such fragments however, are part of a complex landscape mosaic of habitats, urbanisation and industrialisation that relate to the fragmenting agents, which have affected the structure of the landscape (Section 2.1.1). Many of the remaining marshes have managed however, despite much adversity to maintain much of their characteristic features, with only the openness and big skies of Dickens (1861) and Cobham (1990) being lost in the Inner Thames Marshes and influenced by their surroundings in the Outer Thames Marshes.

Identification of grazing marshes does not rely on a single factor but on a complete inventory of the many facets that comprise a grazing marsh as outlined in this study, specifically the landscape characteristics and features together with the plant community type. The continued presence of grazing marsh will require the management and monitoring of all the landscape characteristics and features, i.e. ditches, embankments, counter walls, homogeneity, tussocky grassland, rills and wet hollows, the vegetation communities and the control of invasive species and scrub. Currently ditches are monitored by English Nature, and the Environment Agency, who also monitor the condition of the embankments, whereas DEFRA monitors the levels of grazing and overall management on the ESA marshes. The remaining characteristics and features, i.e. homogeneity, counter walls, rills and wet hollows, the condition of the tussocky grassland, the maintenance of the typical vegetation communities and the presence of invasive species is not monitored, but should be included within any monitoring strategy. The landscape characteristics and features aided by a detailed vegetation comparison should then be used to verify if the fragments are still to be regarded as grazing marsh.

In this study the landscape characteristics and features that constitute the ideal grazing marsh habitat have been identified together with the typical vegetation communities of the North Kent Grazing Marshes. Although research into the influence of the landscape characteristics and features on key bird species has been conducted by Milsom et al (2000, 2002) and Vickery et al (2001), no previous studies have been carried out which link the landscape characteristics and features to the vegetation communities. Identifying these links means that by monitoring the vegetation communities, any changes in the landscape characteristics and features, which comprise the minimal structure of the grazing marsh habitat, will become apparent, and which may influence the future conservation value of the grazing marsh. Further research however, needs to be carried out, particularly in respect of the hydrology of the Inner Thames Marshes, to further understand how management influences and affects the landscape characteristics and features. This is due to a lack of historical data on the pre-fragmentation state of many grazing marshes.

Results in this study have shown that there is a correlation between the size of a fragment and the condition of the landscape characteristics and features. Indications are therefore that as fragments become smaller, the minimal structural elements of the grazing marsh habitat are affected both directly and indirectly with consequences for the conservation value. There are however, fragments, which do not always follow the anticipated trends in terms of losing their minimal or configurational structure, e.g. homogeneity on Crayford 2b, or that smaller areas contain fewer numbers of key species, e.g. Diggs Marsh (Kent Ornithological Trust 1996).

The requirements to retain large areas of grazing marsh to provide habitat for the large numbers of bird species has been used as the primary argument for protecting the North Kent Grazing Marshes (English Nature *pers com.*), and the conservation designations awarded to the area reflects this importance. Retention of the landscape characteristics and features together with sympathetic management however, need to be brought together if the habitat is to remain conducive to the presence of birds and invertebrates and to maintain their conservation status. The characteristic physical condition of the grazing marsh habitat, which is defined by the landscape characteristics and features identify grazing marsh as an individual habitat type, distinct from other lowland wet grasslands and mesotrophic grasslands. The decline in quality of the landscape features and characteristics is due as much to a lack of sympathetic management as to fragmentation, as can be seen on fragments such as Stone Marsh 2f. In this respect, management should be through grazing of sheep and cattle or both at a stocking density of 0.75 livestock units/ha (ADAS 1997), and during periods when trampling will not cause damage to the sward through excessive poaching, and not random horse grazing.

Fragmentation is the root cause that leads to the creation of smaller fragments, i.e. those under 30ha, which in turn are deemed too small to be productive and are therefore left unmanaged, or designated for future development. Grazing marshes were created by human activities when they enclosed the Thames saltmarshes. They have been maintained by human management techniques, and management is therefore the key to their survival. Fragmented and developed grazing marshes may however require new forms of management, and therefore the need for research, so their future lies very much in the hands of man.

The North Kent Grazing Marshes have been described as suffering the 'death by a thousand cuts' (English Nature 1990), i.e. fragmentation is resulting in the loss and decline in status. Results in this study indicate that fragmentation may not be directly causing 'death by a thousand cuts', but perhaps more accurately described as 'mortal wounding by a thousand cuts', and then perhaps death through a lack of care and management.

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Appendix 1

Mesotrophic grassland communities identified by Rodwell (1990):-

MG1 *Arrhenatherum elatius* grassland

Pastinaca sativa sub-community

Filipendula ulmaria sub-community

Urtica dioica sub-community

Centaurea nigra sub-community

Festuca rubra sub-community

MG2 *Arrhenatherum elatius – Filipendula ulmaria* tall-herb grassland

Polemonium caeruleum sub-community

Filipendula ulmaria sub-community

MG3 *Athoxanthum odoratum – Geranium sylvatica* grassland

Arrhenatherum elatius sub-community

Bromus hordeaceus sub-community

Briza media sub-community

MG4 *Alopecurus pratensis – Sanguisorba officinalis* grassland

MG5 *Cynosurus cristatus – Centaurea nigra* grassland

Galium verum sub-community

Danthonia decumbens sub-community

Lathyrus pratensis sub-community

MG6 *Lolium perenne – Cynosurus cristatus* grassland

Typical sub-community

Trisetum flavescens sub-community

Anthoxanthum odoratum sub-community

MG7 *Lolium perenne* grassland leys

Lolium perenne – Trifolium repens

Lolium perenne – Poa trivialis

Lolium perenne – Alopecurus pratensis

Lolium perenne – Alopecurus pratensis – Festuca pratensis

Lolium perenne – Plantago major

Lolium perenne – Poa pratensis

MG8 *Cynosurus cristatus – Caltha palustris*

MG9 *Holcus lanatus – Deschampsia cespitosa* grassland

Arrhentharium elatius sub-community

Poa trivialis sub-community

MG10 *Holcus lanatus – Juncus effusus* rush pasture

Juncus inflexus sub-community

Iris pseudacorus sub-community

Typical sub-community

MG11 *Festuca rubra –Agrostis stolonifera – Potentilla anserina* grassland

Honkenya peploides sub-community

Atriplex prostrata sub-community

Lolium perenne sub-community

MG12 *Festuca arundinacea* grassland

Oenanthe lachenalii sub-community

Lolium perenne – Holcus lanatus sub-community

MG13 *Agrostis stolinfera – Alopecurus geniculatus* inundation grassland

Appendix 2

Grazing Marsh Monitoring form

Location Erith Marsh 2a Date 7/5/00

Grid Reference TQ494800

Site Description

Small fragment bounded to east and south by roads, to west by Crossness incinerator, and derelict land to north. Southern end also bordered by scrub development. Ditches generally good condition, but no embankment. Some invasion by species such as *Cirsium* and *Senecio*. Site grazed by horses.

Cause of Fragmentation
Roads - divisive
Incinerator, power station (derelict) - intrusive

No. of fragments - 1

Any Disturbance to Habitat (state nature of disturbance)

None visible, although new developments to east of fragment will increase noise and vehicular movement in future.

Nature of edge (ie what forms the boundary)
Roads,

Connectivity_ - Ditch, Road

Grazing Marsh Indicators

Key Habitat Attributes

a) Landscape Characteristics

Favourably maintained (5) Partially maintained (4) Unfavourably maintained (3)

Attributes declining (2) Attributes partially destroyed (1) Destroyed (0)

b) Ditches

Favourably maintained (5) Partially maintained (4) Unfavourably maintained (3)

Attributes declining (2) Attributes partially declining (1) Destroyed (0)

c) Vegetation Characteristics

Favourably maintained (5) Partially maintained (4) Unfavourably maintained (3)

Attributes declining (2) Attributes partially declining (1) Destroyed (0)

d) Management

Sheep Cattle Horses Rabbits Drained Mown

Increased nutrients Seeded None

e) Fragmentation Process (Past)

Encroaching Divisive Intrusive Regressive Enveloping

f) Fragmentation Process (Current)

Encroaching Divisive Intrusive Regressive Enveloping

g) Fragmentating Agent

Industry Housing Road River Embankment

Waste disposal Recreation Agriculture Utilities L. Industry

h) Connectivity

Ditch River Road Embankment

i) Surrounding Land Use

Arable Grazing Nature conservation Urban Industrial

Waste disposal Recreation Road

3) Site Characteristics

	1	2	3	4	5	6	7	8	9	10
Habitat Type										
Wet grassland										
Dry grassland										
Saltmarsh	0	0	0	0	0	0	0	0	0	0
Hedgerows	X	-	-	-	X	-	-	-	-	-
Trees	0	0	0	0	0	0	0	0	0	0
Scrub	-	-	1	-	-	-	-	-	-	-
Urban influence										
Urban dominance	4	3	4	5	5	4	4	5	5	5
Ditches										
Open	N/A		X	X	X		N/A	X		X
Overgrown		X								
Choked		X								
Isolated		X								
Infilled									X	
Managed			X		X			X		X
Unmanaged		X				X				
Traditional		X		X						
Straight			X		X	X				
Score	0	2	4	4	4	4	0	4	0	4
Sward										
Homogenous	3	4	5	3	5	4	3	4	5	5
Heterogeneous	2	1	0	3	0	1	3	3	0	1
Tussocky	2	3	3	2	3	3	3	2	0	0
Height in cm	15	25	10	10	3	2	5	1	3	1
Rills/Wet flushes	2	1	2	2	3	2	0	1	3	3
Invasives	3	3	0	3	2	2	3	3	1	1
~~**Embankments**~~ →					N/A					
Grazed										
Mown										
Unmanaged										
Score										
Other Uses										
Recreation	X	X	X	X	X	X	X	X	X	X
Arable	-	X	-	-	-	-	-	-	-	-
Industry	-	-	-	-	-	-	-	-	-	-
Waste disposal	-	-	-	-	-	-	-	-	-	X
Nature conservation										
← ~~Bird watching~~ →					X					
Wildfowling	-	-	-	-	-	-	-	-	-	-
Grazing										
Cattle	-	-	-	-	-	-	-	-	-	-
Sheep	-	-	-	-	-	-	-	-	-	-
Horses	X	X	X	X	X	X	X	X	X	X
Rabbit	-	X	-	-	-	-	X	-	-	X

Grazing Marsh Fragmentation scoring form

Indicators	Present	Absent	Ave Score	Comments
LANDSCAPE CHARACTERISTICS				
Grazing marsh	P			Small fragment, horses grazing
Cultivated marsh		A		
Marsh urban/industrial influence				
Marsh urban/industrial dominance	P		4.4	Dominated by incinerator and derelict power station
Flat	P			
Rolling	P			
Rills/anthills			1.9	
Embankments			0	
Counter walls			2	
DITCHES:-			3.71	
VEGETATION CHARACTERISTICS				
Homogeneous			4.1	
Heterogeneous			0.9	
Tussocky			2.1	
Sward height			17.5cm	
Invasive species			2.1	
Scrub				Small amount associated with hedge
Hedgerows				Around southern boundary
Trees				Few intermingled in hedge

Presence and absence should indicate whether they are a positive or negative factor.

Comments

Ditches:- record number of each type

LAC – Limit of Acceptable change -

Scale to record conditions of individual features:-

5) All characteristics present with minimal evidence of change/impact
4) Main characteristics present with evidence of deterioration in secondary attributes
3) Characteristics present but with evidence of deterioration in primary attributes
2) Characteristics present but deterioration in primary and secondary attributes
1) Less than 50% characteristics present major evidence of deterioration
0) No characteristics present
X) Indicates that the characteristic is present.

Average score:- calculated from totals of scores for site characteristics (3)

Appendix 3 Community Matches for Individual Fragments

Erith Marsh 2A

The N.V.C. communities most closely matching the test data are:

1. OV23 coefficient = 51.0 4 sub communities.
2. MG 7A coefficient = 48.5 0 sub communities.
3. OV21 coefficient = 47.0 3 sub communities.
4. MG 6 coefficient = 46.6 3 sub communities.
5. MG11 coefficient = 46.3 3 sub communities.
6. MG 7B coefficient = 43.4 0 sub communities.
7. MG 7E coefficient = 40.7 0 sub communities.
8. MG 7F coefficient = 39.9 0 sub communities.
9. MG 7C coefficient = 39.2 0 sub communities.
10. MG 7D coefficient = 38.4 0 sub communities.

Erith Marsh 2B

The N.V.C. communities most closely matching the test data are:

1. OV23 coefficient = 53.7 4 sub communities.
2. OV21 coefficient = 44.3 3 sub communities.
3. MG 7A coefficient = 42.9 0 sub communities.
4. MG 6 coefficient = 41.6 3 sub communities.
5. MG 7F coefficient = 38.5 0 sub communities.
6. MG 7E coefficient = 37.9 0 sub communities.
7. OV22 coefficient = 37.4 3 sub communities.
8. MG 7D coefficient = 36.7 0 sub communities.
9. OV19 coefficient = 36.1 5 sub communities.
10. MG 7B coefficient = 35.3 0 sub communities.

Crayford Marsh 1

The N.V.C. communities most closely matching the test data are:

1. OV23 coefficient = 62.5, 4 sub communities.
2. MG 7A coefficient = 59.1, 0 sub communities.
3. MG 7F coefficient = 54.9, 0 sub communities.
4. MG 7E coefficient = 53.8, 0 sub communities.
5. MG 7B coefficient = 53.3, 0 sub communities.
6. MG 7C coefficient = 51.4, 0 sub communities.
7. OV21 coefficient = 50.7, 3 sub communities.
8. MG11 coefficient = 50.2, 3 sub communities.
9. MG 6 coefficient = 49.8, 3 sub communities.
10. MG 7D coefficient = 49.1, 0 sub communities.

Crayford Marsh 2A

The N.V.C. communities most closely matching the test data are:

1. OV23 coefficient = 60.3, 4 sub communities.
2. MG 7A coefficient = 57.8, 0 sub communities.

3. MG11 coefficient = 56.8, 3 sub communities.
4. MG 6 coefficient = 53.3, 3 sub communities.
5. MG 7F coefficient = 52.8, 0 sub communities.
6. OV21 coefficient = 52.3, 3 sub communities.
7. MG 7B coefficient = 50.0, 0 sub communities.
8. MG 7C coefficient = 49.6, 0 sub communities.
9. MG 7E coefficient = 49.2, 0 sub communities.
10. MG 7D coefficient = 48.7, 0 sub communities.

<u>Crayford Fragment 3A</u>

The N.V.C. communities most closely matching the test data are:
1. OV23 coefficient = 55.0, 4 sub communities.
2. OV21 coefficient = 49.3, 3 sub communities.
3. MG11 coefficient = 45.9, 3 sub communities.
4. MG 7A coefficient = 44.0, 0 sub communities.
5. OV28 coefficient = 42.3, 2 sub communities.
6. OV20 coefficient = 41.0, 2 sub communities.
7. OV19 coefficient = 40.5, 5 sub communities.
8. MG 7E coefficient = 40.3, 0 sub communities.
9. MG 7F coefficient = 39.7, 0 sub communities.
10. OV24 coefficient = 38.2, 2 sub communities.

<u>Crayford Fragment 3B</u>

The N.V.C. communities most closely matching the test data are:
1. OV23 coefficient = 61.0, 4 sub communities.
2. OV19 coefficient = 44.9, 5 sub communities.
3. OV21 coefficient = 44.8, 3 sub communities.
4. OV25 coefficient = 43.6, 3 sub communities.
5. OV18 coefficient = 42.6, 2 sub communities.
6. OV10 coefficient = 41.5, 4 sub communities.
7. OV22 coefficient = 40.5, 3 sub communities.
8. MG 7E coefficient = 39.0, 0 sub communities.
9. MG11 coefficient = 38.4, 3 sub communities.
10. MG 7F coefficient = 38.2, 0 sub communities.

<u>Barnes Cray</u>

The N.V.C. communities most closely matching the test data are:
1. MG11 coefficient = 47.4, 3 sub communities.
2. OV28 coefficient = 46.5, 2 sub communities.
3. OV26 coefficient = 42.0, 5 sub communities.
4. MG 9 coefficient = 39.9, 2 sub communities.
5. MG10 coefficient = 38.0, 3 sub communities.
6. S26 coefficient = 37.7, 4 sub communities.
7. OV21 coefficient = 37.0, 3 sub communities.
8. MG 7D coefficient = 36.4, 0 sub communities.
9. MG13 coefficient = 36.0, 0 sub communities.
10. OV27 coefficient = 35.3, 5 sub communities.

Dartford Marsh 1a

The N.V.C. communities most closely matching the test data are:
1. OV23 coefficient = 59.9, 4 sub communities.
2. OV21 coefficient = 55.4, 3 sub communities.
3. MG11 coefficient = 54.1, 3 sub communities.
4. OV19 coefficient = 50.2, 5 sub communities.
5. OV10 coefficient = 49.9, 4 sub communities.
6. MG 7F coefficient = 48.0, 0 sub communities.
7. OV25 coefficient = 47.5, 3 sub communities.
8. OV22 coefficient = 46.8, 3 sub communities.
9. MG 7A coefficient = 45.6, 0 sub communities.
10. MG 7E coefficient = 44.2, 0 sub communities.

Dartford Fresh Marsh

The N.V.C. communities most closely matching the test data are:
1. OV26 coefficient = 48.6, 5 subcommunities.
2. MG10 coefficient = 48.5, 3 subcommunities.
3. MG 9 coefficient = 47.2, 2 subcommunities.
4. MG13 coefficient = 45.2, 0 subcommunities.
5. MG11 coefficient = 44.5, 3 subcommunities.
6. OV21 coefficient = 41.3, 3 subcommunities.
7. M27 coefficient = 40.9, 3 subcommunities.
8. OV23 coefficient = 40.7, 4 subcommunities.
9. OV28 coefficient = 40.6, 2 subcommunities.
10. S26 coefficient = 40.5, 4 subcommunities.

Stone Marsh 2a

The N.V.C. communities most closely matching the test data are:
1. OV21 coefficient = 45.9, 3 sub communities.
2. OV23 coefficient = 45.8, 4 sub communities.
3. OV20 coefficient = 42.9, 2 sub communities.
4. MG11 coefficient = 40.4, 3 sub communities.
5. OV10 coefficient = 39.5, 4 sub communities.
6. OV25 coefficient = 38.4, 3 sub communities.
7. OV19 coefficient = 36.8, 5 sub communities.
8. MG 7A coefficient = 36.3, 0 sub communities.
9. OV22 coefficient = 36.1, 3 sub communities.
10. MG 7E coefficient = 35.3, 0 sub communities.

Stone Marsh 2b

The N.V.C. communities most closely matching the test data are:
1. OV10 coefficient = 37.7, 4 sub communities.
2. OV21 coefficient = 37.5, 3 sub communities.
3. OV23 coefficient = 35.7, 4 sub communities.
4. OV19 coefficient = 32.7, 5 sub communities.
5. OV24 coefficient = 31.9, 2 sub communities.

6. U 1 coefficient = 31.3, 6 sub communities.
7. MG11 coefficient = 30.4, 3 sub communities.
8. MG 1 coefficient = 30.3, 5 sub communities.
9. MG 7D coefficient = 30.1, 0 sub communities.
10. OV20 coefficient = 29.2, 2 sub communities.

Stone Marshes 2c

The N.V.C. communities most closely matching the test data are:
1. MG 7A coefficient = 56.4, 0 sub communities.
2. MG 7D coefficient = 49.8, 0 sub communities.
3. MG 7F coefficient = 49.6, 0 sub communities.
4. OV23 coefficient = 48.7, 4 sub communities.
5. MG 7E coefficient = 46.0, 0 sub communities.
6. MG 7B coefficient = 45.7, 0 sub communities.
7. MG 6 coefficient = 43.6, 3 sub communities.
8. MG11 coefficient = 38.7, 3 sub communities.
9. OV21 coefficient = 37.5, 3 sub communities.
10. MG 7C coefficient = 37.3, 0 sub communities.

Stone Marshes 2d

The N.V.C. communities most closely matching the test data are:
1. OV23 coefficient = 48.7, 4 sub communities.
2. OV19 coefficient = 38.9, 5 sub communities.
3. OV10 coefficient = 37.8, 4 sub communities.
4. MG11 coefficient = 37.5, 3 sub communities.
5. MG12 coefficient = 37.5, 2 sub communities.
6. OV25 coefficient = 36.7, 3 sub communities.
7. MG 1 coefficient = 36.3, 5 sub communities.
8. SM28 coefficient = 36.2, 0 sub communities.
9. MG 7F coefficient = 35.9, 0 sub communities.
10. OV21 coefficient = 35.5, 3 sub communities.

Swanscombe Marsh

The N.V.C. communities most closely matching the test data are:
1. OV23 coefficient = 39.4, 4 sub communities.
2. OV21 coefficient = 39.3, 3 sub communities.
3. MG11 coefficient = 38.7, 3 sub communities.
4. OV10 coefficient = 36.9, 4 sub communities.
5. OV19 coefficient = 35.4, 5 sub communities.
6. OV18 coefficient = 34.0, 2 sub communities.
7. OV25 coefficient = 33.9, 3 sub communities.
8. S18 coefficient = 33.1, 2 sub communities.
9. OV28 coefficient = 31.1, 2 sub communities.
10. S 4 coefficient = 31.1, 4 sub communities.

Botany Marsh

The N.V.C. communities most closely matching the test data are:

1. OV23 coefficient = 45.8, 4 sub communities.
2. OV21 coefficient = 44.4, 3 sub communities.
3. OV19 coefficient = 43.8, 5 sub communities.
4. MG 1 coefficient = 43.5, 5 sub communities.
5. MG11 coefficient = 43.4, 3 sub communities.
6. OV25 coefficient = 43.1, 3 sub communities.
7. MG 9 coefficient = 39.2, 2 sub communities.
8. OV10 coefficient = 38.5, 4 sub communities.
9. OV22 coefficient = 38.4, 3 sub communities.
10. OV24 coefficient = 38.3, 2 sub communities.

Denton Marsh

The N.V.C. communities most closely matching the test data are:

1. OV23 coefficient = 56.0, 4 sub communities.
2. OV21 coefficient = 52.8, 3 sub communities.
3. MG 7A coefficient = 48.5, 0 sub communities.
4. MG11 coefficient = 46.3, 3 sub communities.
5. MG 7E coefficient = 46.1, 0 sub communities.
6. MG 6 coefficient = 45.5, 3 sub communities.
7. MG 7B coefficient = 44.0, 0 sub communities.
8. MG 7F coefficient = 43.3, 0 sub communities.
9. OV18 coefficient = 40.5, 2 sub communities.
10. OV22 coefficient = 40.1, 3 sub communities.

Filborough Marsh

The N.V.C. communities most closely matching the test data are:

1. OV23 coefficient = 49.6, 4 sub communities.
2. MG 7A coefficient = 47.5, 0 sub communities.
3. MG 7B coefficient = 46.6, 0 sub communities.
4. MG11 coefficient = 42.9, 3 sub communities.
5. MG 7D coefficient = 42.0, 0 sub communities.
6. MG 6 coefficient = 41.9, 3 sub communities.
7. OV21 coefficient = 39.5, 3 sub communities.
8. MG 7E coefficient = 38.9, 0 sub communities.
9. MG 7F coefficient = 38.0, 0 sub communities.
10. MG 7C coefficient = 37.7, 0 sub communities.

Shorne Marsh

The N.V.C. communities most closely matching the test data are:

1. OV23 coefficient = 49.1, 4 sub communities.
2. MG11 coefficient = 46.7, 3 sub communities.
3. MG 6 coefficient = 46.6, 3 sub communities.
4. OV21 coefficient = 45.9, 3 sub communities.

5. MG 7B coefficient = 45.3, 0 sub communities.
6. MG 7A coefficient = 44.2, 0 sub communities.
7. MG 7F coefficient = 44.1, 0 sub communities.
8. MG 9 coefficient = 41.5, 2 sub communities.
9. MG 7E coefficient = 41.5, 0 sub communities.
10. MG 7C coefficient = 41.4, 0 sub communities.

Higham Marsh 1A

The N.V.C. communities most closely matching the test data are:
1. MG 7A coefficient = 47.1, 0 sub communities.
2. OV23 coefficient = 46.5, 4 sub communities.
3. MG11 coefficient = 42.4, 3 sub communities.
4. MG 7B coefficient = 41.9, 0 sub communities.
5. MG 6 coefficient = 40.5, 3 sub communities.
6. OV21 coefficient = 39.6, 3 sub communities.
7. MG 7D coefficient = 38.1, 0 sub communities.
8. OV10 coefficient = 36.9, 4 sub communities.
9. OV25 coefficient = 36.3, 3 sub communities.
10. MG 7F coefficient = 36.3, 0 sub communities.

Higham Marsh 1C

The N.V.C. communities most closely matching the test data are:
1. MG 6 coefficient = 43.9, 3 sub communities.
2. MG 7B coefficient = 43.6, 0 sub communities.
3. MG 7A coefficient = 43.0, 0 sub communities.
4. MG11 coefficient = 41.7, 3 sub communities.
5. OV21 coefficient = 41.4, 3 sub communities.
6. OV23 coefficient = 39.6, 4 sub communities.
7. MG 7D coefficient = 36.3, 0 sub communities.
8. MG 7F coefficient = 35.7, 0 sub communities.
9. MG 7C coefficient = 35.6, 0 sub communities.
10. MG 9 coefficient = 35.1, 2 sub communities.

Cliffe Marsh

The N.V.C. communities most closely matching the test data are:
1. MG11 coefficient = 48.4, 3 sub communities.
2. MG 7B coefficient = 45.8, 0 sub communities.
3. OV23 coefficient = 44.7, 4 sub communities.
4. MG 6 coefficient = 44.5, 3 sub communities.
5. MG 9 coefficient = 43.9, 2 sub communities.
6. MG 7A coefficient = 43.1, 0 sub communities.
7. OV21 coefficient = 41.4, 3 sub communities.
8. MG 7C coefficient = 39.9, 0 sub communities.
9. MG10 coefficient = 39.0, 3 sub communities.
10. MG 7F coefficient = 38.9, 0 sub communities.

Allhallows Marsh

The N.V.C. communities most closely matching the test data are:

1. MG 6 coefficient = 50.2, 3 sub communities.
2. OV23 coefficient = 46.1, 4 sub communities.
3. MG11 coefficient = 46.0, 3 sub communities.
4. OV21 coefficient = 44.3, 3 sub communities.
5. MG 7F coefficient = 44.1, 0 sub communities.
6. MG 7B coefficient = 43.4, 0 sub communities.
7. MG 7A coefficient = 43.4, 0 sub communities.
8. MG 7D coefficient = 42.7, 0 sub communities.
9. MG 7E coefficient = 41.3, 0 sub communities.
10. MG12 coefficient = 38.4, 2 sub communities.

Chetney Marsh

The N.V.C. communities most closely matching the test data are:

1. MG 7B coefficient = 51.3, 0 sub communities.
2. MG 7D coefficient = 43.9, 0 sub communities.
3. MG 6 coefficient = 43.8, 3 sub communities.
4. MG 7A coefficient = 42.4, 0 sub communities.
5. MG11 coefficient = 42.0, 3 sub communities.
6. MG 7E coefficient = 41.8, 0 sub communities.
7. MG 7C coefficient = 41.2, 0 sub communities.
8. MG 9 coefficient = 39.5, 2 sub communities.
9. OV28 coefficient = 39.4, 2 sub communities.
10. OV23 coefficient = 38.5, 4 sub communities.

Table 8.8 Individual Quadrat Summary of MATCH analysis, recording the occurrence of each community in the individual samples for all fragments

	E2a	E2b	E2c	C1	C2a	C3a	C3b	Bc	D	Dfr	S2a	S2b	S2c	S2d	Sw	Bo	De	F	Sh	H1a	H1c	Cl	A	Ch
MG1				8	2		2	6	5	26		4	2	4	1	13	4	17	1	4	1	2	2	
MG3								1																
MG4	4	4	2					1	1									1			1	1	1	
MG5	4	4	5	4				1	2			1		1		2	3	1			1	1	6	
MG6	24	24	10	16	17	3	2	32	5	8	2	4	2	3	11	7	10	69	14	36	14	58	27	18
MG7A	25	25	10	24	24	13	2	58	9	2	5		2		20	12	12	98	24	51	15	75	26	21
MG7B	24	24	10	21	18	7	4	47	4	71	4	4	5	1	16	10	10	96	18	39	13	70	26	24
MG7C	15	15	5	10	8		1	12	1	14	1	1		1	5	1	1	24	5	5	1	13	10	10
MG7D	23	23	8	22	21	11	5	48	5	12	5	7	5	7	9	9	8	79	24	42	13	71	25	19
MG7E	25	25	8	20	15	9	1	40	12	21	5	7	1	7	9	12	12	58	16	14	8	19	21	15
MG7F	24	25	9	21	19	8	4	36	8	1	4	7	4	5	10	8	12	66	12	12	10	26	20	7
MG8	4	4	1	1	1			2		7										4	4	1	2	
MG9				3	3		3	2	1	81			3	3		3	1	29	4	16	4	19	12	10
MG10				11	7	1	7	15		90			7	1	1	1	1	23	2	21	3	27	1	17
MG11	5	5	7	13	24	11	6	53	11	25	2	2	6	7	19	10	10	83	19	45	10	75	26	21
MG12	1	1	2	1	4	1		9			1			4	3	1		9	1	9	1	16	10	2
MG13				6	10	4	8	23	2	87	2		8	6	6	5		29	11	33	6	46	4	12
OV3														1										
OV4										1				1	2									
OV5								1																
OV8								1																
OV9						1		1			1	1		1	4			1						
OV10				1	2	3		14	6		6	1		6	4	6	2	22	1	5	1	7	6	6
OV11								2		1		1		1	1									
OV12								5	2	29		1		3	1		1	4		1				3
OV13															1									
OV14												1												
OV15					2			2																
OV16								2							1									

OV17								1				1		1										
OV18	2	2	1	2	2	8		30	12		7			2	12	4	7	29	7	16	5	10	9	4
OV19	2	2	1		2	1		15	13	26	3	1		7	7	10	3	5		1			2	1
OV20	1			5	8	13		35	10		7	1		8	17	5	6	34	12	19	5	28	5	10
OV21	24	24	8	12	9	13	6	46	13	33	6	1	6	8	11	3	11	67	18	36	15	52	13	14
OV22	12	12				1		4	3	1	3				4	4	2		1					
OV23	25	25	9	19	17	14	1	56	16	8	6	3	1	10	19	17	14	65	21	32	11	43	19	7
OV24				6		2	3	8	1	21	1		3		2	9	3	7	1	2	1	1	1	
OV25				5	2	1	3	13	7	24	2		3	5	14	17		16	4	9	4	22		2
OV26						1	4			16	1		1	2	2	7	1							
OV27							1			23			1			1								
OV28	6	6	2	7	14	13	8	35	6	77	4	1	8	7	17	6	4	54	15	39	6	66	5	16
OV29								2		66				1										
OV30										6														
OV31							2			6			1											
OV32							1			10			1					1				1		
OV33							1			1			1				1							
OV37												4												
SM16					1									1	1	2				1			2	
SM18								1																
SM19							1			1			1		1	1		1		1			2	
SM20					3	1	1	7	1	19	2			2	2	3		10	7	14	3	20	2	1
SM23																							2	
SM28					2		1	7		27	1	1	1	8	6	5		6	1	6		17	7	1
S2										3	2			2	1									
S3										2					2									
S4								1		16	2			4	3	1		1						
S5										6	1			1										
S6										4	1			1	1									
S7										1														
S8										1														
S9														1										
S11										1														

S12							1			10			1		3									
S13										9	2				1									
S14										12														
S15										1														
S16										3														
S17										7	1			1	1	5						1		
S18					1		1	2		2	1		1	2	1			2						
S19							1			40			1											
S20										2	1				1			3		2	1			
S21											1			1	1			3		1	1			
S22										59					1									
S25										1	1		3	1	1									
S26							1			13	1		3	4	3	8								
S28							1	1		10			3											
SD1										2					1	12								
SD3								2		1	1													
SD5								1																
SD6								1				3			1									
SD7										1		5						1						
SD8			1									3	1	2		2							1	
SD9				1						4		5		2		3		2					1	
SD12												5												
SD13								1																
SD17					1		5			11			5					2	1	3	1		1	
SD18				1			3			2		1	3			9								
MC3														1										
MC7					2					1		1		1								1		
MC8											1			1								1		
MC9					1			2	1			2		6								2		
MC10								6				1		4		3								
MC11													1	1			1	1			1			
M23								1		4														
M27										5														

M35										6														
A1																								
A2																								
A3										9														
A4																								
A5					1																			
A9										3														
A10										6														
A18										3														
A19										12														
A20										10														
CG3																1								
CG4									1							1								
CG6								1								1								
CG7									1															
W2										1	1													
W6							1						1											
W21																1								
W23												4												
W24							2			14			2			2		1						
W25							2						2											
U1											1	6												
U4												3												
U5												3												
U13												3												
No. of samples	25	25	10	24	24	14	10	70	16	115	10	10	10	10	27	31	14	24	102	52	16	79	30	24

Key

E – Erith C – Crayford Bc – Barnes Cray D – Dartford Dfr – Dartford Fresh Marsh S – Stone
Sw – Swanscombe Bo – Botany De – Denton F – Filborough Sh – Shorne H – Higham
Cl – Cliffe A – Allhallows Ch - Chetney