# *The Conservation of Rare Arable Weeds on Set-aside land : Ecological, Socio-economic and Political Implications.*

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by

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## Abstract

Following the 1992 reform of the Common Agricultural Policy (CAP), which resulted in the introduction of the Arable Area Payments Scheme, set-aside land has become a widespread feature of the British countryside. Results are presented from an integrated, ecological and socio-economic analysis of the actual, perceived and realised wildlife conservation potential of this land. Consideration is given to future developments which will ensure that set-aside land occupies an appropriate place in a nature conservation framework for agricultural land within the British Isles.

An initial farm-based questionnaire survey sought to determine farmers' attitudes towards, and perceptions of the 1992 CAP reform, set-aside land and nature conservation, and created a baseline of data for the ways in which set-aside land was being managed within three discrete agricultural regions in England (the east, south-east and north-west). In general, farmers were not opposed to the outcome of the CAP reform, however, attitudes to the concept of set-aside were far less favourable. Only 49ha (<1%) of the set-aside area surveyed was being managed specifically for nature conservation in accordance with MAFF's guidelines for "management for environmental objectives". Overall, attitudes towards wildlife and nature conservation were favourable, with many farmers acknowledging the potential of set-aside land to enhance the wildlife resource on arable land. Possible reasons for this disparity between farmers' attitudes and their actions on set-aside land are ; the lack of financial incentives for positive conservation management on set-aside land, a general dislike, and mistrust of set-aside within the farming community, a lack of awareness of conservation options, uncertainty over future policy developments, and in some cases, disinterest in nature conservation.

A second survey sought to explore in greater detail, the factors which were constraining the uptake of conservation-based management on set-aside land. Key amongst these was the absence of financial incentives, or even compensation for additional expenditure incurred. Farmers were invited to indicate what they believed would be appropriate payment rates, many indicating a requirement for relatively low 'top-up' payments to encourage them to take up these options. Opposition to set-aside policy is a more fundamental barrier to participation, however, one of the farming communities major concerns was the impression that set-aside gave to the public ('paying farmers to do nothing'), and this can be easily addressed by appropriate management for wildlife and environmental benefits. Many farmers were willing to embrace a dual role in the countryside as producers of food and 'countryside stewards' and modifications to set-aside policy are discussed which may ensure that the perceived nature conservation potential of set-aside land is fully realised in the future.

Ecological glasshouse and field trials were conducted to determine the actual potential of set-aside land for the establishment, from seed, of diverse, stable and persistent communities of rare arable weeds. Autecological experimentation investigated aspects of the seedbank dynamics of species which were sown in a large-scale field trial on 'set-aside' land. These differentiated between species which formed transient (*A. githago* and *B. interruptus*) and persistent (*C. cyanus, C. segetum* and *P. rhoeas*) soil seed banks, and determined seasonal patterns of seedling emergence for these species.

Rare arable weed communities, established under a range of management regimes on 'set-aside' land were rapidly dominated by *A. githago* to the detriment of overall species diversity. Cover type had no effect on the population density of *A. githago*, but natural regeneration, as opposed to a sown grass cover, benefited other rare weed species. Cutting regimes had little effect on community structure and it is recommended that the timing of the annual cut is determined on a yearly basis depending on climatic and other extrinsic factors. Population densities of *A. githago* were significantly reduced by a biennial cultivation, but no benefits in terms of overall diversity of rare weed communities were observed. A double (autumn and spring) cultivation in year 3 created significant benefits in terms of community diversity, and appears to be the most suitable regime for the mixture of species sown in this experiment. A critical factor in determining community structure is the interaction between cultivation time and the periodicities of emergence of individual species. Exact management requirements will be dependent on the range of species sown in the initial seed mixture.

Together, these two approaches are considered in the final chapter to assess current constraints and future prospects for the management of set-aside for nature conservation objectives.

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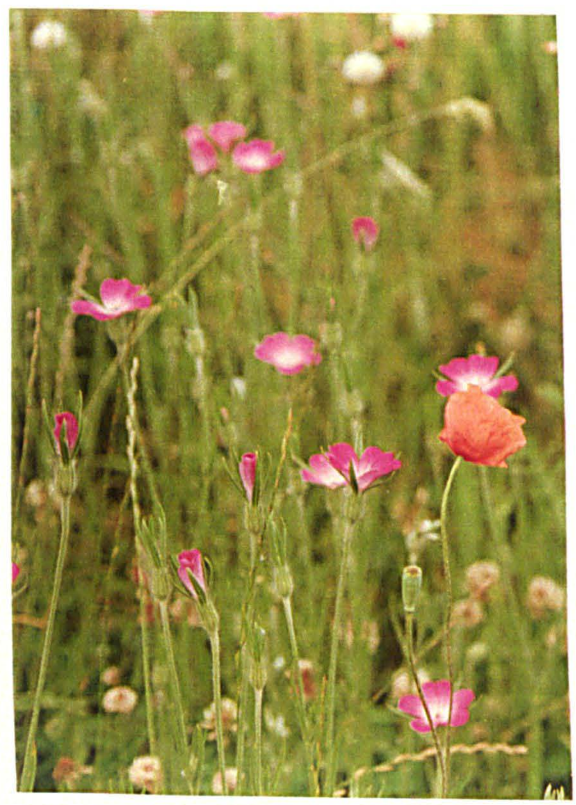


Photographs showing flowering rare arable weed species and communities in summer 1996

# *Chapter 1*

## *General Introduction*

## 1.1 Project Outline

'Set-aside' is agricultural land which has been diverted from productive to non-productive uses in order to achieve supply control objectives. The concept of set-aside is not new, the US government having operated land diversion schemes under various guises since the 1930s (Ervin, 1988). Under the reformed Common Agricultural Policy (CAP), arable producers in the European Union (EU) are required to set-aside an annually determined percentage of their land in order to qualify for support payments (Commission of the European Communities, 1993).

This study aims to assess the **actual, perceived and realised** conservation potential of set-aside land, and will discuss modifications which may result in a policy which more effectively takes nature conservation into the 'wider countryside'. Aims are summarised below :

1. To consider the causes, and consequences of the conflict between agriculture and the nature conservation interest of the countryside. To review the current range of agri-environmental policies available within the British Isles, and the success of these in securing environmental and conservation objectives, and to examine future prospects for a greater degree of integration between agricultural and nature conservation land-use concerns, with special reference to the potential of set-aside land (Chapter 1).

2. To determine a) farmers' attitudes towards, and perceptions of, the 1992 CAP reform, nature conservation and set-aside policy, b) the ways in which set-aside land is being managed, and c) measures which could potentially increase the realisation of wildlife potential on set-aside land (Chapters 2 and 3).

3. To conduct a series of glasshouse and field trials to determine the autecological characteristics and seedbank dynamics of the rare arable weed species[1] used in large-scale field trials (Chapter 4).

4. To determine, by large-scale field experimentation, management guidelines for the creation, from seed, of diverse, persistent and stable communities of rare arable weeds, and for their subsequent maintenance on set-aside land (Chapter 5).

The introduction to this thesis is presented in two parts. Part one discusses the evolution of UK agricultural policy and its economic and environmental consequences. Issues and options for the integration of conservation and agricultural policies are explored, and the wildlife conservation

[1] For the purposes of this thesis rare arable weeds are defined as historically characteristic components of the arable flora of the British Isles, whose abundance has dramatically declined, range of distribution contracted, or which have become extinct during the present century.

potential of set-aside land and its place in a nature conservation framework for the British Isles is considered. Part two introduces aspects of the ecology and conservation biology of rare arable weeds.

# Part 1 - Issues And Options For Agri-Environmental Policy In The UK.

## 1.2 The Agri-environmental conflict.

Countryside politics in Britain has entered a period of unprecedented change (Countryside Commission, 1991a). Never has there existed a greater need, or a better opportunity, to resolve the escalating conflict between agricultural (food production) and environmental (nature conservation, recreation and amenity) land-use objectives. The countryside is a dynamic system which has evolved over thousands of years, but the main agent in this evolution has been human influence. Throughout history, man has exploited the resources of the land to create a multi-use countryside where farming, forestry, settlement, recreation and extraction all co-exist. Agriculture, covering 80% of the UK land surface (Green, 1981), is the dominant land use, and as such exerts the greatest influence on the character of the countryside. Historically, the impact of agriculture on wildlife and landscape features has been benign and even beneficial, creating a more diverse and interesting landscape than the continuous forest which it replaced (Green, 1991). Indeed, many of todays most valued and threatened habitats were created and maintained as a result of traditional extensive farming systems (Ratcliffe, 1984 ; Hoskins, 1978). Tansley (1939) referred to these as 'semi-natural' habitats ; those composed of indigenous vegetation and with a structure approximating to that of natural types. Retrospectively, the farmers who managed these extensive systems have come to be regarded as stewards or guardians of the countryside, keeping the land in good and tidy condition and providing food as well high quality environmental, landscape and wildlife features. Scott (1942) commented that :

> "Farmers and foresters are unconsciously the nations landscape gardeners .... even were there no economic, social or strategic reasons for the maintenance of agriculture, the cheapest, indeed the only way, of preserving the countryside in anything like its traditional aspect would still be to farm it"

Increasingly in the post-war period, however, farmers have been encouraged by government policy to increase production, and to farm more intensively with the result that agricultural and environmental land use concerns have become decoupled, and the philosophy of stewardship has largely given way to one of agri-business, where the maximisation of food production is the over-riding aim. This is reflected in the observations of Strutt (1978) :

> "There is an evident concern about the harmful effects of many current farming practices upon both landscape and nature conservation, coupled with a widespread feeling that agriculture can no longer be accounted the prime architect of conservation nor farmers accepted as the natural custodians of the countryside"

Agricultural and countryside policies have now reached a cross-roads. There is widespread acknowledgement that the goals of intensive agriculture are increasingly incompatible with those of environmental protection within the countryside, and that there is a need for greater integration between agricultural and conservation policy. The Countryside Commission (1991a) have acknowledged that "policy instruments for the countryside often fail to act in a dynamic and integrated way". Attempts to increase the productivity and efficiency of European agriculture have been remarkably successful, to the point where the EU now produces a surplus of certain foodstuffs at a considerable cost in both budgetary and environmental terms (Commission of the European Communities, 1993). During the 1980s a number of modifications were made to the European Union's Common Agricultural Policy (CAP) with a view to containing costs and reducing its environmental impact. These changes culminated in the May 1992 reform, and the introduction of set-aside policy. Now more than at any time in the past there exists an opportunity for conservationists to make their voices heard and to ensure that in the future the countryside is managed in a more integrated way.

This review will discuss the history of agricultural production and government support within the UK and the EC, of the environmental consequences of this, and of the changes which led to the 1992 reform of the CAP. Consideration is then given to options for the integration of conservation and agriculture, and to ways in which set-aside land may be managed to increase the nature conservation potential of the 'wider countryside'.

## 1.3 The Evolution of British Agriculture and it's Impact on Vegetation and Landscape pre 1939.

The impact of *Homo sapiens*, the agriculturalist, on the British landscape and vegetation began following the last great ice-age which ended between 11,000 and 8,000 years ago. Prior to this period, early Palaeolithic human population densities were too low to have caused much of an impact on other species and their environment ; *Homo sapiens* existed as a part of nature, where climate was the main determinant of landscape and vegetation patterns. Subsequently, as man and agriculture have co-evolved, human activity has become the dominant ecological influence.

Deposits from the late and post-glacial periods (12,000 to 8,000 BC) are composed of minerals arising from the extensive erosion which took place in the bare landscape. These deposits contain remains of tundra species - the dwarf birch (*Betula nana*), Arctic willow (*Salix herbacea*) and the mountain avens (*Dryas octapetala*). They also contain opportunist weeds and ruderals such as the knot grasses (*Polygonaceae*) and the goose foots (*Chenopodiaceae*) ; species which represent early successional stages on warmer and more fertile soils. Subsequent deposits are increasingly organic, containing remains of invasive tree species such as the birches (*Betula pubescens and B. pendula*) and aspen (*Populus tremulus*). These successional trends continued until about 6,000 BC, by which time all of Britain up to a tree line of 750m was covered by continuous mixed deciduous forest. Species of open habitats persisted in refuges above the tree line, in coastal areas where processes of erosion were most severe, or in forest clearings created by fire and avalanche, and maintained by grazing animals and human settlement.

The arrival of Neolithic man, about 5000 years ago, marks the beginning of agriculture. Before this, human populations had survived in a hunter-gatherer economy. Pollen analysis of soil horizons formed during this period reveal the presence of weeds of human settlement such as ribwort plantain (*Plantago lanceolata*) and nettle (*Urtica dioica*). At the same time, there was a fall in the presence of tree pollen, and an increase in the pollen of grasses and cereals. The presence of charcoal, and evidence for the recolonisation of forest clearings by bracken (*Pteridium aquilinium*) and birch (*Betula spp.*) suggest the practice of 'slash and burn' agriculture.

The Bronze Age, which began around 1700 BC, was characterised by permanent and more extensive forest clearance giving rise to large tracts of heathland and downland vegetation, which today may only be prevented from reverting to woodland by periodic fire, grazing or cutting. Iron Age and Celtic civilisations continued to exploit these lowland heaths and downlands, and when the Romans arrived in Britain they found a well cleared countryside. The Romans commenced the drainage and reclamation of vast areas of Fenland and wetland in the south and east of England, and continued the process of widespread forest clearance, although extensive areas of lowland Britain on heavy clay soils remained as forest.

Forest clearance continued during the Dark and Middle Ages, and by 1700 AD the bulk of tree cover had been replaced by farmed land, either arable or grassland (Ratcliffe, 1984). By the end of the Middle ages farming had developed into the major land use and economic mainstay of the British Isles, with agriculture having evolved on a largely ecological basis.

Farming, up to this point, had been carried out on a large open field system. During the 18th century these open field systems greatly declined as common grazing areas became increasingly reduced and fragmented, a process culminating in the Parliamentary Enclosures of 1780 to 1820. These gave rise to small fields of about four hectares in size, which were ditched and hedged, usually with hawthorn giving rise to what has become regarded as the traditional English landscape. The introduction of the Corn Laws in 1815, to sustain farm incomes following the Napoleonic Wars gave a further boost to cereal growing and led to a period of 'high farming' which continued until the 1870s. New rotations, manuring and other agricultural innovations led to the cultivation of large areas of heathland, downland and other 'wasteland'. At the same time, domestic livestock husbandry created and maintained semi-natural habitat on unenclosed land.

These patterns of farming continued through most of the 19th century. Compared with today, agriculture was practised as a low-input, low-output regime resulting in man-made plant communities which were floristically rich. Hay meadows were full of colourful flowering dicotyledenous species and arable fields had developed a diverse and characteristic weed flora (Ratcliffe, 1984).

The 1870s saw a turnaround in the fortunes of British agriculture. The Corn Laws had been repealed in 1846, and this had enabled cheap foreign grain from the New World to flood the UK market, reducing prices for cereals and depressing agriculture in general. The need to increase home production during World War 1 marked a slight revival in fortunes, but it was not until similar pressures caused by World War 2 that a full agricultural recovery began.

Between 1870 and 1939, the arable area of England and Wales declined from 5.9m ha to 3.6m ha, whilst at the same time permanent grassland increased in area from 4.4m ha to 6.3m ha (Collins, 1985). The processes which had characterised the agricultural revolution of the 18th and early 19th centuries swiftly moved into reverse as land was managed more extensively, and marginal land was abandoned. This change resulted in a range of environmental benefits and disbenefits, demonstrating the interdependence of agricultural practices, and vegetation and landscape patterns. By the 1930s vast areas of the landscape had 'run wild' and excessive 'general weediness' was a characteristic of many pastures. At the same time, in the uplands, the 'cultivated margin' began to retreat allowing recovery of moorland and rough pasture (Collins, 1985). Collins suggests that :

> "the natural environment existing in 1939 was not .... the exclusive product of many centuries of gradual evolution, but also of a dramatic reversal, beginning in the 1870's, of a progressive trend which reached it's apogee in the third quarter of the 19th Century, in the 'Golden Age' immediately preceding the Great Depression"

The period since 1939 has been called the 'Second Agricultural Revolution' being characterised by state intervention and support for agriculture.

## 1.4 Fifty Years of Agricultural Support in Britain.

### 1.4.1. Agricultural policy in Britain, 1947 - 1973.

Until the 1930s there had been very little direct government involvement in agriculture; farming, like other industries, had been subject to the economics of *laissez-faire*. This approach, however, was largely responsible for the agricultural depression, which together with the food shortages of the two World Wars, provided the impetus for increasing government intervention. Agricultural policy has undergone a number of changes since the 1930s, but has been and continues to be, the major determinant of land use patterns and agricultural practices in the UK.

Government intervention has operated through a number of mechanisms. Grants and subsidies have been made available to encourage farmers to adopt favoured practices or as guarantees of minimum prices for produce. Under the 1932 Wheat Act, wheat producers were offered a subsidy to make up any shortfall between average prices and a guaranteed price - a deficiency payment (Robinson, 1991). The Agricultural Marketing Acts of 1931 and 1933 set up the producer controlled marketing boards which guaranteed an outlet for agricultural products. The 1930s also saw the introduction of limited import protection through 10-20% tariffs on imported products. These first steps led the way for the wide-ranging 1947 Agriculture Act.

#### 1.4.1.1. The 1947 Agriculture Act

The 1947 Agriculture Act, implemented in response to food shortages during World War 2, became the cornerstone of British agricultural policy until the UK joined the EC in 1973. It had four main objectives :

1. to promote a stable and efficient agricultural industry ;
2. to increase agricultural productivity and levels of self-sufficiency in Britain ;
3. to improve farm incomes ;
4. to provide adequate food at cheap prices.

These objectives were to be achieved via a system of price support and guaranteed prices, together with grants and subsidies which ensured an expansionist agricultural industry in the UK. An annual price review was conducted which set a guaranteed price for supported commodities regardless of the volume produced. Farmers then sold their produce at market prices, and if, as was invariably the case, these were below the guaranteed price, a deficiency payment was made. At the same time, farmers could apply for grants to increase production and improve efficiency. These grants could be used to improve farm buildings, purchase machinery, drain farmland, plough up permanent pasture and a variety of other operations (Ilbery, 1992a). The increased security that these guarantees and grants provided gave farmers the confidence to expand, and acted as the catalyst for biological and technological innovation. Plant breeding led to the development of higher yielding crops, farming operations became more mechanised, and the agrochemical industry developed inorganic fertilisers and a range of pesticides which increased crop protection. At the same time, marginal land was brought into arable production (Green, 1981)

Improved efficiency of agricultural production is most readily achieved by taking land out of livestock production and converting it to arable (Green, 1981). Approximately ten times more food can be produced per unit area from plant as opposed to animal production due to inefficient energy conversion through food chains. This consideration resulted in the area under arable crops increasing from 25% of the land area in England and Wales in 1939 to 38% in 1971; conversely the area under permanent grass fell from 42% to 26%. During the same period, rough grazing land declined in area from 15% to 12.5%.

### 1.4.2. The Agricultural Lobby.

Fundamental to the success of post-war agricultural policy in achieving its goals was the strength and cohesion of the agricultural lobby. Farmers exerted far less influence before 1940 than they have post 1947 ;

> "In the 1930's it was industry, and the Dominions which were dominant interests in agricultural policy and this resulted in an agricultural policy which favoured consumers over farmers" (Smith, 1988)

This situation was altered by the 1947 Act which obliged the Ministry of Agriculture, Fisheries and Food (MAFF) ' to consult with such persons as appear to represent the interests of the producer'. The National Farmers Union (NFU) fulfilled this role and from this point onwards the relationship between the NFU and MAFF has given rise to a close-knit and closed community. The agricultural lobby has been strengthened further by the significant role played by the Country Landowners Association (CLA), and by those parties which have a vested interest in the well-being and continued expansion of the agricultural industry such as the suppliers of fertilisers, agrochemicals and farm machinery. This alliance forms a formidable barrier to 'outsiders' wishing to partake in the agricultural policy debate. In many cases the only way to become informed about matters relating to this debate is via members of this lobby who will often react by trying to co-opt outsiders or by trying to shut them out (Grant, 1989).

In recent years, since Britain joined the EC and British agriculture came under the control of the Common Agricultural Policy (CAP), farming issues have become more politicised, as concerns have been voiced over the budgetary and environmental costs of supported agriculture. The environmental lobby had become increasingly vocal and environmentalists have found MAFF to be the "least accessible governmental department and the most unreceptive one" (Cox *et al.*, 1985). Cox *et al.* (1986) commented that "the policy community for rural conservation is characterised as large, diverse and pluralistic ; that for agriculture as small, tightly knit and corporatist"

The success of the agricultural lobby can be summarised in three words ; exceptionalism, protectionism and autonomy (Grant, 1989).

*Exceptionalism* refers to the extent to which agriculture is made exempt from regulations and laws which apply to other industries. Farmers are exempt from paying rates on their land, and agriculture is not subject to normal planning controls. Agriculture also has its own complex infrastructure of research, advisory and educational services. It is the only industry with a separate system of education, the Agricultural Colleges, and also has its own technical advice service, the Agricultural Development and Advisory Service (ADAS) whose prime objective is the development, transfer and application of advanced technology (Lowe *et al.*, 1986). ADAS services were, until 1987, provided free of charge.

The concept of *protectionism* has been discussed with reference to the 1947 Act and will be pursued further in the following section.

Advances in agricultural policy have been achieved without any loss of *autonomy* . This led Cox *et al.* (1986) to consider agriculture as operating under a dual autonomy ;

> "first the autonomy of the Ministry and of the farming community in the administration and implementation of agricultural policy ; and second the autonomy of the farmer in making production and land use decisions"

## 1.4.3. The European Community and the Common Agricultural Policy

The European Economic Community (EEC) (now the EU) was established by the Treaty of Rome in March 1957. Initially it comprised six Member States, all of whom, through various mechanisms, supported their national farming industry. In order to standardise trade in agricultural commodities between these states, it was agreed that a common system of agricultural support be devised. Provisions for a Common Agricultural Policy (CAP) were set out under Article 39 of the Treaty. It's main objectives were to be :

1. to increase productivity by promoting technical progress and ensuring the rational development of agricultural policy ;
2. to ensure a fair standard of living for the agricultural population ;
3. to stabilise markets ;
4. to guarantee a secure supply of food ;

5. to ensure reasonable retail prices to consumers.

(Commission of the European Communities, 1993)

Three principles orientate the operation of the CAP. These are 'community preference' which ensures that priority is given to the sale of community agricultural products ; 'financial solidarity' which requires the policy to be funded at community level and 'unity of the market' which stipulates that a single market for agricultural produce and free trade between member states should exist.

UK agriculture came under the control of the CAP with Britain's accession to the EEC in 1973. The objectives of the CAP were broadly similar to those of national agricultural policy which were in place at the time.

1.4.3.1 CAP funding

The cost of the CAP to Member States is wholly, or partly reimbursed from EU funds. These funds are raised by individual member states, through taxes and levies, and paid into a central community budget. Agricultural support has historically accounted for the bulk of EC spending, rising to a high of 70% in 1988, before falling to 58% in 1992 (Commission of the European Communities, 1993). The sector of the EC budget from which agricultural support is paid is called the European Guidance and Guarantee Fund (FEOGA). This fund is split into a 'Guarantee' and 'Guidance' sector. The Guarantee sector accounts for all market support expenditure (intervention buying, direct payments) and consumes 95% of the total FEOGA budget. The Guidance sector pays for structural, social and environmental aspects of the CAP, accounting for the remaining 5% of the FEOGA budget.

1.4.3.2. The operation of the CAP, 1973 - 1992.

Traditionally, the Guarantee sector of the CAP has operated through a system of controlled prices which have guaranteed the producer a competitive, minimum price for agricultural produce, regardless of the volume produced. This has been achieved by means of a 'dual control system' (Robinson, 1991). This system has three basic elements ; the target price, the intervention price and the threshold price.

The target price is set by the Community, and is the price that the farmer should hope to obtain for his produce in the market place. If the target price is not reached, Member States guarantee that they will buy all produce at the intervention price which is also set by the Community.

This is referred to as 'intervention buying'. These intervention stocks are stored by the Community and may either be sold within the Community when market prices become more appropriate, or exported from the Community. However, the price of commodities on the world market is often lower than the EC intervention price. Traders selling intervention stocks onto the world market are paid an export refund to compensate for the difference between world and internal prices.

The threshold price applies to imports of foodstuffs into the EC. These are often cheaper, and so to prevent the EC being flooded by cheap foreign produce, an import levy is imposed which makes up the shortfall between world prices and the threshold price. This mechanism safeguards the principle of community preference.

## 1.5 The Economic and Social Impacts of Agricultural Support and the Common Agricultural Policy.

The post-war period has witnessed massive increases in crop productivity, and in the efficiency of production. This has been achieved through technical progress and the rational development of agricultural policy, one of the original objectives of Article 39. In Britain the total volume of wheat harvested doubled to 8.6 million tonnes in the period between 1975 and 1981 (Lowe *et al.*, 1986).

Self-sufficiency in food in Britain has risen from 49 to 60 %, whilst the figure for self-sufficiency in temperate foodstuffs was 75% in 1986 (Robinson, 1991). Market management has resulted in price stability and there is now free trade in agricultural produce throughout the Community. Consumers have also benefited from a wider choice of foods (CEC, 1992).

These changes have not been achieved without considerable changes in land use patterns, farm structures and the social fabric of the rural community. Since 1950, there have been significant changes in farm size, the number of farms and the size of the farm labour force. Table 1.1 shows changes in farm size and the number of farms in Britain between 1950 and 1987:

Table 1.1 Farm size changes in Great Britain, 1950 - 1987 (from Ilbery, 1992a, source : Agricultural census).

| | Farm size groups (ha) (% change) | | | No of Farms (1000s) | |
|---|---|---|---|---|---|
| | < 20 | 20-100 | > 100 | 1950 | 1987 |
| England | -66 | -41 | +113 | 318 | 156 |
| Wales | -67 | -20 | +763 | 55 | 29 |
| Scotland | -81 | -45 | +317 | 75 | 31 |
| Great Britain | -69 | -39 | +154 | 448 | 215 |

During this period, farms have also become increasingly fragmented as farmers have purchased blocks of land at varying distances from the main farmstead. There has also been a major shift in farm tenure, from a landlord-tenant system, to one which is dominated by owner-occupancy. In 1987, 72% of holdings were wholly or mainly owned, compared to 38% in 1950 (Ilbery, 1992a).

Despite the benefits already discussed, the CAP has been far from an unqualified success. The cost of supported agriculture within the EC has been prodigious, rising to a high of 36 billion ECU (European Currency Units) in 1992 (CEC, 1993). These costs have been absorbed by guaranteed prices for a continuously increasing volume of end product. By 1990, the EC was producing 20% more cereals than it needed. These surpluses had to be stockpiled at a considerable cost.

From a social and structural perspective farmers have been forced onto a 'technological treadmill', where increased output can only be achieved through capital expenditure in the form of increased inputs of land, chemicals and machinery. The CAP has amply rewarded those farmers able or willing to do this, but has disadvantaged small producers, resulting in a situation where 80 percent of EC spending goes to 20% of farmers. In this way the CAP has failed in one of its original objectives "to ensure a fair standard of living for the agricultural population." The high cost of the CAP has also resulted in inflated food prices, violating another central tenet of the CAP which was to ensure reasonable retail prices to the consumer.

However, perhaps the most devastating and long-term effect of agricultural support policies has been their impact on the environment of the countryside.

## 1.6 The Environmental Impact of Modern Intensive Agriculture

> " Many critics would see the most serious failure of the conservation movement as the sheer scale of loss or damage to wildlife, its' habitat and physical features that has taken place since 1949"

These words were written in 1983 by Derek Ratcliffe, Chief Scientist for what was then the Nature Conservancy Council. Modern intensive agricultural methods, and the policies which have fostered these, bear a good deal of the responsibility for this loss and damage. Green (1981) characterises three ways in which modern agricultural impacts on the wildlife and landscape features of the countryside ; more intensive use of better quality land, the conversion of pastoral land to arable cultivation and the abandonment of marginal land.

### 1.6.1 Increased intensification on productive land

Traditional constraints on production have been removed by a host of technological and biological innovations. Increased mechanisation, the use of inorganic fertilisers, pesticides and herbicides, the development of new varieties of crop through selective breeding, improved advisory services, more continual cultivation and larger scale systems have all contributed to larger yields per unit area. All of these developments have entailed environmental costs.

*Pesticides* - since the early 1950s a formidable array of organic compounds have been developed as herbicides, insecticides and fungicides. The range of pesticides available to the farmer continues to expand. During the 1960s and 1970s, perhaps two or three compounds would be applied to a cereal crop during the growing season. However, as the agrochemical industry has developed compounds which are more specific, killing only target organisms, the range of available pesticides has greatly increased. A cereal crop may now receive as many as a dozen different sprays. Pesticides have been an unqualified success in terms of increased crop yields and reliability, but there have also been unwanted side-effects (Carson, 1962 ; Moore, 1969a ; Newton, 1974 ; Green, 1981).

The continuing development of a huge range of organic herbicides has had wide-ranging consequences, resulting in the widespread decline, and in some cases, loss of plant species which were formerly common on agricultural land. Many invertebrates of agricultural land have very specific food requirements. If the plant species on which they feed are removed their populations inevitably decline, resulting in similar declines in bird species and the small mammals which predate these. The decline of the common partridge (*Perdix perdix*) has been attributed to herbicides (Potts, 1980, 1986).

The conflict between conservationists and agriculturalists in terms of herbicide use are difficult to reconcile, as the *raison d'être* of these compounds is to eliminate precisely those species which the conservationist seeks to conserve. A long-term solution may only be found when agricultural policy reduces their cost-effectiveness (Green, 1981), or when alternative solutions to the management of weed populations become economically competitive (Lampkin, 1986 ; Ramsay, 1992).

*Inorganic fertilisers* - In the post-war period. fertiliser use per unit area has increased two to seven-fold on arable land and by as much as forty times on grass (Environmental Data Services, 1983). A consequence of increased fertiliser on grassland has been a decrease in the diversity of the sward, vigorous competitive species being favoured at the expense of slower growing ones ; the same is true on arable land. Crop plants, by their nature, are highly competitive and plant breeding programmes have sought to maximise this characteristic. At the same time, many of the most vigorous weeds such as nettles (*Urtica dioica*), blackgrass (*Alopecurus myosuroides*) and cleavers (*Galium aparine*) are the most responsive to increased soil fertility, so that increased fertiliser use has necessitated a simultaneous increase in herbicide application.

Often, arable crops recover no more than 10% of the nitrogen applied. Nitrates are very soluble and nitrogen compounds are not held in the soil, resulting in surface run-off and leaching, and consequently high concentrations of nitrogen in rivers and other water sources. This leads to eutrophication of rivers and lakes with the same consequences as observed on grassland ; vigorous waterweeds are favoured resulting in decreased ecosystem diversity and downstream effects on fish and other aquatic animals.

There is also concern that agricultural nitrogen is contaminating domestic water supplies. Under certain conditions, nitrate may be converted to nitrite which is toxic to humans. The World Health Organisation has a recommended limit of 11.3mg $NO_3^-$ $litre^{-1}$ in drinking water and levels exceeding this have been measured in a number of water sources in the UK. Perhaps the most worrying finding has been that percolation of nitrates through acquifers is very slow, and that today's contamination represents pollution which took place 25 - 30 years ago, so that the benefits of any measures to reduce nitrate contamination will only be apparent 25 - 30 years after their introduction (Royal Commission on Environmental Pollution, 1979).

## 1.6.2 Reclamation and abandonment of marginal land

The most severe losses of wildlife from the countryside have occurred through processes of habitat destruction and modification. These processes have been encouraged by agricultural policies which have offered grants for drainage and reclamation of marginal lands and for the conversion of unimproved grazing land to arable production.

*Hedgerows* - It has been estimated that in 1945 there were in the region of 1 million kilometres of hedgerows in Britain, covering an area of 200,000 hectares. In the period between 1945 and 1970 these were lost at a rate of 8,000km / annum, 1200 km of this carried out with MAFF grant aid (Pollard *et al.*, 1974). In more recent times the rate of loss has declined, although considerable losses continue to occur especially in the arable heartlands of the east of England. Moore (1969b) estimated that 21 of 28 species of mammals, 65 of 91 species of birds and 23 of 54 species of butterfly breed in hedges in Britain, although none is confined exclusively to this habitat.

*Wetlands* - these range from estuaries, saltmarsh and freshwater meadows to peat bogs, raised bogs and drained grazing marshes. Between 1949 and 1986, about 50% of lowland fens and mires were drained and reclaimed, and 60 percent of raised bogs lost to afforestation. In Lancashire 99.5% of lowland bogs have been reclaimed (Lowe *et al.*, 1986). Once again, much of this drainage has been carried out with MAFF grant aid.

*Calcareous grassland* - until the late 18th century vast tracts of the southern lowlands were maintained as chalk grassland by sheep grazing ; close cropping encouraging a remarkably diverse grass sward. Today much of this grassland has reverted to scrub, as sheep grazing on this land has become uneconomic, and rabbit populations have declined. Other areas have been fertilised and converted to improved grassland, or ploughed and brought into arable cultivation. Between 1949 and 1986, 80% of calcareous grassland has been lost to these processes (Lowe *et al.*, 1986).

*Lowland heath* - lowland heath vegetation is a plagioclimax community which has been created and maintained by traditional extensive farming systems. Its fate has been similar to that of calcareous grassland, and lowland heath has suffered widespread losses to scrub invasion, nutrient enrichment and ploughing. Heathland does not have to be completely eliminated to be ecologically destroyed, fragmentation may have equally disastrous effects. The NCC estimated that 60% of this habitat type has been lost, and Moore (1962) found that the extent of heathland in Dorset had declined from 30,000 ha in 1811 to 10,000 ha in 1960, a 67 percent decline. This loss has continued although at a reduced rate (Webb, 1990).

*Neutral grassland* - the range of unimproved grasslands in this category have all declined in extent since 1940, the majority being seeded with high yielding grasses such as *Lolium perenne*.

Habitat losses which have been described above have occurred not only as a result of agricultural intensification but also through rationalisation, and the abandonment of marginal land, which even in an atmosphere of grant aid and expansionist agriculture could not be made profitable.

Thus, it is effectively demonstrated that these plagioclimax communities with their considerable wildlife value are created and maintained by neither modern intensive agricultural practices nor by leaving nature to take its course. Recent overproduction provides an opportunity for farmers to retreat from the role of agri-businessmen, and return to a system of countryside stewardship where they are responsible for delivering goals of both food production and environmental value. However, they may only do so if encouraged by agricultural and countryside policies, and appropriate economic signals and incentives.

## 1.7 CAP Reforms 1984 - 1992

1984 was an important watershed in the development and operation of the CAP. By the early 1980s, the EU had achieved self-sufficiency in most major temperate foodstuffs, and had entered a period of surplus production. Productivity continued to increase by an average of 2% per year, and for the first time the economic and environmental sustainability of an ever enlarging agricultural industry was being questioned. 1984 marked the beginning of a rationalisation which culminated in the wide-ranging reform of the CAP in May 1992.

### 1.7.1 Production controls and environmental initiatives, 1984 - 1992.

In 1984, the EU introduced a series of guarantee thresholds, whereby farmers were offered guaranteed prices up to specified production levels. These were aimed primarily at the cereal and milk sectors, and their goals were entirely economic in nature. In 1986 environmental concerns were addressed with the introduction of the Environmentally Sensitive Areas (ESA) Scheme. Within designated areas farmers were offered payments to adopt 'environmentally friendly' farming practices for which they would receive payments for profits forgone over a five year period. Entry to these schemes was (and remains) entirely voluntary, but payment rates were set at levels which aimed to make participation financially attractive. Since the initial designations in 1986, three further rounds of designation have been completed and their are now 22 ESAs in England.

In 1987, MAFF launched its ALURE scheme (Alternative Land Use and Rural Enterprise) which aimed to encourage farm diversification through alternative uses of farmland and the expansion of environmentally friendly farming (Robinson, 1991). It consisted of the following measures :

i) £10m / annum to encourage the development of on-farm woodlands;
ii) £7m to be allocated to doubling the number of ESAs;
iii) £5m to encourage diversification of farm businesses.

The policy of SET-ASIDE first appeared in 1988, when it was introduced by the EU as regulation 1094/88 for set-aside of arable land. The scheme was entirely voluntary, with participating farmers eligible for compensation payments if they set-aside, or removed from production, 20 percent of land which had been used to produce surplus crops. Farmers were required to enter the scheme for five years, and withdrawn land could be made fallow, planted with trees or used for non-agricultural purposes (Ansell and Tranter, 1992 ; Robinson, 1991 ; Hilton, 1991). Adoption rates were low (Ansell, 1992) and uptake was concentrated in the marginal cereal producing regions around London (Ilbery, 1990, 1992b ; Ansell and Tranter, 1992), where compensation rates were more realistic than in the core arable areas. The scheme was designed primarily with production control and economic objectives, leading many commentators to remark on its lack of environmental benefits (Ansell and Tranter, 1992 ; Robinson, 1991). In 1989, the Countryside Commission introduced the Countryside Premium Scheme for set-aside land which was available to farmers in counties of eastern England, and provided financial incentives to farmers for "positive management of land entered into MAFF's five-year set-aside scheme, to benefit wildlife, the landscape and the local community" (Countryside Commission, 1991b). A one year voluntary set-aside scheme was introduced in 1991.

New measures were also introduced to encourage the afforestation of land formerly under arable and grassland. The Farm Woodland Premium Scheme (FWPS) was introduced as part of the Farmland and Rural Development Act passed in October 1988. The scheme operates over a three year period, offering payments of £190/ha for converted land. Payments are intended to provide an income in the period between tree planting and the first income received from timber.

In response to increased concerns about the environmental and public health consequences of nitrate run-off and leaching from agricultural land, the Nitrate Sensitive Areas (NSA) Scheme (MAFF, 1994a) was launched in 1990. In these areas, farmers are offered payments to apply measures which reduce the application of fertilisers and animal manure.

The modifications discussed above, which aimed at cutting costs, reducing surpluses, and to some extent limiting the environmental consequences of the CAP were, overall, unsuccessful. The cost of the EC budget continued to rise (CEC, 1993) as did retail food prices. At the same time, environmentalists and conservationists argued that measures to alleviate environmental stress were essentially 'tinkering with the consequences of agricultural support rather than serious attempts to redress the balance' (Robinson, 1991). Together, these considerations led to proposals in the spring of 1991 for a far-reaching reform of the CAP.

## 1.8 The 1992 CAP Reform Process

When negotiations for a wide-ranging reform of the CAP were initiated in 1991 the EC stated that ;

> "the reform process should encourage farmers to use less intensive production methods, thereby reducing their impact on the environment and on the creation of surpluses" (Commission of the European Communities, 1993)

Five main objectives were outlined :

1. To maintain the Community's position as a major agricultural producer and exporter by making it's farmers competitive on home and export markets;
2. To bring production down to levels more in line with market demand;
3. To focus support for farmers' incomes where it is most needed;
4. To encourage farmers to remain on the land;
5. To protect the environment and develop the natural protection of the countryside.

In addition to internal pressures, a large part of the reform process was dominated by international trade negotiations taking place within GATT (the General Agreement on Trade and Tariffs)(Baldock & Beaufoy, 1992). The Uruguay round of GATT negotiations was due to be completed in December 1991, and for the first time agricultural produce was to be included within the agreement. Pressure was brought to bear, primarily by the Americans and Australians, for the EC to pursue a less protectionist agricultural policy through reductions in production subsidies, and import and export tariffs. The final agreement on CAP reform which was reached in May 1992, was preceded by vigorous discussions which sought to determine which policy mechanisms could best satisfy the range of internal and external requirements. The EC maintained a stance that CAP reform and GATT negotiations were unconnected (Baldock and Beaufoy, 1992), and in May 1992, declared that " the council affirms its commitment to pursuing the requirements of environmental protection as an integral part of the CAP." However, the World Wide Fund for Nature (WWF) and other environmental organisations have contested that the social and environmental costs of production are not taken into account in the market place which is the main concern of the GATT (Arden - Clarke, 1992). Before presenting the outcome of the reforms, a brief consideration will be given to the policy options which were considered. This account will concentrate on the economic and social aspects of these options. A more in-depth analysis of policy options which would result in a greater degree of integration between conservation and agriculture follows.

## 1.8.1 Policy options for reforming the CAP

In the broadest sense, reform of the CAP was possible through :

ii) complete cessation of state support and the conversion of agriculture to a free-market economy **- the market led approach**;
i) the maintenance of agricultural support, but with new and modified policies to reflect changing priorities - **the state led approach**;

With **market led adjustment** it was argued that an open market for agricultural products would unleash 'the natural forces of readjustment' until now held in check by market support (Coleman and Traill, 1984). Few would doubt the potential success of such a policy in bringing production into line with demand. It would result in a more efficient, streamlined industry with a small number of low cost producers farming vast areas of land. However, the social and structural costs in terms of unemployment, land abandonment and rural depopulation would be huge, and in direct conflict with objectives 3 and 4 outlined above (section 1.8). An approach which would overcome these social problems, but also allow a greater degree of market orientation would be to create a two tier system of agriculture (Pexton, 1994), with a supported sector consisting of smaller farmers operating with the aid of state support and a 'free trade' sector operating in an unsupported market place.

Mechanisms of **state-led adjustment** may take the form of price reduction, income support in the form of direct payments which were not linked to levels of production, or quotas on inputs and outputs.

*Price reduction* - the price of EC agricultural products may be brought more into line with world markets by simply reducing guaranteed prices paid to farmers from the EC budget. This would discourage production, as high cost producers would face losses, forcing them to improve their performance or leave the sector and supply would be brought more closely into line with demand. However, this mechanism would entail undesirable social consequences, as small and marginal farmers were squeezed out of the industry (Marsh, 1991). Some of these effects could be avoided by linking price reduction to a system of direct payments to those producers most hard hit. These 'decoupled farm supports' (Jenkins, 1990) would be a form of direct income support, and could supplement rather than replace price policy, ensuring that high cost or marginal producers were not forced out of the industry. However, such a policy whilst reducing prices paid for agricultural products would not lead to substantial reductions in production levels.

*Output quotas* - these would operate by limiting the amount of produce which farmers are allowed to sell. The community already has such schemes for milk and sugar, and the guarantee thresholds for cereals, introduced in 1984 were a form of output quota. Harvey (1989) proposed a system of Production Entitlement Guarantees (PEGs), whereby guaranteed prices for agricultural output would be paid up to a predetermined level on a per farm basis. Any produce which exceeded this level would have to be sold at world market prices.

*Levies and input quotas* - input quotas operate by restricting the levels of certain inputs, thereby reducing the capacity for agricultural output. Set-aside or land diversion is a form of input quota, restricting the area of land on which crops are grown. Other quotas may limit the application of yield enhancing inputs. Nitrogen fertilisers are an obvious candidate. Maximum levels of nitrogen application could be fixed on a regional level and would deliver environmental as well as supply control benefits. The Nitrate Sensitive Areas Scheme operates on a similar basis and could be extended to cover all agricultural land. Farmers may also be encouraged to reduce inputs through a system of taxes or levies. Clunies-Ross (1993) has called for nitrogen fertilisers to be taxed. Studies in Germany have indicated that a 200% fertiliser tax would reduce their use by 30% and water pollution by 50% (Jenkins, 1990). Similar taxes could be applied to herbicides and pesticides. Others have proposed levies on machinery and fuel.

*The Bond system* - under this system, individual farmers' entitlement to subsidy, via price support or direct payments, would be assessed and converted to a guaranteed 'income stream' over time, either indefinitely or over a fixed period. Bond holders would be entitled to a single annual payment, and could exercise the option of taking this payment, or selling it for a capital sum in the market (Country Landowners Association, 1994).

### 1.8.2 The CAP reform settlement

In January 1991, Ray MacSharry, the Irish Commissioner for Agriculture, outlined a number of proposals for reform of the CAP. This account will deal only with the arable sector. The basic elements were as follows:

i) that levels of support in the cereals sector would be substantially reduced, bringing them much closer to world market levels;
ii) farmers would be compensated for lost income through a system of acreage payments;
iii) this compensation would, however, be 'modulated'. Small farmers being compensated in full, but beyond a certain size only partial compensation would be paid;
iv) compensation would be linked to a set-aside scheme;

Structural and environmental proposals aimed to : maintain the maximum number of farmers on the land; recognise the dual role of farmers as food producers and countryside custodians; and encourage extensification and other types of environmentally friendly farming (Gilg, 1992).

Reactions to these proposals were unfavourable, especially with the British farm minister who claimed that they maintained the high cost of the CAP and unfairly discriminated against larger farms, of which Britain has a high proportion. After protracted negotiations, a final reform agreement was reached in May 1992. It retained most of the features of the MacSharry plan, except the concept of modulation. The reformed cereal sector was to operate under an integrated system of direct payments and input quotas in the form of set-aside.

The main thrust of the reforms was a 29 percent cut in intervention prices for cereals over a three year period to 1996, bringing the intervention price down to £80/tonne. Farmers would be compensated for lost income by entry into the Arable Area Payments Scheme (AAPS), whereby they are given direct payments proportional to the area of land under eligible crops at the 1992 harvest. Payment rates are set on a regional basis and calculated in relation to historic average yields within those areas. UK agriculture has been separated into five regions ; England, Scotland (less favoured area), Scotland (non less favoured area), Wales and Northern Ireland.

In order to qualify for these payments farmers are required to **set-aside** an annually determined percentage (initially this was 15% for rotational, and 18% for non-rotational set-aside[2] . These two options are now interchangeable as 'obligatory set-aside' whose 'normal' rate is set at 17.5%, however, in 1996/97 this was reduced to 5%) of their land which had been growing eligible crops in 1992. Area compensation payments are payable on this land, according to the regionally determined rate. The scheme is entirely voluntary, but those who do not set-aside must forgo area payments (MAFF, 1993a ; CEC, 1993).

A simplified scheme is available under the Arable Area Payments Scheme, whereby small farmers with an area of less than 15.51 ha under eligible crops can claim area payments, but are exempt from the set-aside obligation.

EC regulations establishing this new support scheme gave minimal recognition to environmental concerns :

i) concerning the new direct payments
"Member states shall take the necessary measures to remind applicants of the need to respect existing environmental legislation" ;

[2] see section 1.11.1 (p. 33) for a distinction between rotational and non-rotational set-aside land.

ii) concerning the new set-aside scheme

" Member states shall apply appropriate measures which correspond to the specific situation of the land set-aside so as to ensure the protection of the environment."

(Official Journal of the European Community, No. L221/19, 1992)

The CAP reform also included a number of **'accompanying measures'** which were appended in response to the social and environmental aspects of the MacSharry plan. This approach has disappointed environmental lobby as it maintains a clear separation between price support and environmental policies, failing to foster a greater degree of cross-compliance and integration of agricultural and conservation objectives.

There are three strands to the accompanying measures:

1. **An agri-environment regulation (Regulation 2078/92)** 'to give recognition to the dual role as producers and as stewards of the countryside, and to encourage farming practices which are less intensive and more in tune with environmental constraints' (Commission of the European Communities, 1993). This regulation is obligatory to all member states. However, schemes are designed and implemented at a national level and should reflect environmental priorities within individual Member States. Payments to farmers are funded partly by the EC, and partly by national government. UK proposals for agri-environmental schemes were submitted to the EC Commission in July 1993. The following schemes now operate :

i) *Environmentally Sensitive Areas* - the expansion of the existing ESA scheme formed the main plank of the agri-environmental package (MAFF, 1996a);

ii) *Nitrate Sensitive Areas* - an expanded programme of NSAs has been implemented under the package (MAFF, 1994a);

iii) *Organic farming* - payments have been made available to encourage conversion to organic production methods;

iv) *Moorland Scheme* - aimed at reducing overgrazing on grassland and heather moorland;

v) *Habitat Scheme* - 20 year set-aside to promote the establishment of semi-natural habitats through recreation and restoration (MAFF, 1994b).

Other recommended schemes, not implemented by the UK Government included upkeep of abandoned farmland and woodland, aid for growing 'useful plants' and environmental training for farmers.

**2. An early retirement scheme for farmers (Regulation 2079/92)** - enabling farmers aged 55 or over, but not in receipt of a pension to retire. Their land must be either taken out of production or amalgamated with other land with a view to improving the production structure and ensuring economic viability (Swinbank, 1993).

**3. A forestry aid scheme (Regulation 2080/92)** - providing a new subsidy for afforestation of agricultural land.

### 1.8.3 Set-aside - an economic critique - Lessons from the US

Setting aside of surplus agricultural land (cropland diversion) is not a novel concept. US agriculture has employed some form of set-aside for 48 of the last 58 years (Ervin, 1992), and this experience, together with that gained within the EC since the introduction of voluntary set-aside in 1988 provides valuable lessons about the efficacy of set-aside as a supply control measure.

Set-aside programmes can be designed with a number of goals in mind (Bowers, 1987) :

i) as a market management tool to eliminate surpluses, thereby reducing budgetary costs;
ii) as a mechanism for soil conservation;
iii) as an environmental policy increasing the area of benign and ecologically valuable habitats on farmland.

US experience has illustrated the need for clear goal prioritisation (Ervin, 1990), as policies designed to satisfy more than one criteria have suffered from "dual goal conflict", considerably reducing the efficiency of schemes in terms of both policy objectives. Buckwell (1986) anticipated the same potential problems in any EU set-aside scheme. With this in mind, Ervin and Dicks (1987) recommended that set-aside is best viewed as 'a compensation scheme for injecting capital into agriculture during a difficult transition stage in exchange for important non-market conservation benefits.' In other words, land diversion schemes should be structured with conservation goals in mind. Bowers (1987) suggested, in contrast to this view, that environmental factors will only be considered once schemes have been designed to achieve supply control goals; conservation benefits being incidental to supply control. The current EU scheme has been designed according to this principle.

In terms of supply control, US experience has shown that set-aside has a number of shortcomings. Setting aside 15 % of agricultural land is unlikely to produce similar reductions in yield due to what has become known as 'slippage' (Bowers, 1987 ; Ervin, 1992 ; Ilbery, 1992b) :

i) farmers will choose to set-aside their least productive land, so that the fall in output will be less than the fall in acreage;
ii) they will intensify production on land still in use.

Only time will tell to what extent set-aside is successful in reducing production and to what extent it results in environmental benefits.

## 1.9 Towards a Greater Degree of Integration between Agriculture and Nature Conservation

The relationship between agricultural intensity and environmental value is neatly summarised in Figure 1.1.

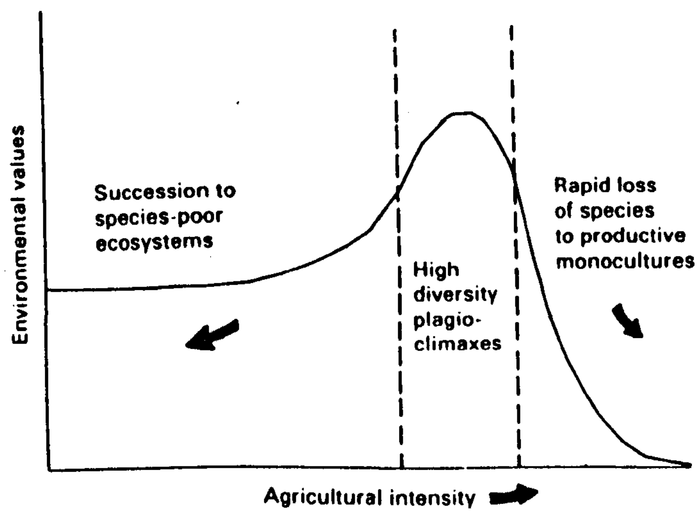



Figure 1.1 A model of agricultural impact on the environment (from Green, 1981)

Plagioclimax communities, such as heathland and downland are created and maintained by traditional extensive farming systems such as those which are now encouraged in ESAs. When land is abandoned or the level of exploitation falls below a certain intensity these communities become degraded, and typically revert to scrub, woodland or species-poor ecosystems. Increased intensification has a more dramatic effect, rapidly resulting in the loss of species and the production of high yielding monocultures. It becomes clear that stewardship of these highly valued wildlife habitats is in the hands of farmers and that in order for them to do so they must reduce the intensity of production on some or all of their land. If consumers and society at large desire a diverse and beautiful countryside, then in a modern market economy it must be acknowledged that there is a need to pay those who produce it. Environmental quality and nature conservation are not easily valued in the market place and this has resulted in a whole range of decisions failing to reflect environmental concerns. Jenkins (1990) has commented that ;

> "the lack of market in environmental resources means the overvaluation of market output relative to environmental output in the private calculations of farmers as compared to the calculations of society at large"

In conclusion, economic efficiency in agricultural production has now been achieved and the next challenge is to ensure greater social and environmental efficiency through the integration of agricultural and environmental goals.

A brief review of post-war policies for habitat protection is presented, before considering in greater detail, options for fostering closer links between agriculture and conservation in the current policy environment.

### 1.9.1 Habitat protection in post-war Britain - Matrix Conservation.

Post-war policies for the countryside, whilst overwhelmingly driven by the goals of increased agricultural production have not been totally devoid of measures for habitat and landscape protection. These have been achieved through a system of matrix conservation (Adams, 1988) and the application of the voluntary principle (Francis, 1994 ; Green, 1981). If there has been one feature which has characterised nature conservation in the British countryside, it is the concept of zoning ; the selection and partitioning of particular sites of conservation interest, with very little concern for the 'wider countryside' where agricultural intensification has continued to destroy wildlife and habitat features. This concept of matrix conservation has fostered the view that "wildlife lives in special places, round which real or imaginary fences can be drawn" (Adams, 1988), and has resulted in the fragmentation of the countryside.

1.9.1.1 The 1949 National Parks and Access to the Countryside Act.

This Act established a National Parks Commission with powers to designate National Parks and Areas of Outstanding Natural Beauty (AONBs). National Parks were created 'to preserve and enhance the natural beauty of the British countryside, and to promote their enjoyment by the public, executing both with regard to the needs of agriculture and forestry.' Very little funding was made available to the National Parks Authorities, and conflicts of interest quickly arose. Many of the National Parks are in upland areas and are composed of moorland vegetation. However, much of this area has been lost, as MAFF grants have been used by farmers to convert semi-natural vegetation into cultivated pasture. It is estimated that farmers have been given £400 million as MAFF grants for such operations, compared to an overall budget of £7 million for the National Parks authorities. At the same time, Forestry Commission policy has encouraged planting of coniferous forest at the expense of moorland and deciduous forest in the National Parks.

Areas of Outstanding Natural Beauty were designated primarily to protect landscape features and are smaller in area than the National Parks. They are defined as 'any area ....... not being a National Park but of such outstanding natural beauty that some provision of National Parks apply.'

Another provision of the Act was the formation of the Nature Conservancy (now English Nature). Its primary functions were the establishment and maintenance of National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs) to safeguard sites with a special flora, fauna or geology. SSSIs were not specifically managed as nature reserves, and consequently many of these sites were severely damaged in the years which followed as they were afforded little protection from agricultural and industrial development (Adams, 1991). Concern at the rate of loss and damage to these sites resulted in the controversial 1981 Wildlife and Countryside Act.

1.9.1.2 The 1981 Wildlife and Countryside Act

This Act sought to strengthen habitat protection within SSSIs. The Act embraced the 'voluntary principle' which was favoured by the agricultural lobby and has formed the basis of nature conservation and wildlife protection on agricultural land :

> "This approach allows that a farmer prevented from receiving grant aid from MAFF because of the NCC's objections on nature conservation grounds will be offered a management agreement by the NCC based on set government financial guidelines"
>
> (Adams, 1984)

Under the new Act, the NCC was to renotify all SSSIs, and supply landowners with a list of potentially damaging operations (PDOs) which could cause damage to SSSIs on their land. If, subsequently farmers wish to carry out any of these operations to improve the productivity of their farm, and MAFF is willing to provide grant aid for these actions, then the Department of the Environment (DoE) has to be consulted. If the DoE supports the NCC view, then the NCC must seek a management agreement with the farmer to compensate him for profits foregone by not carrying out these actions (Robinson, 1991 ; Adams, 1988). The outcome of the 1981 Act was met with considerable scepticism from conservationists (Adams, 1984 ; Cox and Lowe, 1983 ; Lowe *et al*, 1986) on two fronts: First, the three month consultation period following renotification by the NCC allowed PDOs to be carried out with impunity during this period ; and second, because of the cost of management agreements. The 1985 amendment to the Act closed some of the initial loopholes (Brotherton, 1990a) but costs to the NCC (English Nature) remain high.

During the 1980s management agreements and the voluntary principle were the mainstay of attempts to protect wildlife on farms, (Francis, 1994 ; Ratcliffe, 1995 ; Lomas, 1994 ; Gilg, 1991), and they continue to represent an important aspect of this objective. Increasingly in the late 1980s and 1990s, however, other methods are being considered.

## 1.9.2 The call for Greater Integration

Over the past decade, there has been considerable discussion in the literature of ways in which farmers may be regulated towards, and rewarded for, positive environmental action on agricultural land (Countryside Commission, 1992 ; Country Landowners Association, 1994 ; Russell, 1994 ; Waters, 1994 ; Hodge, 1991 ; Russell and Fraser, 1995 ; Jenkins, 1990 ; Adams, 1988 ; Gilg, 1991 ; Hodge, 1992). In 1992, the Countryside Commission commented that in simple terms, a 'hierarchy of mechanisms' had evolved. These mechanisms are:

1. Regulation;
2. Cross - compliance;
3. Payment schemes / financial incentives.

*Regulation* - involves the use of law to prohibit actions which are deemed to be publicly undesirable. The use of regulation in the agricultural sector has increased markedly in recent years and now controls the use of farm chemicals and the disposal of farm wastes and straw burning (Countryside Commission, 1992). Many argue, however, that environmental regulations impose inappropriate and costly constraints over farm businesses (Hodge, 1991), and can, in some cases, lead to increasing hostility to environmental concerns. The Countryside Commission (1992) concludes that regulation plays an important role in 'raising the baseline' of environmental standards.

*Cross-compliance* - a policy mechanism which requires compliance with environmental safeguards or management requirements in order to qualify for payments for other policy objectives. The recent CAP reform presented an excellent opportunity for arable area payments to be linked to the production of environmental value on set-aside land. However, the EU insisted that supply-control and environmental policies remain entirely separate (Countryside Commission, 1992). The cross-compliance method of integration between agricultural and environmental concerns has been widely ignored within the EU.

*Payment Schemes* - these reward farmers financially for positive investments of their time and management skills in order to produce public benefits, both environmental and recreational. These 'products' cannot be sold by the farmer and must be paid for from the public purse. By their nature, countryside payments can only work as a voluntary mechanism, and depend for their success on their popularity with farmers and land managers. Payments schemes and management agreements remain at the forefront of countryside policies. In recent years, however, there has been a shift in emphasis, away from the old style management agreements for SSSIs and Nature Reserves, which offered compensation to farmers if they desisted from PDOs, towards a more proactive approach which offers incentives to farmers for positive environmental management. This approach is typified by a number of policy initiatives in the last decade. These include the ESAs, countryside stewardship scheme, hedgerow incentive scheme and many others. Whilst these are all welcomed, many are still targeted at specific blocks of the countryside, and hence maintain the principle of a partitioned countryside.

Targeting (which ultimately leads to a partitioned countryside) is a necessary evil for any public policy faced with limited funding. It enables policymakers to direct funds and set priorities so that the maximum social and environmental return can be achieved (Potter *et al.*,1993). The Countryside Commission has proposed a system whereby farmers could be paid for countryside products, as opposed to the management processes which are intended to produce these. In this way, limited public funds can be targeted at outputs as opposed to inputs. 'Payment for products' has a number of other advantages :

i) they appeal to the entrepreneurial interest of the land manager ;
ii) monitoring based on management practices can be difficult, whereas the end-product, measured for instance as diversity of species per unit area gives a clearer indication of success and value for money ;
iii) land managers best understand the capabilities of their land ;
iv) farmers are more familiar with payments for end-products ;
v) if farmers and land managers are encouraged to pursue their own methods, a greater understanding of how to produce the desired benefits will be achieved.

This approach has been encompassed as a 'nature result payment' in new schemes in Germany and the Netherlands (Melman, 1994)

A further possibility promoted by some environmentalists, classifies land into three 'tiers of protection' (Hilton, 1991). Agriculture and conservation objectives will be sought in all three tiers, but their relative importance will depend on land classification :

1. SANCTUARIES or RESERVE AREAS - objectives primarily wildlife and landscape protection ; food production would be a by-product ;
2. LANDSCAPE AREAS - maintenance and enhancement of landscape would be the primary objective, with food production as a secondary objective rather than simply a by-product ;
3. BEST AGRICULTURAL LAND - food production would be primary objective. Landscape and wildlife conservation would be important secondary objectives.

Similar systems of land classification have been proposed by Green and Potter (1987) and CPRE (1989).

### 1.9.3 Taking Conservation into the Wider Countryside

The term 'wider countryside' refers to that part of the British countryside which is not designated and managed within the system of protected sites. It has most relevance in the lowlands, where the conservation resource is spread more evenly across the countryside, and where the remaining 'parcels' of valuable semi-natural and wildlife habitat are often small and fragmented - features which make demarcation of the countryside more difficult. Two factors are stimulating an increased concern to extend policies for nature conservation into the wider countryside (Adams *et al.*, 1994):

i) an increased realisation that on their own, protected sites are insufficient to safeguard the wildlife resource of lowland Britain. In previous decades many 'wildlife sites' have become degraded and fragmented, resulting in these sites becoming increasingly isolated from each other. The extent of this isolation and the effects of fragmentation have been well documented (Ratcliffe, 1984 ; Fuller, 1987 ; Peterken and Hughes, 1990) ;
ii) opportunities which arise from agricultural overproduction and pressures to reduce the intensity of production in the lowlands (Adams *et al.*, 1994).

Before considering the role that set-aside can play in achieving these goals, other policy mechanisms and suggestions will be reviewed.

1.9.3.1 A 'Menu' Approach

The Countryside Commission has called for the integration of all countryside conservation schemes into a single nationwide menu of payments (Countryside Commission, 1992). This approach will require considerable co-ordination and a coherent relationship between the various agencies which offer these schemes. All farmers would be eligible for some form of environmental payment, with some having longer menus to choose from depending on individual circumstances, and the conservation potential of their land (Potter *et al.*, 1993). To some extent, this approach has been encompassed in the new Countryside Stewardship Scheme (MAFF, 1996b).

A similar system of Environmental Management Payments (EMPs) has been proposed by the CPRE (Jenkins, 1990). All farmers would be eligible for EMPs, with an annual payment calculated on the basis of farm area, the length of field boundaries and the extent of wildlife habitat. The scheme would be entirely voluntary with farmers signing five year management agreements which specify the management of environmental features on their farm.

1.9.3.2 Extensification

Perhaps the simplest way to enhance the wildlife and environmental value of the wider countryside would be to reduce the intensity of production on all agricultural land. This approach is favoured by many environmentalists. It could be achieved via a number of mechanisms ; input and output quotas, the removal of all agricultural support or fertiliser taxes, all of which have been discussed.

## 1.10 A Place for Set-aside (Land Diversion)

Before considering what can realistically be achieved in terms of nature conservation within the existing set-aside regime, consideration will be given to proposals for the creation of a conservation reserve on land diverted from agriculture (Potter *et al.* , 1991 ; Burnham *et al.*, 1987). These proposals were formulated prior to the CAP settlement in May 1992, and unlike the AAPS, approached set-aside from an environmental, as opposed to a supply control viewpoint.

### 1.10.1 A Conservation Reserve

Even the most conservative estimates suggest that by the year 2000 there will be a surplus of 3-4 million hectares of agricultural land in the UK (Edwards, 1986). The establishment of a conservation reserve on this land would legitimise conservation as an alternative land use in its own right (Potter *et al.*, 1991). This would be a voluntary 'opt-in' programme, which in order to achieve maximum conservation benefits would need to be targeted at the most suitable land (Burnham *et al.*, 1987). This would maintain the principle of a 'partitioned' countryside, opposed by Adams (1988), but as previously discussed 'it is hard to escape the essential logic of targeting in a world where funds for conservation are finite' (Potter *et al.*, 1993).

### 1.10.2 Which Land?

Land would be targeted according to three criteria (Burnham *et al.*, 1987) :

i) *The Mismatch criterion* - to match cropping patterns more appropriately to those environmental conditions best able to sustain them. In other words, to restrict agriculture, particularly arable production, to land to which it is most suited i.e. Grade 1 and 2 land ;

ii) *The Vulnerability criterion* - to protect environmentally vulnerable land from degrading uses ;

iii) *The Conservation Potential criterion* - to protect areas of high wildlife and nature conservation potential or to enhance those areas where semi-natural habitat may be restored or recreated.

The attributes for criteria for targeting land in a conservation reserve are summarised in Table 1.2.

An attempt was made to draw up a map of potential target areas (Burnham *et al.*, 1987). The attributes described in Table 1.2 were identified, and their presence, absence and extent measured within 10km squares on the National Grid. The result was a composite map of potential sites.

Table 1.2 Attributes of the criteria for targeting 'Conservation Reserve' land (from Potter *et al.*, 1991).

| 'Mismatch' | 'Environmental vulnerability' | 'Conservation potential' |
|---|---|---|
| 1. squares with over 30% crops and fallow by area, where over 25 % Grade 4 land, and less than 5% Grade 1 and 2 land | 1. soils liable to wind erosion<br>2. soils liable to water erosion<br>3. land liable to flooding<br>4. aquifer present | 1. presence of National Nature Reserves<br>2. over 10% by area of deciduous woodland<br>3. over 10% by area of moorland<br>4. potential wetland (i.e gley soils present<br>5. potential heathland (i.e. podzols present)<br>6. potential calcareous grassland (i.e. rendzinas present) |

Four options for habitat creation and restoration were identified. These were :

1. Forestry
2. Grasslands
3. Wilderness
4. Specialised habitats

One further suggestion which has been made with regard to both the conservation reserve (Potter, 1987) and the Countryside Commission's 'menu' approach (Countryside Commission, 1992) is that farmers could be required to tender bids for conservation payments with management agreements going to the lowest bidders.

## 1.11 The CAP Set-aside Regime - A place for conservation ?

### 1.11.1 Wildlife benefits from non-specific management of set-aside land.

Even in the absence of specific conservation-oriented management, wildlife benefits have been reported on set-aside land (Andrews, 1992 ; Baldock and Beaufoy, 1992 ; Warren, 1995 ; Sears, 1992 ; Boag, 1992 ; Wilson, 1992). Following set-aside in 1993 a widespread comment from farmers was that it had increased the amount of wildlife over winter compared to previous years (Farming News, 1993).

Under present regulations, the majority of set-aside land is managed on a rotational basis following cereals. Baldock and Beaufoy (1992) have argued that the limited fallow period (7 to 8 months) on rotational set-aside, together with some of the rules for managing this land, greatly reduce the scope for achieving positive environmental benefits. Whilst this view should not be dismissed, it ignores the potential for limited wildlife gains. Set-aside land is commonly allowed to 'tumbledown' and natural regeneration gives rise to a vegetation of arable weeds and volunteers from the previous crop (Clarke and Cooper, 1992). Whilst this is often visually unappealing, giving the impression of low quality countryside, if managed appropriately it can result in a range of wildlife benefits (Firbank and Wilson, 1994). The Game Conservancy found 243 plant species on set-aside land following natural regeneration, many of which were uncommon, and Andrews (1992) commented on "the unforeseen blossoming of a wide variety of flowering plants" on set-aside land. The potential for establishment and replenishment of populations and communities of rare arable weeds has been widely acknowledged (Wilson, 1993 ; Firbank and Wilson, 1994 ; Andrews, 1992 ; Andrews and Rebane, 1995 ; Firbank *et al*, 1993) and will be considered in greater detail. Increased botanical diversity provides a more diverse food source for invertebrates which in turn encourages birds and small mammals, and ultimately predators such as the kestrel, *Falco tinnunculus* and the barn owl, *Tyto alba* (Andrews, 1992). The increased abundance of undisturbed habitat on farmland has been particularly beneficial to ground nesting, overwintering and migrating birds (Farming News, 1993 ; Baldock and Beaufoy, 1992). However, all of the benefits described above require that the set-aside be left undisturbed. Cutting and cultivation will destroy the habitats and nesting sites of birds, and prevent seed production in rare weed species, and the sowing of a grass cover crop greatly reduces botanical diversity (Clarke, 1995 ; Poulton and Swash, 1992).

The rotational set-aside obligation is moved around the holding on a six year rotation, so that any field or part-field is set-aside for one in every six years. and hence wildlife benefits are transient. Non-rotational set-aside land is removed from production for a period of five consecutive years, offering greater potential for wildlife benefits to accrue. Carefully considered management may enable the creation or restoration of scarce semi-natural habitats or the reintroduction of rare species. The potential to attain these will depend on the soil type and the location of the land in relation to existing habitat fragments (Andrews, 1992 ; Baldock and Beaufoy, 1992).

### 1.11.2 Managing Set-aside land for Wildlife

In August 1992 MAFF commissioned the Institute of Terrestrial Ecology (ITE) to conduct research to determine habitats and species which could benefit from positive management of set-aside land, and to establish guidelines in order to realise this potential (Firbank *et al.*, 1993,1994). The results formed the basis of guidelines given to farmers for the management of set-aside for environmental objectives (MAFF, 1996c). Management prescriptions were devised for both

Table 1.3 MAFF directed options for the management of set-aside land to achieve environmental objectives (from MAFF, 1996c)

| Option | Suitable land | Exemptions[3] required |
|---|---|---|
| **Minimal cultivation for rare arable weeds and other plants** | Primarily suitable for set-aside being left in place for one year only, or field margins being set-aside for more than one year | Yes, will need to till the soil, and in some circumstances may also need an exemption from the cutting requirement |
| **Sites for ground-nesting birds** | any set-aside | Yes, may need to disc land in early spring and to delay cutting and, or cultivation |
| **Pasture for wildfowl** | any set-aside | Yes, management involves fertilising the grass cover |
| **Wild bird cover** | Primarily suitable for set-aside left in place for more than one year, but it can also be used on set-aside which is rotated | No |
| **Otter havens** | only set-aside that is being left in place for a number of years | Yes, the option involves leaving the vegetation uncut |
| **Creation of wildflower meadows** | only set-aside that is being left in place for a number of years | Yes, the option requires removal grass cuttings |
| **Restoration of sandy grassland and heathland** | only set-aside that is being left in place for a number of years | No |
| **Restoration of calcareous grassland** | onlyset-aside that is being left in place for a number of years | Yes, the option requires removal of cuttings |
| **Restoration of damp lowland grassland** | only set-aside that is being left in place for a number of years | No |

[3] exemptions from standard set-aside management requirements

rotational and non-rotational set-aside with objectives ranging from conservation of individual species or groups of species, to habitat restoration and recreation. ITE's guidelines are summarised in Table 1.3.

Whilst these guidelines represent a welcome acknowledgement of wildlife potential, their implementation by farmers is entirely discretionary. Many of the options require exemptions from standard set-aside regulations and MAFF has indicated that these may be applied for. However, in most cases, they also require extra time, effort and expense, whilst no provision has been made for incentive or compensation payments to encourage their uptake.

One of the options recommended by Firbank *et al*, (1993) was **rotational set-aside for rare arable weeds** (Table 1.3). Two alternatives were suggested, the first involves the management and enhancement of existing populations, and the second, the creation of rare weed floras from seed.

# Part 2 - The Ecology And Conservation Biology Of Rare Arable Weeds.

## 1.12 The Wildlife Conservation Potential of Arable Land

Until very recently, the mere suggestion that arable fields might constitute a valuable wildlife resource within the British landscape would have been met with considerable scepticism from many conservationists. Agricultural intensification and the shift in emphasis towards arable cultivation has led to the ploughing-up and loss of valuable wildlife habitats, and their replacement by vast tracts of chemically maintained cereal monocultures, considered by many as ecological deserts, devoid of any wildlife interest. Tansley (1939) in his study of British vegetation types gave no consideration to the arable habitat, and this attitude has tended to persist (Firbank and Wilson, 1994). Certainly, in a typical arable system, species diversity is low (Pearson, 1992), and on the most intensively farmed land may be almost entirely absent, however, this is not always the case.

It has been estimated that over 700 species of plant are found in cereal fields in central and western Europe (Hanf, 1983), with up to 300 in Britain, or 17 percent of Britain's flora (Wilson, 1990). Lack (1992) stated that 61 common bird species were found on lowland farms, many of them using arable fields and Potts (1991) estimates that as many as 1800 species of insects and spiders are associated with the arable habitat.

Traditionally, attempts at conservation on arable land have been concentrated on field edges or margins (Bunce *et al,* 1994 ; Wilson, 1994 ; Jepson, 1994 ; Lakhani, 1994 ; Tew *et al,* 1994 ; Aebischer, Blake and Boatman, 1994). Wild plants are most likely to survive here, where competition from the crop is less severe. Once established these will attract invertebrates, birds and mammals (Andrews and Rebane, 1995). Insects, birds and mammals which use the field edge also require the habitat and shelter provided by hedgerows. In the mid 1980s the Game Conservancy developed the concept of 'conservation headlands' (Sotherton, Rands and Moreby, 1985 ; Boatman, 1987 ; Boatman and Sotherton, 1988) which effectively extended the boundaries of conservation within arable fields. Initially, this technique was developed to increase the numbers of wild game birds on arable land, and involved the omission of herbicide spraying from a 6m strip around the field edge (Boatman and Sotherton, 1988). These management techniques resulted in increased weed populations, often with the reappearance of rare or uncommon species, which in turn encouraged invertebrates which were the food source for game birds. The emergence of rare arable weeds as a legitimate conservation concern owes much to the work of Wilson (1990).

Many of the 'weed' species associated with cereal crops in Britain are non-native or 'exotic', and were introduced with cereal grain imported from the Mediterranean and Middle East, and their exotic status has been used as a justification for their lack of recognition as a wildlife resource. Cereal cultivation began in Britain over 7000 years ago (Edwards and Hirons, 1984), and the cereal ecosystem pre-dates other ecosystems such as heathland and downland which are so valued by conservationists. Even if its value in terms of conservation of biodiversity is ignored, the weed flora represents a valuable historic record of human settlement and agriculture in the British Isles (Godwin, 1960).

Set-aside policy represents one way in which an element of conservation may be introduced into the arable rotation. It may be used to reintroduce populations, and or communities of rare arable weeds which will in turn encourage invertebrates, birds and mammals onto farmland. The remainder of this chapter will discuss the origin and evolution of Britain's weed flora, its current status and decline and will conclude with a consideration of the ecology of these species.

## 1.13 The Development and Evolution of Britain's Weed Flora

It was established in the previous section that much of the justification for a lack of conservation interest in arable weeds is based on the assumption that these species are not native, and therefore not truly representative of the British flora. Hanf (1983) stated that "weed species ..... of the various parts of Europe do not for the most part belong to the native flora." Whilst this is undoubtedly true for many species, far from all weeds are introductions. The techniques of archaeobotany, the study of fossilised plant remains, have been employed to study the origins and development of Britain's flora (Godwin, 1956 ; Greig, 1988), and have provided valuable information. Godwin (1956) found 78 species of disturbed habitats (ruderal species) during the mid to late Weichselian period (50,000 to 10,000 years ago), 31 of which are now characteristic of arable land. Many of these weeds such as plantains, mugwort and shepherd's purse were originally arctic plants which survived in the tundra of late glacial Britain (Rackham, 1986). Table 1.4 gives details of the first known records for a number of weed species from early Weichselian through to Roman times. Those species which were present before the onset of agriculture during the Neolithic period, about 5,500 years ago (Greig, 1988), were not well adapted to survive in the 'wildwood' which covered much of Britain's surface following the last Ice Age. However, large areas of moraine, outwash sand and gravel, and land uncovered by melting ice offered ideal conditions for colonisation by these ruderal species (Godwin, 1960). These sites acted as refuges for weed species until man's agricultural activities opened up the landscape.

Most of the other weeds now present in Britain seem to have first appeared in the period between the Neolithic and Saxon Ages, their introduction and relative abundance largely a result of agriculture (Greig, 1988 ; Holzner, 1978). They were first introduced as contaminants of crop seeds, imported from the Middle East 'cradle of agriculture' and from Central and Eastern Europe (Holzner, 1978). Those species considered as arable weeds in this account may occur in three types of vegetation ;

i) as **segetals** in arable land
ii) as **ruderals** in one of a range of disturbed sites
iii) as components of the natural vegetation from which they originate

(Holzner, 1978)

Many species introduced to the British Isles exist at the limit of their ecological range. Evidence of this is provided by their almost exclusive occurrence as segetals in man-made agricultural habitats, and complete absence from the natural vegetation. This is not the case in the Mediterranean and Middle East where many of these weed species occur in natural vegetation adjacent to cultivated land (Holzner, 1978).

Table 1.4 - First recorded presence in archaeobotanical records for a range of arable weed species (compiled from Greig, 1988 ; Godwin, 1956)

| | |
|---|---|
| **EARLY WEICHSELIAN**<br>(70,000 to 50,000 BP) | *Ranunculus repens*<br>*Stellaria media*<br>*Atriplex hastata* |
| **MID WEICHSELIAN**<br>(50,000 to 20,000 BP) | *Aphanes arvensis*<br>*Capsella bursa-pastoris*<br>*Chenopodium album*<br>*Poa annua*<br>*Polygonum aviculare*<br>*Ranunculus acris*<br>*Rumex acetosella*<br>*Rumex acetosa*<br>*Taraxacum officinale*<br>*Tripleurospermum inodorum*<br>*Urtica dioica* |
| **LATE WEICHSELIAN**<br>(20,000 to 10,000 BP) | *Centaurea cyanus*<br>*Cirsium arvense*<br>*Cirsium vulagre*<br>*Galeopsis tetrahit*<br>*Galium aparine*<br>*Lotus corniculatus*<br>*Plantago spp.*<br>*Sonchus arvensis*<br>*Spergula arvensis* |
| **BRONZE AGE** | *Fumaria spp.*<br>*Thlaspi arvense*<br>*Papaver argemone*<br>*Polygonum convolvulus* |
| **IRON AGE** | *Agrostemma githago*<br>*Anthemis cotula*<br>*Valerianella rimosa*<br>*Scleranthus annuus*<br>*Chrysanthemum segetum*<br>*Scandix pecten-veneris*<br>*Silene noctiflora*<br>*Adonis annua* |
| **ROMAN AGE** | *Ranunculus arvensis*<br>*Bupleurum rotundifolium*<br>*Anthemis arvensis* |

Evidence from the Neolithic period (3,500 BC) indicates an undifferentiated weed flora with low species diversity (Greig, 1988). Subsequently, the diversity of weeds of autumn and spring sown cereal crops increased and as agriculture evolved species introductions increased. Almost all summer annual weeds known in the UK today were present by the Bronze Age. A number of winter annuals are first recorded in Iron Age deposits, although in small numbers, with *Chrysanthemum segetum* the only notable addition to the spring germinating flora. Weed species indicative of calcareous soils begin to appear in the late Iron Age, reflecting the advance of arable agriculture from the most easily tilled alluvial soils in the river valleys to calcareous substrates on higher land. Additions to the winter annual flora continue during Roman and Saxon periods and by Medieval times (1066 AD - 1500 AD) all taxa with arable weed representatives in the British Isles are present. However, during this period the abundance of many species increases greatly, of particular note are seeds of *Agrostemma githago, Anthemis cotula, Lithospermum arvense, Vicia sativa, Centaurea cyanus and Chrysanthemum segetum.*

The weed flora of cornfields changed little from medieval times to the start of this century, the few introductions which have been noted being from the Americas (Salisbury, 1961). The following section discusses the widespread changes to the arable weed flora which have occurred in the present century, and examines the causes and consequences of these changes.

## 1.14 The Changing Status of Britain's Cornfield Weeds.

### 1.14.1 Britain's Changing Weed Flora

The weed flora of an arable field evolves and develops in response to past and present management practices. The most successful weeds are those which are most closely adapted to the environmental conditions under which the crop is grown, and which exhibit similar germination periodicities and phenologies to those of the crop. In summary, a particular type of agroecology will bring with it a characteristic weed flora, with changing agricultural practices resulting in changes to that weed flora.

Salisbury (1961) noted that "the cornfield weed flora of (England) probably exhibited no striking qualitative changes .... until comparatively recent times." The intensification of agricultural production which has occurred during the current century has had a dramatic impact on the botanical communities of arable land (Firbank and Wilson, 1994). The decline, and in some cases extinction of species which were once common weeds of arable land has been so severe that it is probable that arable land now has more species of "Red Data Book" status than any other habitat type (Perring and Farrell, 1983). A number of factors have interacted to bring about the decline of individual species ; improved methods of seed cleaning and the advent of herbicides are two of the most influential and frequently cited (Fryer and Chancellor, 1970). However, the increased use of inorganic fertilisers, the trend towards autumn cultivation and the adoption of minimum tillage techniques are all also important. Wilson (1990) reports the impact of these changing practices on a range of rare arable weed species. Whilst these widespread changes in management have resulted in the decline or loss of many species, others have been advantaged, their abundance and distribution increasing (Rich and Woodruff, 1996 ; Whitehead and Wright, 1989 ; Chancellor and Froud-Williams, 1984). Overall, the arable weed flora has been transformed from one dominated by dicotyledenous species (Salisbury, 1961) to one where grass weeds and a few of the more competitive dicotyledons pose the main threat to crop yields (Firbank and Wilson, 1994). Before considering in greater depth the evidence for, and causes of loss of botanical diversity in arable fields, consideration will be given to the changing abundances of the most common and pernicious weed species.

In 1809 William Pitt produced a list of what were at that time the most widespread weeds of arable land. These were *Anthemis arvensis, Capsella bursa-pastoris, Chenopodium album, Cirsium arvense, Cirsium vulgare, Agropyron repens, Polygonum aviculare, Ranunculus arvensis, Raphanus raphanistrum, Rumex crispus, Sinapsis arvensis, Sonchus spp., Stellaria media, Thlaspi arvense* and *Veronica hederifolia* (from Salisbury, 1961). By 1917 the most common species remained dicotyledenous ; in order these were *Fallopia convolvulus, Galium aparine, R. raphanistrum* and *Persicaria maculosa. Agrostemma githago* which is now extinct was twelfth in the list (Anon, 1918 from Firbank and Wilson, 1994). Whilst still composed largely of broad-leaved species Salisbury's list compiled in 1961 did include the grass species, *Agropyron repens, Agrostis stolonifera, Alopecurus myosuroides, Arrhenatherum elatius, Avena fatua* and *Poa annua.* A survey of cereal fields by Chancellor and Froud-Williams (1984) illustrated the increasing abundance of grass weeds. The most widespread were in order ; *A. repens, Avena spp., A. myosuroides, P.trivialis* and *B.sterilis.* The most frequent dicotyledons were *Viola arvensis, G. aparine, S. media, Myosotis arvensis* and *P.aviculare*, all of which display a degree of tolerance to herbicides. The results from a survey by Whitehead and Wright (1989) differ slightly in the relative abundance of species and are shown in Table 1.5.

The evidence presented above is of a rapidly evolving weed flora. Attempts at chemical weed control coupled with other changes in agricultural husbandry have been successful in reducing the diversity of the weed flora. Cereal fields are now dominated by a few highly specialised, competitive species which have developed, and continue to develop resistance to herbicides. Grass weeds are now undoubtedly the major concern in cereal crops (Chancellor and Froud-Williams, 1986) and will continue to be so. The major problems today, and in the future, are these grasses and a small band of competitive, herbicide resistant dicotyledons.

Table 1.5 The results of a survey to assess the presence and absence of common weed species in 2359 winter cereal fields in the UK (from Whitehead and Wright, 1989)

| Species | % of fields infested |
|---|---|
| *Stellaria media* | 94 |
| *Poa annua* | 79 |
| *Veronica persicaria* | 72 |
| *Matricaria spp* | 67 |
| *Galium aparine* | 58 |
| *Lamium purpureum* | 47 |
| *Viola arvensis* | 45 |
| *Avena spp* | 42 |
| *Alopecurus myosuroides* | 38 |
| *Sinapsis arvensis* | 36 |

1.14.2 The Decline and Loss of Weed Species

It is the rapid and widespread loss of botanical diversity on arable land with the consequent loss and decline of species which were once common weeds that concerns conservationists. Perring and Farrell (1983) regarded arable weeds as "the most severely threatened group of plants in the British flora" ; 23 arable weed species were afforded Red Data Book status, six having become extinct. Between 1978 and 1990, the ITE land cover plots exhibited a 38% decline in the numbers of arable species, and provided further evidence of a shift towards grass dominated communities (Barr *et al.*, 1993). The Botanical Society of the British Isles (BSBI) and the Nature Conservancy Council (NCC) conducted a survey between 1987 and 1988 to assess changes in the vascular plant flora of the British Isles (Smith, 1986 ; Rich and Woodruff, 1996). Data collected between 1930 and 1960, which formed the basis of the Atlas of the British Flora (Perring and Walters, 1962) were used as a baseline from which changes in the extent and distribution of species could be assessed. A breakdown of these results by habitat type is presented in Table 1.6. Rates of decline for some of the most severely threatened arable weeds are given in Table 1.7.

Table 1.6 Increases and decreases by habitat type of vascular plant species in England, 1930-1988 (from Rich and Woodruff, 1996)

| Habitat | Number of species in England | |
|---|---|---|
| | Decreases | Increases |
| Woodland, scrub, hedges etc | 15 | 12 |
| General grassland | 1 | 10 |
| Calcareous grassland | 22 | 0 |
| Wet grassland | 17 | 4 |
| Unimproved grassland | 22 | 5 |
| Open grassland | 12 | 3 |
| Heathland, acidic grassland | 24 | 0 |
| Uplands | 2 | 0 |
| Aquatics, swamps | 24 | 6 |
| Coast | 8 | 1 |
| Arable weeds | 31 | 13 |
| Introductions | 17 | 110 |

Table 1.7 Decline of arable weed species in Britain (data from Perring and Walters, 1976 ; Smith, 1986 ; Rich and Woodruff, 1996 ; Wilson, 1990)

| Species | Number of 10km squares in which species were recorded | |
|---|---|---|
| | 1930 | 1986-1990 |
| *Adonis annua* | 36 | 12 |
| *Agrostemma githago* | 150 | 0 |
| *Buglossoides arvense* | 310 | 42 |
| *Bupleurum rotundifolium* | 17 | 0 |
| *Centaurea cyanus* | 264 | 3 |
| *Galeopsis angustifolia* | 238 | 18 |
| *Galium tricornutum* | 77 | 2 |
| *Myosurus minimus* | 59 | 13 |
| *Ranunculus arvensis* | 432 | 22 |
| *Scandix pecten-veneris* | 426 | 20 |
| *Silene gallica* | 132 | 5 |
| *Torilis arvensis* | 136 | 10 |

*Centaurea cyanus, Scandix pecten-veneris* and *Ranunculus arvensis* may now have to be added to the Red Data Book (Firbank and Wilson, 1994). Other species such as *Agrostemma githago, Arnoseris minima, Bupleurum rotundifolium* and *Caucalis platycarpos* are already extinct, whilst *Papaver rhoeas* and *Sinapsis arvensis* have become much less widely distributed. A more recent survey of scarce plants (Stewart *et al*, 1994) has indicated that even more arable plants will qualify for Red Data Status in the near future. Table 1.8 gives a more complete list of extinct, rare, scarce and declining plants of arable habitats.

### 1.14.3 Factors influencing the decline of the Arable Weed Flora

**Seed cleaning** - many arable weed species were first introduced to Britain as contaminants of imported crop seed, and many others whose seed had similar dimensions and whose phenology coincided with that of the crop were harvested, threshed, stored and resown with the crop (Salisbury, 1961). The introduction of the Seeds Act in 1920, which placed statutory requirements on the quality of crop seed, together with the development of efficient seed cleaning machinery greatly reduced the influence of this method of dispersal. Species such as *A. githago* and *Bromus interruptus* which relied heavily on this means of dispersal declined rapidly. The effects were particularly severe for species which exhibited no persistent soil seedbank.

**Herbicides** - the development of herbicides has revolutionised agriculture, and impacted greatly on the composition of the arable flora. Those species which are most susceptible have declined dramatically to the point where they are seldom important, and often rare. Examples include *S. arvensis, P. rhoeas* , *R. arvensis* and *S. pecten-veneris* (Fryer and Chancellor, 1970). Once again, those species with poorly persistent seedbanks have been most severely affected. Some declining species such as *Chrysanthemum segetum* are inherently moderately resistant to a wide range of herbicides (Wilson, 1990) and in these cases other factors have been more influential. Species which are tolerant of a range of herbicides, or which have evolved resistance have become more widespread (*Avena spp,. Alopecurus myosuroides, S. media, G. aparine* and *Veronica spp.*)

**Fertiliser inputs** - A vigorously growing, heavily fertilised crop can have a similar effect to herbicides in terms of the weed population densities and the performance of individuals within these populations. Wilson (1990) conducted experiments to investigate the success of a number of rare arable weed species in fertilised and unfertilised cereal plots. Of 13 species sown, the population sizes of 9 were significantly reduced by fertiliser application, as a result of increased competition from the crop. Three species were completely eliminated. It is probable that the increased application of nitrogen fertiliser, and the development of more competitive cereal varieties has resulted in a decline of many of the less competitive arable weed species.

| **Extinct** | **Red Data Book** status (fewer than 15 10km squares) | **Scarce** (found in between 16 and 100 10km squares) | **Declining** (found in over 100 10km squares) |
|---|---|---|---|
| *Agrostemma githago* | *Adonis annua* | *Apera spica-venti* | *Chenopodium ficifolium* |
| *Arnoseris minima* | *Alyssum alyssoides* | *Briza minor* | *Chrysanthemum segetum* |
| *Bromus interruptus* | *Anthoxanthum aristatum* | *Centaurea cyanus* | *Geranium columbinum* |
| *Bupleurum rotundifolium* | *Bunium bulbocastanum* | *Euphorbia platyphyllos* | *Kickxia elatine* |
| *Caucalis platycarpos* | *Echium plantagineum* | *Fumaria parviflora* | *Kickxia spuria* |
| *Galeopsis segetum* | *Filago lutescens* | *Fumaria vaillantii* | *Lithospermum arvense* |
| *Lolium temulentum* | *Filago pyrimidata* | *Galeopsis angustifolium* | *Misopates orontium* |
| | *Fumaria reuteri* | *Lathyrus aphaca* | *Myosurus minimus* |
| | *Fumaria occidentalis* | *Scandix pecten-veneris* | *Papaver argemone* |
| | *Galium spurium* | *Silene gallica* | *Papaver hybridum* |
| | *Galium tricornutum* | *Torilis arvensis* | *Silene noctiflora* |
| | *Gastridium ventricosum* | *Vicia parviflora* | *Stachys arvensis* |
| | *Lythrum hyssopifolia* | | |
| | *Melampyrum arvense* | | |
| | *Rhinanthus serotinus* | | |
| | *Veronica praecox* | | |
| | *Veronica triphyllos* | | |
| | *Veronica verna* | | |

Table 1.8 - Extinct, rare, scarce and uncommon arable weed species in Britain (from Firbank *et al*, 1994 ; Firbank and Wilson, 1994)

**Changes in the cropping cycle** - since the 1930s there has been a major shift from spring to autumn sown cereals. This has been accompanied by earlier cultivation and drilling. The time at which a crop is planted is the major determinant of the composition of the subsequent weed flora (Brenchley and Warington, 1933), the most successful weeds being those which germinate from the seedbank at the same time as the crop. Early sowing favours those species which germinate in late summer and early autumn (*Alopecurus myosuroides, Viola arvensis, P. trivialis, Veronica spp*). Once common species such as *S. arvensis* , *Polygonum spp* , *C. segetum* and *M. orontium* which germinate in spring have declined as a result of changes in the cropping cycle.

**Minimum tillage and direct drilling** - the last 25 years have seen the widespread cessation of complete soil inversion by ploughing, and an increased trend towards reduced cultivation, and in some instances, direct drilling of the crop. Many annual weeds, particularly dicotyledons require regular deep soil disturbance to bring buried seeds to the surface where conditions are favourable for germination (Chancellor and Froud-Williams, 1986).

### 1.14.4 The Distribution of Rare Arable Weeds

Communities and populations of rare arable weeds are not evenly distributed throughout the UK and this localised distribution has become more marked as populations have declined. Remaining populations are concentrated in the south and east of England (Firbank and Wilson 1994).

A number of environmental variables affect this distribution (Wilson, 1990). Weed communities tend to be more diverse, and rare species more common on lighter soils. Typically, where large numbers of rare species are found, soils tend to be based on chalk or limestone, however, some species are confined to heavier soils (*S. pecten-veneris* and *R. arvensis*), and others to calcium poor sandy soils (*C. segetum* and *M. orontium*). High levels of summer sunshine are also correlated with an increase in scarce arable plants (Wilson, 1990). As discussed previously, many of the rare arable weeds are introductions from warmer climates and are at the limit of their ecological range in the British Isles. As agricultural practices become less conducive to the survival of these species their range will tend to contract (Holzner, 1978).

Arable weeds are also distributed unevenly within cereal fields, tending to be concentrated in the outermost six metres of the field (Wilson, 1989). In terms of the conservation of these species this observation is critical and may form the basis of strategies for their protection.

### 1.14.5 A Framework for Protection

i) Sites of Special Scientific Interest - where it is appropriate arable fields containing communities of rare arable weeds may be designated as SSSIs. Four such sites currently exist (Wilson, 1993) and are managed under regimes which omit agrochemical applications, farmers being compensated for lost income under English Nature management agreements.

ii) The National Trust and County Wildlife Trusts have expressed interest in cornfield flower conservation.

iii) The Game Conservancy's conservation headland technique (Boatman, 1987), whilst designed primarily for the benefit of game birds, has resulted in considerable benefits to rare arable weed species. These observations led to the establishment of the "Wildflower Project" (Wilson, 1990, 1993), to investigate the biology of rare weeds, and to apply this to possible techniques for their conservation.

iv) Set-aside land - techniques for the conservation of these species on set-aside land are presented.

v) Countryside Stewardship - provides for the establishment of conservation headlands.

vi) ESAs - four of these offer payments for conservation headlands

Concern for the decline of rare weed species has not been restricted to the UK, indeed in Germany schemes for the conservation of cornfield flowers have been a priority since the 1980s, when programmes involving the omission of herbicides and nitrogen from field margins were initiated in many states (Schumacher, 1987 ; Eggers, 1984,1987)

## 1.15 The Biology of Arable Weeds

In a botanical sense, weeds are not easily defined. They do not conform to a common set of taxonomic, morphological or phenological characteristics (Mortimer, 1990). Attempts to classify weeds on an ecological basis have defined life history characteristics which confer 'weediness' to a species. In short, a general purpose strategy encompasses a high reproductive capacity, well developed powers of dispersal and a short life cycle. From an anthropocentric or economic point of view, weeds have been variously described as, 'natural hazards to the activities of man', and 'any vegetation interfering with the objectives of people' or more simply as 'a plant out of place' (Mortimer, 1990).

Within an arable rotation the best indicator of the success of a weed species is its ability to return seed to the soil. This will depend upon the synchronisation of the annual cycles of germination, flowering and seed production with farming practices, and on the ability of the weed to compete with the crop for water, light and nutrients. The most successful weeds will be those whose life cycles most closely coincide with that of the crops in which they occur, and many weeds have evolved to mimic crops - the so-called mimetic weeds. This phenomenon led King (1966) to comment that "(Man) has been a breeder of weeds as well as crops!"

The weeds of arable land have annual, biennial and perennial representatives. The remainder of this discussion will be devoted to the ecology and population dynamics of annual weeds, as the overwhelming majority of species which have been lost or have declined severely from the arable habitat display this life history strategy. These species require the open habitats created by regular soil disturbance, their perpetuation being entirely dependent on their ability to germinate, establish and produce seed in a single growing season. Winter annual species germinate and become established in late summer or autumn, they survive winter as dormant, or slow-growing seedlings. Spring annuals germinate in spring and exhibit no dormant phase continuing to actively grow to maturity during spring and summer.

The majority of research to investigate the population dynamics of annual weeds has been conducted with their control and elimination from crops in mind, however, these principles are equally applicable to their conservation. What follows is a discussion of the factors which influence the density and persistence of weed populations, and of the interactions between species which occur in communities of weeds. It is only intended as an overview of the important processes, and will be expanded upon at the beginning of subsequent chapters where appropriate.

## 1.15.1 The Population Biology of Annual Weeds

The population size of an annual weed species at a particular time is a function of i) the number of individuals per unit area which have germinated and established as components of the above-ground weed flora, and ii) the number of viable, ungerminated seeds per unit soil volume. Weed control practices attempt to eliminate adult individuals from the above-ground vegetation and maximise the rate of decline of seeds from the soil seedbank. In contrast, conservation will attempt to maximise their above-ground survival and consequently, the number of seeds which are returned to the seedbank.

Only those species whose seeds possess mechanisms of dormancy are able to form a persistent seedbank. Thompson and Grime (1979) classified a range of seedbank types which were essentially described as either transient or persistent in nature. The seeds of species with transient seedbanks have no dormancy mechanisms and are unable to persist in the soil for long periods. During the growing season their populations are represented solely by those individuals present in the above-ground flora. In agronomic terms, the absence of a seedbank makes them more easy to control, in terms of conservation, these species are more easily lost from communities. For species displaying persistent seedbanks, dormancy is maintained via a number of physiological mechanisms which ensure that the seed is able to survive periods of adverse conditions and germinate when edaphic and climatic conditions become favourable. The possession of seed dormancy represents a less aggressive life history strategy, which prohibits plant species from 'putting all their eggs in one basket' and is an important adaptation for the long-term persistence of 'weedy' species (Mortimer, 1990). However, it is disadvantageous in terms of the ability to rapidly colonise and become dominant in recently disturbed areas.

The germination and seedling emergence from transient and persistent seedbanks may be synchronous, occurring as a single flush of germination, episodic, occurring in distinct flushes at different periods during the year or continuous, occurring at a constant rate throughout the year. Seedling periodicity is once again adaptive, depending on the individual requirements of species, and is of great importance in determining the relationship between cropping cycles and their associated weed floras. Three main patterns are recognised : predominantly autumn germinators, predominantly spring germinators and year round germinators.

Explaining or predicting the abundance of a weed species in a crop, or in a mixture of weed species requires an understanding of the demographic processes (losses and gains) which regulate population densities (Mortimer, 1990). Once seeds have germinated, losses may occur prior to establishment as a result of predation, competition, herbicide application or cultivation. Similar pressures act as vegetative adult plants develop into reproductive adults. Competitive interactions between individuals of the same species (intraspecific competition) and of different species (interspecific competition) are density dependent. Density dependent mortality results in a reduction of the number of individuals which become established, or which reach reproductive maturity. If density related competitive effects do not result in the death of individuals, they will act by reducing their fecundity, so that the number of potential offspring from each parent plant is reduced. Studies of weed species at very high densities in monocultures, where competition for resources is extreme have shown that even very small individuals are able to produce progeny, but that the fecundity of these individuals is proportional to their size. This plasticity is a common attribute of weedy species (Mortimer, 1990). Density dependent effects operate over different density ranges for these two components of population regulation and together they are able to stabilise the dynamics of the population.

The overall fecundity of individuals is also reduced if seed produced does not become incorporated into the seedbank. This will occur if seeds are predated or are removed at harvest.

## 1.15.2 Arable Weed Community Dynamics

The aim of the work reported in chapter 5 is to determine by means of field based trials, management guidelines for the establishment, from seed, of diverse, persistent and stable communities of rare arable weed species. On a more theoretical level, results will examine the trajectory and species assembly of colonising communities of rare arable weed species in the context of set-aside management practices. Implicit to the study of any mixture of species is the assumption that individuals within that community will compete for limited growth resources, and that the outcome of this competition will be uneven distribution of these resources and of species within the community (Mortimer, 1990). Many studies have been conducted to examine the outcomes of crop-weed and weed-weed interactions, and the implications in terms of establishment and co-existence of stable weed communities have been presented (Marhall and Jain, 1969 ; Wu and Jain, 1979 ; Gulman, 1979 ; Sutton, 1988 ; Mack and Harper, 1977). The extent and outcome of competition in species mixtures will be density dependent and will be influenced by a number of other factors including seedbank dynamics, germination periodicity and the intrinsic competitiveness of the species involved.

Theories of plant community structure and species assembly are discussed in greater detail in the introduction to chapter 5.

# *Chapter 2*

## *Farmers' Attitudes Towards, and Perceptions of Set-aside, CAP Reform and Nature Conservation - a Baseline Survey*

## 2.1 Introduction

Results are reported in this chapter from a farm-based questionnaire survey which sought to determine farmers' attitudes towards, and perceptions of set-aside, the 1992 CAP reform and nature conservation. A behavioural approach is adopted, by which farmers' decision-making processes with respect to the management of set-aside land, are assessed in relation to attitudinal, structural and economic factors.

### 2.1.1 Farmer Participation in Voluntary Agri-environmental Schemes.

The factors which constrain, or motivate, farmer participation in agri-environmental and conservation-oriented management programs on agricultural land have been the subject of much recent research (Wilson, 1996 ; Battershill and Gilg, 1996a, 1996b; Morris and Potter, 1995 ; Brotherton, 1990b ; 1991 ; Adams *et al*, 1994 ; Potter and Gasson, 1988 ; Mc Henry, 1996). Much of this research has been conducted with respect to the potential and actual uptake of ESAs and similar conservation based management agreements, and provides a valuable insight into the circumstances, motivations, perceptions and attitudes which regulate farmers' conservation behaviour.

Others have studied the implications of gamebird management for landscape features and nature conservation (Piddington, 1980, 1981 ; Cox *et al.*, 1996 ; Howard and Carroll, 1997). Game bird production is commonly associated with large farms and estates (Howard and Carroll, 1997), and game management is often cited as a motivation for the retention of a range of habitats and landscape features, including ponds, hedgerows and areas of rough pasture (Cox *et al.*, 1996). Attempts to increase survival rates in gane bird chicks have given rise to the 'conservation headland technique' (Boatman and Sotherton, 1988), which has the potential to secure a number of wildlife benefits in arable field margins. However, whilst game management undoubtedly produces a number of landscape and conservation benefits, it remains a minority interest, which is opposed on moral grounds by large sections of the public and the farming community. In their survey, Howard and Carroll (1997) reported that only 26% of shooting farmers cited conservation as a reason for establishing driven shooting on their land, and that 60% of non-shoot farmers were "unwilling rather than unable to provide game shooting"

Agri-environmental schemes are voluntary in nature and, as such, their success in achieving policy objectives relies to a large extent on farmers' willingness to participate. Participation in set-aside, on the other hand, can, in practical and economic terms, be considered as obligatory. In this sense, the two policies are very different in their ability to produce environmental and conservation benefits. Farmers who subscribe to an ESA agreement are required to operate within a 'green box'

(Morris and Potter, 1995) which 'guarantees' environmental returns. Set-aside land is also subject to a range of management restrictions, but these have been designated in order to maximise its efficiency in achieving its primary objective; that of supply control. The level of environmental benefit derived from set-aside land is entirely dependent on the way in which an individual farmer chooses to manage this land. Whilst MAFF has issued guidelines for the *management of set-aside land for environmental objectives* (MAFF, 1996c), it is participation in these and not the scheme itself which is voluntary. Therefore the success of ESAs in achieving nature conservation objectives is dependent on farmers willingness to participate, whereas for set-aside these benefits are dependent on their willingness to manage land appropriately.

One further point should be made before considering the factors which influence farmers' decision-making processes with respect to the above. ESA payments are designed to reward farmers for increasing or maintaining environmental value on their holding. Set-aside payments, in contrast, are a form of direct income support and, as such, do not attract a system of incentives or premiums for environmentally beneficial management.

Studies examining farmers' attitudes to nature conservation and their participation in agri-environmental and related schemes have evolved over time, but a common thread in all of these has been a recognition of the interdependence of structural (external) and attitudinal (internal) variables. Key amongst the so-called structural variables have been financial considerations ; the extent to which economic factors constrain, or enable conservation behaviour. Others include farm size, farm type, quality of agricultural land, farmer age and tenancy status (Wilson, 1996 ; Battershill and Gilg, 1996a ; Morris and Potter, 1995 ; Carr and Tait, 1991 ; Brotherton 1990b ; 1991 ; MacDonald, 1984 ; Gasson and Potter, 1988 ; Mc Henry, 1996 ; Newby *et al*, 1977). The most important attitudinal determinant of (non) participation is farmers' attitudes to environmental and wildlife concerns, and these too have been studied extensively (Newby *et al*, 1977 ; ADAS, 1976 ; MacDonald, 1984 ; Carr and Tait, 1991 ; Westmacott and Worthington, 1984). Such studies and surveys have illustrated that farmers are seldom motivated by financial considerations alone, and that many are interested in conservation and wildlife on the farm. However, as Newby (1979) commented ;

> "in the final analysis a farmer must make a profit and all of the economic pressures will eventually lead them to place agricultural before environmental concerns"

This apparent baseline of favourable attitudes towards wildlife conceals two important qualifications. Firstly, attitudes do not always correspond to behaviour (O'Riordan, 1973 ; Tuan, 1968 ; 1970), a fact which led Morris (1993) to suggest that conservation actions should be considered in preference to conservation attitudes, and secondly, farmers' perceptions of conservation and wildlife are often very different from those of conservationists. Carr and Tait (1991) found that, in superficial terms, the attitudes of farmers and conservationists were very similar, both perceiving the benefits of conservation as "making the farm a nicer place to live" and "improving public relations." Their attitudes to issues such as hedge removal and pesticide use were, however, very different from conservationists, and unfarmed areas were often described in negative terms as 'untidy', 'overgrown' and 'neglected.' At the same time, farmers tended to reserve the term 'wildlife' for species which were beneficial to agriculture such as pheasants and earthworms.

Mc Henry (1996) found that Scottish farmers in the southern lowlands ESA expected conservation to be productive, increasing returns from tourism and sporting interests, and saw nature as something to be controlled, exploited, or at best appeased.

The complex relationship between structural and attitudinal factors is increasingly recognised in farmer behavioural studies. In two theoretical papers, Brotherton (1990b ; 1991) attempted to derive a model for participation in UK voluntary set-aside and ESA schemes, based on the interaction and relative importance of economic considerations and farmer attitudes. He argued that entry decisions would be based on the schemes financial attractiveness and on farmer attitudes to the scheme type or scheme details. If attitudes were determined by scheme type, then the way in which farmers view MAFF, bureaucracy, nature conservation and risk would determine the extent to which individuals were favourable disposed. In contrast, attitudes determined by scheme details would primarily reflect its financial attractiveness. He also characterised farmers as either **profit-maximisers**, for whom profit was the sole motivation, and **profit-traders**, those who would forgo profits if they were favourably disposed to the scheme type. The resulting model classified four groups of farmers depending on their perceptions of the relative importance of attitudes and economics.

In a survey which assessed farmers' willingness to enter land into voluntary land diversion schemes, Gasson and Potter (1988) found that farmers who were the least financially constrained consistently offered the most land, whereas those who were most constrained, rather than viewing this as a means to secure additional income, envisaged the scheme in terms of reduced returns and increased bureaucracy. Similarly, they found that the most profitable farmers were the most inclined towards conservation and wildlife management. In post-war Britain, since the introduction of agricultural support policies, it has often been the largest farms which have been the most profitable, and farm size has proved another important determinant of attitudes towards nature conservation. Newby *et al* (1977) found that the largest farmers were the most hostile, and the most sympathetic to conservation, being able to both invest the large capital sums which inevitably lead to increased intensification and habitat loss, and in some cases to desist from such potentially damaging operations without financial penalty because of the large size and associated financial flexibility of their holding. Clark and O'Riordan (1989) found expansionist farmers to be amongst the most active in undertaking creative conservation, but also commented that conservation was very rarely integrated into the farming system.

In their study of farmer participation in the South Downs ESA Morris and Potter (1995), used the innovation-adoption approach (Jones 1963, 1975 ; Bultena and Hoiberg, 1983 ; Korsching *et al.*, 1983 ; Ilbery, 1985) to categorise farmers as **adopters** (passive and active) and **non-adopters** (conditional and resistant) and from this derived a 'participation spectrum' along which each of these four groups could be placed (Figure 2.1).

This research revealed that adopters tended to occupy the largest farms, and also that active adopters tended to have a history of conservation activity, and that to some extent ESAs were paying them to do what they had already planned - the so-called 'selectivity effect' (Battershill and Gilg, 1996a). Perhaps the most important long term goal of any agri-environmental policy is to bring about permanent changes in farmers' attitudes towards, and perceptions of nature conservation. In other words, to move them along the participation spectrum (Morris and Potter, 1995), so that non-adopters eventually, through a shift in attitudes become adopters, and passive adopters become committed conservationists. The success of any agri-environmental or conservation-oriented scheme should be measured in terms of its 'additionality effect' - the extent to which it brings about permanent changes in attitudes and actions which would not otherwise have occurred.

NON - ADOPTION ⟶ PASSIVE ADOPTION ⟶ ACTIVE ADOPTERS

| **Resistant non-adopters** | **Conditional non-adopters** | **Passive adopters** | **Active adopters** |
|---|---|---|---|
| Would not participate under any circumstances | Decided not to participate under existing circumstances but persuadable provided subsidy is made more commensurate with scheme conditions and/ or a change in farm/farmer family circumstances | The 'new conservationists' - participants attracted by the financial inducements on offer and able to stay inside the 'green box' at minimal cost and inconvenience | The most committed participants, often conservationist farms with a history of countryside management activity - environmental innovators and potential demonstrators of best practice |

Figure 2.1 A participation spectrum for uptake of ESA agreements in the South Downs (from Morris and Potter, 1995)

A change in attitude and production orientation amongst the farming community is likely to be a gradual process as farmers are often considered very resistant to change (Battershill and Gilg, 1996a). Battershill and Gilg (1996b), however, found that some farmers were being made more aware of conservation issues by participating in agri-environmental schemes, and it would be fair to hope, in light of Potter's comments below, that farmers might be inclined to respond *en masse* once a groundswell of positive actions and attitudes is established. Indeed, such hopes are given substance by Young *et al.* (1995) who acknowledged the role of 'farming culture' and peer influence in agricultural decision making.

> "it is important to relate the pattern of landscape change in a locality to the process of farm business growth and development rather than to typical farm or farmer characteristics such as farm size ..... the process of countryside change has an inbuilt momentum and will continue to be driven forward by factors which are embedded within the present structure of the industry and the value systems of individual farmers. These will be slower to change than the policy setting which nourished their development (Potter, 1990)

When considering the potential role of set-aside in leading nature conservation management out of the designated areas and into the wider countryside, other factors must be considered. Whilst Battershill and Gilg (1996b) concluded that financial incentives alone would not move farmers along the participation spectrum, few would contest that these have a significant role to play. At present a single payment rate is attached to set-aside, and farmers who choose to manage this land for conservation objectives, not only receive no incentive payment, but will be discouraged from doing so by the additional expense which will inevitably result. Adams *et al.* (1994) found that farmers in the east of England were reluctant to manage islands of semi-natural habitat in the absence of incentive payments and, similarly, Crabtree and Appleton (1992) found that farmers expected such payments to increase their net income.

Another important factor in attitude formation will be the way in which farmers perceive the objectives of set-aside. If MAFF presents set-aside purely on the basis of its supply control capabilities, farmers are less likely to realise its environmental and wildlife potential.

## 2.2 Questionnaire Design and Attitude Measurement

" A survey is a form of planned collection of data for the purpose of description or prediction as a guide to action, or for the purpose of analysing the relationships between certain variables" (Oppenheim, 1966)

Usually, survey data is gathered by means of a questionnaire, by personal interview or by observational techniques. Before commencing with any survey it's design must be carefully considered with respect to the research aims, and the resources (time and money) which are available. A number of issues must be addressed :

what form will the survey take ?
what will the survey attempt to measure ?
what questions will be asked and how will these be arranged ?
in what form will questions be presented ?
how large will the survey be ?
how will the sampling frame be derived ?
how will data be collated and analysed in order to achieve research goals ?

The following discussion will briefly consider each of these aspects of survey protocol as a prelude to a discussion of the methods employed in the current survey.

In any survey a major consideration is the method of data collection which will be employed. In broad terms, this collection may be by personal or telephone interview or as mail questionnaires, each of which have associated advantages and disadvantages. Personal interviews allow a rapport to be established between the interviewer and the respondent and they are more flexible, as the presence of the interviewer means that responses can be clarified, confusion avoided and respondents probed further when particular responses are encountered. On the negative side, the presence of the interviewer may introduce sources of bias (Oppenheim, 1966), and personal interviews are expensive, in terms of time spent and travel and subsistence allowances for the interviewer. In practice, however, few would refute the advantages personal interviews provide in terms of richness, and spontaneity of information. It is often their cost which is prohibitive. The chief advantage of mail questionnaires is their cheapness, and ability to provide large data sets without the necessity for trained field workers. They also eliminate interviewer bias, yet, one of their main disadvantages is that they introduce another source of bias in the form of non-responses or non-returns. Table 2.1 summarises the major advantages and disadvantages of mail questionnaires.

Table 2.1 The advantages and disadvantages of mail questionnaires

| **Advantages** | **Disadvantages** |
|---|---|
| They are cheap to conduct ; | Questions must be simple and unambiguous ; |
| They reduce the time spent per response; | They are inflexible - offering no opportunity for expansion / clarification ; |
| They increase the geographic scope of the survey ; | They do not enable responses to be supplemented with observational data ; |
| They give respondents time to consider questions or look up facts and figures ; | Non-response. |
| Respondents are often more honest if not face to face with interviewer. | |

Non-response is not a random process and, as such, it inherently constitutes a source of bias as the circumstances and attitudes of 'non-responders' will invariably influence their decision not to return completed questionnaires. This resistance can be overcome to an extent by sending out suitably worded reminders, but if, as is usually the case, returns are confidential it is impossible to determine which members of the original sample have responded and which have not. Other methods for increasing response rates are discussed in Moser and Kalton (1971). Efforts to accommodate this potential source of error in the current study will be discussed in the methodology.

In general, questionnaires measure the attitudes and perceptions of their subjects and frame these in context of their personal circumstances and behavioural patterns. Often models are developed which attempt to predict behaviour patterns in terms of these attitudes, perceptions and personal circumstances.

Essentially questions may be either 'open' or 'closed'. A closed question is one for which the respondent is provided with a choice of replies. Such questions have the advantage that they are easily collated and analysed. In designing such questions, care must be taken to ensure that the full range of attitudes or circumstances are covered and that they in no way bias the respondent or 'plant ideas in his/her head.' Open questions require a full written response with no choice of answers. They have the advantage of allowing the respondent to express his own opinion more fully but are less amenable to statistical analysis. Often questionnaires composed largely of closed questions will elicit a greater response as they require less time to complete. One further consideration in questionnaire design is whether questions are arranged into discrete sections whose content is related, or arranged entirely randomly.

The aim of any survey is to measure the response to a set of variables of a sub-sample of the entire population (in this case arable farmers in England) and to infer, as far as is possible, the attitudes and perceptions of the entire population from this sub-sample. The scope of inference from a survey may be enhanced ; firstly by increasing the sample size and, secondly, by increasing the representativeness of the sample. In terms of sample size, a compromise is sought according to the resources available ; the larger the sample the greater the cost. A survey sample is made more representative by ensuring that all of the constituent parts of the overall population are equally represented. For example, in the current survey, all sizes of farm, all ages of farmers and all grades of agricultural land should be represented in approximately equal proportions. Sample selection ensures that the most representative sample is obtained with the resources available.

Finally, a carefully worded and personally addressed covering letter should be sent with each questionnaire to explain the purposes of the research and what it is hoped the research will achieve. This letter should assure respondents that all information will be treated confidentially and invite them to contact those who are conducting the survey if any further details or clarification is required.

## 2.3 Methodology

### 2.3.1 Questionnaire Aims and Design

Due to constraints of time and resources, arising from the inter-disciplinary approach of this thesis, the survey was conducted as a mail questionnaire, enabling a large data set to be collected from geographically discrete agricultural regions. The questionnaire consisted of 41 questions which were sub-divided into 5 sections which largely reflected the aims of the survey as outlined below. 'Closed' questions were used when attitudes and perceptions were being sought, 'open' questions required simple one word answers or values (farm size, area of set-aside on farm *etc.*). A space was left at the end of the questionnaire in which farmers were invited to make any comments which they thought would be relevant to the study, or would qualify or expand their responses to individual questions. These will be paraphrased and referred to in the results section when appropriate. A copy of the questionnaire is included in Appendix 1.

The questionnaire was designed to investigate :

1. farmers' perceptions of, and attitudes towards the Common Agricultural Policy reform settlement of 1992 ;
2. the current uptake and management of set-aside land, and the perceived effects of the introduction of set-aside policy on farm management ;
3. farmers' attitudes towards farm wildlife and nature conservation ;
4. the present extent of, and the future prospects for the management of set-aside land for environmental and conservation objectives ;
5. farm and personal details.

### 2.3.2 A 'Pilot' Survey

The initial stages of questionnaire design required familiarisation with the outcome of the CAP reform settlement, its consequences and policy mechanisms, together with an extensive review of relevant literature and reference to previous farm-based surveys. This process enabled the aims of the survey to be clearly defined so that potential questions could be formulated and a draft questionnaire constructed. This draft was sent to a number of farmers who were known to members of the University and who indicated that they would be willing to take part in a pilot survey. These farmers were asked to complete the questionnaire, and in subsequent telephone conversations their views were sought on the content and structure of the questionnaire, on areas which they thought to be ambiguous or unclear, on the wording of questions and, in general, on changes which they believed would increase the overall return rate and efficacy of the survey. Their views and comments were incorporated into the final copy of the questionnaire.

### 2.3.3 Selecting the Sample

The first stage in sampling was the selection of appropriate agricultural regions in which to base the survey. Three regions were identified and will subsequently be referred to as the **north-west, south-east** and **eastern** regions. These regions were chosen on the grounds of their contrasting agricultural characteristics : the east of England represents the arable heartlands where large-scale intensive agri-business predominates; in the north-western region arable production is the major use of agricultural land but is generally practised on a smaller scale than in eastern England; the south-east is characterised by a more mixed system where arable production is often carried out on lower yielding soils. The definitions given above encompass a good deal of generalisation, but on the whole the geographical coverage of the survey has ensured that arable systems operating across a range of circumstances were covered.

Farmers' names and addresses were selected at random from the Farms section of the appropriate Yellow Pages telephone directories. For each region, the areas covered by telephone directory were :

Eastern - Peterborough, Cambridge and Lincoln ;
North-west - Merseyside, Chester and Wirral, Manchester south and Stoke ;
South-east - Brighton, Gatwick and Tonbridge.

This approach has been used in previous farm-based surveys (Gasson and Potter, 1988 ; Morris and Potter, 1995) and has a number of limitations which should be acknowledged. Certain farms and farmers will not be included, information may be out of date and large businesses may be entered under more than one address, thus increasing their chances of selection. These considerations will inevitably result in sources of sample bias (Errington, 1985). MAFF was approached for lists of farmers' names and addresses but these were only available to those working on MAFF sponsored projects. The NFU was able to supply membership lists but these were only available at prohibitive cost which was not considered to be justified as these would incorporate their own sources of sample bias.

A 'questionnaire pack' was sent to each of the farms chosen for the survey. This consisted of the questionnaire itself together with a covering letter and an explanatory brochure which gave details of the background and aims of the project. A freepost envelope was supplied for returns and confidentiality was assured. Questionnaires were colour coded according to region so that returns could be easily classified.

Questionnaires were dispatched in June 1994 and the sample size was 1076, numbers dispatched by region were : eastern (420); north-west (336); and south-east (320).

### 2.3.4 A Problem of Non-response

By August 1994, a total of 194 completed questionnaires had been returned, a response rate of 18%. Numbers returned by region were :

| | | |
|---|---|---|
| Eastern | 84 | (20.0%) |
| North-west | 58 | (17.2%) |
| South-east | 53 | (16.5%) |

The initial survey size was chosen in anticipation of a return rate of 20 to 25%, giving between 200 and 250 completed returns. Return rates as low as those encountered here are generally regarded to be undesirable, as they inevitably raise concerns over sampling bias. The Farms section of the Yellow pages does not differentiate between arable, livestock and mixed farms and for this reason an unknown proportion of questionnaires were sent to farms which had no set-aside obligation. The covering letter explained these sampling difficulties and asked farmers who were not arable producers to discard the questionnaire as its contents were not appropriate to their holdings. It was not possible to quantify the number of questionnaires which were sent to 'non-target' farms but it should be acknowledged that this factor was, to a large degree, responsible for artificially low return rates.

As discussed in a previous section, non-responders may represent a discrete group of farmers whose attitudes and perceptions to some extent determine their decision not to take part in the survey. For example, those farmers who are fundamentally opposed to set-aside may feel less inclined to discuss their views. In order to eliminate or reduce this bias, a follow-up survey was conducted. A random sub-sample of 150 farmers from the initial survey was selected and sent a follow-up questionnaire in January 1995. This consisted of six 'key' questions from the original (see Appendix 2). Farmers were asked to ignore this follow-up if they had completed the initial questionnaire, whilst it was explained to those who had not returned the original, that the purpose of this exercise was to ensure that a fair and representative sample of farmer attitudes was obtained. A total of 67 completed follow-ups were received and the response to the six questions in these follow-ups statistically compared. A Chi-squared test was conducted for each of the six questions, with response frequencies from the initial 'population' as 'expected' frequencies. These were statistically compared with 'observed' frequencies from the 'follow-up' survey and no significant differences were found in responses to any of the questions. For the purposes of subsequent analysis the responses to these follow-ups were combined with the original data set.

### 2.3.5 A conceptual basis for the analysis of farmers' decision-making processes on set-aside land.

Ultimately, the questionnaire survey described in this chapter aims to determine the factors which constrain and enable farm and farmer participation in conservation oriented management on set-aside land. A behavioural approach, i.e. one which seeks to determine the relative importance of a number of attitudinal and structural variables in farmers' decision-making processes, has been adopted. This approach has been widely utilised in agricultural geography, primarily in the form of innovation-adoption research (Ilbery, 1985), which studies the spread, or diffusion of innovative technologies and, or policies within the agricultural sector (Jones, 1963, 1975). Jones (1975) identified a number of factors which influenced the diffusion of innovations amongst farmers, these included : situational characteristics (farm size, farm type) ; personal characteristics (education, age) ; psychological characteristics (attitudes, beliefs, values) ; and macro-environmental characteristics (economic situation). The innovation-adoption model has been successfully applied to the uptake of soil conservation programmes in the US (Earle *et al.*, 1979 ; Bultena and Hoiberg, 1983 ; Davies, 1985), and to the uptake of environmental practices (Taylor and Miller, 1978 ; Morris and Potter, 1995).

Results from the current survey are analysed with a view to establishing a 'participation spectrum' (Morris and Potter, 1995) for the conservation management of set-aside land. Through consideration of the factors which constrain uptake, suggestions are made for policy initiatives which will ultimately move farmers along this spectrum, resulting in a greater realisation of the conservation potential of set-aside land.

### 2.3.6 Data Collation and Analysis

Individual questions were assigned a 'variable name' and responses were numerically encoded. Data from completed questionnaires were initially captured in an Excel spreadsheet, and subsequently converted to an SPSS (Statistical Package for Social Sciences) data file. All data analyses were performed using SPSS (SPSS, 1990). A simple descriptive summary of data (calculation of frequencies and means) was conducted. Analyses to measure associations between variables were based on cross-tabulation. When one or both of the variables were nominal (region, tenancy status), the Chi-squared Test of Independence was employed to test the hypotheses that responses to the two variables were independent of each other. Where both variables were ordinal (conservation-orientation, farm size, satisfaction with CAP reform), the Mantel-Haenszel Chi-square statistic, a measure of linear association, and Spearman's correlation co-efficient were calculated (SPSS, 1990). The results of these analyses have been incorporated into graphics and text where required. Analysis of variance was employed where appropriate.

## 2.4 Results

### 2.4.1 A Profile of Surveyed Agricultural Land

The initial questionnaire survey (excluding follow-ups) covered a total agricultural area of 45,978 hectares (ha), of which 28,486 ha was eligible for payments under the Arable Area Payments Scheme. A mean of 18.34% of eligible land had been set-aside per holding giving a total set-aside area of 5,322 ha. The mean size of farm covered by the survey was 239 ha. The distribution of farm sizes about this mean was not normal, with two very large holdings in the eastern region (6000 and 3200 ha) causing a left-skewed distribution. The coverage of total agricultural and set-aside land within the three surveyed regions is shown in Table 2.2

Table 2.2 Survey coverage of agricultural and set-aside land by region (Figures in brackets are standard errors)

| | Agricultural land (ha) | | Set-aside land (ha) | |
|---|---|---|---|---|
| | Total area | Mean farm size | Total area | Mean area per farm |
| East | 26,838 | 320 (77.5) | 2,964 | 35.3 |
| North-west | 8,564 | 148 (38.6) | 1,576 | 27.2 |
| South-east | 10,154 | 195 (40.0) | 782 | 15.0 |

For the purposes of subsequent analysis, farm size has been recoded into 3 size classes ; 90 of the farms surveyed were under 100ha, 54 between 100 and 250 ha, and 50 were over 250 ha. Mean farm size varied considerably between regions (Table 2.2). Farmers were also asked to indicate if they operated under a mixed or purely arable system. Only 27% of farms surveyed were exclusively arable. This figure rose to 59% in the eastern region, with only 3 and 4% respectively of north-western and south-eastern farms having no livestock interest on their holding.

#### 2.4.1.1 The Management of Set-aside Land

The Arable Area Payment Scheme (AAPS) operates under a two-tier system, whereby those producers with less than 15.51 ha of eligible land are not required to set-aside in order to qualify for area payments. Eighteen (9.3%) of the farmers covered by this survey were registered under this simplified scheme. Entry into the AAPS is entirely at the discretion of the individual farmer. However, payment rates have been set so that participation is, on the whole, financially advantageous. Only 4 (2.1%) farmers had exercised the right to 'opt-out' of the scheme highlighting the financial expediency of participation. As one north-western farmer commented :

> "whilst it pains me to leave good agricultural land idle and unproductive, I cannot afford to give up area payments and must therefore set-aside to keep my business viable, even though this goes against every one of my farming instincts"

The set-aside obligation may be satisfied by setting aside whole fields, part fields, strips within fields or field margins. Table 2.3 summarises the allocation to these various options in the current survey where this was specified.

Table 2.3 Allocation of set-aside to field types.

| | Number of farmers | Total Area (ha) |
|---|---|---|
| Whole fields | 135 | 3530 |
| Part fields | 56 | 462 |
| Strips | 3 | 7 |
| Field margins | 9 | 72 |

A primary objective of this survey was to create a baseline of data which established how farmers were managing their set-aside obligation, what factors were influencing this management and how set-aside was allocated between fields around the holding. At the time of the first survey, shortly after the introduction of the AAPS, farmers were required to set-aside land under either the rotational or non-rotational option. A combination of these two options to fulfil the set-aside obligation was not permitted[1]. The rotational option required that 15% of eligible land be set-aside, and that this 15% be rotated around the holding on an annual basis over 6 years, whilst the non-rotational option allowed setting aside of fields for 5 years, but required 18% set-aside (MAFF, 1993a). Of the 5,322 ha of set-aside land covered by the survey, 81% was set-aside under the rotational option and only 19% as non-rotational set-aside. The additional benefits which can be obtained from non-rotational set-aside have been discussed, and the widespread allocation of set-aside to the rotational option must be considered

[1] In subsequent years the scheme has been modified and allows such combinations (MAFF, 1996d)

disappointing to the conservation interest. Considerable variations exist in the way land is being set-aside in the three regions (Table 2.4)

Table 2.4 The Allocation of set-aside to rotational and non-rotational options

| Region | Rotational (%) | Non-rotational (%) |
|---|---|---|
| East | 89 | 11 |
| North-west | 57 | 43 |
| South-east | 71 | 29 |
| **Total** | 81 | 19 |

North-western, and to a lesser extent, south-eastern farmers were more inclined to set-aside on a non-rotational basis. It is likely that this tendency is more closely linked to sound agronomic reasoning than to any perceived conservation benefits. In these two regions, land tends to be of varying quality in terms of yield potential, and for this reason farmers will be benefited to a greater degree by setting aside lower yielding fields for five year periods than in the arable heartlands of the east of England, where high yielding arable land is more widespread and universally occurring.

Whilst it is acknowledged that non-rotational set-aside accommodates more potential for long-term wildlife benefits, the nature of cover establishment is of over-riding significance. Broadly speaking, set-aside regulations permit four types of cover to be established on rotational and non-rotational land. The land may be left to regenerate naturally, or 'tumbledown' from the preceding crop, a grass cover may be sown, non-agricultural crops may be planted or the land may be managed more specifically for conservation objectives. The management of land under each of these options is summarised in Figure 2.2, and is illustrated separately for each region in Figure 2.3

Natural regeneration was the most popular (67%) means of cover establishment on rotational set-aside land, planting of non-agricultural crops and a sown grass cover accounting for 21% and 12% respectively. In the absence of non-agricultural production, natural regeneration is the obvious choice of cover for rotational set-aside, where problems of weed infestation are less likely to become severe and can be treated with selective herbicide where necessary. Sowing a grass cover greatly reduces the risk of weed infestation but incurs additional input expenditure. This expense is more easily justified on non-rotational set-aside where the potential for the establishment of pernicious and perennial weed populations is greater. This fact is reflected in the 74% of non-rotational set-aside which is sown to

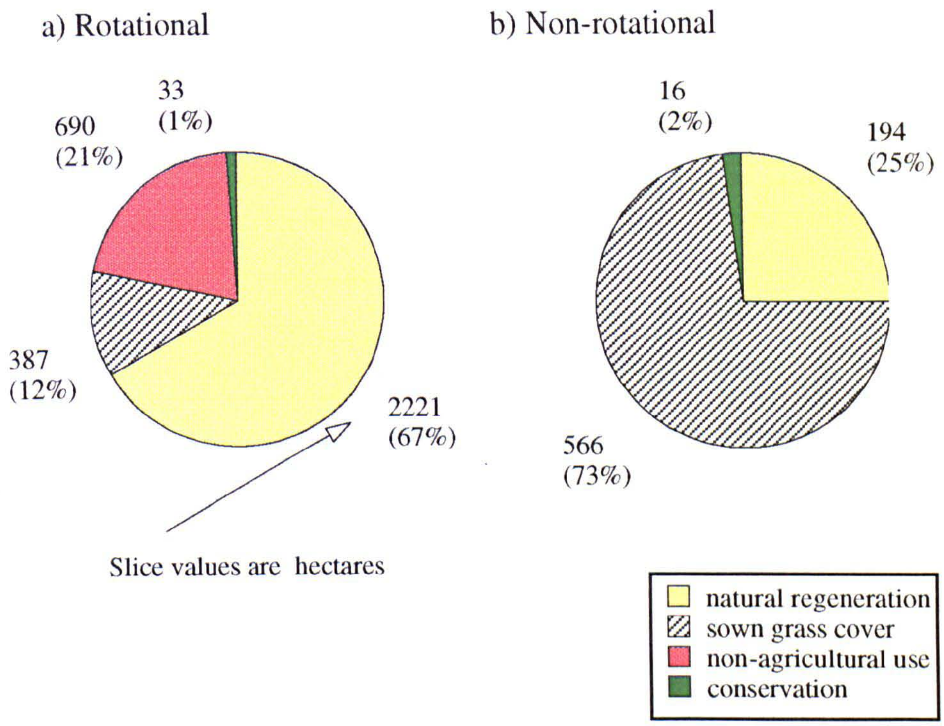



Figure 2.2 Pie charts summarising the nature of cover establishment on a) rotational and b) non-rotational set-aside land

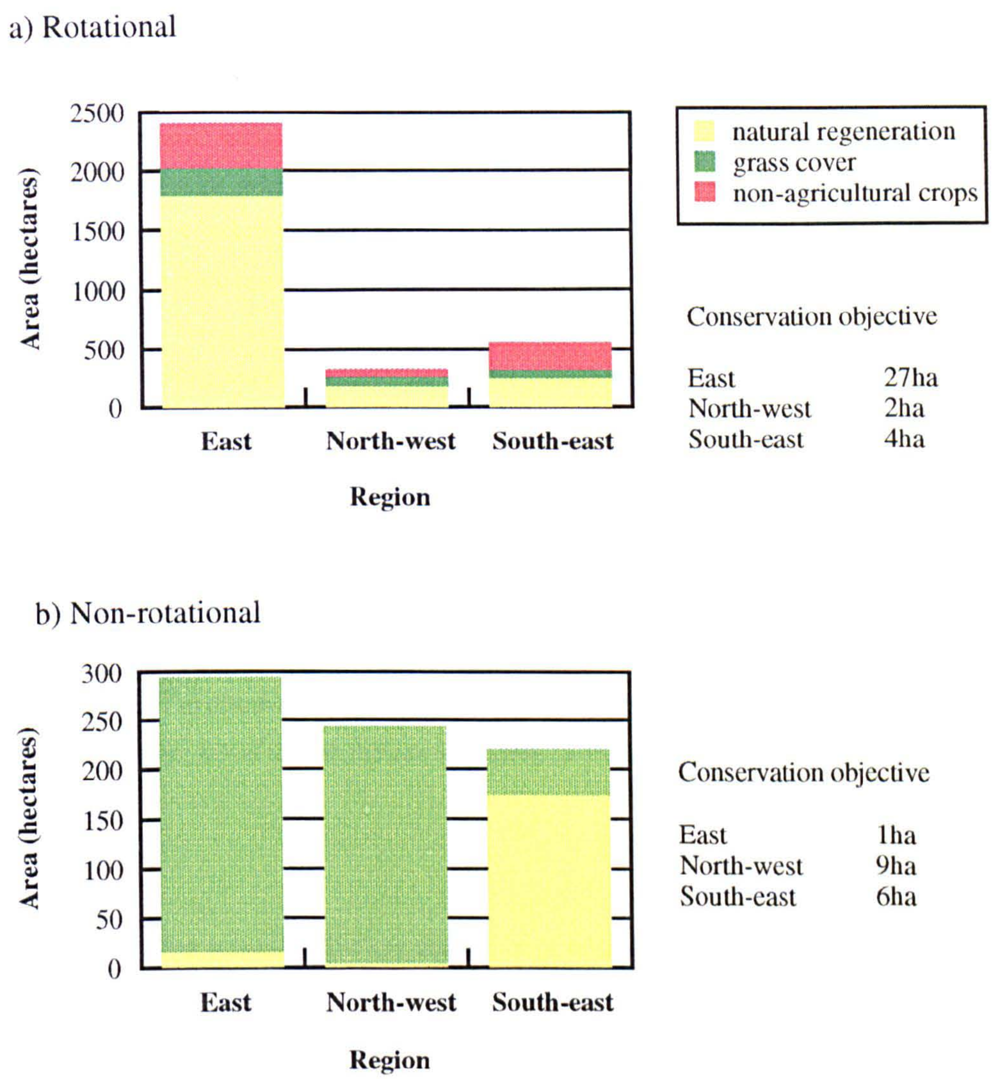



Figure 2.3 The nature of cover establishment by region for a) rotational and b) non-rotational set-aside land.

grass. As discussed in the previous chapter, sowing a grass cover greatly reduces the potential benefit of set-aside land to wildlife, and for this reason the high proportion of naturally regenerating rotational set-aside should be welcomed and encouraged. In the current survey non-agricultural crops were planted on rotational set-aside only, where it is likely that they are viewed as a 'break' crop within the arable rotation. The most notable difference between regions (Figure 2.3) is the proportion of south-eastern rotational set-aside which has been planted to non-agricultural crops, and the tendency of south-eastern farmers to allow non-rotational land to naturally regenerate, a practice which should result in significant wildlife benefits in the longer term.

Across the entire survey, only 49 ha (33 ha rotational and 16 ha non-rotational) was being managed specifically for conservation objectives (less than 1% of the total area). This result obviously reflects an extremely low rate of participation in conservation-oriented management on set-aside land. Whilst these results do not preclude wildlife gains, which may accrue on set-aside land as a result of non conservation specific management, they do suggest that at the time of survey the potential benefits of set-aside to wildlife were being significantly underexploited.

In an attempt to discover which factors had the greatest influence on farmers allocation of set-aside, respondents were asked to rank the considerations in Table 2.5, from 1, the most important to 5, the least important

Table 2.5 Mean ranking scores for five key determinants in the allocation of set-aside land

| | Mean ranking score | Rank |
|---|---|---|
| Poor agricultural land | 1.69 | **1** |
| Land which would benefit from resting | 2.35 | **2** |
| Land with access[2] problems | 2.91 | **3** |
| Land with conservation potential | 3.68 | **4** |
| Land with trespass[3] problems | 4.33 | **5** |

Wildlife conservation potential was consistently perceived to be of minor importance compared to agricultural considerations. If the full wildlife potential of set-aside is to be realised farmers must be encouraged to view this potential as a major determinant of set-aside allocation on

[2] Cropped areas which were remote, difficult to reach or difficult to work (i.e. steep slopes)

[3] Areas which were often subject to yield losses as a result of public trespass

their holding. The relative ranking of these factors was similar for all regions, with slight deviations in the south-east, where poor agricultural land had a mean ranking of 1.38 reflecting the marginal nature of much arable land in this region. Similarly, in the south-east, land with access difficulties was more common. In a survey reported by Ansell and Tranter (1992), farmers who had entered land into the five year voluntary set-aside scheme were asked to indicate their motivations for joining. To remove poor or inaccessible land from the arable rotation was cited by 40% of respondents, 31% regarded the scheme as a source of additional income and 26% said that increasing the conservation interest of their farm was a major motivation. This scheme was not linked to the price support mechanism, meaning that participation was independent of qualifying for price support. Farmers who joined the scheme did so on its perceived merits to their holding and were, therefore, more likely to exercise a positive attitude to set-aside land when considering management alternatives.

Respondents were asked to list any other factors which contributed to their decisions but were not listed on the questionnaire. A common reply was that fields with heavy weed infestations were often set-aside to enable control of these populations.

### 2.4.1.2 The Conservation Resource

Previous surveys have established a link between the extent of existing semi-natural habitat on farmland, and farmers' attitudes and behaviour towards conservation (Wilson, 1996 ; Morris and Potter, 1995 ; ADAS, 1976). Wilson (1996) reported a correlation between the extent of semi-natural habitat and ESA participation. Within the South Downs ESA Morris and Potter's 'active adopters' often had a history of conservation management. It has also been suggested that participation in agri-environmental schemes increases future conservation-orientation and the likely uptake of such schemes (Morris and Potter, 1995 ; Battershill and Gilg, 1996a).

In the current survey, farmers were asked to indicate which semi-natural habitat types were represented on their holding, and whether any of these, or any other areas of agricultural land were currently being managed within agri-environmental schemes. Results are in Tables 2.6 and 2.7.

Farmers were classified into 3 groups according to the number of semi-natural habitat types which occurred on their holding. Whilst this measure is acknowledged as somewhat superficial, as it takes no account of the extent of these areas, it does reflect farmers range of experience in managing different semi-natural habitat types. Only 12 farms were completely devoid of semi-natural habitat, 50 farms had less than two habitat types, 78 between two and three, and 66 more than three. The range of habitats varied significantly ($p<0.001$) according to region. Farms in the south-east containing a more diverse network of sites (Table 2.8). 43 of the surveyed farms were managing parcels of land under one or more of the agri-environment agreements listed (Table 2.7).

Table 2.6 The occurrence of semi-natural habitats on surveyed farmland

| Habitat type | Number of surveyed farms where present (n = 194) |
|---|---|
| Deciduous woodland | 118 |
| Coniferous woodland | 39 |
| Damp grassland / marshy land | 41 |
| Hedgerows | 161 |
| Scrub | 38 |
| Unimproved grassland / heathland | 73 |
| Open water | 84 |

Table 2.7 The uptake of agri-environmental schemes on surveyed farmland ([1] available in south-eastern region (South Downs ESA) only, [2] at time of survey available only in eastern region, [3] available in eastern region only)

| Agri-environmental Scheme | Number of agreements (n = 194) |
|---|---|
| SSSI Management agreement | 10 |
| ESA Management agreement[1] | 10 |
| Farm Woodland Scheme | 18 |
| MAFF Conservation Grant | 4 |
| Hedgerow Incentive Scheme | 5 |
| Countryside Stewardship[2] | 7 |
| Nitrate Sensitive Area[3] | 6 |

The significance, or otherwise, of these results in terms of their relation to attitudinal and structural variables will be discussed later in this section.

Table 2.8 Regional variations in the range of semi-natural habitat types on farmland.

| Number of habitat types | Percent of farms | | |
|---|---|---|---|
| | East | North-west | South-east |
| 0 - 1 | 38 | 24 | 8 |
| 2 - 3 | 36 | 47 | 40 |
| over 4 | 26 | 29 | 52 |

## 2.4.2 A Profile of Participants

Completed questionnaires were returned by farmers with wide-ranging experience within the agricultural industry, from 2 to 70 years, with a mean of 32 years of active farming experience. Figure 2.4 summarises the distribution of farmers by age group and occupancy status. The remainder of this section will examine the attitudinal and structural factors which relate to set-aside and it's potential management for conservation objectives.

### 2.4.2.1 Farmers' Perceptions of the Economic and Agronomic Consequences of CAP Reform and Set-aside.

The economic and agronomic impacts of the reformed CAP constitute the structural factors which were discussed in the introduction and will be important determinants of overall attitudes towards set-aside land and the new regime in general. Farmers were asked to assess the financial, agricultural and environmental impacts of the AAPS and set-aside on their holding. Results are in Table 2.9.

When the entire surveyed population is considered, no consensus of opinion emerges about the financial and agricultural effects of set-aside. 32% acknowledged the actual and potential benefits for environmental concerns on the farm, whilst a similar percentage indicated that they perceived set-aside to make no difference to the environmental value produced on their holding. 4% believed that set-aside was by some measure environmentally harmful.

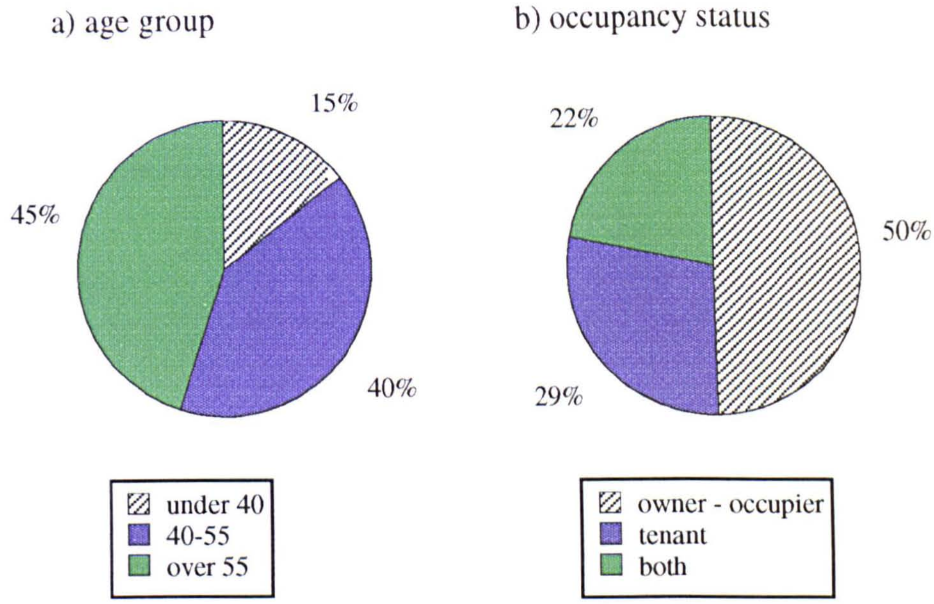



Figure 2.4 Pie charts to illustrate the distribution of participants by a) age group and b) occupancy status

Table 2.9 Farmers' perceptions of the financial, agricultural and environmental implications of set-aside on their holdings

| | Percent of respondents | | |
|---|---|---|---|
| | Beneficial | Harmful | No difference |
| Financially | 18.8 | 24.9 | 24.9 |
| Agriculturally | 20.8 | 20.8 | 25.4 |
| Environmentally | 32.0 | 4.1 | 31.5 |

Responses to these three variables were analysed with respect to region, farm size, farmer age and farm type. The statistical significance of these associations was tested using the Chi-squared Test of Independence. Perceptions of the agricultural and environmental consequences of set-aside were independent of all the variables against which they were measured. A significant association ($p < 0.05$) existed between financial consequences and region ; 52% of south-eastern farmers indicated that set-aside policy had been financially beneficial to their farm business, compared with only 21% and 23% respectively in the east and north-west. Once again, this result is probably a reflection of the relatively higher incidence of marginal arable land in the south-east. Payment rates for set-aside land are calculated on the basis of a mean cereal yield of 5.93 tonnes/ha throughout England. Wherever land which is set-aside yielded less than this figure, a net gain will result as input costs are significantly reduced, resulting in increased net margins. 51% of purely arable producers, compared with only 26% of mixed farmers ($P < 0.05$), found the new regime financially disadvantageous.

In a later section of the questionnaire, farmers described the profitability of their farm since the CAP reform of 1992, 22% said that it was increasing, 18% that it was decreasing and 53% that it had remained static. Regional variations and variations by farm type were identical to those described above. The economic analysis of CAP reform presented is admittedly an oversimplified one, with overall effects proving difficult to define, over half of surveyed farmers having indicated that net margins have remained static. Where profitability has been affected, this has been mediated by individual and regional circumstance. It should also be noted at this point that, at the time of the survey world prices for grain were very high, and that the financial consequences of set-aside are to some extent dependent on these, and will therefore fluctuate with the vagaries of global economics. When prices are high, set-aside may constrain potential profits, whereas conversely, when these are low, it may act as a buffer against reduced margins.

The low intensity management which is commonly practised on set-aside land allows more time for crop husbandry on the remaining arable area, facilitating more precise timing of operations ('slippage') and the potential for higher yields. 24% of farmers said that management time on set-aside was reduced compared with arable production, 29% that it remained the same and 8% that it increased the management requirement, while 39% of farmers gave no response. Finally, farmers were asked if they believed that set-aside would enable them to increase production on cropped areas. 16% thought that potentially it could, and 52% that it would make no difference.

2.4.2.2 Attitudes towards, and perceptions of CAP reform and set-aside.

Overall levels of satisfaction with CAP reform were measured by responses to the question *"In general, were you satisfied with the outcome of the 1992 CAP reform process ?"* Results are shown in Table 2.10.

Table 2.10 Farmer satisfaction with CAP reform

| | Percent of respondents |
|---|---|
| very satisfied | 4.0 |
| quite satisfied | 39.5 |
| indifferent | 37.9 |
| quite opposed | 13.7 |
| very opposed | 4.8 |

Overall, very strong views, either for or against, the reforms were uncommon, the majority of respondents indicating that they were quite satisfied with, or indifferent to, the reform package. The influence of a number of social and structural factors on attitudes to CAP reform were analysed. Farmer age, farm type and the presence and extent of semi-natural habitat were not significantly associated with attitudes to the new CAP regime. Levels of satisfaction, however, were dependent on region, farm size and profitability. These relationships are illustrated graphically in Figure 2.5.

Farmers from the arable heartlands of the east of England, as a group, tended to be better disposed to the new CAP regime (Figure 2.5a, 56% satisfied) than those from the north-west and south-east (35 and 38% respectively). The modal response for north-western farmers was indifference (46%). Farmers from the south-east were the most commonly opposed (25%), 11% being very opposed, a much greater proportion than in the other regions.

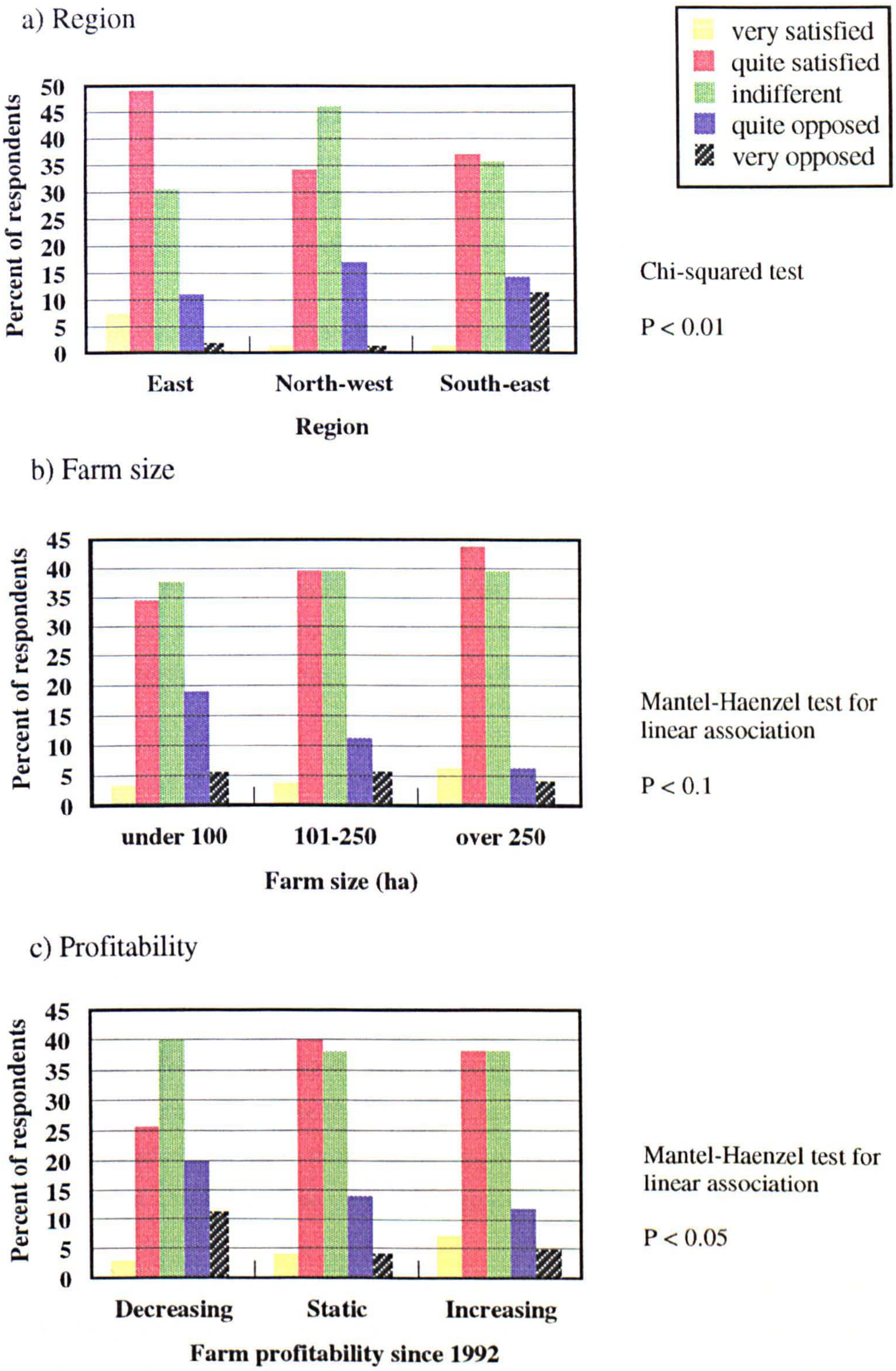



Figure 2.5 Associations of a) region, b) farm size, and c) profitability since 1992, with farmer satisfaction with the 1992 CAP reform outcome

A positive linear association existed between farm size and satisfaction (Pearson's $R^2$ = 0.135, p = 0.063). 38% of small farms, 44% of intermediate and 50% of large farms indicating overall satisfaction with the new regime (25%, 17% and 11% respectively were opposed). A similar association (Pearsons's R = 0.143, p = 0.053) existed between profitability and levels of satisfaction, (Figure 2.5c) demonstrating the important influence of economic factors in determining attitudes to set-aside and CAP reform. Overall, a regional trend emerges with large farmers, particularly on the high grade arable land in the east of England, being generally the most satisfied, and small farmers, and those who farm the marginal soils of the south-east, the least satisfied.

A central assumption underpinning the current survey is that farmers' perceptions of, and attitudes towards set-aside policy will be key determinants of their management intentions on this land, and their inclination to exploit its wildlife potential. Respondents were asked if they believed that *"set-aside was a step in the right direction towards reform of the arable sector"*. Only 34% indicated in the affirmative, suggesting that, while a majority were favourably disposed, or at least neutral to the overall outcome of the reform, the obligation to set-aside was viewed unenthusiastically by most. Whilst admittedly an oversimplification, it appears that most cereal producers are satisfied with the introduction of direct area payments to compensate for reductions in guaranteed prices, but less welcoming of the principle of set-aside. Attitudes towards set-aside were independent of all structural variables.

In an attempt to explore farmers' perceptions of the objectives of the AAPS and set-aside, respondents were asked to select from a range of objectives which they thought were the most important. Results are in Table 2.11

A large proportion of participating farmers perceived the major goals of the new regime to be economic in nature, balancing supply and demand and reducing EC expenditure on the CAP, social and environmental objectives were rarely seen as primary policy concerns. It should not be concluded from this finding that farmers believe that the AAPS has no environmental or welfare benefits. These have been acknowledged elsewhere in the questionnaire, but are not seen as constituting the primary aim in policy design. One farmer from the eastern region commented that :

> "we are all aware of the need to protect the environment and wildlife but any industry is driven by economic concerns and as such any agricultural support policy must firstly consider these. If farmers are making a reasonable living they will be more likely to listen to the views of conservationists. Set-aside does have environmental benefits and these should be encouraged, but only where they can be achieved at no cost to the farmer."

Table 2.11 Farmers' perceptions of the most important objective of the Arable Area Payments Scheme

| Objective | Percent of respondents |
|---|---|
| to balance supply and demand for surplus products | 61.1 |
| to reduce overall expenditure on agricultural support | 24.3 |
| to secure environmental benefits | 3.2 |
| to provide welfare payments for particular farmer groups | 4.9 |

2.4.2.3 Farmers' Attitudes and Intentions Toward Nature Conservation and the Wildlife Resource on Farmland.

The importance of farmers' attitudes towards wildlife and nature conservation for securing participation in agri-environmental schemes was discussed in the introduction to this chapter. As a baseline from which attitudes could be explored in greater detail the questionnaire asked *"would you consider yourself to be generally interested in, and sympathetic towards wildlife on your farm ?"* (Figure 2.6), and, if interested, what were the primary reasons for this interest ? 90% of farmers surveyed indicated that they were either very (36%) or quite (54%) interested, only 2% (6 farmers) were uninterested. This result suggests a very favourable baseline of attitudes towards wildlife within the farming population. Similar results have been reported by other authors (ADAS, 1976 ; MacDonald, 1984 ; Newby *et al*, 1977 ; Carr and Tait, 1991 ; Westmacott and Worthington, 1984) and should be interpreted with a measure of caution, as farmers often tend to reserve the term wildlife for species which are considered beneficial to agriculture. Farmers in the current survey were provided with a definition of wildlife on which to base their answers. Wildlife was defined as "any animal or plant species, or associations of these species which are not deliberately introduced to farmland as part of normal agricultural practices, but which co-exist with crops and livestock."

Farmers were asked what were their motivations for this interest. 60% of respondents cited personal pleasure, 52% considered that achieving 'a balance of nature', was beneficial to agriculture and 24% encouraged wildlife for sporting reasons. The latter two reasons suggest a preference for 'beneficial' species, whereas an interest motivated by personal pleasure implies a more pervasive attitude to wildlife. 40% of larger producers (over 250ha), compared to 32% and 17% respectively of intermediate and smaller producers ($P < 0.05$) were motivated by sporting interests, similarly, this interest was more widespread in the arable heartlands of the east of England. These observations concur with those of Howard and Carroll (1997) who commented that the gaming interest was

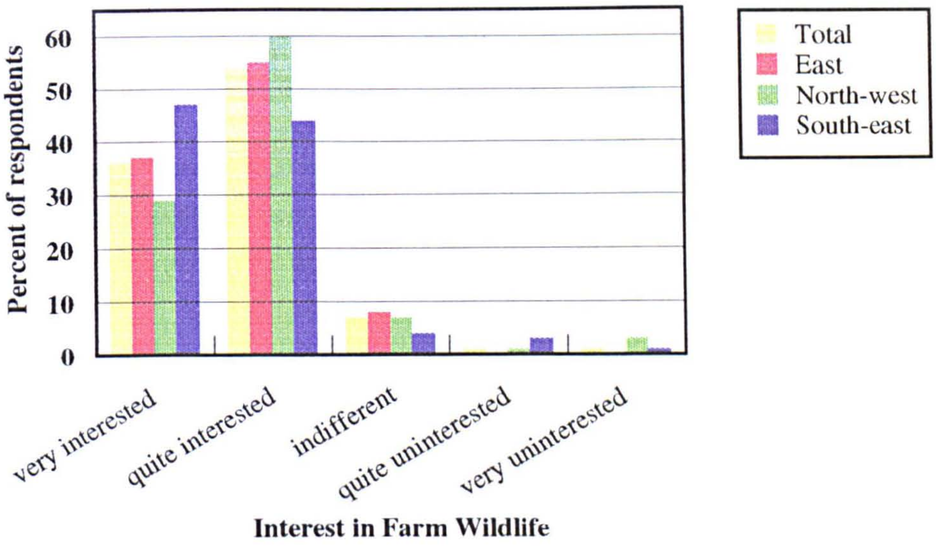
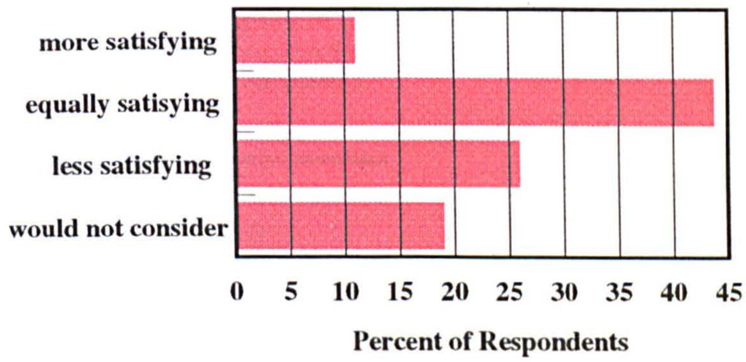



Figure 2.6 "Do you consider yourself to be interested in, and sympathetic towards farm wildlife? "

a)




b)

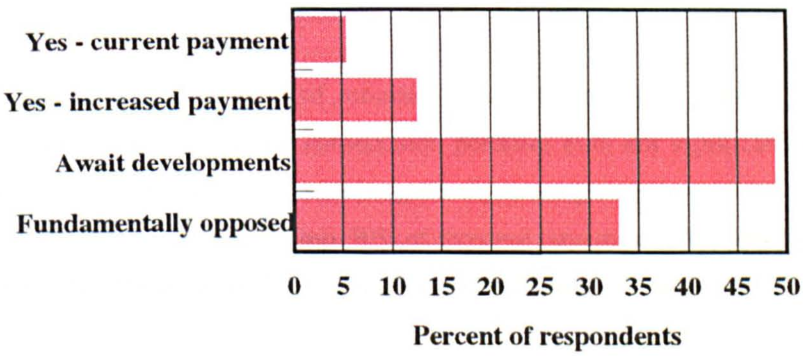



Figure 2.7 a) "How would you view managing some of your land for conservation as opposed to agricultural production ?"
b) " Would you be prepared to enter some of your land into long-term set-aside ?"

concentrated on large farms and estates. No differences were observed in the distribution of farmers motivated by personal pleasure, whilst the 'balance of nature' was most commonly cited by farmers from the north-western and south-eastern regions (70% and 64% respectively compared to 49% of eastern farmers, $P < 0.05$).

Regional variations in attitudes to wildlife, whilst not statistically significant, are illustrated in Figure 2.6. South-eastern farmers were considerably more inclined to indicate that they were very interested in wildlife (47%) than those from the eastern (37%) and north-western (29%) regions.

Further variables assessed farmers' attitudes to wildlife through less direct questioning which measured conservation actions, attitudes and intentions in the context of recent changes to agricultural policy. Respondents were asked if they agreed with the statement that *"set-aside is an effective policy for enhancing the conservation and wildlife potential of set-aside land"* (Table 2.12).

Table 2.12 Farmers' perceptions of the wildlife conservation potential of set-aside land *"Do you agree that set-aside is an effective policy for enhancing the conservation and wildlife potential of set-aside land"*

| | Percent of respondents |
|---|---|
| Strongly agree | 2.6 |
| agree | 37.0 |
| neutral | 28.6 |
| disagree | 24.0 |
| strongly disagree | 7.8 |

No consensus of the value of set-aside to wildlife emerged amongst surveyed farmers. Regional differences in its perceived conservation potential were not significant, although analysis showed that farmers from the south-east, who generally had a greater interest in wildlife, were more likely to disagree with this statement. Only 30% of surveyed farmers said that they had noticed specific wildlife benefits on their set-aside land during the previous year, the nature of these benefits was not determined.

Differing perceptions between farmers and conservationists of the goals and intentions of nature conservation on farmland, highlighted by the work of Carr and Tait (1991), may be addressed by effective communication between the two parties. Only 41% of farmers surveyed had some degree of contact with conservationists or conservation organisations, and these farmers exhibited a consistently more knowledgeable and sympathetic attitude to wildlife. The nature of this contact was not investigated, and the extent to which contact increases interest and awareness is not clear. Where contact is initiated by farmers, these individuals are likely to have an established interest in wildlife on their farm. Conversely, where conservationists are initiating contact they may be fostering an increased concern and consideration amongst the farming population, leading to a greater integration of production-oriented goals and wildlife concerns.

Farmers' views on the legitimacy of wildlife concerns in the derivation of agricultural policy give a more meaningful measure of their attitudes to nature conservation. Results are presented in Table 2.13 of responses to the question *"do you think that MAFF has done enough to incorporate wildlife concerns into agricultural policy."*

Table 2.13 "Has MAFF done enough to incorporate wildlife concerns into agricultural policy? "

| Response | Percentage of respondents |
|---|---|
| enough | 32.1 |
| too little | 35.0 |
| too much | 3.3 |
| no view | 29.6 |

These results are encouraging for the conservation interest, with over one-third of farmers indicating that, in their view, too little had been done ; only 3% thought that too many concessions had been made to wildlife concerns. That these attitudes are not reflected in the uptake of conservation-oriented management suggests that, either farmers are not aware of the options available, or that generally unfavourable attitudes to set-aside policy are precluding these positive attitudes and deterring farmers from managing set-aside land for conservation. The lack of financial incentives, or even compensation for additional expenditure incurred as a result of positive management, may also be an important determinant.

The results reported in this section to date have established goodwill towards nature conservation amongst a significant proportion of the farming population. However, harnessing this goodwill to bring about a major shift away from intensive farming and towards a more holistic approach, where wildlife and landscape goals are treated by farmers as equally desirable as food production may not be easily achieved. As one farmer from the eastern region commented :

> "for the past 30 or more years we have been encouraged to produce as much as possible and this has become a matter of pride to farmers who measure the success of their enterprise in terms of the volume they produce, not just because of the money this earns them, but also as a matter of prestige. To suddenly expect farmers to abandon these hard earned successes in favour of farming for wildlife is a hard pill for many of us to swallow."

Perhaps the best indication of farmers' intentions towards wildlife in a changing policy environment is gained by seeking directly their views on land management for conservation as opposed to production goals and asking if they would be prepared to enter some of their land into long-term set-aside (20years)[4]. Responses to these questions are illustrated in Figure 2.7

Over half of farmers surveyed considered management for wildlife either more (11%), or equally satisfying (44%). Only 19% said that they would not consider such an option, with comments such as "I'm a farmer, not a Park Keeper" and "if I wanted to look after furry animals I'd have worked in a Zoo" illustrating that a small proportion of farmers remain vehemently opposed to conservation on farmland.

Whilst most farmers were reluctant at the time of the survey to commit any of their land to a period of 20 years out of production, most preferring to await policy developments, only a third of those surveyed were fundamentally opposed to the concept of long term set-aside. Again, this result demonstrates the potential for developing valuable wildlife resources on set-aside land if farmers are given appropriate policy signals, guarantees and financial incentives.

## 2.4.3 The Derivation of a Conservation Orientation

Clearly, a number of variables derived from the questionnaire and discussed in the previous section are measuring attitudes and intentions towards farm wildlife. Rather than undertaking a lengthy analysis of the association of each of these with social and structural variables it was possible to reduce this data to a single measure of **"conservation orientation"** which was subsequently analysed in terms of these factors. Seven response variables were considered as determinants of overall conservation-orientation. These are listed below :

---

[4] At the time of writing this questionnaire such a scheme had been proposed (the Habitat Scheme) but was still in the development stage. The Habitat Scheme was implemented in 1994 and now forms part of the 'agri-environment' package.

| Variable Code | Question |
|---|---|
| WILD | *"would you consider yourself to be generally interested in, and sympathetic towards wildlife on your farm ?"* |
| WILDOB | *"do you think that MAFF has done enough to incorporate conservation objectives into set-aside policy ?"* |
| MANCON | *"how would you view managing some of your land for conservation objectives as opposed to agricultural production ?"* |
| LONGT | *"would you be prepared to enter some of your land into long-term set-aside (20 years) ?"* |
| CONTACT | *"are you in contact with conservationists or conservation organisations ?"* |
| MANAGREE | *"do you have any land entered into agri-environmental management agreements ?"* |
| SNH2 | presence, and extent of semi-natural habitat |

In order to ensure that each of these was measuring a 'common factor' (**conservation orientation**) Chi-squared Tests of Independence were conducted on cross-tabulated data. Results are summarised in Table 2.14

Table 2.14 Chi-squared significance of associations between conservation related variables (*** $P < 0.01$, ** $P < 0.05$, *$P < 0.1$)

| | WILD | WILDOB | MANCON | LONGT | SNH2 | MANAGREE | CONTACT |
|---|---|---|---|---|---|---|---|
| WILD | | *** | *** | ** | ns | * | ns |
| WILDOB | *** | | *** | ns | ns | * | ns |
| MANCON | *** | *** | | *** | ns | ** | ** |
| LONGT | ** | ns | *** | | ns | ns | ** |
| SNH2 | ns | ns | ns | ns | | *** | *** |
| MANAGREE | * | ns | ** | ns | *** | | * |
| CONTACT | ns | ns | ** | ** | *** | * | |

The purpose of this analysis was to determine whether these variables were significantly associated. The seven variables can be divided into two groups - attitudinal (WILD, WILDOB, MANCON, LONGT) and circumstantial (MANAGREE, CONTACT, SNH2). Attitudinal variables are all strongly associated with one another and less strongly associated with circumstantial variables. MANCON appears to be the best overall determinant of conservation orientation. The presence and extent of semi-natural habitat is, not surprisingly, strongly associated with contact with conservationists and the existence of management agreements. Contact with conservationists, whilst not affecting overall levels of interest in, and sympathy towards farm wildlife (WILD) is associated with more favourable attitudes to management for conservation and long-term set-aside, suggesting that this contact is more influential than the existence of semi-natural habitats.

On the basis of this analysis these variables were recoded as follows, and scores summed to derive a measure for conservation orientation.

MANCON

| | |
|---|---|
| more satisfying | +3 |
| equally satisfying | +1 |
| less satisfying | -1 |
| would not consider | -3 |

LONGT

| | |
|---|---|
| Yes - at current payment | +2 |
| Yes - at increased payment | +1 |
| Will await developments | 0 |
| Fundamentally opposed | -2 |

WILDOB

| | |
|---|---|
| enough | 0 |
| too little | +2 |
| too much | -2 |
| no view | -1 |

WILD

| | |
|---|---|
| very interested | +2 |
| quite interested | +1 |
| indifferent | 0 |
| quite uninterested | -1 |
| very uninterested | -2 |

MANAGREE

| | |
|---|---|
| yes | +1 |

CONTACT

| | |
|---|---|
| yes | +1 |

SNH2

| | |
|---|---|
| 0 - 1 | 0 |
| 2 - 3 | +0.5 |
| more than 3 | +1 |

Scores for conservation orientation may range from -9 to +12. The histogram in Figure 2.8 illustrates the distribution of these scores for surveyed farmers. On the basis of this, farmers have been classified into four groups according to their conservation-orientation. These groups are summarised in Table 2.15.

Previous work establishing the importance of attitudes towards nature conservation and the environment in determining farmer participation in voluntary conservation based schemes on agricultural land was discussed in the introduction to this chapter. This survey has enabled four groups of farmers to be identified according to their conservation behaviour, attitudes and future intentions.

The four groups can be qualitatively characterised as follows :

**Conservation opponents** - opposed to the very concept of nature conservation on farmland, and unlikely in the absence of extreme financial pressure to reorientate farming practices to more environmentally friendly or wildlife conscious systems. Will remain strictly production-oriented.

**Reluctant conservationists** - generally opposed to nature conservation, viewing maximisation of production as their primary goal in agriculture. May consider voluntary conservation-oriented schemes only where these entail a financial advantage.

**Opportunistic conservationists** - acknowledge the requirement for a more holistic and environmentally benign agriculture, having considerable sympathy for wildlife concerns. Will readily manage land for environmental / conservation objectives where this option is financially viable.

**Enthusiastic conservationists** - committed conservationists who view environmental and wildlife concerns as equally and often more important than the maximisation of production. May already be managing significant parcels of their holding to achieve these objectives even where this entails a reduction in net margins.

Table 2.15 The Derivation of farmer groups based on conservation orientation

| | Conservation Orientation Score | Farmer Group |
|---|---|---|
| Group 1 | -6 to -1 | Conservation opponents |
| Group 2 | 0 to +2 | Reluctant conservationists |
| Group 3 | +2 to +3 | Opportunistic conservationists |
| Group 4 | +4 to +12 | Enthusiastic conservationists |

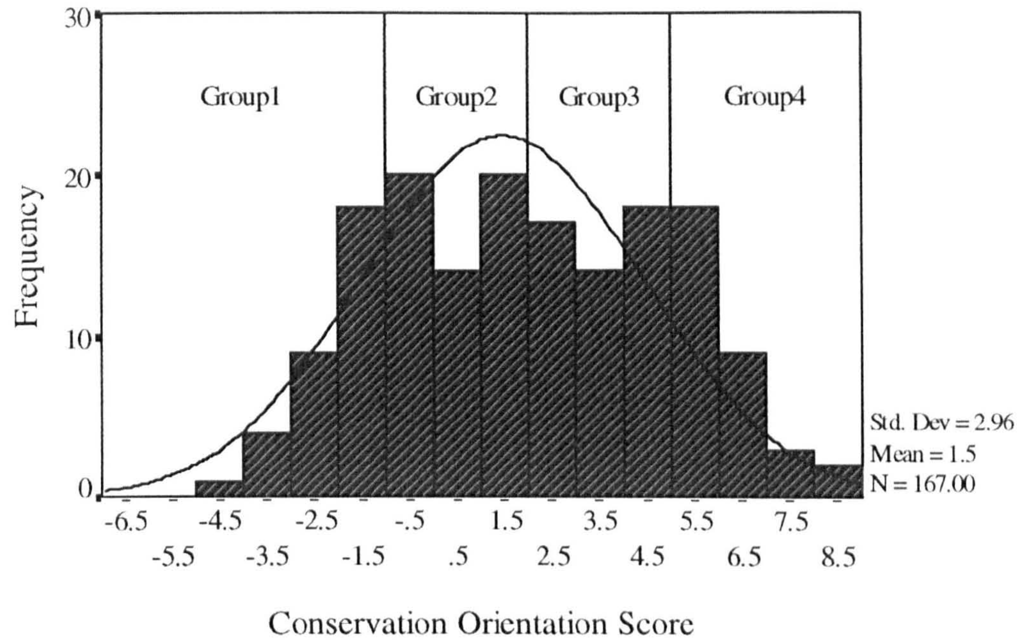



Figure 2.8 A Histogram (with normal curve) of Conservation Orientation Score for Surveyed Farmers.

| | |
|---|---|
| Group 1 | Conservation opponents |
| Group 2 | Reluctant conservationists |
| Group 3 | Opportunistic conservationists |
| Group 4 | Enthusiastic conservationists |

These four groups are broadly comparable with those which formed Morris and Potter's (1995) 'participation spectrum' in the South Downs ESA. The major difference in this study, however, is that these groups cannot be correlated to levels of participation due to the very low baseline of uptake of conservation-oriented management on set-aside which was discussed earlier in this chapter. Possible reasons for this will be discussed at the end of this chapter, and investigated further in chapter 3. It should not be concluded from these results that conservation-orientation has no influence on the management of set-aside land, rather that other more fundamental factors are precluding participation. When these are addressed conservation-orientation is likely to be very important in determining subsequent patterns of adoption and non-adoption.

In order to ascertain if, and how, social and structural variables (region, farmer age, farm size, farm type, farm profitability) related to conservation-orientation, these associations were analysed using the Chi-squared test of independence. At the same time, analyses of variance were performed on conservation-orientation scores with social and structural variables as treatment effects. Results are in Figure 2.9.

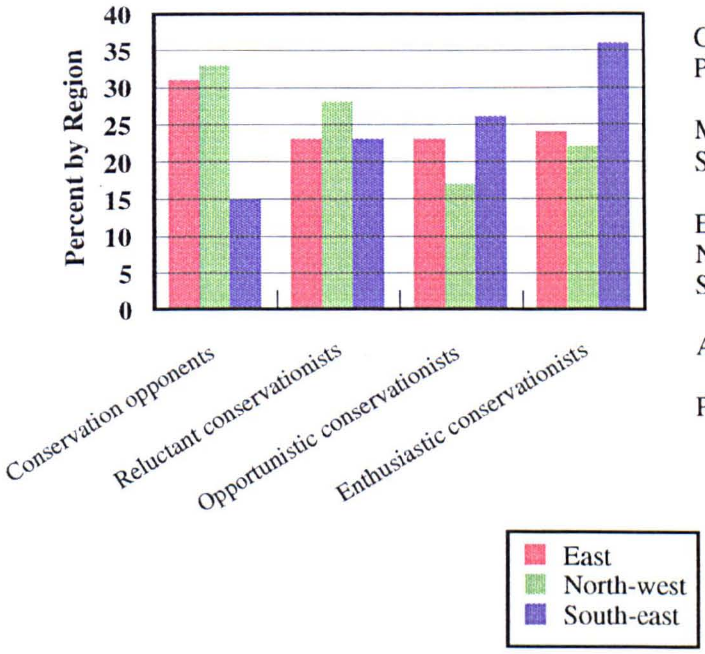
The incidence of the four farmer groups varied significantly between regions (Figure 2.9a), with farmers from the south-east demonstrating a greater sympathy for, and more positive intentions towards the conservation interest. If the conservation-orientation groups are aggregated into productionist (conservation opponents and reluctant conservationists) and holistic (opportunistic conservationists and enthusiastic conservationists) this difference becomes even clearer, with 62% of south-eastern compared to 47 and 39% respectively of eastern and north-western farmers subscribing to the holistic approach. Whilst differences between east and north-west are not significant, regions can be ranked as follows according to relative conservation-orientation.

South-east > East > North-west

In previous surveys, farm size has often been cited as a determinant of conservation-orientation, larger farms often exhibiting a greater degree of positive conservation behaviour (Battershill and Gilg, 1996a ; Morris and Potter, 1995 ; Gasson and Potter, 1988). Whilst not inherently more conservation minded, these farmers have more land at their disposal, are more flexible in both financial and management terms and are more likely to have experience of conservation management. In the current survey, differences were not significant (Figure 2.9c), but larger farmers, as a group, did exhibit a higher mean conservation score.

The pre-eminence amongst the structural variables of financial considerations in determining conservation-orientation has been discussed by other authors (Brotherton, 1989, 1991 ; Morris and Potter, 1995 ; Battershill and Gilg, 1996a ; Gasson and Potter, 1988) and has been analysed here (Figure 2.9b). Those farmers who indicated that profitability had increased since the 1992 reform were

**a) Region**




Chi-squared probability
$P < 0.05$

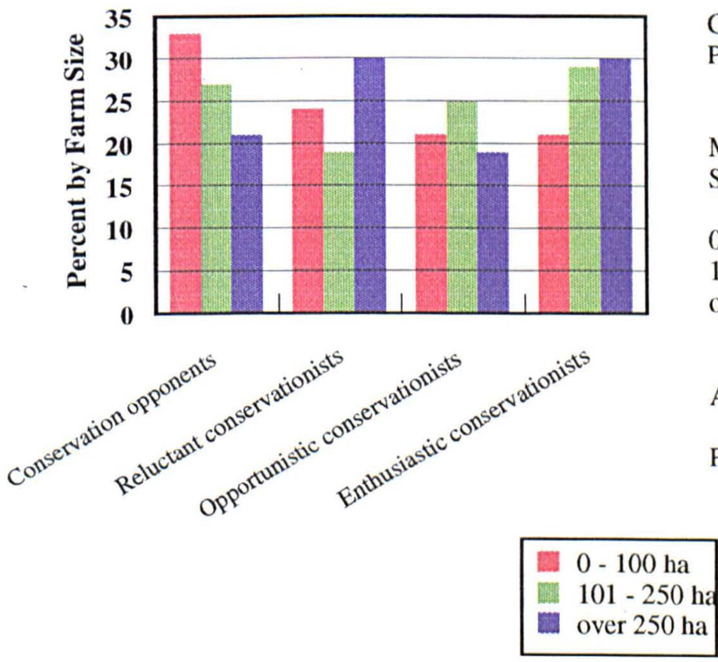
Mean Conservation Orientation Scores

| | |
|---|---|
| East | 1.74 |
| North-west | 1.39 |
| South-east | 3.23 |

Analysis of Variance

$P = 0.070$ LSD = 1.498 (ns)

**b) Farm size**




Chi-squared probability
$P = 0.684$ (ns)

Mean Conservation Orientation Scores

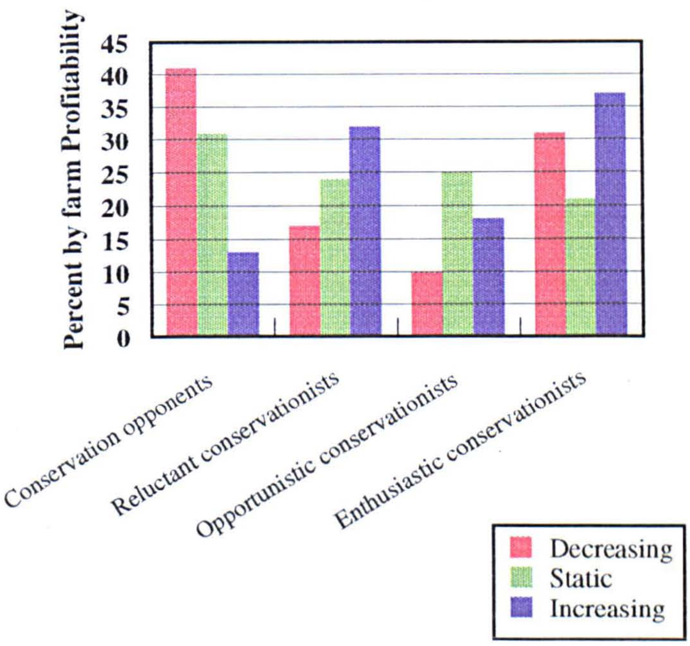
| | |
|---|---|
| 0 - 100 ha | 1.36 |
| 101 - 250 ha | 2.17 |
| over 250 ha | 2.77 |

Analysis of Variance

$P = 0.154$ LSD = 1.45 (ns)

Figure 2.9 Bar charts illustrating the associations between farmer conservation-orientation group and a) region, b) farm size, c) farm profitability, d) farm type and e) satisfaction with CAP reform.

c) Farm profitabilty



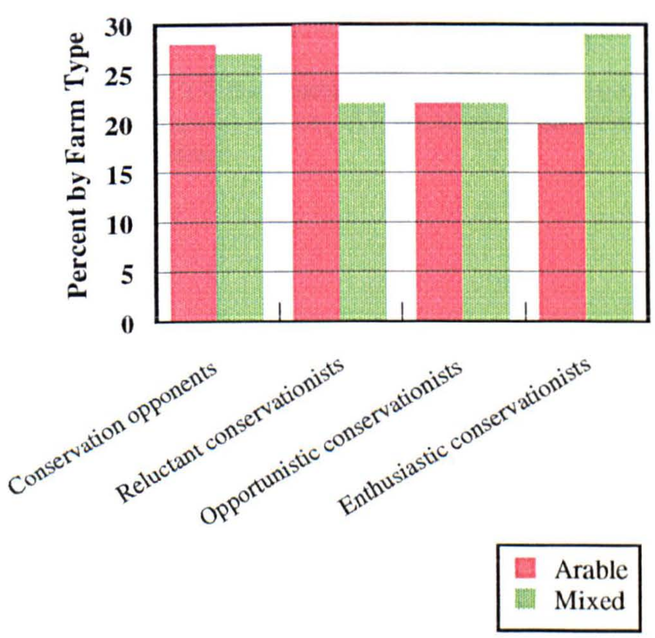

Chi-squared probability
P = 0.067 (ns)

Mean Conservation Orientation Score

| | |
|---|---|
| Decreasing | 1.72 |
| Static | 1.65 |
| Increasing | 2.97 |

Analysis of Variance
P = 0.215 LSD = 1.82 (ns)

d) Farm type




Chi-squared probability
P = 0.573 (ns)

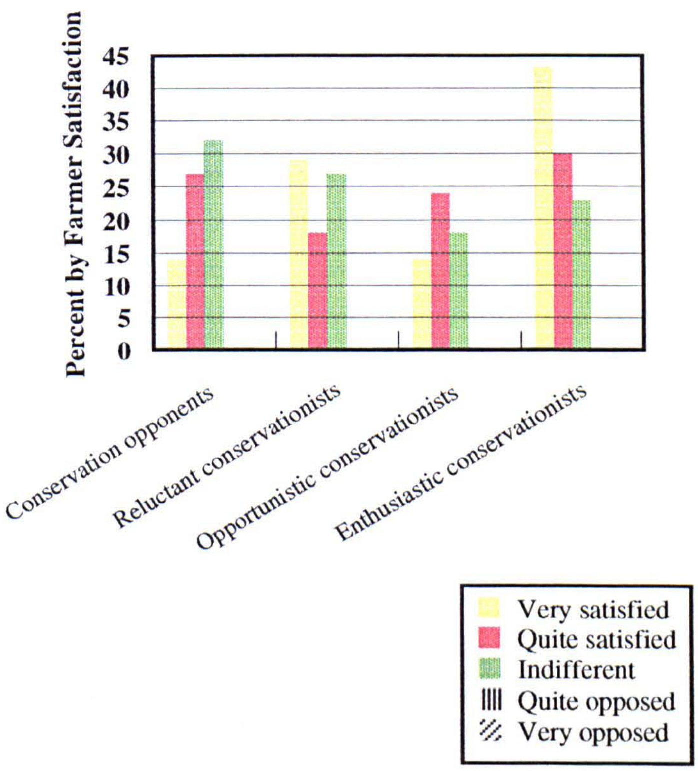
Mean Conservation Orientation Score

| | |
|---|---|
| Arable | 1.66 |
| Mixed | 2.18 |

Analysis of Variance
P = 0.44 (ns)

Figure 2.9 Bar charts illustrating the associations between farmer conservation orientation group and a) region, b) farm size, c) farm profitability, d) farm type and e) satisfaction with CAP reform.

e) Satisfaction with CAP reform




Chi-squared probability
P = 0.707 (ns)

Mean Conservation Orientation Score

| | |
|---|---|
| Very satisfied | 2.86 |
| Quite satisfied | 2.35 |
| Indifferent | 1.52 |
| Quite opposed | 1.40 |
| Very opposed | 4.37 |

Analysis of Variance
P = 0.567 LSD = 4.41 (ns)

Figure 2.9 Bar charts illustrating the associations between farmerconservation orientation group and a) Region, b) Farm sizec) Farm profitability d) farm type and e) satisfaction with CAPreform more inclined towards a positive attitude to nature conservation ; 37% were enthusiastic conservationists, and only 13% ranked as conservation opponents. Farmers whose profitability had decreased tended to have extreme attitudes ; 41% being conservation opponents and 31% enthusiastic conservationists. In general, previous surveys have reported that the most financially constrained are the least sympathetic to the conservation interest, regarding this as a luxury which they are unable to afford. This finding may be true for those farmers in the present survey who have emerged as conservation opponents. However, the 31% who are enthusiastic conservationists would seem to recognise a 'window of opportunity' regarding conservation as a legitimate alternative land use in a changing policy environment. Given the correct policy signals and appropriate financial incentives, these farmers would happily embrace conservation as an additional source of income, and a means to 'stepping-off' the productionist treadmill which is not benefiting their farm business in the present climate.

Although mixed farmers were found to be slightly more inclined towards conservation, these differences were not significant (Figure 2.9d). Similarly, conservation-orientation was completely independent of farmer age.

Whilst once again not statistically significant the association between farmers' conservation status and their level of satisfaction with the CAP reform outcome did produce some noteworthy results, with enthusiastic conservationists tending to be the most satisfied, and the most opposed to the reforms. This result suggests mixed feelings amongst the most conservation-oriented farmers in respect of the environmental benefits of the reform package.

## 2.4.5 Levels of Awareness

One further factor, completely separate from the structural and attitudinal variables considered to this point, will inevitably influence the rate, and extent of uptake of conservation-oriented management on set-aside land. Surveyed farmers were asked if they were aware of MAFF's guidelines for the management of set-aside land for environmental objectives. Results are in Table 2.16

38% of surveyed farmers were not even aware of the existence of these options. This lack of awareness will obviously over-ride all structural and attitudinal variables discussed and may only be overcome in time by more vigorous 'marketing' of these options by MAFF. Regional differences ($p = 0.07$) were apparent (though not significant), with farmers in the arable heartlands of the east of England tending to have a more informed appreciation of the range of options for set-aside land. Awareness varied significantly ($P < 0.01$) with farm size ; 84% of large farmers compared to 61% of intermediate and only 49% of small farmers being aware of these options, suggesting that larger farmers in the east of England were by some means better informed than others.

Table 2.16 Levels of awareness of MAFF guidelines for the management of set-aside land for environmental objectives.

| | | Percent of respondents | | |
|---|---|---|---|---|
| | Total | East | North-west | South-east |
| Yes | 62 | 71 | 54 | 56 |
| No | 38 | 29 | 46 | 44 |

## 2.4 Concluding Discussion - Farmer Participation in Conservation Oriented Set-aside : A Baseline for Further Research

Without doubt, the single most significant finding of this initial baseline survey has been the almost complete absence of uptake of MAFF's conservation-oriented management guidelines for set-aside land by farmers up to 1994. This result precludes an analysis of causal relationships between the attitudinal and structural factors which differentiate between participants and non-participants, necessitating a broader approach to explain why the farming community at large has not chosen to participate. To draw, once more, on an analogy with the work of Morris and Potter (1995), factors which influence farmers to move along the 'participation spectrum' on set-aside land can only be determined if these options are considered as viable uses of set-aside land by the farming community, or in other words, once a spectrum of participation has been established.

Previous studies have investigated key determinants of farmers' decision-making processes and conservation behaviour. Particular to the uptake of conservation management on set-aside land will be farmers' attitudes to the CAP reform process and the principle of set-aside, and their perceptions of the major objectives of these policies. On the whole, surveyed farmers did not express widespread disapproval of the CAP reform, but were far less enthusiastic towards the principle of land diversion (set-aside). Most farmers perceived the principal objectives of set-aside in terms of reducing over-production, few acknowledging its potential for nature conservation in the wider countryside as a major consideration. These findings are important ; farmers are unlikely to exercise positive environmentally based management if they disagree with the principle of set-aside and ignore, or fail to appreciate its wildlife potential. The lack of awareness of the existence of MAFF-directed conservation options amongst a considerable proportion of the farming community forms a fundamental barrier to participation, but is more easily addressed than other constraints.

In common with previous farm-based surveys, a high degree of interest in, and sympathy towards, farm wildlife was encountered within the farming community. Many farmers acknowledged that set-aside enhances the wildlife potential of arable land, and considered that MAFF had done too little to maximise and realise this potential. Divergent attitudes became apparent, however, when farmers were asked how they would view managing some of their land for conservation as opposed to food production objectives. When a range of variables relating to conservation attitudes, intentions and experience were combined to derive a 'conservation-orientation', it became apparent that attitudes towards conservation were more diverse than originally perceived. If, and when, conservation-specific management becomes established in the psyche of farmers as a legitimate and viable alternative use for set-aside these differences may become important in determining a 'participation spectrum.'

Those farmers whose profitability had increased since the introduction of the new regime were, not surprisingly, the most satisfied with the outcome of the CAP reform. However, financial considerations did not influence farmers' disposition towards the principle of land diversion which was independent of all structural and attitudinal factors. The least financially constrained farmers tended to have the highest conservation-orientation, but results were not clear cut, with many of the most constrained emerging as enthusiastic conservationists. These results should be interpreted with care as they do not relate to overall margins, but only to the financial implications of the Arable Area Payments Scheme.

Farm size was an important determinant of attitudes to CAP reform and nature conservation, and also of the level of awareness of conservation-oriented options for set-aside land. The relationship between size and profitability was discussed in the results section. The largest farms tended to be the most satisfied with the outcome of the CAP reform and the most conservation-oriented, they were also more likely to be informed or aware of conservation options.

Of all the structural variables against which associations with attitudes and circumstances were measured, region consistently emerged as the most discriminating, and these analyses have enabled a regional typology of farmers to be established on the basis of the issues raised by the questionnaire.

*EASTERN FARMERS* - these are typically intensive arable producers who farm large areas within the arable heartlands (59% had solely arable concerns). The uniformity of high-grade agricultural land means that rotational set-aside (89%) is prevalent. Profitability is more commonly decreasing following CAP reform than in the other two regions, but nevertheless, this group are the most satisfied with the CAP reform outcome. Eastern farmers show a good deal of awareness of conservation issues, being more conservation-oriented than those from the north-west. This greater awareness of, and interest in wildlife compared to north-western farmers probably reflects the widespread practice of wild game conservation in this region. This group is more in tune with policy developments in general, and exhibited the highest levels of awareness of conservation management options for set-aside land.

*SOUTH-EASTERN FARMERS* - typically these are farming within a mixed enterprise (only 4% were solely arable), with a significant proportion of marginal arable land (poor quality agricultural land and land with access difficulties was frequently set-aside) which has led to a greater allocation of land to the non-rotational option. South-eastern farmers were the most financially benefited by CAP reform ( but probably the most constrained overall), but also most frequently opposed (25%) to the CAP reform outcome. This group was the most interested in, and sympathetic towards wildlife (47% very interested) and had a significantly greater mean conservation-orientation score than the other two groups. This attitude was reflected in their willingness to consider nature conservation as an alternative land use. The south-east had the highest incidence of semi-natural habitat on farmland and south-eastern farmers were the most inclined to join agri-environmental and related schemes. However, despite this widespread conservation interest only 56% were aware of MAFF guidelines for the conservation management of set-aside land.

*NORTH-WESTERN FARMERS* - are the most difficult group to define. They were most inclined to set-aside on a non-rotational basis (43% of land area), yet the least conservation-oriented. The financial effects of the reform were intermediate and the modal response to its outcome was indifference. North-western farms had the lowest occurrence of semi-natural habitats, and these farmers were the least aware (54%) of conservation options on set-aside land.

These observations are fundamental to the survey as they would appear to indicate that geographical location is a more reliable determinant of attitudes, intentions and conservation behaviour than other structural variables which have been measured. These results seem to concur with those of Battershill and Gilg (1996b) who concluded that the influence of geography was the principal determinant for participation in conservation-oriented schemes in south-west England, and that beyond these considerations, farmers attitudes were more important than their socio-economic circumstances. Three factors may be interacting to underpin the over-riding significance of the geographical variable :

*1. Farmland quality* - the inherent geographical characteristics of a region, such as its geology, soils, topography and climate will all interact to endow that region with its own distinct agricultural characteristics and nature conservation interest. Agricultural land in the east of England is typically of a high quality, with fertile soils, a good climate and large tracts of uncontoured land. Farmers in this region have been encouraged to practice a productionist agriculture, with little consideration for wildlife (aside from wild game conservation), partly because much of this interest has been eradicated and partly because the intrinsic wildlife value is low. The reverse is true in the south-east, where geographical characteristics have endowed the region with a greater conservation resource and lower quality agricultural land so that farmers are more 'in tune' with wildlife concerns. The increase in nature conservation management on poor quality agricultural land has been reported by others (Battershill and Gilg, 1996b).

*2. Farming 'Culture'* - farmers are to a large extent peer-influenced so that attitudes amongst farmers in discrete geographical regions will tend to converge to produce a regional farming philosophy.

*3. The influence of designations and existing semi-natural habitat* - previous surveys have identified a link between the extent of semi-natural habitat on a holding and positive conservation behaviour (Wilson, 1996 ; Morris and Potter, 1995 ; ADAS, 1976), whilst others have noted that the designation of agri-environmental features within a region has enhanced and informed conservation activity (Battershill and Gilg, 1996b). These observations may explain the widespread differences in conservation-orientation between south-eastern and north-western farmers who might otherwise, given agricultural considerations, be expected to be more alike in their outlook. The south-east region has a higher incidence of semi-natural habitat, and perhaps more importantly many of the farmers surveyed in this region were within the South Downs ESA, predisposing them to a higher conservation-orientation.

These results add weight to calls for targeted conservation set-aside (Burnham *et al.*, 1987) which, it is claimed, will enhance the potential of set-aside policy for achieving conservation objectives. This and other options will be considered in Chapter 3.

Results from the survey reported in this Chapter have gone some way to establishing the factors which motivate farmers with regard to set-aside policy and which to an almost universal extent are constraining participation in conservation oriented options on set-aside land. In Chapter 3, the results from a second survey will be presented, whose purpose is to explore, in greater depth, the major factors which have emerged from this baseline study. These can be grouped under four headings :

*1. Financial considerations* - these are fundamental to farmers' decision-making processes on two levels. Firstly, the current level of financial buoyancy of the farm business may pre-define farmers' attitudes towards conservation-based management schemes. The relationship between profitability and conservation-orientation is not clear ; larger more profitable farmers are often well disposed to nature, as they have a greater degree of financial and management flexibility, and are more able to consider the wider implications of farm management. Small, financially constrained farmers may regard time spent on conservation as a luxury, or conversely, may consider these options as a means of stepping-off the 'technological treadmill' and generating farm income from alternative sources. Secondly, and related to the last point, farmers will consider the financial implications of the scheme in question - will it increase or decrease net margins? In the case of set-aside for conservation this is a pertinent issue when the lack of financial reward or even compensation for increased expenditure is considered. These issues will be explored in greater depth.

*2. Attitudes to Set-aside* - this survey has established that two-thirds of farmers do not welcome the principle of land diversion. The second survey will attempt to establish in greater detail, the perceptions, attitudes and fears which underpin this observation.

*3. Attitudes to nature conservation* - the apparent contradictions between attitudes and actions will be explored further.

*4. Levels of awareness and availability of advice* - it is essential that farmers are made aware of the range of options available, and that conservation based advice for set-aside land is available when it is sought.

In the light of this second survey, a comprehensive review of the actual conservation potential, and present and future role for conservation set-aside in the wider countryside will be presented at the end of Chapter 3.

# *Chapter 3*

## *Farmer Participation in Conservation-oriented Management on Set-aside Land : An Exploration of Current Constraints and Future Prospects*

## 3.1 Introduction.

Chapter 3 presents and discusses results from a second farm-based questionnaire survey conducted in 1996. In 1994, the second year in which arable production had come under the control of the Arable Area Payments Scheme (AAPS), less than 1% of surveyed set-aside land was being managed in accordance with voluntary guidelines for environmental objectives. In consideration of the entirely voluntary nature of these options, the initial survey sought to establish a baseline of information on factors which motivated and constrained farmer participation. These factors were analysed with respect to a range of 'structural' (external) variables such as region, farm size, farmer age and farm type and were presented in the concluding discussion to chapter 2 under four headings :

1. Financial considerations ;
2. Attitudes to set-aside policy ;
3. Attitudes to nature conservation ;
4. Levels of awareness and availability of advice.

The rationale for this second survey was primarily to establish in greater depth the relative importance of each of these factors, their inter-relationships, ways in which potential barriers to participation could be removed and the individual perceptions, motivations and concerns which underpin farmers' attitudes to nature conservation and set-aside policy.

## 3.2 Methodology

### 3.2.1 Questionnaire design

The questionnaire was designed according to the principles discussed in section 2.2. The second questionnaire was sub-divided into five sections, and as a result of the clearly defined aims outlined above, was shorter than the initial baseline questionnaire. The majority of questions required respondents to tick the most appropriate box ('closed' questions) and to provide simple one word answers. The five sections were :

*SECTION 1 - Set-aside on your holding* - questions relating to the extent of, and current management practices on set-aside land.

*SECTION 2 - Attitudes towards set-aside policy* - the initial survey indicated that two-thirds of surveyed farmers were by some measure opposed to set-aside. Respondents were presented with a range of positive and negative "attitude statements" which related to set-aside policy and were invited to indicate for each whether they agreed or disagreed. This analysis will provide an insight into the major factors which determine positive and negative attitudes to set-aside policy.

*SECTION 3 - Attitudes towards nature conservation* - a range of "attitude statements" were derived to establish farmers' perceptions of the role of nature conservation in the agricultural landscape, and their willingness to integrate wildlife concerns and agricultural production.

*SECTION 4 - Awareness and uptake of conservation management on set-aside land* - this section sought to determine levels of awareness of conservation options for set-aside land, the extent of uptake of these options and farmers' perceptions of the key factors which constrain uptake.

*SECTION 5 - Farm and farmer details* - farm size, farmer age, occupancy status and farm profitability

The questionnaire was entitled *"Attitudes towards set-aside, nature conservation and changing agricultural policy ; an exploration of further issues."* A copy is included in Appendix 3.

The second questionnaire was dispatched to sampled farmers in April 1996.

## 3.2.2 Sample selection

In anticipation of similarly low response rates to those encountered for the initial baseline survey, an alternative approach was attempted. Farmers' names and addresses were once again randomly selected from the Farms section of the appropriate Yellow Pages Telephone Directories (coverage by region was identical to the first survey). Selected farmers were contacted by telephone, the aims of the survey were explained, and if they were sufficiently interested, and had a set-aside requirement on their holding they were asked if they would take part in the current survey. It was hoped that this more personal approach would engender a greater interest amongst surveyed farmers, and ensure that questionnaires were sent only to those farmers who had a set-aside interest on their holding. By avoiding the dispatch of large numbers of questionnaires to 'non-target' farms, considerable savings would be made in photocopying and postage costs. However, despite these perceived benefits, this method of sample selection proved impractical. Farmers proved to be difficult to contact, so that each day there was only a two hour 'window of opportunity' (after dark) when calls could be made. Telephone calls often became protracted, which whilst encouraging from the point of view of farmer interest in the survey contents, considerably added to sampling time. At the same time, a large number of contacted farmers had no set-aside obligation on their holding, and thus the survey contents were not relevant. After careful consideration, it was decided that potential benefits in terms of cost and return rates could not compensate for the very large increases in sampling time which this method entailed, and sample selection was as for the first questionnaire.

A total of 650 questionnaires were sent to randomly selected farmers ; 350 to the eastern region and 150 each to the north-western and south-eastern regions. The bias in favour of eastern farmers reflected the increased likelihood of encountering 'target' (arable and mixed) farms in the 'arable heartlands.' This approach precluded, to some extent, a detailed analysis of regional variations as performed for the initial survey, but ensured an adequate return rate.

Dispatched questionnaires were accompanied by a covering letter which briefly summarised the major findings of the initial survey and explained how the current survey sought to explore these further. Confidentiality was assured and a freepost envelope was supplied for replies.

### 3.2.3 Follow-ups

A follow-up letter was sent to a random sub-sample of 100 farmers in June 1996. The contents and aim of this letter were as explained for the previous survey (section 2.2.4)

### 3.2.3 Data Collation and analysis

Questionnaire responses were encoded and captured in an Excel spreadsheet. This spreadsheet was subsequently converted to an SPSS data file and data analysis performed as in chapter 2.

## 3.3 Results

### 3.3.1. A Profile of Respondents and Surveyed Agricultural Land

110 completed questionnaires (initial dispatch and follow-ups) were returned, a response rate of 17%. Once again, this low response rate raises concerns over sampling bias, but given the sampling method employed, and the limitations discussed earlier, these were unavoidable. Returns by region were as follows :

| | |
|---|---|
| EAST | 80 (72.7%) |
| NORTH-WEST | 16 (14.5%) |
| SOUTH-EAST | 14 (12.7%) |

The total area of agricultural land covered by this second survey was 24,914 ha ; a mean farm size of 235 ha. 21,028 ha of this area was eligible for payments under the Arable Area Payments Scheme, and the total area of land set-aside was 2,091 ha, 9.9 % of the eligible area. Total and mean farm size, eligible area and set-aside area for each region are presented in Table 3.1

Table 3.1 Farm size, eligible area and set-aside area by region (Figures in brackets are standard errors of the mean)

| | Farm size (ha) | | Eligible area (ha) | | Set-aside area (ha) | |
|---|---|---|---|---|---|---|
| Region | Total | Mean | Total | Mean | Total | Mean |
| East | 19,110 | 245 (30.4) | 17,051 | 219 (27.0) | 1650 | 20.89 (2.8) |
| North-west | 3,062 | 204 (24.4) | 2,042 | 136 (21.9) | 228 | 15.20 (2.6) |
| South-east | 1685 | 211 (30.2) | 1324 | 102 (17.3) | 213 | 15.21 (1.9) |

As in the previous survey, farm size was recoded into three size classes. The distributions of respondents by farm size, set-aside management option, farmer age and occupancy status are shown in Figure 3.1. Whilst mean farm size was very similar for the two survey samples (239 and 235 ha respectively), the profile of farm sizes varied markedly (Figure 3.1a). In the initial survey, 46% of farms were under 100ha ; in the present sample the modal farm size was 101-250 ha (46%). This second survey also had a lower age profile (Figure 3.1c) with 50% of respondents under 40 years of age (compared to 15% in baseline survey). The proportion of owner/occupiers and tenants was very similar for the two samples (Figure 3.1d).

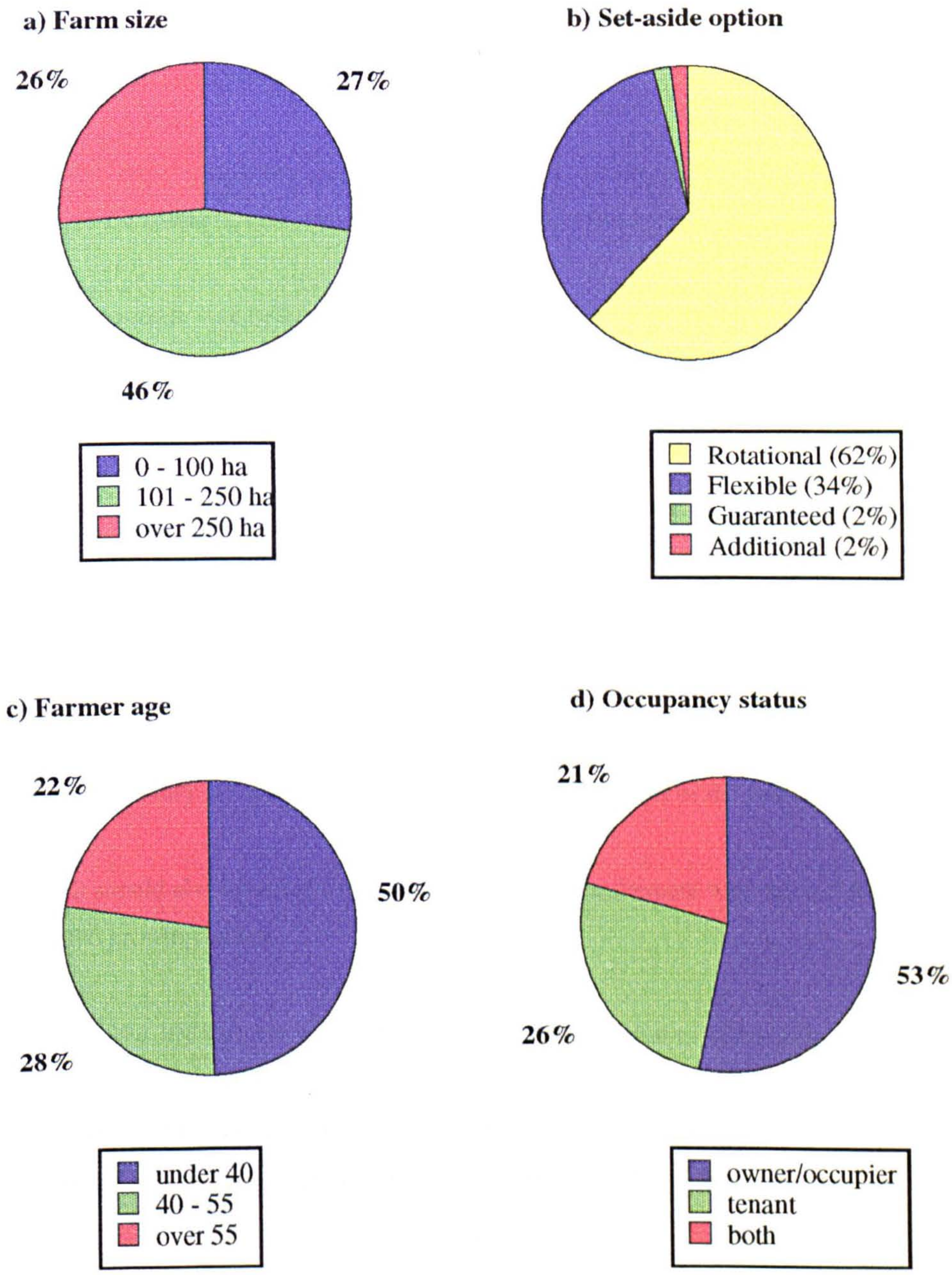



Figure 3.1 Survey coverage by a) Farm size b) Set-aside option c) Farmer age and d) occupancy status

During the two year period between surveys, the types of set-aside options available and the percentage set-aside requirement had changed. A brief explanation is given below before discussing the uptake of these options by farmers in the present survey.

The basic distinction between rotational and non-rotational set-aside remained. From the 1994/95 season onwards, however, farmers could choose from three rather than two basic options :

*Rotational set-aside* - as before, land is set-aside on a six year rotation with any parcel of land set-aside once in six years. To qualify for rotational set-aside, **all** set-aside land owned by a holding must be subject to a six year rotation.

*Flexible set-aside* - set-aside obligation may be rotated around the farm, or remain in the same place at the discretion of the individual.

*Guaranteed set-aside* - land which must be set-aside for five years in return for a guaranteed payment rate for that period (old non-rotational option).

*Additional voluntary set-aside* - land which is set-aside in excess of the basic obligation.

It should also be noted that the basic set-aside requirement was reduced from 15% to 10% for the 1995/96 growing season.

Of the 108 farmers who indicated the set-aside option to which they subscribed, only 2 had entered the guaranteed scheme (Figure 3.1b). It appears that those farmers who wished to set-aside land on a non-rotational basis did so from within the flexible option. The allocation of set-aside to rotational and non-rotational options by region is summarised in Table 3.2

Table 3.2 The allocation of set-aside land to rotational and non-rotational options

| **Set-aside option** | East | North-west | South-east | Total |
|---|---|---|---|---|
| | | Area (%) | | |
| Rotational | 1225 (74%) | 175 (86%) | 86 (41%) | 1486 (72%) |
| Non-rotational | 423 (26%) | 29 (14%) | 123 (59%) | 575 (28%) |

### 3.3.2 An Exploration of Farmers' Attitudes Towards, and Perceptions of Set-aside.

Baseline results, presented in the previous chapter, indicated that, in general, farmers were not favourably disposed to the principle of land diversion. It was concluded that these attitudes were a probable key determinant constraining participation in voluntary conservation-oriented management on set-aside land. In order to establish the factors which underpin these negative attitudes to set-aside, surveyed farmers were presented with a list of attitude statements and asked to indicate if they agreed or disagreed with each. Results are in Table 3.3. This list encompassed both positive (emboldened) and negative (italicised) statements.

This second survey was conducted almost two years after the initial baseline of opinions had been established and, as such, it was implicit that overall attitudes and perceptions be redefined in the light of two years' further experience of set-aside policy and its implications for farm management. Survey participants were asked to respond to the statement *"Overall, I believe the introduction of set-aside has been beneficial to the arable sector"* (Table 3.3). Responses were identical to those given in the initial survey, 66% of farmers disagreeing with this statement, indicating that overall attitudes had changed very little, and that on the whole farmers remained opposed to the principle of land diversion.

For each attitude statement an **overall attitude score** has been calculated for the entire surveyed population. Each response from individual questionnaires was assigned a value, as shown below. These values were summed to derive the overall attitude score.

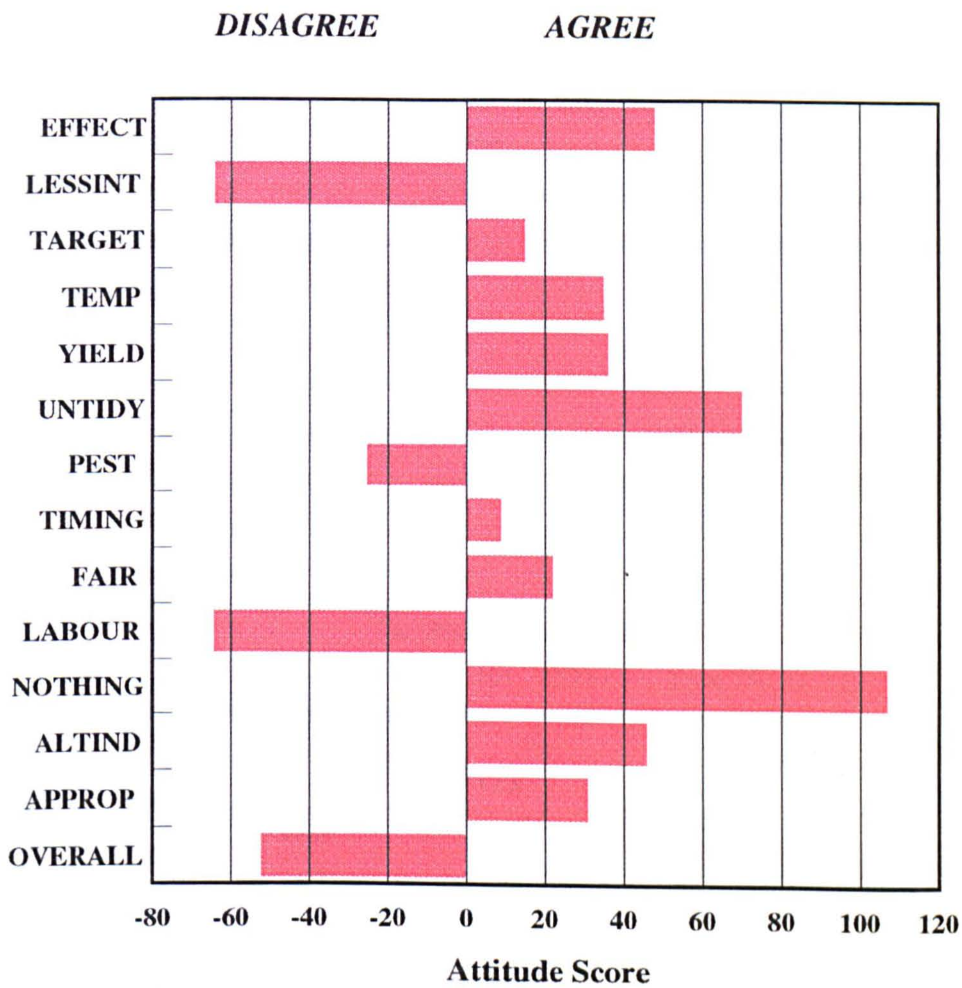
| | |
|---|---|
| Strongly agree | +2 |
| Agree | +1 |
| Neutral | 0 |
| Disagree | -1 |
| Strongly disagree | -2 |

If all responses were neutral the attitude score would be zero, a positive value indicates that as a population, farmers agreed with the statement, a negative value that they disagreed. Attitude scores are illustrated graphically in Figure 3.2.

Broadly speaking, given acceptance of the necessity for production controls, two options are available ; to divert land out of arable production (set-aside) or to reduce the intensity of production across the entire cropped area (which may be achieved via a number of mechanisms discussed in section 1.8.1). Despite the widespread assertion that set-aside had not been beneficial to the arable sector (attitude score, -52), surveyed farmers overwhelmingly indicated that they believed set-aside was the most effective means of achieving this objective (Figure 3.2, attitude score, +48), widely

Table 3.3 Participants responses to attitude statements relating to set-aside land

| | Response (%) | | | | |
|---|---|---|---|---|---|
| **Attitude Statement** | Strongly agree | Agree | Neutral | Disagree | Strongly disagree |
| **1. Set-aside is the most effective policy for reducing over-production of surplus arable crops** | 14.0 | 49.5 | 12.1 | 19.6 | 4.7 |
| *2. Less intensive production across the entire cropped area would be a more effective means of reducing production* | 0.9 | 19.6 | 19.6 | 34.6 | 25.2 |
| *3. Set-aside should be targeted towards the least productive arable land* | 8.2 | 43.9 | 13.1 | 23.4 | 11.2 |
| *4. Set-aside is an attempt at a temporary solution to the longer-term problem of over-production* | 2.9 | 57.3 | 19.4 | 12.6 | 7.8 |
| **5. Set-aside policy will achieve the desired reduction in total crop yields within the European Union** | 12.3 | 42.5 | 19.8 | 19.8 | 5.7 |
| *6. Set-aside land appears untidy and unkempt giving the impression of neglect to the public* | 17.8 | 53.3 | 11.2 | 15.9 | 5.7 |
| *7. Set-aside land increases pest and disease problems across the whole farm, and in subsequent crops* | 8.4 | 18.7 | 20.6 | 43.9 | 8.4 |
| **8. Reducing the area of land in intensive arable production enables more precise timing of operations on the remaining cropped area** | 6.5 | 36.4 | 24.3 | 25.2 | 7.5 |
| **9. Set-aside is a fair policy and does not discriminate on the basis of farm size** | 6.4 | 48.2 | 19.1 | 16.4 | 7.3 |
| **10. Set-aside reduces farm labour costs resulting in increased profits per unit of production** | 1.0 | 15.4 | 17.3 | 51.0 | 15.4 |
| *11. Set-aside is viewed by the public as 'paying farmers to do nothing'* | 29.2 | 57.5 | 7.5 | 2.8 | 2.8 |
| *12. Surplus arable land should be diverted to production of alternative and, or industrial crops, rather than set-aside* | 18.9 | 29.2 | 34.9 | 13.2 | 3.8 |
| *13. Nature conservation would be a more appropriate use for set-aside land* | 10.3 | 36.4 | 29.9 | 20.6 | 2.8 |
| **14. Overall, I believe the introduction of set-aside has been beneficial to the arable sector** | 3.7 | 15.9 | 14.0 | 57.9 | 8.4 |




KEY

EFFECT - Set-aside is most effective policy for reducing over-production
LESSINT - Less intensive production more effective means of reducing production
TARGET - Set-aside should be targeted to least productive land
TEMP - Set-aside is a temporary solution
YIELD - Set-aside will achieve the desired reduction in total crop yields
UNTIDY - Set-aside land appears untidy and unkempt
PEST - Set-aside increases pest and disease problems
TIMING - Set-aside enables more precise timing of operations on remaining cropped area
FAIR - Set-aside is a fair policy and does not discriminate on the basis of farm size
LABOUR - Set-aside reduces farm labour costs
NOTHING - Set-aside is viewed by the public as paying farmers to do nothing
ALTIND - Surplus land should be diverted to alternative and industrial crops
APPROP - Nature conservation would be a more appropriate use for set-aside land
OVERALL - Overall set-aside has been beneficial for the arable sector

Figure 3.2 A bar chart illustrating overall attitude scores for individual attitude statements relating to set-aside policy refuting any suggestion that less intensive production would be a more effective policy instrument (Figure 3.2, attitude score, -64). Hence, whilst farmers exhibit a good deal of apprehension towards set-aside, they are considerably more in favour of this, at least in terms of its supply control potential, than the most viable alternative. Responses to these statements were analysed by region and farm size. Regional differences were not significant. However, larger farms (over 100ha) were significantly more inclined to acknowledge the effectiveness of set-aside policy (Table 3.4), and to a lesser, non-significant extent, small farmers were more in favour of a reduction in intensity across the entire cropped area (Table 3.5).

Table 3.4 Responses to the statement " *Set-aside is the most effective policy for reducing over-production of surplus arable crops*" by farm size. Chi-squared statistic : $P < 0.05$

| | Per cent of respondents | | |
|---|---|---|---|
| **Response** | 0 - 100 ha | 101 - 250 ha | Over 250 ha |
| Strongly agree | 14.3 | 12.8 | 14.3 |
| Agree | 25.0 | 59.6 | 60.7 |
| Neutral | 14.3 | 12.8 | 7.1 |
| Disagree | 35.7 | 10.6 | 17.9 |
| Strongly disagree | 10.7 | 4.3 | 0.0 |

Table 3.5 Responses to the statement "*Less intensive production across the entire cropped area would be a more effective means of reducing production*" by farm size. Chi-squared statistic : $P$ = 0.102.

| | Per cent of respondents | | |
|---|---|---|---|
| **Response** | 0 - 100 ha | 101 - 250 ha | Over 250 ha |
| Strongly agree | 3.6 | 0.0 | 0.0 |
| Agree | 25.0 | 14.9 | 21.4 |
| Neutral | 25.0 | 14.9 | 21.4 |
| Disagree | 28.6 | 42.6 | 32.1 |
| Strongly disagree | 17.9 | 27.7 | 25.0 |

A number of statements were devised to probe the attitudes and perceptions which contributed to the farming populations' widespread disenchantment with, and mistrust of set-aside policy. These statements are numbered 4 to 11 in Table 3.3, and overall attitude scores for each are presented in Figure 3.2. Responses to questions 11 and 6 respectively highlighted farmers sensitivity to the publics' perceptions of farming practices ; 87% of farmers agreed that set-aside was viewed by the public as 'paying farmers to do nothing' (Attitude score, +107), and 71% thought that set-aside gave the impression of untidy and unkempt farmland (Attitude score, +70). This observation concurs with those of Carr and Tait (1991) who reported that farmers discounted the conservation value of 'wilderness' areas and described these in terms of 'neglect' and 'untidiness'. Often farmers have equated conservation with operations such as hedge trimming, buildings maintenance, and, in general, with keeping the farm in good and tidy condition. One farmer commented :

> "Generally the public want the countryside to play in ; shoot, fish, play golf, walk the dog and ride ponies. They want a tidy countryside which is accessible. They couldn't give a toss about the animals and plants that surround them" (Surrey farmer with 80 ha).

60% of surveyed farmers perceived set-aside to be a temporary solution to the problem of over-production, an observation which will undoubtedly instil and perpetuate negative attitudes towards set-aside, and preclude consideration of long-term management options which will harness the full conservation potential of set-aside land in the wider countryside. A number of comments made by farmers confirm this :

> "Any conservation scheme on set-aside land is doomed to fail when the policy is scrapped. There is no point in creating habitats only to plough them up in a few years when policies change" (Eastern farmer with 62 ha).

> "As set-aside may only be temporary, it is more important to consider the whole farm habitat as a long-term strategy" (North-western farmer with 350 ha).

> "There is no guarantee of a fixed set-aside percentage in future years to allow/encourage wildlife establishment on this land" (Essex farmer with 540 ha).

65% of respondents believed that set-aside would achieve its primary objective of reducing over-production.

The four remaining statements explore some of the agronomic and economic consequences of set-aside. The downstream effects of set-aside policy on farm profitability and the management of remaining and subsequent cropped areas will inevitably influence farmers' overall attitudes. On the whole, farmers did not agree that set-aside increased pest and disease problems across the farm, and in subsequent crops (Attitude score, -25). Clarke (1995) conducted a series of experiments to investigate the incidence of weed, pest and disease problems in crops following set-aside and found that given appropriate management to restrict these, few problems were encountered, and that in some instances the likelihood of infestations could be reduced.

No consensus emerged amongst surveyed farmers in respect of the potential of set-side to enable more precise timing of operations on areas remaining within the cropping cycle (Table 3.3, Figure 3.2). Obviously where this potential exists it may create the opportunity for increased yields, a form of 'slippage' whose existence farmers may be reluctant to acknowledge publicly. Few respondents agreed that the introduction of set-aside had reduced labour requirements (Table 3.3, Figure 3.2) on their holding.

Finally, surveyed farmers were asked if they believed set-aside to be a fair policy which did not discriminate on the basis of farm size. 55% agreed that it was a fair policy (Attitude score, +22). Responses to this statement were influenced by farm size (Table 3.6, Chi-squared $P < 0.005$), with smaller farms more inclined to disagree.

Table 3.6 Responses to the statement *"Set-aside is a fair policy and does not discriminate on the basis of farm size"* by farm size.

| | Per cent of respondents | | |
|---|---|---|---|
| **Response** | 0 - 100 ha | 101 - 250 ha | over 250 ha |
| Strongly agree | 3.6 | 2.1 | 14.3 |
| Agree | 25.0 | 59.6 | 60.7 |
| Neutral | 32.1 | 12.8 | 14.3 |
| Disagree | 32.1 | 12.8 | 10.7 |
| Strongly disagree | 7.1 | 12.8 | 0.0 |
| **Attitude score** | **-14.1** | **+25.4** | **+78.6** |

It is argued that responses to the eight statements relating to agronomic and economic considerations on set-aside land discussed above will form the basis of farmers attitudes to set-aside land, and as such responses to these eight variables have been combined to derive a 'set-aside attitude orientation' for individual farmers. Four of these statements are positive (numbers 5,8,9 and 10) and were scored as follows ; strongly agree, +2 ; agree, +1 ; neutral, 0 ; disagree, -1 ; strongly disagree, -2

; the remaining four are negative statements (numbers 4,6,7 and 11) and were scored ; strongly agree, -2 ; agree, -1 ; neutral, 0 ; disagree, +1 ; strongly disagree, +2. These scores were summed to derive 'set-aside attitude orientation' which potentially ranges between +16 and -16, positive values indicating an overall positive attitude to set-aside and negative values a negative attitude. Where farmers had neglected or declined to give a response to one or more of these eight statements, it was not possible to derive an attitude score. For this reason, only 100 (from a sample of 110 farmers) scores are included in subsequent analyses. Actual values were between -9 and +7. The distribution of these scores is illustrated in Figure 3.3.

On the basis of this orientation, three groups of farmers were defined :

| **Set-aside attitude orientation** | **Score** | **n** |
|---|---|---|
| HOSTILE | -9 to -4 | 33 |
| OPPOSED | -3 to 0 | 40 |
| FAVOURABLE | +1 to +7 | 27 |

These three derived 'farmer classes' are not discrete, since within each a continuum of attitudes exists. However, they do enable subsequent analysis to explore more succinctly the relationship between attitudes to set-aside and a number of structural variables. Only 27% of surveyed farmers exhibited, to varying degrees (+1 to +7), favourable attitudes to set-aside.

The three farmer groups were cross-tabulated with data for region, farmer age, farm size and occupancy status, and Chi-squared tests of independence performed. Pearson's $R^2$ correlation was calculated for ordinal variables (farm size and farmer age). Analyses of variance were also performed on set-aside attitude orientation scores with the structural variables listed above as treatment effects. Results from these analyses are presented in Figure 3.4.

Older farmers (over 55 years) tended to be the most hostile to set-aside (Figure 3.4a). Only 4.3% exhibiting a favourable attitude, suggesting that these farmers, rather than welcoming set-aside as a means to 'winding-down' their production unit, were the most reluctant to change their farming practices.

Regional differences, whilst not statistically significant (sample sizes for north-western and south-eastern populations were small), were apparent, with farmers from the south-eastern region being the most opposed to set-aside (Mean orientation score, -3.2 compared to -1.4 for eastern and -1.5 for north-western farmers) (Figure 3.4b).

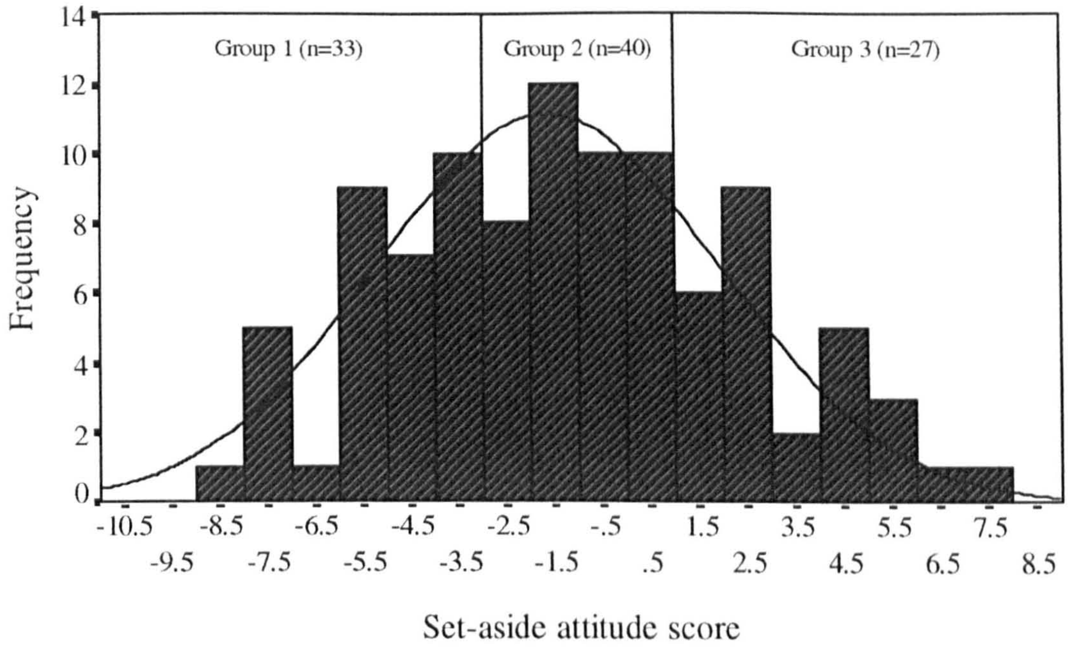



Figure 3.3 A histogram (with normal curve) illustrating the distribution of farmer set-aside attitude orientation

**Set-aside attitude orientation**

| | |
|---|---|
| Group 1 | Hostile |
| Group 2 | Opposed |
| Group 3 | Favourable |

The most significant association was between farm size and set-aside attitude orientation (Figure 3.4c). Small farmers (under 100 ha) were the most opposed to set-aside (58% hostile) and the largest farmers the most favourably disposed (35% favourable). Whilst these results illustrate that farmer age, region and farm size do influence attitudes to set-aside, they do not preclude the main finding from the analysis presented here, which is the widespread antipathy amongst the farming population towards set-aside as an agricultural policy instrument.

These results, whilst often not statistically significant, effectively demonstrate the value of a range of attitude statements to derive an overall attitude orientation. In the previous survey, attitudes to set-aside were measured by a single variable, and were found to be independent of all structural and attitudinal variables.

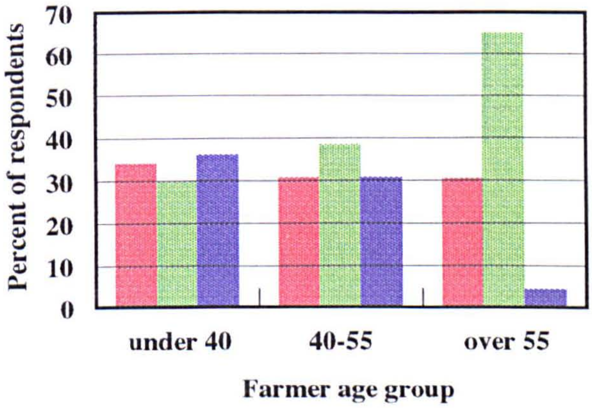
Three remaining statements sought to determine farmers' enthusiasm for options which encourage the diversion of surplus agricultural land to the production of alternative agricultural and countryside products. These alternative products can be broadly divided into three groups : nature conservation ; industrial crops ; and alternative non-food crops. Current set-aside management regulations allow the production of 'non-food' and so-called 'industrial crops', lists of which are given in MAFF's explanatory guide to the Arable Area Payments Scheme (MAFF, 1996d). Land sown to these crops is eligible for set-aside payments provided end products are not intended for human and, or livestock consumption. Lists of accepted end products are also provided by MAFF, and include biofuels and a variety of waxes, gums and resins. The previous survey indicated that these options had proved considerably more popular amongst surveyed farmers (particularly in the south-east), than management for nature conservation objectives. Respondents in this second survey were asked if they believed that surplus agricultural land should be diverted to the production of these alternative crops (Table 3.3). Very few farmers disagreed with this principle (17%, Attitude score, +46) and, on the whole, surveyed farmers believed this to be a slightly more favourable option than employing set-aside land to secure conservation objectives (46% were in favour of this option, Attitude score, +31, compared to 50% for alternative crops, see Table 3.3 and Figure 3.2), reflecting a preference for production-oriented management on agricultural land.

The frequent link between low-yielding agricultural land and nature conservation potential was established in the previous chapter and has led to calls (Burnham *et al.*,1987 ; Potter *et al.*, 1991) for the least productive land to be targeted within a conservation reserve on set-aside land (the mismatch criterion, section 1.10.2). Whilst 52% (Table 3.3) of surveyed farmers agreed that *"set-aside should be targeted towards the least productive arable land"*, a significant minority of 35% disagreed with this principle (Attitude score, +14).

In principle, the diversion of surplus arable land to the production of alternative agricultural and countryside products was welcomed by farmers. A major concern expressed by survey

Hostile
Opposed
Favourable

a) Farmer age



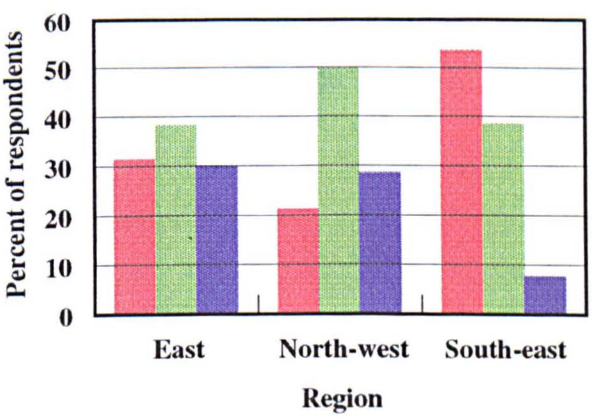

Chi-squared statistic
P < 0.05
Pearson's R : P = 0.182

Mean attitude scores

under 401.30
40-55 1.38
over 55 2.57

ANOVA : P = 0.351 (ns)

b) Region



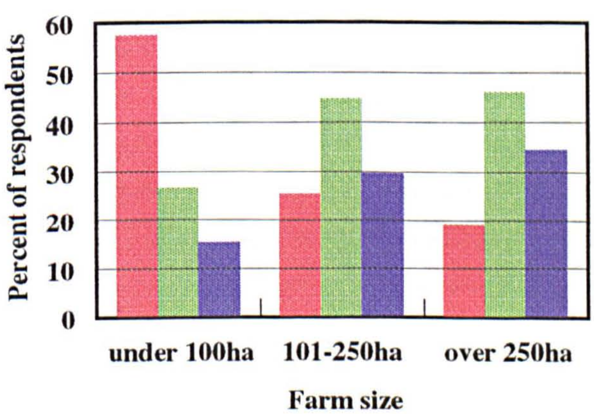

Chi-squared statistic
P = 0.307 (ns)
Pearson's R : P = 0.117

Mean attitude scores

East 1.40
North-west 1.50
South-east 3.23

ANOVA : P = 0.233 (ns)

c) Farm size




Chi-squared statistic
P < 0.05
Pearson's R : P < 0.01

Mean attitude score

under 100ha 3.35
101 - 250ha 1.17
over 250ha 0.69

ANOVA : P < 0.05

Figure 3.4 Set-aside attitude groups by a) Farmer age, b) Region and c) Farm size participants was that the public viewed set-aside as paying them to do nothing. These opportunities could do a good deal to dispel these public perceptions. In practice, however, their uptake will depend not only farmers' attitudes but on the financial attractiveness of these options, and on farmers' willingness to invest time and resources in alternative enterprises on diverted land when the future of set-aside policy appears increasingly uncertain.

## 3.3.3 Nature Conservation on Set-aside and Agricultural Land : An Exploration of Attitudes, Perceptions and Intentions in a Changing Policy Environment.

The initial farm-based survey identified a significant baseline of favourable attitudes towards, interest in and sympathy for farm wildlife. Beyond this somewhat superficial measure of attitudes towards the conservation resource, a significant proportion of surveyed farmers indicated that, given appropriate policy signals, advice and financial security, they would readily embrace nature conservation as an alternative land use objective on set-aside and other agricultural land. As a prelude to the more rigorous analysis of these issues which will be presented in this section, participants in the second survey were initially asked *"Would you consider yourself to be interested in, and sympathetic towards wildlife on your farm ?"* Results were even more emphatic than those presented in Chapter 2 ; 84% of farmers were interested (39% very interested), 15% were neutral and only one respondent indicated disinterest.

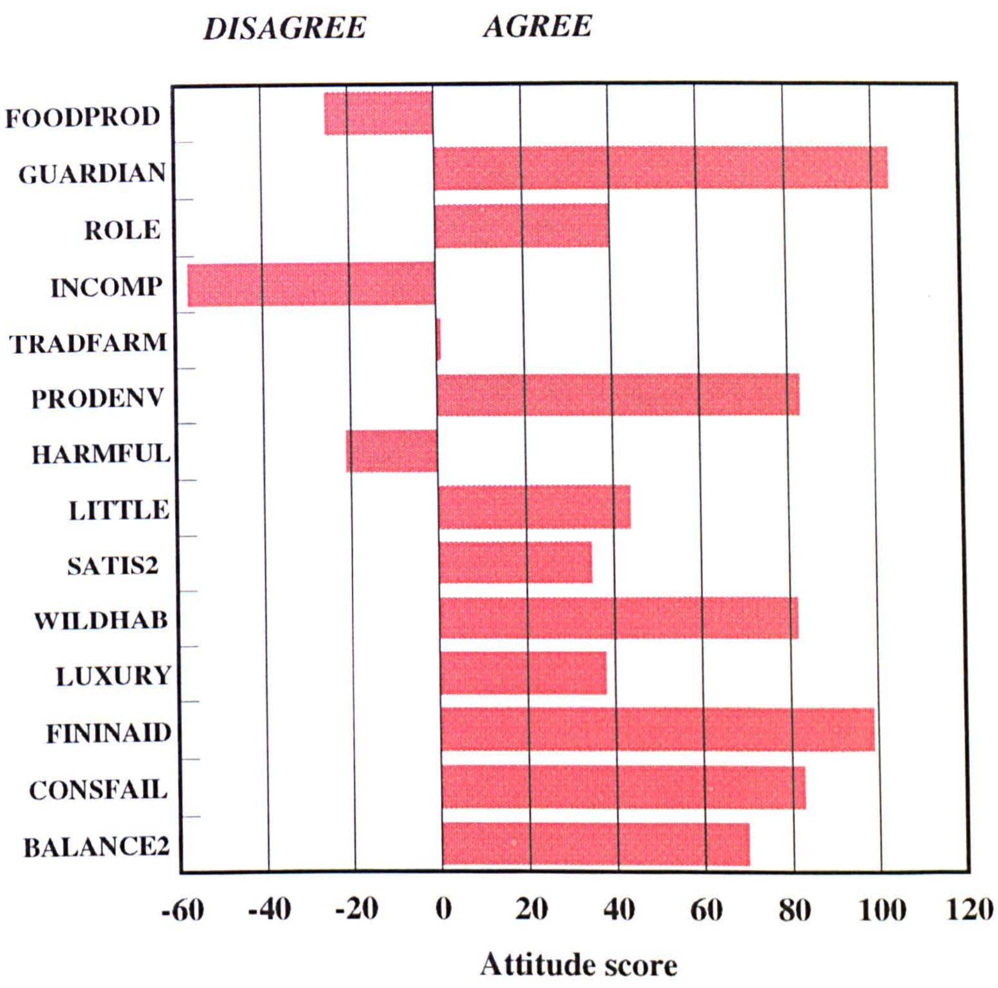
Attitudes to nature conservation have been established as a key determinant in the potential uptake of conservation-oriented management on set-aside land. Participants in this second survey were invited to respond to a list of attitude statements relating to nature conservation and agricultural policy. Results are presented in Table 3.7, and overall attitude scores (derived as discussed in section 3.3.2) in Figure 3.5. These statements sought to explore farmers' perceptions of their role in the countryside, possibilities for the integration of agricultural and environmental policies, willingness to manage for conservation as opposed to food production objectives, the financial consequences of such a switch in orientation and farmers' perceptions of conservation and conservationists. From responses to these statements an overall conservation-orientation was derived.

### 3.3.3.1 Farmers role in the countryside

In the post World War 2 era, as farming has embraced incentives to increase production, there has been a major shift in the perceptions of those outside of the industry towards the role of farmers (Newby *et al*, 1977). Where once farmers were perceived as 'custodians of the land', creating

Table 3.7 Farmers responses to attitude statements relating to nature conservation on farmland.

| | Response (%) | | | | |
|---|---|---|---|---|---|
| **Attitude Statement** | Strongly agree | Agree | Neutral | Disagree | Strongly disagree |
| *1. Farmers should be viewed solely as producers of food* | 6.7 | 22.1 | 17.3 | 47.1 | 6.7 |
| **2. Farmers should be viewed as 'guardians of the land' and as such their activities should reflect a range of land use objectives** | 22.1 | 63.5 | 10.6 | 3.8 | 0.0 |
| **3. The role of farmers should be redefined to encompass nature conservation as well as food production** | 6.8 | 48.5 | 24.3 | 18.4 | 1.9 |
| *4. The goals of intensive agricultural production and nature conservation are entirely incompatible* | 0.0 | 16.3 | 21.2 | 51.9 | 10.6 |
| **5. A return to more traditional (less intensive) farming systems will achieve considerable environmental and wildlife benefits** | 3.8 | 37.5 | 21.2 | 30.8 | 6.7 |
| **6. Agricultural policy should include both production and environmental goals** | 11.5 | 65.4 | 16.3 | 5.8 | 1.0 |
| *7. Intensive farming systems have no harmful effects on semi-natural habitats and, or farm wildlife* | 2.9 | 26.0 | 25.0 | 39.4 | 6.7 |
| **8. Managing land for conservation objectives is equally as satisfying as managing land to maximise crop yields** | 9.6 | 36.5 | 33.7 | 19.2 | 1.0 |
| **9. The authorities have done too little to incorporate environmental and wildlife concerns into agricultural policy** | 13.5 | 39.4 | 26.0 | 20.2 | 1.0 |
| *10. Wildlife habitats should be viewed as agricultural products, and as such farmers should be paid for their creation and maintenance* | 15.4 | 57.7 | 20.2 | 6.7 | 0.0 |
| *11. Nature conservation is a luxury which many farmers are not able to afford* | 9.6 | 48.1 | 14.4 | 26.0 | 1.9 |
| *12. Current financial incentives for farmers to incorporate nature conservation into farm management are inadequate* | 21.2 | 60.6 | 14.4 | 3.8 | 0.0 |
| *13. Conservationists fail to understand modern farming systems* | 21.2 | 48.1 | 23.1 | 7.7 | 0.0 |
| **14. Wildlife on farms maintains 'the balance of nature'** | 7.8 | 63.7 | 18.6 | 9.8 | 0.0 |




FOODPROD - farmers should be viewed solely as producers of food
GUARDIAN - farmers should be viewed as guardians of the land
ROLE - role of farmers should be redefined to encompass nature conservation
INCOMP - agricultural production and nature conservation are entirely incompatible
TRADFARM - return to traditional farming will achieve environmental and wildlife benefits
PRODENV - agricultural policy should include both production and environmental goals
HARMFUL - intensive farming systems have no harmful effects
LITTLE - authorities have done too little to incorporate environmental and wildlife concerns
SATIS2 - managing land for conservation equally satisfying
WILDHAB - widlife habitats should be viewed as agricultural products and as such farmers should be paid for their production
LUXURY - nature conservation is a luxury which farmers are not able to afford
FININAID - current financial incentives to incorporate nature conservation are inadequate
CONSFAIL - conservationists fail to understand modern farming systems
BALANCE2 - wildlife on farms maintains the balance of nature

Figure 3.5 A bar chart illustrating overall attitude scores for individual attitude statements relating to nature conservation

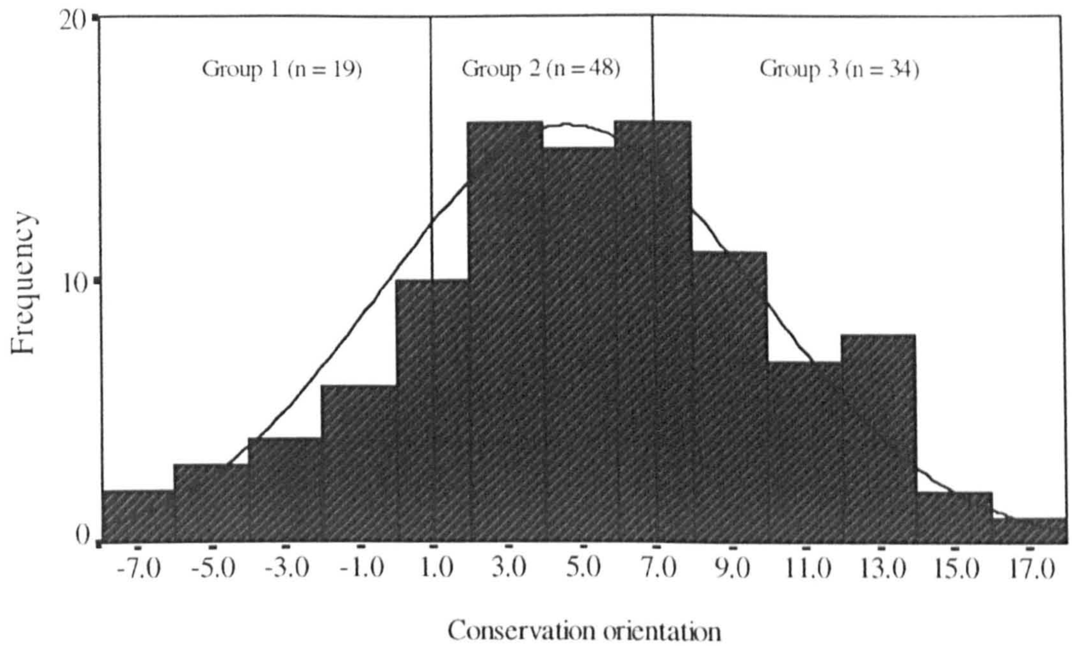



Figure 3.6 A Histogram (with normal curve) illustrating the distribution of farmer conservation-orientation

| | |
|---|---|
| Group 1 | Conservation opponents |
| Group 2 | Sympathetic conservationists |
| Group 3 | Enthusiastic conservationists |

a diverse and environmentally benevolent countryside, this shift has precipitated the widespread advance of 'agri-business' where the maximisation of food production is often the sole aim of farmers.

Recent overproduction within the CAP regime has opened the door for a return to more environmentally benevolent farming systems and the principle of 'custodianship'. However, this shift in orientation can only be achieved if farmers acknowledge a dual role as food producers and countryside stewards.

Only 29% (30 farmers) of surveyed farmers agreed that they *"should be viewed solely as producers of food"* (Attitude score, -25). 26 of these were from the arable heartlands of the east of England where prairie style farming in the post-war era has created vast tracts of cereal monoculture where the nature conservation interest is minimal. Of all the statements listed in Table 3.7 the one promoting the view that *"farmers should be viewed as guardians of the land"* received the most widespread support (Attitude score, +105), 86% of respondents agreeing with the statement. At first, this appears a very encouraging result for the conservation interest, as conservationists have traditionally equated 'guardianship' of the land with maintaining wildlife and environmental features in good condition for the benefit of future generations. However this definition was not implicitly stated, and many farmers may perceive 'guardianship' on the basis of keeping land in good agricultural condition, thereby ensuring future yielding potential. Regardless, this observation identified widespread acknowledgement of the requirement to at least manage land in a sustainable and responsible manner. Farmers with the largest agricultural area (over 250 ha) were most inclined to strongly agree (32%) with this statement, suggesting that larger farms may be more willing, and, or more able to adopt a more holistic approach. Participants were also asked to indicate if they agreed that *"the role of farmers should be redefined to encompass nature conservation as well as food production"*. This statement pre-supposes that farmers perceive themselves solely as food producers, or that current agricultural policy defines them in that way. 55% of respondents agreed that their role should be redefined, 21 farmers (21%) disagreed - 19 of these were from the eastern region.

These results appear to suggest that farmers are willing to embrace a more holistic approach to agricultural decision-making.

#### 3.3.3.2 Integration of agricultural and environmental policy objectives, or a partitioned countryside ?

Given the widespread willingness of farmers to accept a dual role within the countryside, there is an urgent requirement for future agricultural policy to be tailored so that it may more effectively address environmental and wildlife concerns. Post-war agricultural and countryside policies have resulted in a partitioned countryside (Adams, 1988) where valued wildlife habitats are a diverse and environmentally benevolent countryside, this shift has precipitated the widespread advance of 'agri-business' where the maximisation of food production is often the sole aim of farmers.

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Surveyed farmers largely disagreed (62%) with the statement that *"the goals of intensive agricultural production and nature conservation are entirely incompatible"* (Table 3.7), and acknowledged, although less decisively, that modern intensive farming systems were harmful to semi-natural habitats and wildlife on farms. Smaller farmers (<100ha) were less inclined to acknowledge these harmful effects (only 34% disagreed with the statement that *"Intensive farming systems have no harmful effects on semi-natural habitats and farm wildlife"* compared to 49% of intermediate and 55% of larger farmers). Given this acknowledgement, and the apparent perception that agriculture and conservation are compatible, respondents were asked if they agreed that *" a return to more traditional farming systems will achieve considerable environmental and wildlife benefits"*. Responses to this statement were mixed, 41% agreed that it would and 38% disagreed (Attitude score, +1). Smaller farmers were more inclined to agree (58%) than intermediate (34%) and larger farms (36%). These observations appear to reflect farmers' reluctance to 'take a step backwards' and give up hard-gained and government-sponsored yield improvements. A similar response was observed when farmers were asked if they believed a reduction in intensity across their entire cropped area was a more suitable means of reducing overproduction than set-aside (section 3.3.2).

Whilst reluctant to return to traditional low intensity systems, the majority of farmers (77%) were wholly supportive of measures to ensure that future agricultural policy encompasses both production and environmental goals (Attitude score, +83). This widespread acceptance of the need for policies which integrate agricultural production goals and environmental concerns places the onus on the European Union (EU) and MAFF to formulate novel policies which are acceptable to farmers and will secure both of these objectives.

### 3.3.3.3 Managing agricultural land for nature conservation : Management and economic factors

The widespread acceptance within the farming community of the legitimacy of calls for a greater integration of agricultural and environmental policies was illustrated in the present survey when 53% of farmers agreed that *" the authorities have done too little to incorporate wildlife and environmental concerns into agricultural policy"* (Table 3.7). Only 21% of respondents disagreed with this statement (Figure 3.5, Attitude score, +44). These views were largely independent of region and farm size. At the same time, 46% of farmers agreed that managing land for conservation objectives was equally as satisfying as management for the maximisation of crop yield (Table 3.7, Attitude score, +35), further dispelling any notion that the industry has reoriented to such a degree that the majority of farmers perceive themselves as 'agri-businessmen' whose sole concern is food production.

The results presented to date in this section, and in the previous survey, emphatically demonstrate the willingness, at least in principle, of a significant proportion of farmers to acknowledge their dual role in the countryside and to embrace the conservation interest. A major aim of this second survey is to determine why these attitudes are not being reflected in the uptake of conservation oriented management on set-aside land. One possible explanation, the general dislike and mistrust of set-aside policy has been discussed. The perceived and actual success of individuals within any industry is largely a function of their economic returns, or profit, and agricultural policy in the post-war era has reinforced this profit-maximising ethos. Farmers will not respond to agri-environmental policy initiatives if these entail a substantial reduction in their net margins, in short, a market must exist for environmental value (Jenkins, 1990). Surveyed farmers were invited to respond to the statement that *"Wildlife habitats should be viewed as agricultural products, and as such farmers should be paid for their creation and maintenance"*. Perhaps unsurprisingly, 73% agreed with this principle (Attitude score, +82), and 82% suggested that current financial incentives for farmers to incorporate nature conservation into farm management were inadequate (Attitude score, +99). In anticipation of the widespread assertion amongst the farming community that 'conservation costs money', reducing farm profitability, respondents were asked if they agreed that *"nature conservation is a luxury which many farmers are not able to afford"* ; 58% agreed with this statement (see Table 3.7). This result should be interpreted with caution ; increasingly, as agriculture enters a post-productionist phase, incentives are becoming available for farmers to produce alternative countryside products, one of which is conservation. ESAs and the Countryside Stewardship Scheme are examples. To some extent, this response indicates that the farming community is proving resistant to change and slow to adapt to the changing policy environment. In the case of set-aside, however, it is totally justifiable. Conservation-based management attracts no system of incentives, and extra input and management costs must be absorbed by the farm business. This lack of incentives must be considered a key determinant in the poor uptake of conservation based management on set-aside land.

Results presented from the two farm-based surveys have completely refuted any claim that farmers, as a group, are hostile to environmental conservation. However, differing perceptions of environmental and conservation issues between farmers and conservationists have been reported elsewhere (Carr and Tait, 1991). Newby *et al*, 1977 commented that :

> "it is not exaggerated to suggest that farmers suffer from a collective paranoia ...... which simply increases their hostility to the 'meddling' of outsiders"

In view of this, farmers' attitudes to conservationists were sought by asking them to respond to the statement that *"Conservationists fail to understand modern farming systems"*. 69% of surveyed farmers agreed with this statement, highlighting the need for more communication and co-operation between farmers and conservationists which will hopefully result in a greater degree of mutual trust and respect in future years.

3.3.3.4 Conservation orientation

As in the previous chapter, a conservation-orientation was derived for individual farmers. This score was calculated from responses to eleven variables. Nine of these were attitude statements from Table 3.7 (statement numbers 1,2,3,4,6,8,9,10 and 14). Positive statements (emboldened) were recoded as follows : strongly agree, +2 ; agree, +1 ; neutral, 0 ; disagree, -1 and strongly disagree, -2 ; and negative statements (italicised) as strongly agree, -2 ; agree, -1 ; neutral, 0 ; disagree, +1 and strongly disagree, +2. Respondents who were in contact with conservationists (41%) were given an additional score of +1, as were those who actively managed areas of their land for conservation (46%). Scores from these eleven variables were summed to derive a conservation-orientation, which potentially ranged in value from -18 to +20 ; a positive score indicating a positive attitude to nature conservation. The distribution of conservation orientation scores is illustrated in Figure 3.6. Farmers have been classified into three groups according to this orientation. Only 19% of surveyed farmers scored a negative conservation orientation value (conservation opponents).

Groups were ;

| | | |
|---|---|---|
| CONSERVATION OPPONENTS | (-7 to 0) | 19 farmers |
| SYMPATHETIC CONSERVATIONISTS | (1 to 6) | 48 farmers |
| ENTHUSIASTIC CONSERVATIONISTS | (7 to 17) | 34 farmers |

This classification was used as the basis for subsequent analysis which investigated the influence of region, farm size, farmer age, farm profitability and attitudes to set-aside on conservation-orientation. Profitability since the 1992 CAP reform was the only variable which was significantly associated with conservation orientation (Table 3.8, $P < 0.05$). As in the initial survey, farmers who had been most financially benefited by the reforms were the most inclined to display a sympathetic or enthusiastic attitude to wildlife and nature conservation concerns. Conservation-orientation was independent of all other structural variables.

Table 3.8 The association between farm profitability since CAP reform and conservation-orientation
$X^2: P < 0.05$

| **Profitability since CAP reform** | **Conservation orientation** | | |
|---|---|---|---|
| | Opponent | Sympathetic | Enthusiastic |
| | | (% of respondents) | |
| More profitable | 52.6 | 73.3 | 81.8 |
| Static | 42.1 | 15.6 | 15.2 |
| Less profitable | 5.3 | 11.1 | 3.0 |

Regression analyses were performed to determine if statistically significant relationships existed between farm size and conservation-orientation, and between attitudes to set-aside (set-aside attitude-orientation) and conservation-orientation. Attitudes to nature conservation tended to become slightly more benevolent as farm size increased, but this relationship was not statistically significant. Attitudes to set-aside and nature conservation were completely independent.

## 3.3.4 Management of Nature Conservation Objectives on Surveyed Agricultural Land.

### 3.3.4.1 Uptake and Awareness

Whilst it has been hypothesised that attitudes to set-aside policy and nature conservation, and financial circumstances will interact to influence (non) adoption of MAFF-directed conservation options on set-aside land, low levels of awareness of their existence amongst surveyed farmers acts at a more fundamental level to constrain participation. Farmers in the current survey were asked to indicate for eight specific conservation oriented options, whether they were aware of it as an option on set-aside land, and if they were managing any of their set-aside area in accordance with these guidelines. Results are in Table 3.8.

Awareness had generally increased since the first survey in 1994, with 82% of surveyed farmers acknowledging one or more of the listed options. Whether this is due to an increased effort by MAFF to publicise their existence, or to 'word of mouth' within the farming community over the time lapse between the two surveys, is not clear. Rotational set-aside for birds, field margin set-aside and set-aside for woodland establishment were the most widely acknowledged options. Increases in awareness have corresponded to an increased uptake of these options ; 19 farmers (17.3% of respondents) were managing part of their set-aside area in accordance with one or more of these conservation objectives. Unsurprisingly, field margin set-aside and rotational set-aside for birds accounted for the majority of this area (Table 3.9). The more demanding and potentially beneficial options which aimed at habitat creation (long-term set-aside, woodland establishment and meadow strips) were less widely adopted.

Table 3.9 Farmer awareness of, and adoption of, conservation oriented management on set-aside land.

| Option | Awareness n / (%) | Uptake n / (%) |
|---|---|---|
| Rotational set-aside for birds | 68 / (64) | 8 / (7.5) |
| Rotational set-aside for rare arable weeds | 30 / (28) | 1 / (0.9) |
| Non-rotational Brent Geese pasture | 30 / (28) | 0 / (0.0) |
| Non-rotational Stone Curlew meadow | 19 / (18) | 1 / (0.9) |
| Field margin set-aside | 74 / (69) | 7 / (6.5) |
| Field margin set-aside for meadow strips | 51 / (48) | 0 / (0.0) |
| Long-term set-aside for habitat creation | 31 / (29) | 0 / (0.0) |
| Set-aside for woodland establishment | 74 / (69) | 2 / (1.9) |

The continued low rates of uptake, and the relatively small sample size prevented a thorough analysis of the structural and attitudinal factors which correlated to uptake. However, whilst not statistically significant the importance of attitudes to set-aside and nature conservation can be seen from the results presented in Tables 3.10 and 3.11 which suggest that hostility to set-aside policy, and particularly to nature conservation, apparently do constrain participation in conservation management on set-aside land.

Table 3.10 The influence of set-aside attitude orientation on the uptake of conservation oriented options on set-aside land.

| | **Set-aside attitude orientation** | | |
|---|---|---|---|
| **Uptake** | Hostile | Opposed | Favourable |
| Yes | 3 | 6 | 10 |
| No | 28 | 34 | 20 |

Table 3.11 The influence of conservation orientation on the uptake of conservation options on set-aside land

| | **Nature conservation orientation** | | |
|---|---|---|---|
| **Uptake** | Opponent | Sympathetic | Enthusiastic |
| Yes | 0 | 11 | 8 |
| No | 19 | 37 | 28 |

3.3.4.2 Factors constraining participation in conservation management on set-aside land : An analysis of farmer perceptions

The analysis of questionnaire returns reported in chapter 2 identified four key factors which determine the extent of participation in conservation management on set-aside land (attitudes to set-aside, attitudes to nature conservation, awareness, payment and advice). Participants in the current survey were made aware of the very low rates of uptake recorded in the baseline survey, and were asked to rank five statements from 1 (the most important) to 5 (the least important) in accounting for this. Results are summarised in Table 3.12

Table 3.12 Farmers' perceptions of the major factors constraining participation in nature conservation on set-aside land.

| **Statement** | Mean ranking score | **Rank** |
|---|---|---|
| A lack of financial reward for extra expenditure incurred | 1.99 | **1** |
| Set-aside is an unpopular policy with many farmers | 2.59 | **2** |
| A lack of awareness of these opportunities | 2.78 | **3** |
| A lack of available advice on management of set-aside land for conservation objectives | 3.27 | **4** |
| Farmers are not interested in nature conservation | 3.82 | **5** |

46% of respondents believed that the absence of financial incentives was the major factor constraining participation, 35% believed that it was the unpopularity of set-aside policy and 14% blamed a lack of awareness of these opportunities. A lack of interest in wildlife and nature conservation, and the paucity of available advice were not perceived as major constraints. The overall ranking of these factors is shown in Table 3.12.

As discussed in the introduction to chapter 2, the success of set-aside policy in achieving its potential for enhancing the nature conservation value of the wider countryside is entirely dependent on farmers' willingness to manage land appropriately. As such, addressing the major constraints on participation, as these are perceived by the farming community, is crucial to securing future gains on set-aside land. Means of minimising or eliminating these concerns will be discussed in the conclusion to this chapter.

Below is a list of comments made by surveyed farmers with regard to nature conservation and set-aside land :

> "Basically many more farmers would do more for nature conservation if there was a premium paid over and above the standard set-aside payment. At present the set-aside payment is not enough anyway so farmers cannot be expected to do more. Conservation is expensive and farmers should not be the ones to foot the bill entirely. Set-aside is a great opportunity to conserve nature but is very poorly administered by MAFF." (Surrey farmer with 204 ha)

> " Farmers are businessmen, if they were financially rewarded they would put more effort into conservation matters." (Eastern farmer with 1320 ha)

"For set-aside the minimum width of land is 20 metres. On small fields this is a very large proportion of the available land. If the width was reduced to 4 metres many farmers would use this option for set-aside. This could be semi-permanent and managed as advised by wildlife experts." (Suffolk farmer with 180 ha)

"We are convinced that nature conservation would occur naturally if farming was enabled to exist financially under a much less intensive system." (Sussex farmer with 210 ha)

"In my view fields set-aside should be left as such for a minimum of five years, neither the flora nor fauna benefits significantly from the one year rotational set-aside. We use the latter as a useful management tool, much in the same way as land was fallowed for one year in the past, but this decision is dictated by financial pressure, not environmental issues" (Nottinghamshire farmer with 357 ha)

"Farmers who are genuinely interested in conservation will take up environmentally friendly ideas and put them into practice for no payment. Most farmers are food producers, however, and they are unwilling to compromise the efficiency of their unit by adopting such practices unless they can be shown to be beneficial to their business. More demonstrations might help to educate those of us who need convincing." (Eastern farmer with 165 ha)

#### 3.3.4.3 A Nature Conservation Premium for Set-aside Land.

Finally, surveyed farmers were invited to indicate what they thought would be an appropriate additional payment to render each of the listed options financially viable. A number of respondents declined to make a 'bid', many suggesting that without a detailed knowledge of the scheme's management requirements, and appropriate management experience, they were unable to make realistic assessments. Similarly, and perhaps as a result of the above, many 'bids' were unrealistically high. The mean bids for each option, presented in Table 3.13, should be interpreted with some caution, as these include a small number of these unrealistically high bids. Nevertheless, they give a good indication of the relative feasibility and potential uptake of each of these options, and illustrate that a significant number of farmers would be prepared to consider these given moderately small (< £100 / ha) premium or incentive payment. Those options with the lowest mean bids are the ones which have been most widely adopted by surveyed farmers. Woodland establishment and long-term set-aside require substantially higher premiums than all other options, reflecting their long-term commitment and demanding management requirements.

Table 3.13 Farmer 'bids' for appropriate premium payments for conservation oriented options on set-aside land

| **Option** | | **Farmer bids (£ / ha)** | | | |
|---|---|---|---|---|---|
| | | Number of bids in range | | | |
| | **Mean (£)** | £0 - 50 | £51 - 100 | £101 - 250 | over £250 |
| Rotational set-aside for birds | **120** | 16 | 15 | 7 | 4 |
| Field margin set-aside | **138** | 14 | 8 | 9 | 3 |
| Rotational set-aside for rare arable weeds | **158** | 12 | 8 | 6 | 6 |
| Set-aside for meadow strips | **160** | 8 | 8 | 2 | 8 |
| Non-rotational Stone curlew meadow | **186** | 13 | 8 | 9 | 4 |
| Non-rotational Brent Geese pasture | **194** | 6 | 9 | 2 | 7 |
| Set-aside for woodland establishment | **322** | 3 | 9 | 9 | 10 |
| Long-term set-aside | **347** | 9 | 5 | 8 | 11 |

## 3.4 Farmer Participation in Conservation Management on Set-aside Land : Current Constraints and Future Prospects.

The initial survey reported in chapter 2, established a baseline for farmer attitudes to CAP reform, set-aside and nature conservation within a changing agricultural policy environment. These attitudinal (internal) variables were analysed with respect to a number of structural (external) variables (farm size, region, profitability) in an attempt to establish a 'participation spectrum' (Morris and Potter, 1995) for the uptake of conservation-oriented management on set-aside land. In practice, these efforts were hampered by the almost complete absence of uptake of MAFF-directed guidelines for environmental objectives on set-aside land. Nevertheless, this survey was able to determine a number of attitudinal and structural variables, and interactions between these which could account for low rates of participation. In the concluding discussion to chapter 2, four 'key' variables were presented : attitudes to set-aside policy ; attitudes to nature conservation ; financial considerations ; and levels of awareness and availability of advice. The current survey has sought to determine in greater detail the factors which underpin each of these variables, and their relative importance, so that measures to increase farmer participation may be presented.

This second survey was conducted almost two years after the initial baseline had been established, and provides some evidence that participation was increasing. Nineteen surveyed farmers were managing parcels of their set-aside land in accordance with MAFF guidelines (Table 3.8). Whilst it is acknowledged that this represents moderate progress towards realisation of the conservation potential of set-aside land, it should be noted that the uptake of the most environmentally beneficial options - those which aim to secure long-term habitat creation (long-term set-aside, woodland establishment, the creation of meadow strips) - has persisted at a very low level, so that the conservation potential of set-aside land remains underexploited. Nevertheless, these increases should be welcomed, and the shifts in attitudes, circumstances or perceptions which have motivated and enabled them investigated so that they may be exploited to ensure further increases in the future.

Figure 3.7 summarises the attitudinal, structural and circumstantial factors which interact to determine farmer participation in conservation management on set-aside land as these have emerged from the two questionnaire surveys. Two 'tiers of influence' have been identified - the five 'key' determinants which emerged from the initial baseline survey are presented in solid, shaded text boxes in Figure 3.7. 'Secondary' factors are represented in 'broken' text boxes : these are primarily structural or circumstantial in nature. Whilst these do not impact directly on participation, they are often important determinants of farmer-orientation with respect to the key factors discussed above and, as such, constitute equally important if somewhat less tractable variables.

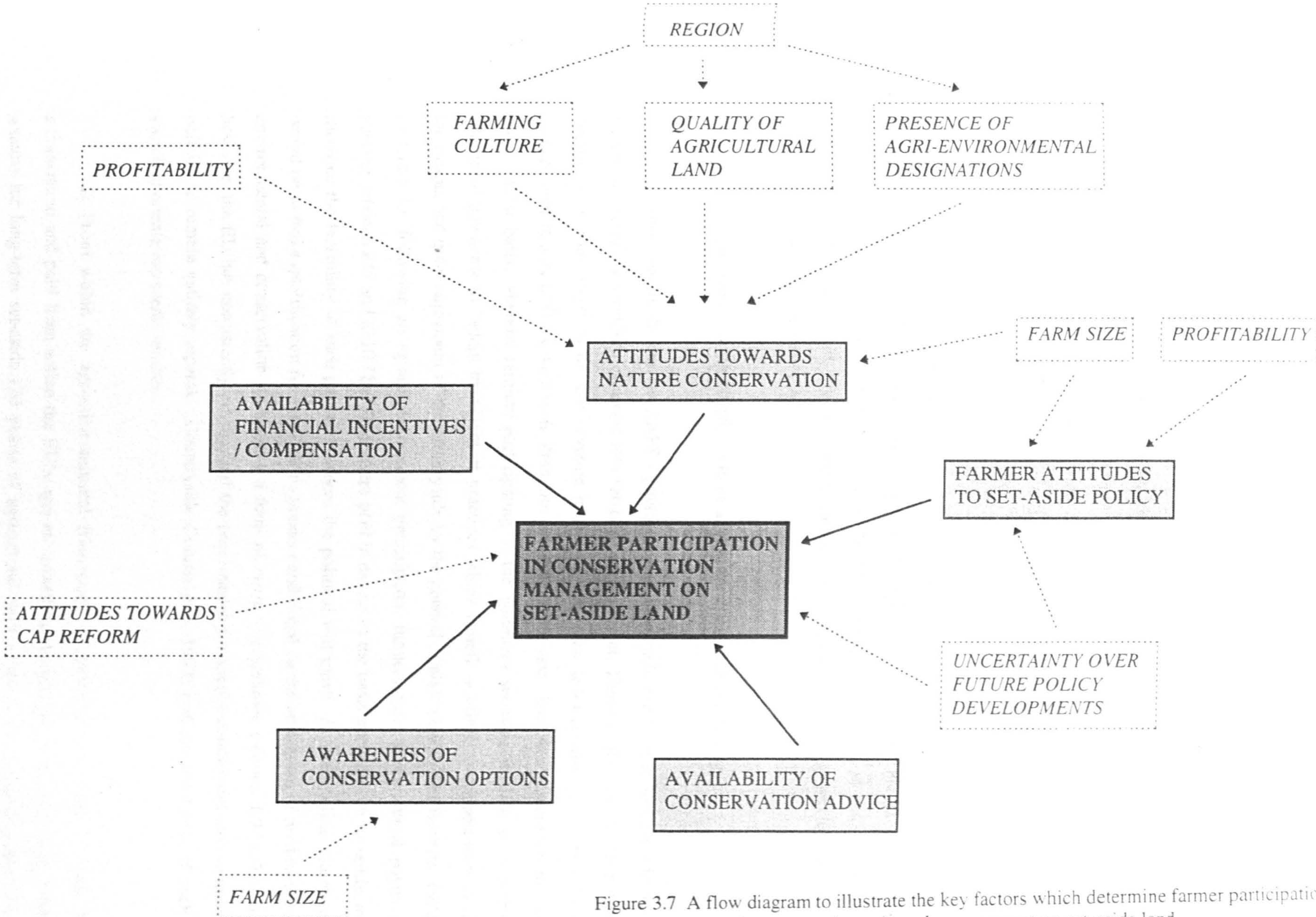



Figure 3.7 A flow diagram to illustrate the key factors which determine farmer participation in conservation oriented management on set-aside land

### 3.4.1 Financial Incentives

Within the current Arable Area Payments Scheme (AAPS), farmers are guaranteed a standard payment based on the area of land which they set-aside. The decision to manage all or part of this area for nature conservation objectives is entirely at the discretion of the individual farmer. In the absence of a 'conservation premium' or 'top-up' payment for those who choose this course of action, any additional expenditure incurred remains uncompensated and must be absorbed as part of the farms operating costs. This state of affairs represents a fundamental barrier to farmer participation in conservation-based management on set-aside land and must be addressed if the conservation potential of set-aside is to be fully realised.

'Bids' offered by surveyed farmers, whilst in some cases unrealistically high, were often within a range (under £100 / ha) which would appear reasonable and attainable if the EU and MAFF's claims for the environmental benefits of set-aside are more than mere rhetoric in response to calls from the conservation lobby for a greater degree of integration between productionist and environmental policy within the CAP.

These payments, if introduced, could be administered in a number of ways :

1. From within the current AAPS - payments could be made available to farmers who were willing to incorporate wildlife concerns into set-aside management. These could take the form of an additional 'top-up' payment or 'conservation premium' with their level related to the intensity of management required. The Countryside Premium Scheme for set-aside land was established in 1989 on a similar basis, whereby farmers participating in the voluntary set-aside scheme were offered additional payments to "adopt management practices which benefit wildlife, the appearance of the landscape, and quiet enjoyment of the countryside by the general public" (Ewins and Roberts, 1992). In return for following an agreed management prescription, farmers were given annual payments varying between £45 and £110 / ha. These were paid in excess of the basic premium for set-aside, and illustrate the feasibility of such payments where the political will exists. A more radical alternative would be to make qualification for set-aside payments conditional on the attainment of predetermined environmental and conservation standards - a form of *cross - compliance* (section 1.9.2). To date, however, the EU has consistently emphasised the requirement for supply control and environmental policies to remain entirely separate (Countryside Commission, 1992) and the possibility of such a switch in orientation seems remote.

2. From within the agri-environmental framework - 'conservation premiums' could be administered and paid from within the EU's agri-environmental budget (section 1.8.2). The habitat scheme for long-term set-aside (20 years) of agricultural land within the UK has to some extent encompassed this approach. However, the range of habitats covered by this scheme is very limited,

and MAFF has recently indicated (MAFF, 1997 pers comm) that farmers are no longer being encouraged to enter pending a budgetary review.

3. Within a single nationwide menu for conservation payments - such an approach has been advocated by the Countryside Commission (Countryside Commission, 1992) (section 1.9.3.1) and could encompass conservation payments for set-aside land.

It is important to recognise that if additional funding were to be made available for conservation management on set-aside land this would be limited, necessitating some means of discrimination or 'targeting' so that environmental and or social returns could be maximised. A number of mechanisms could be considered for targeting these resources :

i) farmers could be invited to submit management plans for their set-aside area, and to 'tender' bids in accordance with these plans. Management agreements could then be awarded on land where the greatest potential wildlife gains could be achieved at the lowest cost.

ii) farmers could be paid on the basis of the quality of habitat they produced on set-aside land - so called 'payment for products' (Countryside Commission, 1992) (section 1.9.2)

iii) set-aside land could be targeted on the basis of 'conservation potential' and conservation payments made available only within those areas where they would be most appropriate and secure the greatest wildlife gains

iv) conservation payments could be made available only to those farmers who had been most disadvantaged by the CAP reforms, or whose profitability was becoming increasingly marginal. In this way payments could encompass social as well as environmental objectives.

### 3.4.2 Attitudes to set-aside

Second only to the absence of financial incentives, farmers' widespread opposition to the principle of land diversion has proved a fundamental barrier to participation in conservation-oriented management on set-aside land. Whilst, in principle at least, financial incentives are easily introduced, it may prove more difficult to move farmers along the 'spectrum' of 'set-aside attitude orientation' in order to secure a more environmentally-friendly approach to management. Previous work has highlighted a pervasive mistrust of, and dislike for, land diversion (Gasson and Potter, 1988 ; Brotherton, 1989) and this finding is supported by the lower than anticipated rates of uptake of the voluntary five year set-aside scheme, introduced in 1988 (Ansell and Tranter, 1992 ; Brotherton, 1990).

Comments made by farmers during the course of the current survey illustrate the fundamental nature of this opposition :

"to set-aside good quality agricultural land when there are people in the world starving is morally wrong" (Eastern farmer with 462 ha)

"I have strived for years to get the most out of my land, and now each day I pass huge tracts of weedy wasteland - it's a crying shame" (Eastern farmer with 990 ha)

"The introduction of set-aside has led me to reconsider my future in farming"
(Sussex farmer with 101 ha)

Attitudes to set-aside are seemingly influenced by agronomic and economic concerns to a far lesser extent, than by the public image which farmers perceive set-aside land creates of the farming industry. It was widely perceived within the farming community that set-aside policy was viewed by the public as 'paying them to do nothing' and gave the impression of a neglected countryside. These concerns may to some extent be justified, but are easily addressed if farmers show a willingness to embrace the conservation and recreational opportunities which set-aside offers. Indeed, respondents' attitudes towards and perceptions of set-aside policy appear to be fraught with contradictions. On the one hand they acknowledge the considerable wildlife potential of diverted land and suggest that MAFF has done to little to enhance these, whilst at the same time indicating that this conservation potential is a minor consideration in deciding which areas of land are to be set-aside.

One further factor with respect to set-aside policy constrains participation in conservation based management - a widespread uncertainty within the farming community of the direction which future policy directives will take. The farming industry is widely perceived to be in a transitional phase, pending further and more fundamental reform of the CAP. This uncertainty, together with the constantly changing set-aside percentage requirement, means that farmers are reluctant to manage this land for environmental or conservation objectives when future policy developments may once again 'shift the goalposts'. Decision-making processes with respect to nature conservation and land use planning will benefit from a stable policy environment whose future is guaranteed in the mid to long-term.

### 3.4.3 Awareness of conservation options for set-aside land.

Ranked by surveyed farmers as the third most important determinant of low participation rates, a lack of awareness of conservation options for set-aside can easily be addressed by more aggressive 'marketing' of these options by MAFF and relevant conservation bodies.

### 3.4.4 Attitudes to nature conservation

Throughout the two surveys a majority of farmers have exhibited a favourable and sympathetic attitude towards nature conservation and wildlife interests on agricultural land. They have acknowledged and embraced a dual role as food producers and countryside stewards, and indicated that, given appropriate signals and financial incentives, they would happily manage land for conservation objectives. They have welcomed calls for a greater degree of integration between agricultural and environmental policy, acknowledged the harmful effects of past practices and accepted, in theory if not in practice, the wildlife conservation potential of set-aside land. When responses to a range of variables pertaining to conservation attitudes and intentions have been combined to derive an overall conservation-orientation, some differences have emerged. A contradiction emerges when the apparent gulf between conservation attitudes and conservation behaviour (in this case the uptake of conservation based options on set-aside land) is considered. This contradiction has been observed in previous surveys (Newby *et al,* 1977 ; Carr and Tait, 1991 ; Battershill and Gilg, 1996a). In the present study other factors discussed previously in this section are undoubtedly important influences accounting for the apparent contradiction between attitudes and actions. Nevertheless, conservation-orientation is closely associated with a range of structural factors and, if more fundamental barriers to participation are removed, their influence may become more important. The largest and most profitable farmers are often the most conservation-oriented, their large farm size and financial buoyancy enabling them to accommodate alternative land use objectives and buffering them to some degree against uncertainty over future policy developments, and an increasingly volatile agricultural industry. The widely held belief that nature conservation was a luxury that many farmers are unable to afford would seem to confirm this.

Perhaps the most important determinants of conservation behaviour are regional and geographical variables. These were discussed at length in the conclusion to the last chapter and the importance of geography, over attitudinal and structural factors has been discussed by others (Battershill and Gilg, 1996c). Widespread regional differences in attitudes towards ('farming culture') and circumstances relating to nature conservation (profitability, quality of agricultural land) add weight to calls for a program of targeted set-aside (Burnham *et al,* 1987 ; Potter, 1991). Target areas where agricultural land quality is low, nature conservation potential high and where farmers are operating at the margins of profitability could be identified so that a "conservation reserve", incorporating a system of financial incentives could be established on set-aside land within these areas.

## 3.5 Conclusions

The results from two farm-based surveys, presented in chapters 2 and 3 of this thesis, have identified a number of key factors which constrain farmer participation in voluntary conservation-oriented management options for set-aside land. If these are to be addressed so that the undoubted conservation potential of set-aside land can be fully realised, there is an urgent requirement for the EU and MAFF to affirm conservation and environmental objectives as an important secondary objective of set-aside policy. Wildlife benefits which accrue as a result of non-conservation specific management (section 1.11.1) should not be dismissed, and the formulation of guidelines for conservation objectives on set-aside within the UK (MAFF, 1993 ; Firbank *et al.*, 1993) has, in principle, been a positive step towards embracing this potential. However, in the absence of appropriate financial incentives and advice to farmers this will prove little more than a cosmetic exercise, and will not result in set-aside occupying a central position in a nature conservation framework for the wider countryside in Britain.

A number of possibilities for assimilating set-aside into such a framework have been presented. With any agricultural policy faced with limited funding, a degree of targeting becomes necessary. The survey results presented suggest that, given appropriate encouragement, a significant proportion of farmers would register an interest in funding to establish a conservation reserve on set-aside land. The remainder of less enthusiastic individuals could continue managing their set-aside obligation in line with standard management restrictions.

# *Chapter 4*

## *An Investigation of the Autecological Characteristics and Seed Bank Dynamics of Selected Rare Arable Weeds*

## 4.1 Introduction

### 4.1.1 An Introduction to the Life Cycle and Population Dynamics of Annual Plants

The weeds of arable land and other regularly disturbed habitats are amongst the most severely threatened and rapidly declining within the British Flora (Perring and Farrell, 1983 ; Smith, 1986 ; Wilson, 1990). Many of these exhibit an annual life cycle (Watkinson, 1981), in which the plant germinates from seed, establishes as a vegetatively growing adult, develops reproductive structures, sets seed and dies within a twelve month period (Cousens and Mortimer, 1995). There are two distinct categories of annual life cycle (Harper, 1977), namely determinate and indeterminate. Plants with a determinate life cycle exhibit two discrete development stages ; a phase of vegetative growth, followed by reproductive development in which the main (apical) meristems are used in the formation of the inflorescence, effectively ending potential for further vegetative growth. The transition between the vegetative and reproductive phases is controlled by photoperiod, and death of the individual follows reproductive maturity. By this means, the life cycle is synchronised with recurrent seasonal events. In contrast, species with indeterminate life cycles produce flowers from lateral meristems from a young age and are able to continue to grow vegetatively, flower and set seed throughout their life cycle. Death results from extrinsic factors (e.g. cold temperature, drought). A further distinction can be made between 'winter' and 'summer' annuals. Winter annuals germinate in the autumn and winter, overwinter as dormant, or slow growing seedlings and resume growth when temperatures rise in spring, flowering in late spring or summer. Other species, the so-called summer annuals are only able to germinate in spring and summer, flowering and dying within the same year.

The large-scale field trial reported in chapter 5 determines optimal management strategies for the establishment, from seed, of diverse, persistent and stable communities of rare arable weeds on set-aside land. It is well known that the population densities of individual weed species fluctuate on a yearly basis (Cousens and Mortimer, 1995), and that these fluctuations are mediated by both intrinsic population processes (density dependent intra and interspecific competition) and extrinsic environmental factors (crop husbandry practices and climate) (Watkinson, 1981 ; Harper, 1977 ; Begon and Mortimer, 1986 ; Cousens and Mortimer, 1995). The relative influence of each of these factors and processes varies according to the time of year and the developmental stage of the individuals within the population, so that over a twelve month period all of these factors interact to determine the population dynamics of individual species, and the community structure which is consequent on these processes. Density dependent and independent processes which regulate plant population density are discussed in greater detail in the introduction to chapter 5.

Fundamental to an understanding of the dynamics of weed populations is an appreciation of the relationship between development stage and, density dependent and environmental effects

(Cousens and Mortimer, 1995). The sequence of development stages in an annual plant can be depicted as a cycle, from seed germination from the soil seedbank through to seed return to this 'bank' by mature reproductive adults. At each stage during this development the relative importance of intrinsic and extrinsic factors varies.

The development processes and population dynamics of a weed population can be expressed algebraically by the equation ;

$$S_{t+1} = g . e . s . F . S_t + b . S_t \qquad \text{Equation 4.1}$$

where $S_t$ and $S_{t+1}$ are the respective sizes of the seed population at the beginning and end of the growth cycle, **g**, the proportion of seeds which germinate from the seedbank, **e**, the proportion of these seedlings which become established, **s**, the proportion which survive to reproductive maturity, **F**, the seed production of an individual adult plant and **b** the proportion of seeds which remain viable but ungerminated within the soil seedbank.

The critical measure in any study of weed population dynamics is the rate of population growth ($S_{t+1}/ S_t$). Partitioning the annual life cycle into a number of developmental phases enables the gains and losses (fluxes) during each phase to be assessed in relation to intrinsic and extrinsic regulatory factors and processes.

Traditionally, most previous work has approached the study of weed population dynamics from an agronomic perspective, attempting to either eradicate or reduce weed population densities to acceptable levels within the cultivated environment (Cousens and Mortimer, 1995). In contrast, the research reported in chapter 5 attempts to maximise and ultimately stabilise weed population densities. No matter, the principles involved in the regulation of population density remain the same.

The total population size of an annual weed species at a given time is a function of :

a) the number of individuals (of all developmental stages) per unit area which have become established as components of the above-ground flora

b) the number of viable ungerminated seeds per unit soil volume

As such, plant population ecology must consider dynamic processes within both populations of growing plants and within the soil seedbank. An increase in the population size of an annual plant species ($S_{t+1}/ S_t > 1$) will occur when the gains from seed production ($g. e. s. F. S_t$), over a given period (usually a growing season), exceed the losses from the seedbank ( $(1 - b). S_t$).

This chapter presents results from glasshouse and field trials which investigate aspects of the seedbank dynamics of the annual arable weed species introduced to the field trials described in subsequent chapters (*Agrostemma githago, Centaurea cyanus, Papaver rhoeas, Bromus interruptus,*and *Chrysanthemum segetum*). These observations will facilitate a thorough understanding of the factors which regulate dynamic processes within soil seedbanks, and aid interpretation of above-ground vegetation processes which ultimately regulate community structure.

## 4.1.2 Seedbank Dynamics

### 4.1.2.1 The Soil Seedbank

An examination of the soil beneath a wide range of vegetation types has identified the presence of a large number of viable, but ungerminated seeds (Harper, 1977 ; Roberts, 1981 ; Thompson, 1978 ; Archibold, 1981). This reserve population of seeds is referred to as the soil seedbank. The seedbank of arable soils is unique, as regular disturbance of the soil profile results in seeds being continually redistributed, so that some become buried, whilst others are brought to the soil surface (Harper, 1977). Particular attention has been paid to the size and composition of arable seedbanks (Kropac, 1966 ; Cavers and Benoit, 1989 ; Roberts, 1968 ; Roberts and Ricketts, 1979) as this knowledge can prove valuable in predicting future weed infestations and enabling pre-emptive action (e.g. the application of pre-emergence herbicides).

The presence, extent and longevity of the seedbank for a particular species is an important aspect of that species life history strategy. The species which most characteristically form seedbanks are the early successional colonisers, of which the arable weeds are an example. These species colonise open ground and can either adopt a strategy of dispersal in space, or in time. Those species which adopt the latter option do so by forming 'banks' of long-lived dormant seeds, which instead of seeking newly disturbed sites (through long-distance seed dispersal), wait for disturbance to occur in the vicinity of the parent plant (Fenner, 1985). Thompson and Grime (1979) characterised a range of seedbank types which were essentially described as either transient or persistent in nature. The seeds of species with transient seedbanks have no, or very limited dormancy mechanisms, and are unable to persist in the soil for long periods. During periods of active growth populations of these species are represented solely by those individuals present in the above-ground flora. For species displaying persistent seedbanks, dormancy is maintained via a number of physiological mechanisms which ensure that the seed is able to survive periods of adverse conditions and germinate when edaphic and climatic conditions become favourable. The possession of seed dormancy allows alternative life history strategies which prohibit a species from 'putting all it's eggs in one basket' and are an important adaptation for the long-term persistence of weedy species (Mortimer, 1990). However, this strategy is disadvantageous in terms of the ability to rapidly colonise and become dominant in recently disturbed areas.

4.1.2.2 The 'Fate of Seed'

The number of seeds which are returned to the soil seedbank (seed rain) at the end of the growing season is mediated by intrinsic and extrinsic factors which ultimately regulate the fecundity of individuals within the above-ground flora. These factors will be discussed in greater detail in chapter 5. The transition probability, **b**, in equation 4.1 is a measure of the proportion of seeds which will remain viable, but ungerminated within the soil seedbank over a generation of growth (growing season). The remainder of this chapter seeks to explore the reasons for, rates of (**1 - b**), and periodicity of seed loss from the seedbank for selected rare arable weed species.

***4.1.2.2.1 Germination***

Seeds of a number of plant species possess physiological mechanisms which enable them to remain dormant during periods which are unfavourable for germination and subsequent seedling establishment (Harper, 1957, 1977 ; Fenner, 1985). In addition to providing seeds with a means to survive adverse conditions, these physiological mechanisms enable them to 'monitor' the soil environment, so that cyclical changes in the dormancy state can be synchronised with prevailing adverse and benign environmental conditions (Angevine and Chabot, 1979 ; Mortimer, 1990 ; Baskin and Baskin, 1985).

Harper (1957) recognised three dormancy states - innate, induced and enforced. Mortimer (1990) has classified dormancy strategies as either predictive or consequential. A predictive germination strategy reflecting an 'innate' physiological mechanism whereby seeds become dormant in response to predictable seasonal fluctuations in advance of the onset of adverse conditions. In contrast, seeds displaying a consequential strategy exhibit 'induced' of 'enforced' dormancy in direct response to the onset of adverse conditions.

The seeds of species present in the soil seedbank will each have their own distinct germination requirements and dormancy strategies, and these will determine the rate, and seasonal periodicity of germination from the seedbank. When seeds are shed from the parent plant they may be either innately dormant or non-dormant. Innate dormancy prevents immediate germination and usually diminishes with time at a rate determined by temperature (Cousens and Mortimer, 1995) - this process is known as after-ripening. Subsequent rates of recruitment from the seedbank are mediated by a range of edaphic and biotic factors. These include temperature and soil moisture content (Nussbaum *et al*, 1985 ; Roberts, 1984 ; Thompson *et al*, 1977 ; Roberts and Potter, 1980), the gaseous environment of the soil (Pareja and Staniforth, 1985) and the chemical soil environment (Popay and Roberts, 1970 ; Roberts, 1973 ; Bostock, 1978). Some species require light to germinate, and as such the depth of seed burial may be an important determinant of germination capacity (Balyan and Bhan, 1986 ; Howard, 1991 ; Watson, 1987). Extensive research has been conducted on the relationship between cultivation, seed burial and seedling emergence (Chancellor, 1986 ; Froud-Williams *et al.*, 1984 ; Egley and Williams, 1990 ; Roberts and Feast, 1973). Germination may also depend on the orientation of seeds at the soil surface (Sheldon, 1974). Ultimately, the number of seeds which germinate from the seedbank will depend on the presence and extent of 'safe sites' (Harper, 1977), or 'regeneration niches' (Grubb, 1977). When one or more of the limiting factors described above render a site 'unsafe', precluding germination, seeds may enter a period of physiologically 'induced' dormancy which requires a specific environmental cue before germination may occur. 'Enforced' dormancy is maintained by similar limiting factors, but germinability is restored when this factor is removed without the requirement for a specific cue (Mortimer, 1990) to reverse the physiological dormancy mechanism.

Harper (1977) discussed the dynamics of soil seedbanks in terms of a 'deposit' account of viable, but physiologically dormant seeds and a 'current' account in which seeds were only prevented from germination by the temporary absence of a safe site. In response to biotic, abiotic and edaphic factors, seasonal fluctuations in the dormancy status of seeds in the soil may cycle during the course of the year (Baskin and Baskin, 1985).

Typically the fraction of arable weed seeds which germinate from the seedbank during a single growing season is small (0.01 to 10%) (Mortimer, 1990 ; Roberts and Ricketts, 1979). Cycles in the dormancy status of seeds ultimately give rise to characteristic, species specific patterns of seedling emergence in the field (seedling periodicity). These seasonal patterns of emergence have been studied for a range of arable weeds (Roberts, 1964 ; Roberts and Feast, 1970 ; Roberts and Neilsen, 1980, 1981 ; Watson, 1987 ; Egley and Williams, 1990), often in relation to soil cultivation practices (Froud-Williams *et al*, 1984 ; Roberts and Potter, 1980 ; Chancellor, 1986 ; Mulugeta and Stoltenberg, 1997). A knowledge and understanding of these episodic germination events is crucial to the timing and efficacy of weed control measures, and may be equally important when the aim is to create diverse communities of rare arable weeds for conservation. The timing of seedling emergence is of fundamental importance in determining the subsequent success of an individual within a plant community (Ross and Harper, 1972). Those species which become established immediately following seed bed preparation are able to 'pre-empt' resources by a process of 'space capture' (Harper, 1977). This 'pre-emptive competition' results in the establishment of dominance hierarchies (Harper, 1977 ; Ross and Harper, 1972 ; White and Harper, 1970 ; Bazazz and Harper, 1976 ; Weiner and Thomas, 1986), whereby initial differences are magnified as the population develops, with individuals which are higher in the initial dominance hierarchy better able to compete for limited resources, thereby further suppressing the growth of their neighbours. This asymmetric competition (Weiner and Thomas, 1986 ; Wilson, 1988 ; Connolly and Wayne, 1996) results in populations and communities composed of relatively few large individuals which dominate and suppress the growth and fecundity of their smaller neighbours.

Four major patterns of emergence have been characterised :

i) emergence entirely in spring

ii) emergence predominantly in autumn

iii) Emergence in both spring and autumn

iv) Emergence indifferent to season

*4.1.2.2.2 Seed losses through processes other than germination*

During a single growing season a fraction of seeds from the soil seedbank will be lost as a result of natural death processes (loss of viability and predation). The ability of seeds of arable weeds to persist in the soil (seed longevity) has been widely studied, and varies markedly (Lewis, 1973 ; Roberts, 1981, 1986 ; Naylor, 1984 ; Burnside *et al.*, 1996). A thorough understanding of the long-term dynamics of weed populations requires some appreciation of the length of time for which seeds are likely to persist in the soil (Chepil, 1946), and of the factors which can influence the longevity of weed populations. Populations of seeds at, or near to the soil surface decline more rapidly than those which are buried (Roberts and Feast, 1972), and as a consequence of this the frequency of cultivation has often been shown to be crucial in determining ultimate longevity (Froud-Williams *et al*, 1984 ; Egley and Williams, 1990 ; Chancellor, 1986 ; Roberts and Feast, 1972, 1973). Regardless of the rate of loss, the decline in abundance of buried seed, both in total and for individual species has been demonstrated to be exponential in nature (Harper, 1981 ; Roberts, 1970).

Seed loss may also occur as a consequence of a number of other biotic and abiotic factors. There may be predation by birds, small mammals, earthworms and seed eating insects (Cousens and Mortimer, 1995). Seed viability may be lost as a result of fungal or bacterial attack, and fire may result in considerable seed mortality. Seeds which do not possess physiological dormancy mechanisms may germinate at depths which preclude subsequent emergence at the soil surface, and finally, pre-emergence herbicide applications may kill seeds before germination is possible. Due to the difficulty encountered in trying to exclude many of these potential sources of seed loss from experimental situations, there is a paucity of quantitative information on their relative importance in the field (Cousens and Mortimer, 1995).

The experiments described in this chapter will investigate the periodicity of emergence, longevity, and ability to emerge from depth, of rare arable weed species. This knowledge will aid interpretation of above-ground vegetation processes, providing quantitative data on the long-term fate of seed in the soil, and facilitating the establishment of optimal management strategies for these species on set-aside land.

## 4.2 Periodicity of Seedling Emergence in the Field.

The experiment reported in this section was designed to investigate seasonal patterns of seedling emergence for six rare arable weed species in a field situation, and the effects of regular soil disturbance on these patterns.

### 4.2.1 Materials and Methods

Five trenches, approximately 30cm in depth, were excavated using a small JCB at a field site adjacent to the set-aside field trial at Ness Botanic Gardens. Excavated soil was stockpiled. A layer of sand was added to the base of these trenches to provide a level surface for plant pots, and to improve drainage. Twelve plant pots (19cm diameter, 30cm depth) were placed in each of the trenches, and were filled to just below the rim with a heat sterilised loamy soil which had been passed through a 10mm sieve. The trenches were then back-filled using stockpiled soil so that only the rim of the plant pots was above the soil surface. Seeds of six rare arable weed species were sown on the soil surface on 1st September 1994. These seeds were collected in July and August from the current years 'crop', and stored over the intervening period in paper sacks in an open ended polythene tunnel. Species and seed sowing rates are given in Table 4.1 below :

Table 4.1 Species and sowing rates for seedling periodicity field trial

| Species | Source / origin [1] | 'Fresh' seeds / pot |
|---|---|---|
| *Agrostemma githago* | Emorsgate Seeds / Oxon [2] | 275 |
| *Centaurea cyanus* | Emorsgate Seeds / England | 250 |
| *Chrysanthemum segetum* | Emorsgate Seeds / Norfolk | 300 |
| *Misopates orontium* | Emorsgate Seeds / Berkshire | 320 |
| *Bromus interruptus* | Dr P M Smith, University of Edinburgh | 300 |
| *Papaver rhoeas* | Emorsgate Seeds / Lincolnshire | 300 |

[1] - Seed source was identical in all subsequent experimentation where these species were sown.

[2] - Seeds supplied by Emorsgate Seeds are all of British origin, and are produced under cultivation in Norfolk, England. The county of origin is given where available.

The experiment was arranged as a randomised block design with two treatments and five replicate blocks (60 pots in total). Treatments were cultivation and no cultivation. Four annual cultivations were simulated by removing the top 10cm of soil and mixing this thoroughly before returning soil to the pots. Cultivation treatments were imposed on the last day of the following months; September 1994, February 1995, May 1995, August 1996, December 1995 and April 1996. Monthly counts of seedling emergence were made and seedlings removed. At the same time, seedlings of all other species were also removed to prevent these occupying potential germination sites. The final count was made at the end of June 1996.

## 4.2.2 Analysis of results

Analyses of variance were performed on cumulative numbers of emerging seedlings during the following periods: 1st September to 30th October 1994 ('initial' germination); 1st November 1994 to 30th April 1995; 1st May 1995 to 30th October 1995 and 1st November 1995 to 30th June 1996. Species and cultivation regime were treatment effects.

### 4.2.3 Results

This trial identified contrasting patterns of seasonal emergence for the six weed species studied. The nature of the data set, which included a large number of zero values, and hence, highly heterogeneous error variance, meant that it was not possible to perform analyses of variance on monthly emergence counts. These data are presented graphically in Figure 4.1, as mean monthly percentage germination of remaining seeds. Analyses of variance were performed, however, on cumulative emergence counts over discrete seasonal periods and have confirmed that seasonal patterns of emergence (periodicity) for these weed species are significantly different (Tables 4.2 to 4.5).

Germination and establishment of *A. githago* and *B. interruptus* seedlings occurs exclusively in autumn. Both species exhibited large 'flushes' (93% and 55% respectively of total seed sown) of synchronous germination in the months immediately following seed sowing (seed sowing is considered to be analogous to dispersal of mature seed from adult plants). A very few seeds (<1%) of *B. interruptus* survived in the soil to germinate the following autumn. No further emergence of *A. githago* was recorded after this initial flush of germination. Both species exhibit synchronous autumn germination and a highly transient seedbank. The absence of a persistent seedbank for these species resulted in cultivation events having no effect on subsequent patterns of emergence. Due to the almost complete lack of emergence after October 1994 of *A. githago* and *B. interruptus* these species were excluded from subsequent analyses.

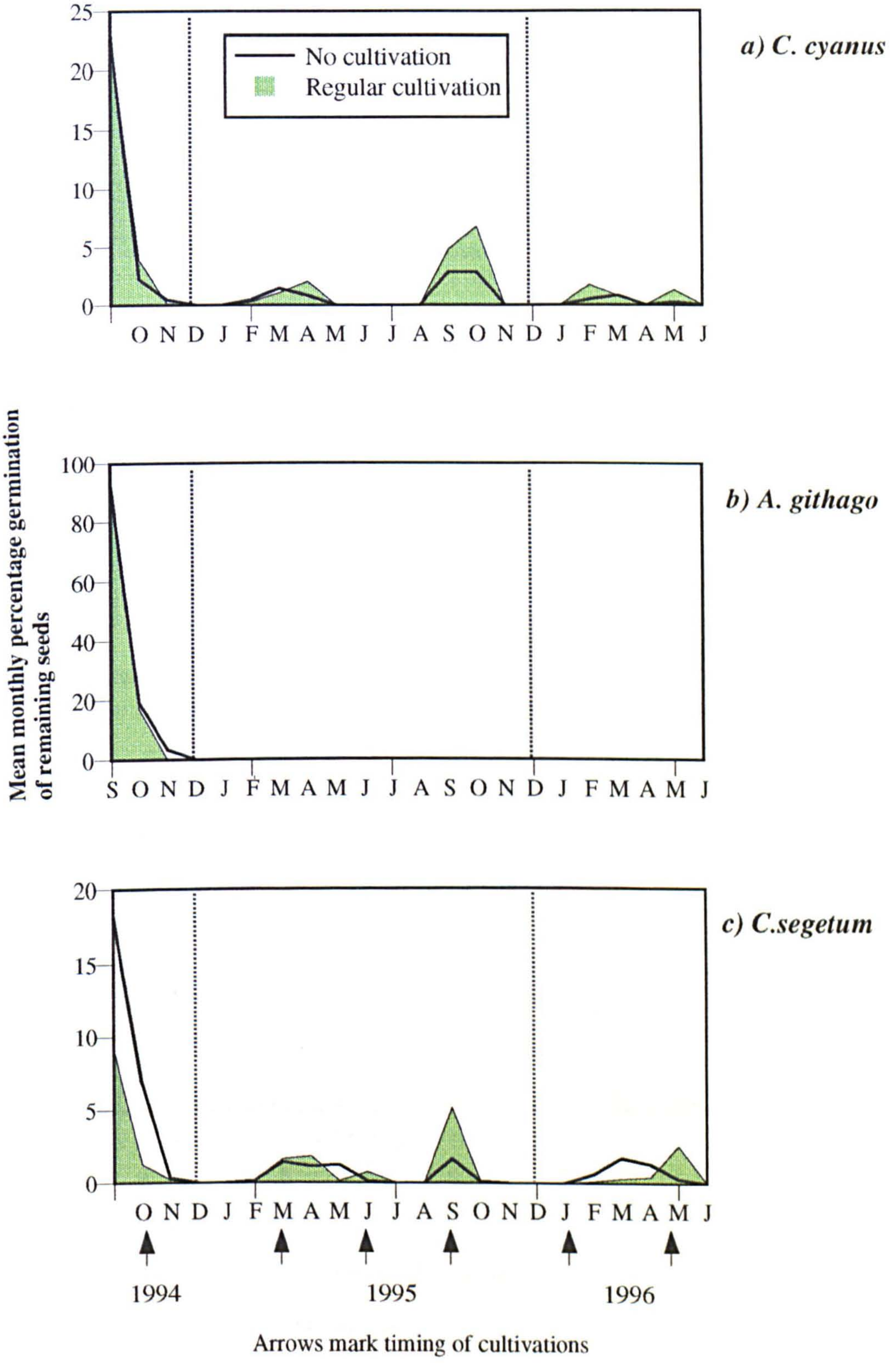



Figure 4.1 a-f Seasonal emergence of rare arable weed species under cultivation and no cultivation regimes.

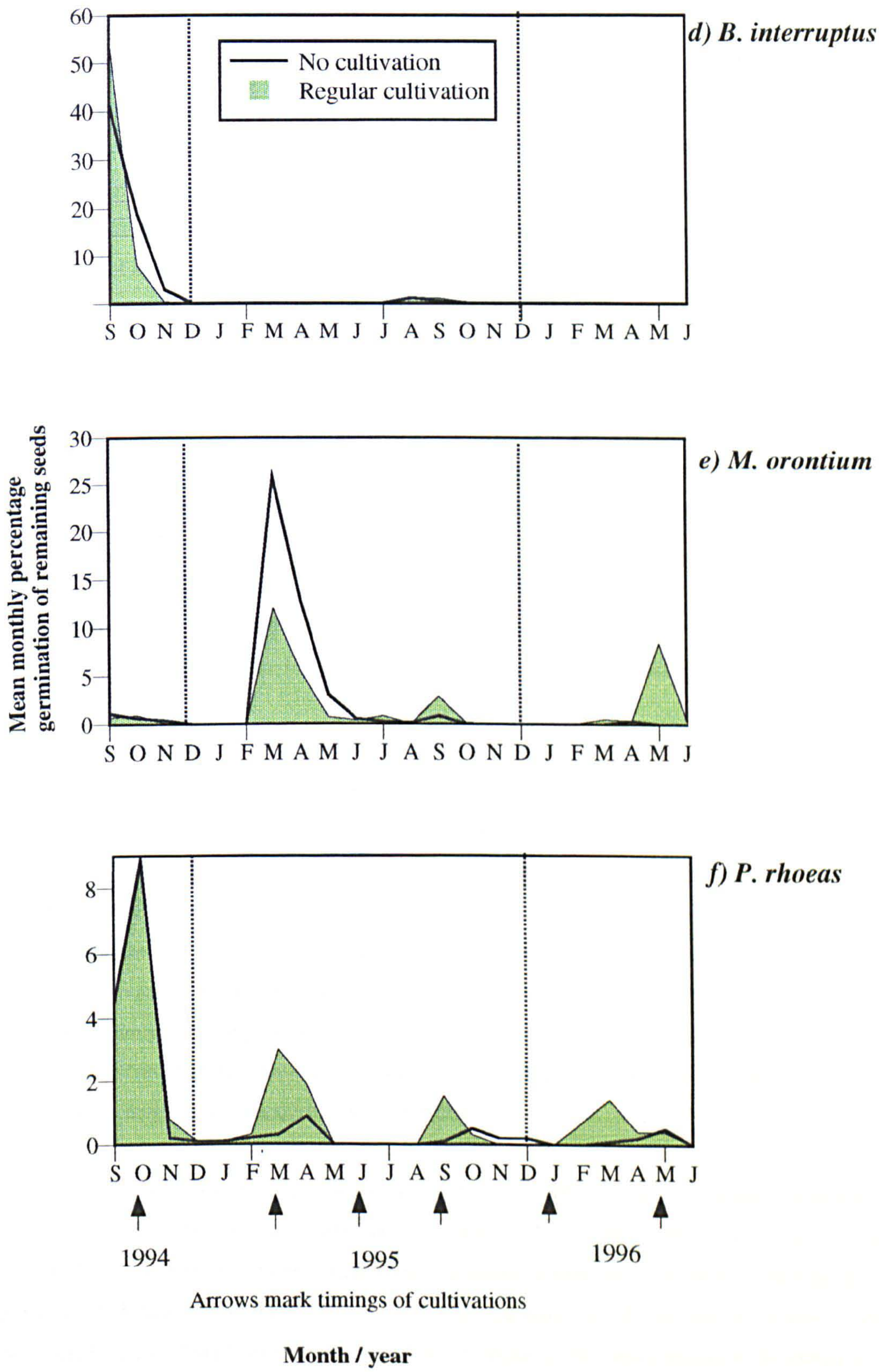


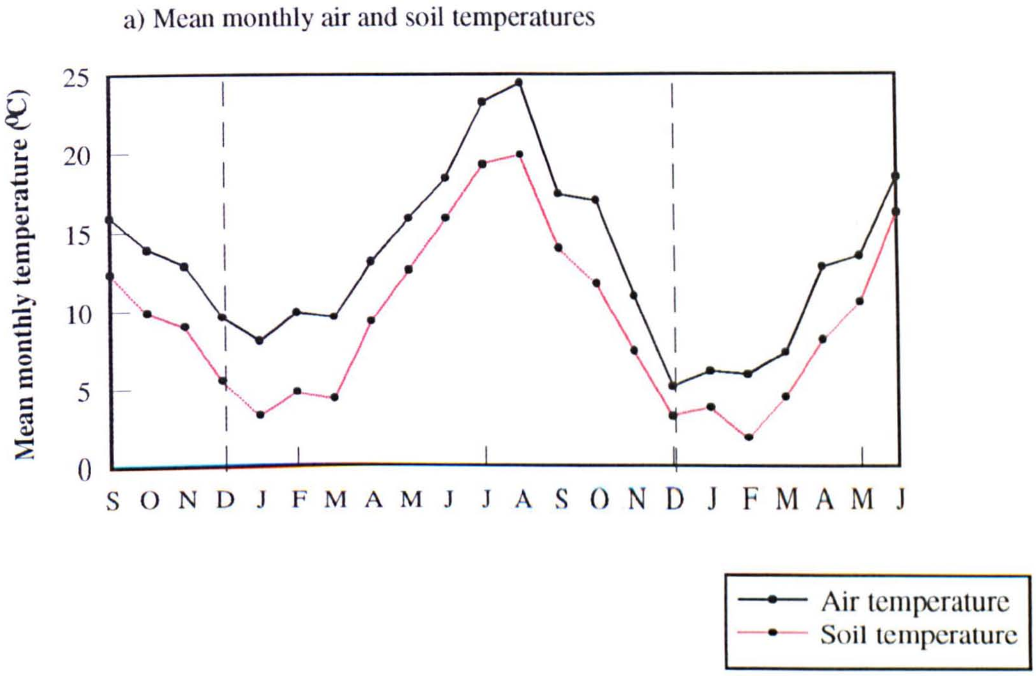

Figure 4.1 a-f Seasonal emergence patterns of rare arable weed species under cultivation and no cultivation regimes

*C. cyanus*, *C. segetum* and *P.rhoeas* all exhibited distinct flushes of germination and establishment in spring and autumn (Figure 4.1). For all three species initial autumn germination (September and October 1994) accounted for a large proportion of the total emergence recorded over the 22 months of the experiment (74%, 65% and 83% for *C. cyanus*, *C. segetum* and *P. rhoeas* respectively). Whilst these three species clearly displayed two annual flushes of emergence, the amplitude and hence, relative importance of these two germination events in terms of seedling recruitment varied significantly (Figure 4.1 and Tables 4.2 to 4.5). Autumn germination of *C. cyanus* was significantly greater ( $P < 0.05$) than for *C. segetum* and *P. rhoeas* (and *M. orontium*), and given these observations this species can be classified as a predominantly autumn germinator. Following the initial flush of autumn germination, the amplitude of cyclic spring and autumn germination events for *C. segetum* is very similar, suggesting that these are equally important for seedling recruitment. Whilst, spring emergence is relatively more important in *P. rhoeas*, both species can be classified as spring and autumn germinators. It should be noted that during the second year of monitoring, *P. rhoeas* exhibited emergence in every month but January, suggesting that it may be a 'year-round' germinator and that climatic conditions from May to August 1995 accounted for its failure during this period. Monthly mean air and soil temperatures and rainfall totals are shown in Figure 4.2.

Very little initial germination was observed for *M. orontium* (1.7%), with 80% of total recorded emergence occurring in the first spring following sowing. Small flushes of germination did occur in the following autumn, but this species can be classified as a predominantly spring germinator.

This experiment also sought to determine the influence of regular soil disturbance on emergence patterns, and on the amplitude of germination events. Cultivation in September 1994 had no overall significant effect on cumulative (September and October 1994) initial germination and emergence (Table 4.2a). Analyses of variance on cumulative emergence between 1st November 1994 and 30th April 1995 and between 1st May 1995 and 30th October 1995 illustrate a significant effect of soil disturbance ( $P < 0.05$) on seedling emergence, and more importantly a significant interaction between cultivation regime and species (Tables 4.3 and 4.4). These results have proved difficult to interpret as analyses were performed on cumulative emergence data and cannot be related to specific cultivation events. For this reason, the influence of soil disturbance on the emergence patterns of the six species is most easily interpreted from Figure 4.1.

The first simulated cultivation, in September 1994, caused a marked reduction in the emergence of *C. segetum* and *B. interruptus* in October 1994, and of *M. orontium* in the following spring. These are species whose germination and establishment are decreased to varying degrees by burial in soil (see section 4.4). Emergence of *A. githago* and *P. rhoeas* in October 1994 was unaffected by soil disturbance at the end of the previous month and appears to be enhanced for *C. cyanus*. Subsequent disturbances bring viable, ungerminated seeds which have been buried by previous cultivations near to the soil surface where they are able to germinate and establish. This



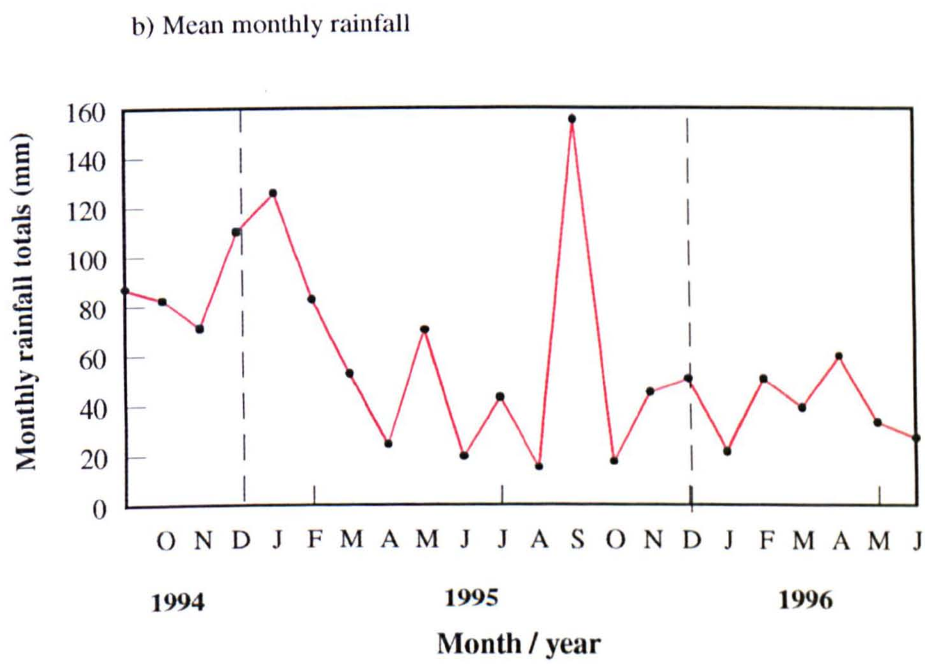




Figure 4.2 a) Mean monthly air and soil (10cm depth) temperatures and b) monthly rainfall totals at Ness Gardens during the duration of the seedling periodicity and longevity field trials

results in elevated emergence for all species possessing persistent seedbanks following soil disturbance events after September 1994 (Figure 4.1).

Table 4.2a Analysis of variance on cumulative numbers of seedlings emerging between **1st September** and **30th October 1994** for six rare arable weed species under two cultivation regimes (No cultivation and one soil 'cultivation' at 30th September 1994) (Significance levels *5%, **1%, ***0.1%)

| **Source** | **DF** | **MS** | **F ratio** | **P (sig level)** |
|---|---|---|---|---|
| Block | 4 | 0.0206 | 3.16 | |
| Species | 5 | 1.1574 | 177.77 | *** |
| Cultivation | 1 | 0.0011 | 0.16 | ns |
| Species*Cultivation | 5 | 0.0093 | 1.42 | ns |
| Error | 44 | 0.0065 | | |

Tables 4.2 b - d Summaries of mean cumulative numbers of seedlings emerging to 30th October 1994 by b) species, c) cultivation regime and d) species and cultivation regime. **sem** = standard error of the mean

b) Species (**sem = 2.25**)

| **Species** | **Mean % emergence** |
|---|---|
| *A. githago* | 93.0 |
| *C.cyanus* | 25.6 |
| *C. segetum* | 16.4 |
| *M.orontium* | 1.8 |
| *P. rhoeas* | 13.0 |
| *B. interruptus* | 55.1 |

c) Cultivation regime

| **Regime** | **Mean % emergence** |
|---|---|
| None | 34.6 |
| Regular | 33.7 |

d) Species x Cultivation regime (**sem = 3.61**)

| **Species** | **Mean % emergence** | |
|---|---|---|
| | **No cultivation** | **Regular cultivation** |
| *A.githago* | 93.2 | 92.8 |
| *C. cyanus* | 24.9 | 26.3 |
| *C. segetum* | 22.6 | 10.3 |
| *M. orontium* | 1.8 | 1.8 |
| *P. rhoeas* | 12.9 | 13.2 |
| *B. interruptus* | 52.1 | 58.1 |

Table 4.3a Analysis of variance on cumulative numbers of seedlings emerging between **1st November 1994** and **30th April 1995** for six rare arable weed species under two cultivation regimes (No cultivation and two soil 'cultivations' at 30/09/94 and 28/02/95) (Significance levels *5%, **1%, ***0.1%)

| **Source** | **DF** | **MS** | **F ratio** | **P (sig level)** |
|---|---|---|---|---|
| Block | 4 | 0.00137 | 0.78 | |
| Species | 3 | 0.13111 | 75.11 | *** |
| Cultivation | 1 | 0.0106 | 6.05 | * |
| Species*Cultivation | 3 | 0.02628 | 15.05 | *** |
| Error | 28 | 0.001745 | | |

Tables 4.3 b - d Summaries of mean cumulative numbers of seedlings emerging from 1st November 1994 to 30th April 1995 by b) species, c) cultivation regime and d) species and cultivation regime

b) Species (sem = **1.32**)

| **Species** | **Mean % emergence** |
|---|---|
| *C.cyanus* | 2.08 |
| *C. segetum* | 2.80 |
| *M.orontium* | 25.63 |
| *P. rhoeas* | 3.37 |

c) Cultivation regime

| **Regime** | **Mean % emergence** |
|---|---|
| None | 10.09 |
| Regular | 6.84 |

d) Species x Cultivation regime (sem = **1.87**)

| **Species** | **Mean % emergence** | |
|---|---|---|
| | **No cultivation** | **Regular cultivation** |
| *C. cyanus* | 1.76 | 2.40 |
| *C. segetum* | 2.20 | 3.40 |
| *M. orontium* | 34.88 | 16.38 |
| *P. rhoeas* | 1.53 | 5.20 |

Table 4.4a Analysis of variance on cumulative numbers of seedlings emerging between **1st May 1995** and **30th October 1995** for six rare arable weed species under two cultivation regimes (No cultivation and four soil 'cultivations' at 30/09/94, 28/02/95, 31/05/95 and 31/08/95)(Significance levels *5%, **1%, ***0.1%)

| **Source** | **DF** | **MS** | **F ratio** | **P (sig level)** |
|---|---|---|---|---|
| Block | 4 | 0.00065 | 1.04 | |
| Species | 3 | 0.00565 | 9.00 | *** |
| Cultivation | 1 | 0.00287 | 4.58 | * |
| Species*Cultivation | 3 | 0.00101 | 1.61 | ns |
| Error | 28 | 0.00063 | | |

Tables 4.4 b - d Summaries of mean cumulative numbers of seedlings emerging from 1st May 1995 to 30th October 1995 by b) species, c) cultivation regime and d) species and cultivation regime

b) Species (sem = **0.79**)

| **Species** | **Mean % emergence** |
|---|---|
| *C.cyanus* | 6.04 |
| *C. segetum* | 3.63 |
| *M.orontium* | 2.50 |
| *P. rhoeas* | 0.33 |

c) Cultivation regime

| **Regime** | **Mean % emergence** |
|---|---|
| None | 2.28 |
| Regular | 3.97 |

d) Species x Cultivation regime (sem = **1.12**)

| **Species** | **Mean % emergence** | |
|---|---|---|
| | **No cultivation** | **Regular cultivation** |
| *C. cyanus* | 4.08 | 8.00 |
| *C. segetum* | 2.20 | 5.07 |
| *M. orontium* | 2.44 | 2.56 |
| *P. rhoeas* | 0.40 | 0.27 |

Table 4.5a Analysis of variance on cumulative numbers of seedlings emerging between **1st November 1995** and **30th June 1996** for six rare arable weed species under two cultivation regimes (No cultivation and six soil 'cultivations' at 30/09/94, 28/02/95, 31/05/95, 31/08/95, 31/12/95 and 30/04/96) (Significance levels *5%, **1%, ***0.1%)

| **Source** | **DF** | **MS** | **F ratio** | **P (sig level)** |
|---|---|---|---|---|
| Block | 4 | 0.00041 | 1.04 | |
| Species | 3 | 0.00041 | 1.04 | ns |
| Cultivation | 1 | 0.00157 | 3.98 | ns |
| Species*Cultivation | 3 | 0.00023 | 0.59 | ns |
| Error | 28 | 0.00039 | | |

Tables 4.5 b - d Summaries of mean cumulative numbers of seedlings emerging from 1st November 1995 to 30th June 1996 by b) species, c) cultivation regime and d) species and cultivation regime

b) Species (sem = 0.63)

| **Species** | **Mean % emergence** |
|---|---|
| *C.cyanus* | 1.72 |
| *C. segetum* | 2.70 |
| *M.orontium* | 1.19 |
| *P. rhoeas* | 1.60 |

c) Cultivation regime

| **Regime** | **Mean % emergence** |
|---|---|
| None | 1.18 |
| Regular | 2.43 |

d) Species x Cultivation regime (sem = 0.89)

| **Species** | **Mean % emergence** | |
|---|---|---|
| | **No cultivation** | **Regular cultivation** |
| *C. cyanus* | 1.04 | 2.40 |
| *C. segetum* | 2.73 | 2.67 |
| *M. orontium* | 0.06 | 2.31 |
| *P. rhoeas* | 0.87 | 2.33 |

### 4.2.4 Discussion

Experiments, similar to that described in this section, where a known number of seeds are mixed with a shallow layer of soil which is then subject to periodic disturbance, have provided valuable data on the seasonal emergence patterns of a wide range of arable weed species (Roberts, 1964 ; Roberts and Feast, 1973 ; Chancellor, 1986 ; Roberts and Neilsen, 1981 ; Froud-Williams *et al*, 1984). The timing of seedling emergence has a critical effect on an individuals ability to capture resources, and on the outcome of subsequent competition with neighbouring plants. In view of this, an appreciation of these seasonal patterns is important, whether the management goal is control or conservation of individual species.

Seasonal emergence patterns in species which possess a persistent seedbank reflect cyclical changes in the dormancy status of seeds (Harper, 1977). These changes are mediated by fluctuations in edaphic and climatic factors which act as stimuli or cues preventing germination during unfavourable periods (Mortimer, 1990 ; Hakansson, 1979). The timing and frequency of soil disturbance may also be an important determinant (Roberts and Potter, 1980 ; Froud-Williams *et al*, 1984 ; Chancellor, 1986), burying seeds at depths from which they are unable to emerge, or bringing them to the surface where light and the greater amplitude of temperature fluctuation is conducive to germination (Wesson and Wareing, 1969).

The occurrence and extent of germination shortly after dissemination (initial germination) depends on the presence, or absence of innate dormancy, and on the existence of the appropriate temperature, light and moisture requirements. In the present experiment, initial emergence (September and October 1994) accounted for 34% of total seeds sown. This figure is considerably greater than the 19% reported in a similar experiment for a range of arable weed species by Roberts and Feast (1973). In their experiment, however, seeds were initially mixed with the top 15cm of soil within pots, as opposed to being surface sown. Inevitably, this will result in burial of a proportion of seeds at depths from which they are unable to germinate and emerge. This difference will account for the greater rates of initial germination observed in the current trial. In both experiments, figures for total emergence mask considerable variation between species ( $P < 0.001$ in the present trial).

93% and 55% initial germination (100% and 97% of total observed emergence) for *A. githago* and *B.interruptus* respectively indicated that these species have very little innate dormancy. Roberts (1986) reported initial and subsequent germination for a number of species from contrasting habitats, and only rarely was the fraction which exhibited 'immediate' germination in excess of 25% (*Crepis capillaris*, 28% ; *Galium mollugo*, 42% and *Sherardia arvensis*, 62%). Thompson (1973) reported that seeds of *A. githago* germinated soon after reaching the soil, provided that there was sufficient moisture, and Firbank (1988) has commented that some seeds which do not reach the soil until late autumn may not emerge until the following spring. Freshly disseminated seed of *B.*

*interruptus* lacked innate dormancy, and was shown by Howard (1991) to be able to germinate over a wide temperature range and at low soil moisture contents. These factors all contribute to its ability to exhibit high levels of synchronous autumn germination following dissemination from the adult plant. Regardless of the broad ecological amplitude of *B. interruptus* for germination, edaphic and climatic factors (soil temperature and monthly rainfall) during September and October 1994 (Figure 4.2) were optimal for promoting optimal germination of all species, with the exception of *M. orontium*. Roberts (1986) classified a range of emergence strategies ; *A. githago* and *B. interruptus* may be categorised in the group of species which exhibit main emergence in the autumn of sowing and have short-lived seeds. Seeds of such species have no innate dormancy and will germinate when rainfall occurs, leaving no persistent seedbank.

The seeds of *C. cyanus, C. segetum, P. rhoeas* and *M. orontium* displayed protracted germination, and by virtue of this, will form persistent seedbanks in the soil. Seasonal patterns of emergence observed for *C. cyanus, C. segetum* and *P. rhoeas* are similar ; all three species exhibited flushes of germination in spring and autumn. However, slight variations in the amplitude and extent of these germination events should be considered in relation to temperature and rainfall patterns. Previous studies of *P. rhoeas* have indicated that this species may have a tendency towards year-round germination (Roberts and Boddrell, 1984 ; Chancellor, 1986), although spring and autumn peaks represent the main periods of seedling recruitment. The ability of a small proportion of seeds to germinate year-round is dependent upon appropriate temperatures, and soil moisture contents, and in the present study a complete absence of seedling emergence corresponded to very warm, dry months in June, July and August 1995. Low soil temperature also considerably reduced emergence. Salisbury (1961) commented that the spring germination event was the most important for *P. rhoeas* recruitment, and evidence from the present study confirms this (Figure 4.1f).

Results obtained for *C. segetum* are widely in agreement with those reported by Chancellor (1986) who observed no emergence in December and January over five seasons, suggesting that dormancy is enforced by low soil temperature during this period. His data indicate spring as the main period for seedling recruitment, with emergence continuing during summer at lower levels and increasing once again to a less pronounced peak in autumn. Summer emergence was not observed in the current trial due to high temperature and very low rainfall during June, July and August 1995, and following the initial flush of germination, peak emergence occurred in Autumn 1995 following heavy rainfall (Figure 4.5). These deviations from previous patterns illustrate the importance of climatic factors in determining emergence events, and would appear to support the assertion that following the spring flush of germination, initiated by rising soil temperature, patterns of rainfall have an over-riding effect on the subsequent distribution of seedling emergence (Roberts and Potter, 1980 ; Vincent and Cavers, 1978).

*C. cyanus* failed to emerge during summer and winter months which corresponded to periods of low rainfall and low temperature respectively. The major emergence event was in autumn, and this species can be classified, according to Roberts (1986), as a species possessing persistent seeds whose emergence occurs mainly in autumn.

In contrast, *M. orontium* displayed a persistent seedbank with emergence mainly in spring. A very few seeds possessed no innate dormancy and germinated in the autumn following sowing, whilst the majority were maintained in the dormant state by cold winter temperatures, dormancy being broken as temperatures rose in spring, resulting in a flush of germination (Figure 4.1e).

Finally, the influence of cultivation on seedling emergence should be considered. Initially, seeds were surface sown to mimic their post-dispersal fate, and the high percentage of initial germination reflects ideal conditions for germination at the soil surface. The first soil disturbance on 30th September 1994 results in the burial of a large proportion of surface sown seeds, and was accompanied by a subsequent reduction in emergence, particularly of small seeded species. Subsequent disturbances resulted in ungerminated seed being returned to, or near to the soil surface and were accompanied by an increase in emergence compared to pots where there was no disturbance. However, in agreement with previous studies it can be concluded that whilst cultivation increases the amplitude of germination events it does not alter the periodicity of emergence, which is governed by temperature and rainfall (Roberts and Potter, 1980 ; Roberts and Feast, 1973 ; Roberts and Boddrell, 1983 ; Froud-Williams *et al*, 1984).

## 4.3 Longevity and Dormancy characteristics of buried seed

This trial was designed to investigate natural rates of seed loss (through processes of germination, death and decay) from populations of buried seeds for five rare arable weed species.

### 4.3.1 Materials and Methods

Thirty-six 30cm x 30cm, by 15cm deep soil pits, arranged in four blocks of nine 'treatments', were excavated at a field site adjacent to the set-aside field trial at Ness Botanic Gardens. A depth of 15cm was chosen to represent the maximum possible depth of burial of seeds following a shallow cultivation. Into each of these pits were placed five 'seed packets' each containing a sample of fifty seeds of one of the following rare weed species : *Agrostemma githago, Centaurea cyanus, Chrysanthemum segetum, Bromus interruptus* or *Misopates orontium*. *Papaver rhoeas* was not included in the experimental design as the seeds are very small, and it proved difficult to contain them within seed packets. Previous literature was available on the longevity characteristics of this species (Robert and Boddrell, 1984 ; McNaughton and Harper, 1964). Soil pits were back-filled with heat sterilised, 10mm sieved loamy soil, and marked with painted canes to aid subsequent location and retrieval.

Two pieces of 200μm nylon gauze were stapled together to produce seed packets, approximately 4cm x 4cm in size (Plate 4.1), into which seeds were placed (seeds were harvested from the 1994 crop and stored as described in section 4.2.1). Staples were coated with Hammerite paint to prevent rusting, and to act as an additional sealant. This method is a slight modification of that employed by Watson (1987), who mounted packets in photographic transparency frames.

Seed packets were buried on 1st September 1994, and were subsequently retrieved from one randomly located pit within each of the four replicate blocks on the last day of each of the following months : November 1994, January 1995, March 1995, May 1995, July 1995, September 1995, December 1995, March 1996 and June 1996. As such the experiment was a fully randomised block design in which treatments were retrieval times.

Retrieved seed packets were opened immediately and an initial assessment made of the number of buried seeds which had germinated. The identification of germinated seed became more difficult as the experiment progressed, and seedlings became impossible to identify due to death and decay. For large seeded species (*C. cyanus, A. githago*), the absence of an embryo (indicating that germination had occurred) was easily detected. A binocular microscope was used for smaller seeded species (*M. orontium, C. segetum*).

Plate 4.1 Nylon gauze 'seed packets' following retrieval from soil pits.

Ungerminated seeds were placed in petri dishes on a double layer of moistened filter paper (Whatman Qualitative No.1) and transferred to a controlled temperature room (20°C). Petri dishes were regularly watered and weekly counts of germination made for 6 weeks. After 6 weeks ungerminated seeds were soaked in 1.44 x $10^{-3}$M giberellic acid for 24 hours (Froud-Williams, 1984) and germination was monitored for a further 2 weeks. Following this, remaining ungerminated seeds were transferred to a cold room (0 °C) for 4 weeks and on removal germination was assessed for a further 2 weeks at 20°C. Finally, any remaining ungerminated seeds were soaked in a 1% solution of Tetrazolium chloride (Moore, 1972) and incubated in the dark for 24 hours. These seeds were subsequently assessed for viability (presence of staining in seed embryo).

## 4.3.2 Analysis of results

Two methods of analysis were applied to data for remaining numbers of viable seeds. An analysis of variance was performed for each species with time of retrieval as the main treatment effect, and regression equations were calculated on the logarithm of numbers of viable seeds remaining against time. The resulting coefficient of regression, **b**, was used to calculate half-lives of seeds as shown below:

$$\text{Half-life} = \frac{\text{Log}_{10} 2}{b} \qquad \text{(Equation 4.2)}$$

### 4.3.3 Results

Seed 'loss' from buried populations occurs via two processes ; germination and death (loss of viability). The relative extent of these two processes in determining the overall rates of decline for the five species studied over 22 months is illustrated in Figure 4.3.

Buried weed seeds were harvested directly from adult plants of the previous growing season, and it was assumed that that the dormancy characteristics of these evenly aged cohorts at time of burial would be identical to those of freshly disseminated seed lots.

The previous experiment illustrated that both *A. githago* and *B. interruptus* are autumn germinating species with no persistent seedbank (a very small proportion (<1%) of *B. interruptus* may persist to germinate and establish in the following spring or autumn - Figure 4.1). The current trial has confirmed this lack of persistence in the soil ; 100 per cent germination occurring within 3 months of

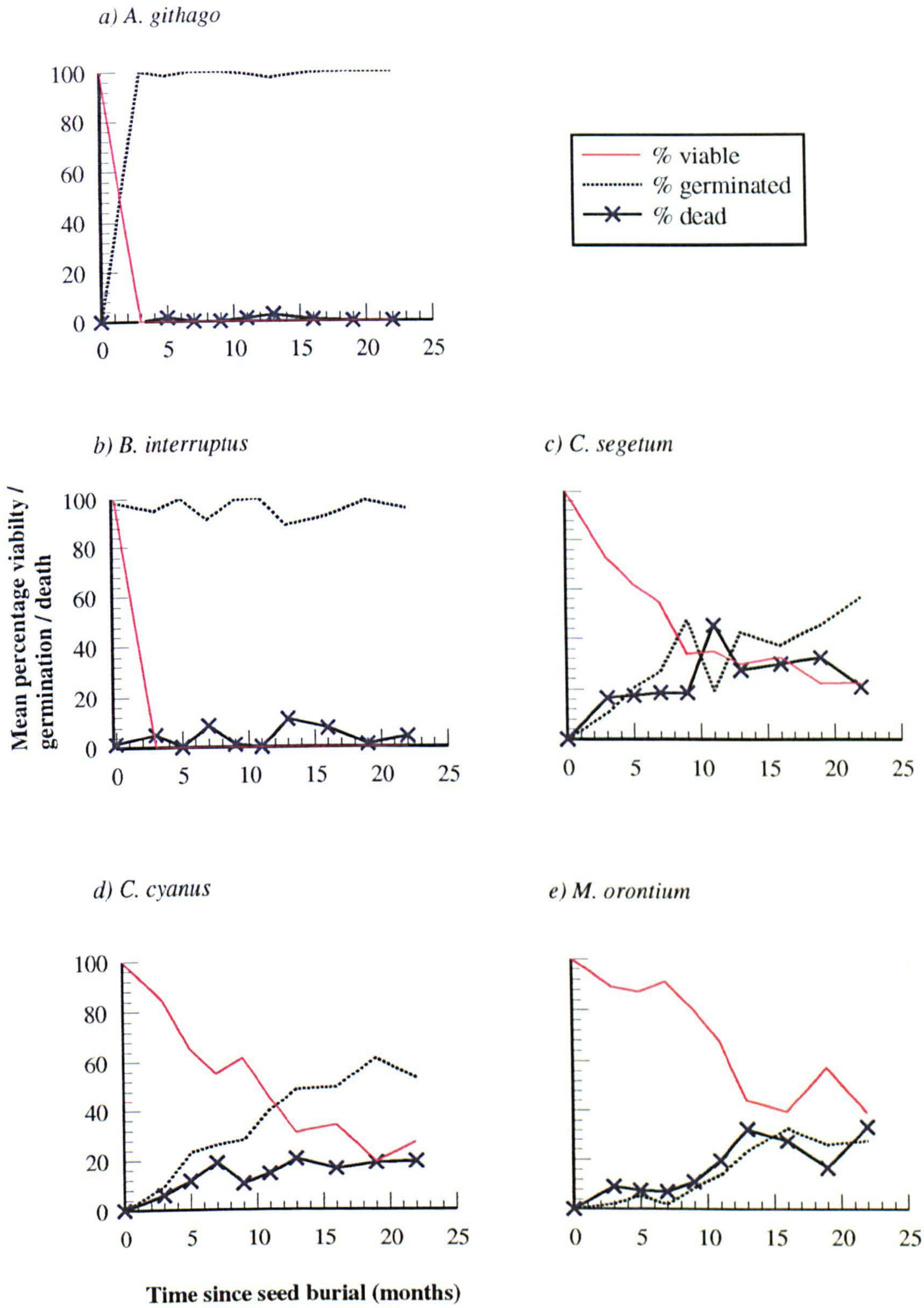



Figure 4.3 Mean percentage death, germination and survival of seeds of rare weed species buried for between 3 and 22 months at 15cm soil depth

burial. Losses due to death were minimal (<10%). The highly seasonal and transient nature of seeds of these two species in the soil precludes a log-linear analysis of seed survival to determine the half-lives of seedbank populations. These species were also not included in the analysis of variance reported in Table 4.6a.

*C. cyanus, C. segetum* and *M. orontium* are able to form persistent soil seedbanks as was demonstrated by their ability to remain viable and ungerminated over two growing seasons when buried at 15cm (Figure 4.3 c-e). Following 22 months of burial, 27, 23 and 39 per cent respectively of even-aged cohorts of *C. cyanus, C.segetum* and *M. orontium* seed remained viable in the soil. The relative contribution of processes of germination and death to overall decline rates varied according to species and season. The extent and temporal patterns of germination and death were very similar for *C. cyanus* and *C. segetum*, with germination representing the major cause of seed loss. *M. orontium* differed, however, with the major cause of loss being death rather than germination (Figure 4.3e). Overall, seasonal patterns of decline were not easily distinguishable, and the assumption of a constant death risk made in the derivation of a log-linear model for rates of seed decline appears reasonable. However, the relative importance of germination and death varied on a seasonal basis. This was most apparent for *C. cyanus* where seasonal patterns of germination, even when seeds were buried, corresponded to those observed in the previous experiment, seed death becoming relatively more important at other times.

An analysis of variance was performed on the number of surviving seeds of the three persistent species over the course of the experiment. Main treatment effects were time of retrieval. The results of this analysis are presented in Tables 4.6 a and b. Significant differences were observed by species and according to the time since burial. The significance of the interaction term confirms the differential rates of decline for these three species.

The log-linear regression models, illustrated in Figure 4.4 have enabled 'half-lives' to be calculated for buried populations of viable seed of *C. cyanus, C. segetum* and *M. orontium.* The goodness of fit of these models, supported by the correlation co-efficients also displayed in Figure 4.4 validate the assumption of a constant death risk. *M. orontium* exhibits the slowest rate of decline, and hence the greatest longevity (half-life - 15.3 months) during soil burial. Rates of decline for *C. cyanus* and *C. segetum* were very similar (half-lives of 9.5 and 9.9 months respectively).

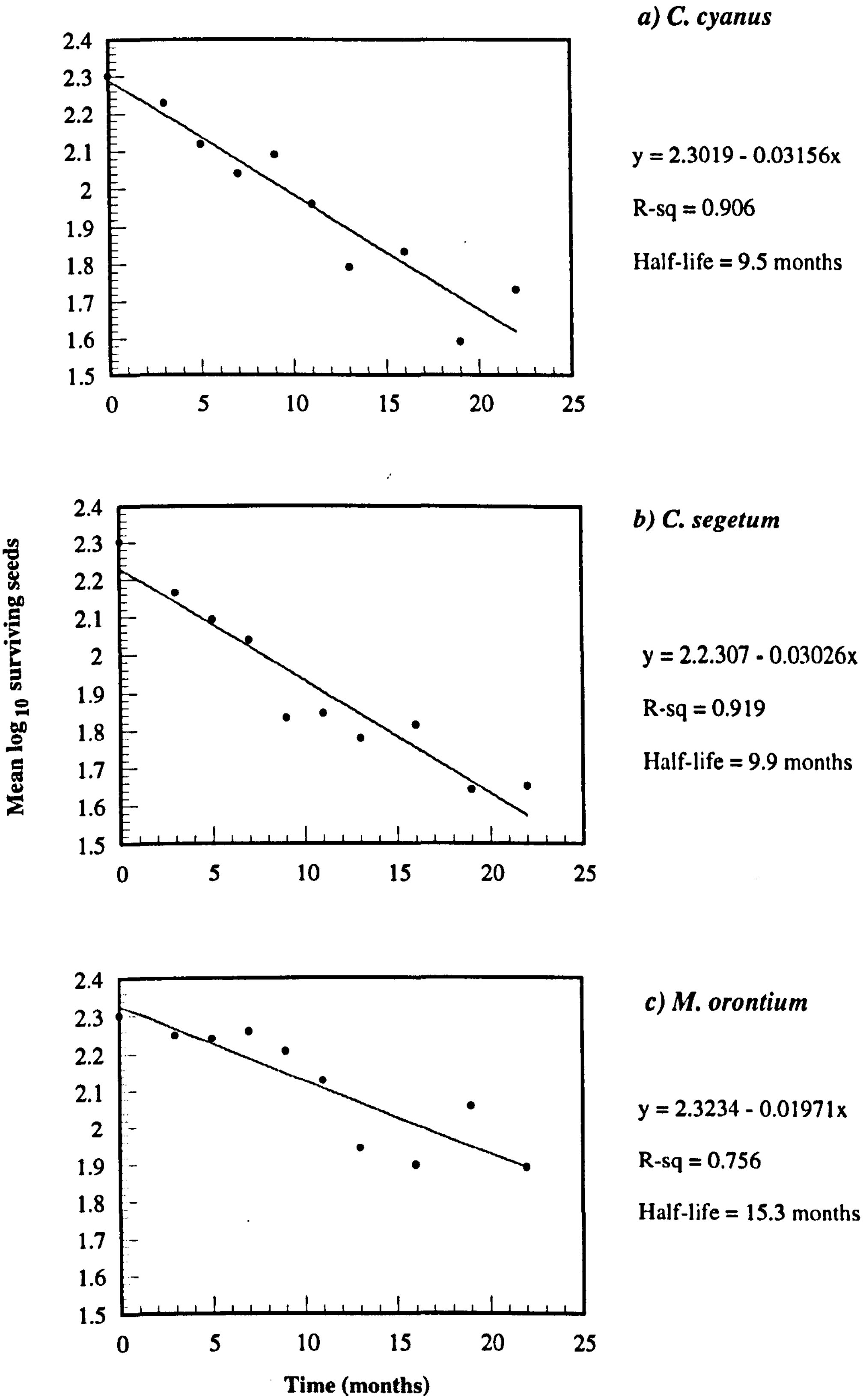



Figure 4.4 a-c Log-linear regression models for survival of populations of buried weed for three rare weed species

Table 4.6a Analysis of variance on percentage of surviving seeds of three rare arable weed species (*C. cyanus, C. segetum* and *M. orontium*) following seed burial for 22 months. Main treatment effects are time of retrieval (Significance levels *5% **1% ***0.1%)

| Source | DF | MS | F ratio | P (sig level) |
|---|---|---|---|---|
| Block | 3 | 21.89 | 0.93 | |
| Species | 2 | 1604.29 | 68.44 | *** |
| Retrieval | 8 | 1124.98 | 47.99 | *** |
| Species*Retrieve | 16 | 66.67 | 2.84 | ** |
| Error | 78 | 23.44 | | |

Table 4.6 b Summaries of mean percentage survival of buried rare arable weed seed at a range of retrieval times.

| | Mean percentage survival | | |
|---|---|---|---|
| **Retrieval time (time since burial)** | *C. cyanus* | *C.segetum* | *M. orontium* |
| Nov 1994 (3 months) | 84.5 | 73.0 | 89.0 |
| Jan 1995 (5 months) | 65.5 | 62.0 | 87.0 |
| March 1995 (7 months) | 55.0 | 54.5 | 91.0 |
| May 1995 (9 months) | 61.5 | 34.0 | 80.5 |
| July 1995 (11 months) | 45.5 | 35.0 | 67.5 |
| Sept 1995 (13 months) | 31.0 | 30.0 | 44.0 |
| Dec 1995 (16 months) | 34.0 | 32.5 | 39.5 |
| Mar 1996 (19 months) | 19.5 | 22.0 | 57.5 |
| June 1996 (22 months) | 27.0 | 22.5 | 39.0 |

### 4.3.4 Discussion

The ability of arable weed species to persist in the seedbank as dormant, but viable seed represents an important life history strategy (Mortimer, 1990) and has been exhibited for a number of weedy and ruderal species (Lewis, 1973 ; Roberts, 1986 ; Roberts and Feast, 1973 ; Chancellor, 1986 ; Roberts and Dawkins, 1967). It has been widely reported that, in the absence of renewal through seed rain, the number of viable seeds in soil declines exponentially with time (Roberts and Feast, 1973 ; Chancellor, 1986 ; Froud-Williams *et al*, 1983), and this phenomenon was exhibited for populations of *C. cyanus, C. segetum* and *M. orontium* buried at 15cm below the soil surface in the current experiment. The mean annual decline rates of these species were 59, 57 and 41% respectively, corresponding to half-lives of 9.5, 9.9 and 15.3 months. In a study of seed longevity under a grass ley Chancellor (1986) reported half-lives for a number of arable weeds ranging from 1.5 years for *C. segetum* to over 20 years for *Fumaria officinalis* and *Aethusa cynapium*, suggesting that seed longevity characteristics exhibited by weed species in the current trial were at the lower range of those typically expected for arable weed species.

Data from the Weed Research Organisation (after Howarth and Williams, 1972), suggested that the maximum longevity for seeds of *C. segetum* in the soil is less than 15 years. Similar data are unavailable for *C. cyanus* and *M. orontium*. In relation to comparative studies on a range of weed species, half-lives measured in the current trial were relatively short (9.9 months for *C. segetum* c.f. 18 months in the study by Chancellor, 1986) and possible explanations for this should be explored. The viability of freshly collected seed was not assessed prior to burial giving rise to the possibility that seed packets contained a proportion of unviable seed, resulting in overestimates of annual decline rates. Whilst this may be considered a potential oversight in experimental design the aim of experiments reported in this chapter was to assess, and quantify processes which determine the post-dispersal fate of seed, and to relate these to above-ground vegetation processes in the field trial reported in the following chapter. To this end, seed 'loss' as a result of an initial absence of viability will be an important determinant of the half-life of the seed population dispersed from adult plants.

Loss of viability within populations of buried seed also occurred via processes of fungal and bacterial infection. When 'retrieved' seeds were placed on moistened filter paper at 20°C, the presence and growth of fungal mycelia on the seed surface indicated fungal infection and usually a loss of viability. Where infection had occurred within a buried seed packet, levels of infection were often considerable resulting in the loss of a high proportion (30 - 40%) of seeds. The proximity and close contact between seeds within packets meant that levels of infection through cross-contamination were greater than when seeds are evenly distributed through the soil and may, in part, have accounted for higher than expected decline rates.

It should be noted, however, that other potential sources of post-dispersal loss have been excluded by the experimental design. Predation on the soil surface by birds and small mammals was prevented by immediate burial of seeds, and ingestion by soil invertebrates, such as earthworms, was obstructed by enclosure in seed packets.

A number of studies have demonstrated the relationship between seed longevity, depth of burial and the frequency and timing of soil disturbances (Roberts and Feast, 1973 ; Watson, 1987 ; Froud-Williams *et al*, 1984 ; Chancellor, 1986 ; Roberts and Boddrell, 1984). In a similar experiment to that described above, Watson (1987) found that losses of *Senecio vulgaris* seed were greater at 1cm than at 7cm. Roberts and Feast (1973) compared the rate of loss of viable seeds in cultivated and undisturbed soils and found that the mean annual percentage loss of arable weed seeds was 32% and 12% respectively, representing half-lives of 2.2 and 5.8 years. The effect of depth of burial on field longevity was not investigated in this trial ; a single depth (15cm) was chosen to represent the maximum possible depth of burial following shallow cultivation in the field trials. The effects of soil disturbance and depth of burial are reported separately in this chapter (sections 4.2 and 4.4 respectively).

## 4.4 Seedling Emergence from Depth

This glasshouse trial was designed to investigate the ability of rare arable weed species to germinate and establish from a range of soil depths.

### 4.4.1 Materials and Methods

Seeds of five arable weed species (*A. githago, C. cyanus, C. segetum, B. interruptus* and *M. orontium*) were sown at a range of depths within plastic plant pots (19cm diameter, 30cm depth) in a controlled glasshouse environment. Prior to sowing, seed stocks were tested for germinability. Two samples of 500 seeds were counted for each species. One of these samples was soaked for 36 hours in a 1% solution of giberellic acid in an attempt to 'break' dormancy and increase the germinability of seed stocks. The two seed samples were then placed on moistened filter paper (Whatman Qualitative No.1) in petri dishes and germination counts were made every day for two weeks. Percentage germinability for seed stocks is shown in Table 4.7 below.

Table 4.7 Percentage germination for treated and untreated seed samples and seeds sown per pot (species marked * were treated with giberellic acid before sowing/burial)

[1] - seeds sown per pot calculated as 25/germinability of seed stock i.e. *A.githago* : 35/0.84 = 30

| | Untreated | Giberellic acid | **Seeds sown per pot[1]** |
|---|---|---|---|
| | Germinability (%) | | (25 viable seeds) |
| *A. githago* | <u>84</u> | 91 | **30** |
| *C. cyanus** | 56 | <u>86</u> | **29** |
| *C. segetum** | 9 | <u>42</u> | **60** |
| *M. orontium** | 13 | <u>99</u> | **25** |
| *B. interruptus* | <u>100</u> | 99 | **25** |

25 **germinable** seeds of each species were sown at four depths ; 5mm, 50mm, 100mm and 150mm. Plant pots were filled to the appropriate level with a 10mm sieved sandy loam soil (from Ness Gardens) and seeds were sown on the soil surface. Pots were subsequently filled to a uniform level and regularly watered from below to ensure that seeds were not washed through the soil. Three replicates of each species/depth combination were sown and arranged as a randomised block design on benches in the glasshouse.

Monitoring was conducted at approximately weekly intervals for the first six weeks of the trial. One further count was made ten weeks after sowing. At each monitoring the number of emerging seedlings was counted and these were removed. No further emergence occurred after ten weeks.

## 4.4.2 Analysis of results

An analysis of variance was performed on final cumulative emergence counts (70 days). As no emergence had occurred for any species at the 150mm burial depth this treatment was excluded from the analysis. Graphs have been plotted of mean percentage emergence at various monitoring intervals for the three sowing depths (Figure 4.5), and enable the effect of burial depth on timing of seedling emergence to be assessed.

### 4.4.3 Results

An analysis of variance, performed on cumulative seedling emergence, 70 days after 'seed sowing' has confirmed the significant effect of burial depth on subsequent seedling emergence ( $P < 0.001$), and the differential ability of the five rare weed species studied to emerge from a range of soil depths ( $P < 0.001$, Table 4.9). Patterns of emergence over the course of the experiment, and final emergence totals are illustrated in Figure 4.5 a-e. No emergence occurred for any of the species from the 150mm planting depth.

The relatively large seeded species, *A. githago*, *C. cyanus* and *B. interruptus* all exhibited an ability to emerge from the 100mm sowing depth, although mean percentage emergence from this depth varied significantly ($LSD_{P,\ 0.05}$ = 13.49). 100 per cent emergence of *A. githago* was achieved from 5mm, 50mm and 100mm, whilst emergence of *C. cyanus* and *B. interruptus* was significantly reduced at the 100mm planting depth (Figure 4.5). No emergence of the smaller seeded species *C. segetum* and *M. orontium* was observed at depths greater than 5mm.

A comparison of the curves in Figure 4.5 suggests that planting depth has little effect on the time taken to achieve maximum emergence for *A. githago* and *C. cyanus*, whilst for *B. interruptus* 100 per cent emergence from 50mm is achieved at 35 days, compared to 28 days at 5mm.

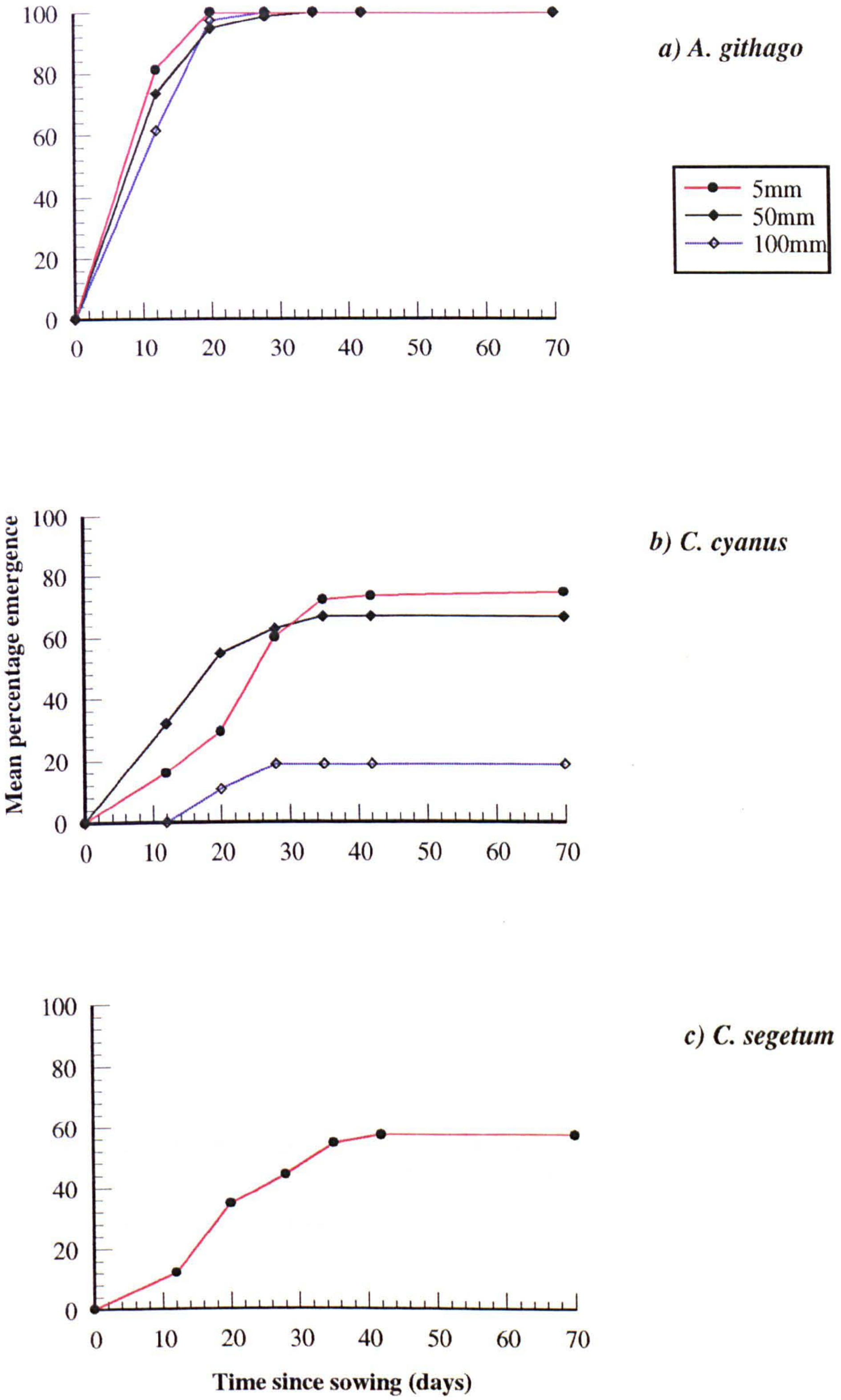
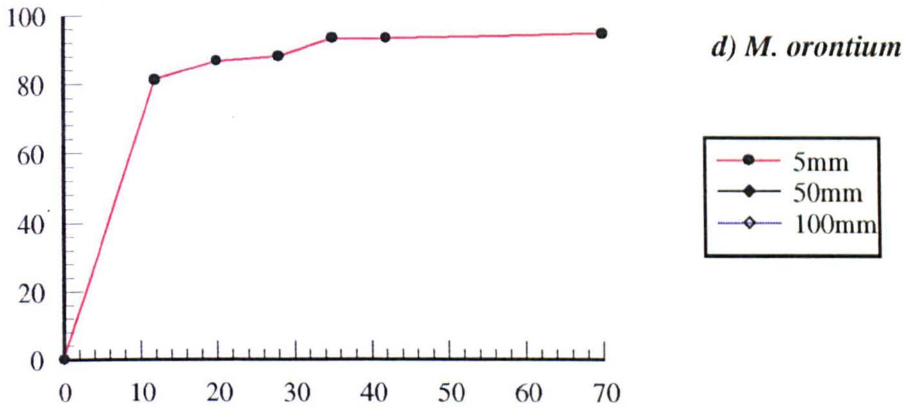



Figure 4.5 a-e Mean percentage seedling emergence over 70 days for five rare arable weed species at three sowing depths, 5mm, 50mm and 100mm.

**Tukey's LSD (P, 0.05) = 13.49**



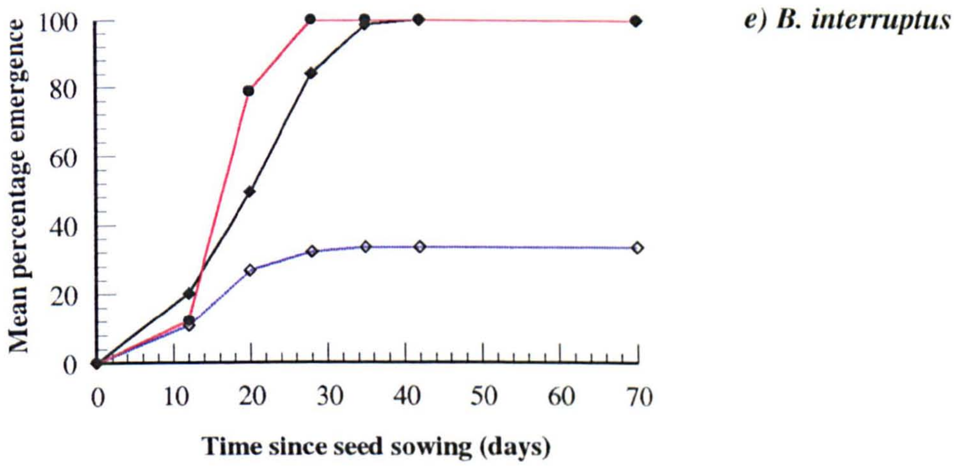




Figure 4.5 a - e Mean percentage seedling emergence over 70 days for five rare arable weed species at three sowing depths, 5mm, 50mm and 100mm.

**Tukey's LSD (P, 0.05) = 13.49**

Table 4.8a Analysis of variance on total numbers of seedlings emerging after 70 days from three sowing depths (significance levels - * 5%, **1% and ***0.1%)

| Source | DF | MS | F ratio | P (sig level) |
|---|---|---|---|---|
| Block | 2 | 201.60 | 2.30 | |
| Species | 4 | 9730.6 | 110.96 | *** |
| Depth | 2 | 5943.5 | 67.77 | *** |
| Species*Cultivation | 8 | 1579.5 | 18.01 | *** |
| Error | 28 | 87.70 | | |

Tables 4.8b - d Summaries of mean total seedling emergence after 70 days by b) species, c) depth of burial and d) species and depth of burial **Tukey's LSD$_{(P = 0.05)}$ = 13.49**

b) Species

| **Species** | **Mean % emergence** |
|---|---|
| *A. githago* | 97.3 |
| *C.cyanus* | 31.6 |
| *C. segetum* | 11.6 |
| *M.orontium* | 28.9 |
| *B. interruptus* | 50.7 |

c) Depth of burial

| **Regime** | **Mean % emergence** |
|---|---|
| 5mm | 65.9 |
| 50mm | 39.2 |
| 100mm | 26.9 |

d) Species x depth of burial

| | **Mean % emergence** | | |
|---|---|---|---|
| | 5mm | 50mm | 100mm |
| *A. githago* | 100.0 | 94.7 | 97.3 |
| *C. cyanus* | 29.3 | 54.7 | 10.7 |
| *C. segetum* | 34.7 | 0.0 | 0.0 |
| *M. orontium* | 86.7 | 0.0 | 0.0 |
| *B. interruptus* | 78.7 | 46.7 | 26.7 |

### 4.4.4 Discussion

An appreciation of the differential ability of weed seeds to germinate and emerge from various soil depths is fundamental to any attempt to relate variations in above ground population densities to differences in cultivation regime. Increases, since the mid 1970s, in the uptake of minimal cultivation systems for cereal production (Froud-Williams *et al.*, 1984) have coincided with changes in the weed flora. Pollard *et al.* (1982) observed an increased occurrence of *Alopecurus myosuroides* under minimal tillage regimes, whereas *Stellaria media* and *Papaver rhoeas* were favoured by frequent cultivations. *Bromus sterilis* has become more widespread under minimal tillage (Cussans, 1976 ; Froud-Williams *et al.*, 1980), this increase being largely due to the inability of seeds of this species to emerge from depth (Froud-Williams, 1981 ; Howard, 1991).

Froud-Williams *et al.* (1984) reported maximum and optimum depths of emergence for a range of monocotyledenous and dicotyledenous weed species. Few dicotyledenous species were capable of emerging from depths in excess of 50mm, and in common with the present study, they found that the emergence of small seeded species was greatly reduced or completely precluded by burial. Small seeded species utilise a greater proportion of their food reserves during germination (Hakansson, 1979), and as a result are capable of less heterotrophic growth prior to emergence and the commencement of photosynthesis by cotyledons. Chancellor (1964) suggests that the emergence of large seeded species from a range of depths is also indicative of their less exacting germination requirements, and this may certainly be the case for *A. githago* and *B. interruptus* which exhibit no seed persistence and a wide environmental amplitude for germination (sections 4.2 and 4.3).

A planting depth of 100mm corresponds to a maximum likely depth of burial of weed seeds following the shallow depth (circa 100mm) cultivation regime adopted in the field trial described in the following chapter. Considering results obtained in this experiment, burial of a proportion of *A. githago* seeds following cultivation will have no effect on the subsequent recruitment of this species to the above-ground flora, populations of *C. cyanus* and *B. interruptus* will be proportionately reduced, whilst populations of the small seeded species *C. segetum* and *M. orontium* will be recruited from seeds buried at less than 50mm. *P. rhoeas* was not included in the current trial, but comparable experiments have shown the optimal depth of emergence for this species to be between 5 and 10mm, with no emergence occurring at depths greater than 20mm (Froud-Williams *et al.*, 1984). Optimum and maximum depths of emergence are given in Table 4.9 below :

Table 4.9 Optimum and maximum depths of emergence for five rare arable weed species.

| Species | Maximum depth of emergence (mm) | Optimum depth of emergence (mm) |
|---|---|---|
| *A. githago* | 100 | 0 - 100 |
| *C. cyanus* | 100 | 50 |
| *C. segetum* | 5 | 5 |
| *B. interruptus* | 100 | 0 - 50 |
| *M. orontium* | 5 | 5 |

## 4.5 General Discussion

The importance of seedbank dynamics and autecological characteristics in determining a general life-history strategy for annual weed species, and also in relation to soil cultivation and management events, and subsequent competitive processes have been discussed. The glasshouse and field experimentation reported in this chapter has investigated some of these characteristics for six rare arable weed species which will be introduced to set-aside land in large-scale field trials. Table 4.11 summarises these results.

A broad distinction between the species can be made in relation to the presence or absence of a persistent seedbank (Grime, 1979). The seeds of *A. githago* and *B. interruptus* exhibit no dormancy mechanisms, and hence do not form a persistent seedbank. Freshly disseminated seed displays synchronous germination in the autumn following dispersal, and these species possess a wide environmental amplitude for germination. Buried seed is able to germinate and emerge from depths of up to, and possibly exceeding 100mm (but not from 150mm). These species exhibit a life history strategy which enables them to rapidly colonise bare or freshly cultivated land, however, the lack of a reserve of viable, but ungerminated seeds makes them liable to complete eradication from weed communities in the event of catastrophic disturbances such as post-emergence cultivation or herbicide application.

The remaining four species do exhibit mechanisms of dormancy, and as such are able to form persistent seedbanks in the soil. Seasonal patterns of emergence vary somewhat between species - *C. cyanus* is a predominantly autumn germinator, whilst *M. orontium* germinates almost exclusively in spring, and *P. rhoeas* and *C. segetum* exhibit flushes of germination in both spring and autumn. The ability to exhibit protracted germination constitutes an important adaptive strategy for long-term persistence of weedy species (Mortimer, 1990) and enables seeds to avoid periods which are unfavourable for germination. Long-term eradication of these species from weed communities is more difficult to achieve, but conversely these species are less capable of rapidly colonising areas of bare ground and as such may be out-competed by species possessing more aggressive strategies. *C. segetum, M. orontium* and *P. rhoeas* are small seeded species and consequently may become buried at depths from which they are unable to emerge. In consequence, these species require regular soil disturbance to return them to the soil surface from where they are able to germinate and establish.

The observations reported in this chapter will have important implications for the management of communities of rare arable weeds on set-aside land. Those species which do not exhibit persistent seedbanks (*A. githago* and *B. interruptus*) will be present in the above-ground flora only, whereas persistent species may survive unfavourable conditions as dormant, but viable seeds. Shallow depth cultivations will result in the burial of a proportion of seeds of some species (*P. rhoeas*, *C. segetum* and *M. orontium*) at depths from which they will be unable to emerge, and the timing of cultivations will be critical in determining patterns of seedling recruitment in the field. These autecological characteristics will be important determinants of results obtained in the field trial described in the following chapter and will aid interpretation of above-ground vegetation processes.

Table 4.10 A table to summarise the seedbank and autecological characteristics of six arable weed species as determined by field and glasshouse experimentation

| **Species** | **Seedbank** | **Periodicity of seedling emergence** | **Initial % germination of 'fresh' seed** | **Total % germination (after 22 months)** | **Seed longevity (half - life)** | **Maximum/*optimum* depth of emergence** |
|---|---|---|---|---|---|---|
| *A. githago* | Transient | Germination entirely in autumn | 93.0 | 93.1 | no soil persistence | 100mm<br>*100mm* |
| *C. cyanus* | Persistent | Germination in spring and autumn | 25.6 | 35.4 | 9.5 months | 100mm<br>*50mm* |
| *C. segetum* | Persistent | Germination in spring and autumn | 16.4 | 25.6 | 9.9 months | 5mm<br>*5mm* |
| *B. interruptus* | Transient | Germination entirely in autumn | 55.1 | 56.9 | no persistence | 100mm<br>*0-50mm* |
| *P. rhoeas* | Persistent | Germination in spring and autumn | 13.0 | 18.3 | no data | 5-10mm<br>*20mm* |
| M. orontium | Persistent | Germination almost entirely in spring | 1.8 | 31.1 | 15.3 months | 5mm<br>*5mm* |

# *Chapter 5*

## *A Large-scale Field Trial to Determine Management Strategies for the Establishment of Persistent, Diverse and Stable Communities of Rare Arable Weeds on set-aside Land*

## 5.1 Introduction

### 5.1.1 Plant populations and communities - a conceptual framework

Before embarking on a more detailed consideration of the processes and factors which combine to determine plant community structure, a few definitions are offered. A plant population is defined as all individuals of a single plant species within a given area, whilst a plant community consists of all individuals of all species within that area. Clearly, these definitions lead to the conclusion that a plant community is an assemblage of all of the plant populations within a given area.. Defining this 'given area' is not always easy and is often, by necessity, arbitrary. In experimental situations, populations and communities may be defined by the boundaries of the experimental plot, whereas in more 'natural' situations, communities occupy discrete geographical areas.

Despite the very clear relationship between plant populations and plant communities, plant population ecology and plant community ecology have evolved into discrete disciplines within the field of plant ecology, and ultimately ask different questions. Population ecology is "the study of the sizes ( and to a lesser extent the distributions) of plant and animal populations, and of the processes - particularly the biological processes - which determine these sizes" (Begon and Mortimer, 1981). As such it concerns itself with the rates and timing of births, deaths, emigrations and immigrations (population dynamics), the relationship between density and population growth and the regulation of population size. Plant community ecology seeks answers to questions relating to species composition and diversity, niche relationships and changes in community structure through time.

In conclusion, despite some recent advances in community theory, the observation by Gray *et al.* (1987) remains largely true today ;

> "Predicting structural patterns of communities from the population dynamics of the constituent species clearly remains a vital unsolved problem"

### 5.1.2 Plant population dynamics and population regulation

The dynamic processes which ultimately regulate plant population size can be considered in two phases. Firstly, those which occur at, or below the soil surface and regulate the relative abundance of individual species within the soil seedbank (seedbank dynamics), and hence the probability of that species occupying a 'safe site' for germination and establishment. These were discussed in the introduction to the previous chapter. Secondly, there are those which regulate the density of individuals within above-ground populations. These will be discussed briefly here in recognition of their undoubted influence on resulting community structure.

When plants grow in close proximity, the presence of one plant will inevitably alter the environment of its neighbours, and may, as a result of density dependent and independent factors change their growth rate and form (Harper, 1977). Such changes in the immediate environment of neighbouring plants are termed 'interference'. Ecologists have been interested in the interactions between competing species since the beginning of the present century and before (Darwin, 1859 ; Tansley, 1917 ; Clements, 1929 ; Gause, 1934), however, much of our understanding of the effects of density on individuals and populations was gained through experimental studies on monocultures in the 1950s and 1960s (Donald, 1951 ; Kira *et al*, 1953 ; Shinozaki and Kira, 1956 ; Harper, 1961 ; Yoda *et al*, 1963).

Individual plants within a population may respond to density in two ways. Phenotypic adjustment may result in a plastic growth response, so that increases in density reduce the yield of component plant parts, and in particular reproductive structures (Clements *et al.*, 1929 ; Hodgson and Blackman, 1957 ; Harper, 1961 ; Shinozaki and Kira, 1961). Ultimately this response results in density dependent fecundity. At the same time individuals may respond to increasing density by dying. This density dependent mortality is often referred to as 'self thinning' (for a review, see Harper, 1977). Often, the first response of individuals within a population is a reduction in the growth rate, density dependent mortality only occurs at a later stage as individuals become larger and interference becomes more intense, or where initial establishment densities are greater (Cousens and Mortimer, 1995). Comprehensive reviews of the inter-relationship between density dependent mortality and plastic growth have been produced by White (1980) and Lonsdale (1990).

To date, this discussion of plant population dynamics has been restricted to losses which result from intrinsic (density-dependent) factors. In a constant, invariant environment these alone will regulate population densities, however, in practice the environment of an actively growing plant population is rarely so constant. A number of extrinsic (density-independent) factors will also influence population densities. These include the effects of agricultural management practices such as cultivation, crop sowing date and sowing density, fertiliser and herbicide application and seed cleaning, weather conditions will also be important, as will interactions with other organisms including herbivores and pests and diseases (these effects may be density dependent). Cousens and Mortimer (1995) present a comprehensive review of the influence of these extrinsic factors on weed populations.

Given knowledge of the effects of, and interactions between these intrinsic and extrinsic regulators of population density, it is possible to develop models which predict the trajectory of weed populations, and to base weed control strategies on these models (Cousens and Mortimer, 1995). The trajectory of a weed population describes the path which population density will follow over time, or over successive generations. It can be described in terms of the rate of population increase (λ) over successive years or generations, and is calculated as $N_{t+1} / N_t$ . In theory, during the early stages of development of a weed population, when densities are low and interference between individuals negligible, the population density will increase at a constant rate, described as the finite rate of population increase, R, for that species within that environment. As population density continues to increase, interference becomes more intense and the rate of increase declines until gains to the population through reproduction are completely compensated by losses as a result of mortality (λ = 1). At this point, the population has reached it's upper density limit, a point referred to as the equilibrium level of the species ($N_e$) or the carrying capacity of the habitat. In practice, however, it could be argued that this situation rarely occurs ; emerging weed populations compete with other weed species and with the crop for space, and the finite rate of population increase is not achieved.

Most studies of the relationship between density and yield report the effects in terms of changes in mean plant weight. This is somewhat misleading, suggesting that all individuals within a population respond in an identical manner to increases in density, when in fact considerable plant to plant variation exists (Obeid *et al.*, 1967 ; Harper, 1977). As a population develops and responds to density, the frequency distribution of plant weights becomes skewed so that a 'dominance hierarchy', with a few large dominants and a large number of suppressed 'weaklings', develops. The driving force behind these 'hierarchies of resource capture' (Harper, 1977) are the initial advantages (Wilson, 1988) conferred to individuals largely as a result of differences in emergence time (Ross and Harper, 1972). It is generally agreed that greater relative size in developing seedling populations confers a competitive advantage, and that this initial advantage becomes compounded as competition intensifies.

> "The advantage which an early emerging seedling gains is far greater than can be accounted for merely by the greater time which it has been allowed to grow" (Harper, 1977)

This phenomenon has been variously referred to as 'asymmetric competition' (Begon, 1984 ; Weiner and Thomas, 1986 ; Hara, 1993), 'one-sided competition' (Firbank and Watkinson, 1987), 'dominance and suppression' (Turner and Rabinowitz, 1983 ; Schmitt *et al*, 1986) and 'snowball cumulation' (Wilson, 1988), and has been reported in intraspecific (Black and Wilkinson, 1963 ; Ross and Harper, 1972 ; Fowler, 1984) and interspecific (Gupta and Tripathi, 1979 ; Van Baalen *et al*, 1984) competition studies.

### 5.1.3 Plant community theory

Central to the study of plant community dynamics, and to attempts to establish assembly rules (Lawton, 1987) for plant communities, are questions relating to the ability of plant species to co-exist in what appear to be relatively homogenous habitats. The competitive exclusion principle (Gause,

1934) states that within a mixture of species, the species which is the best competitor will ultimately exclude all others. However, in plant communities this is clearly not the case and any theory to explain plant community structure must demonstrate how competitive exclusion is avoided.

By necessity, detailed experimental studies have been restricted to examining the outcome of competitive interactions within artificial 'communities' of two, or at most a few species. Such mixtures operate at a level of organisation intermediate between populations and most natural communities and are simple enough to be analysed by the methods employed by population ecologists. Comprehensive reviews of this research are presented by Harper (1977) and Silvertown and Doust (1993).

Theories which attempt to explain patterns of species diversity and co-existence in naturally occurring plant communities, some of which are complementary, others exclusive, have abounded in the last two decades, and have been the subject of a number of recent reviews (Wilson, 1990 ; Zobel, 1992 ; Bengtsson, Fagerstrom and Rydin, 1994). Some of the best documented are introduced and discussed below.

The niche differentiation concept (May and MacArthur, 1972 ; Levin, 1974 ; Tilman, 1982, 1986 ; Ricklefs, 1977) assumes spatial heterogeneity so that the habitat is not uniform. Classical processes of competitive exclusion, it is postulated, operate within these microhabitats to give the impression of co-existence in the habitat as a whole. The non-equilibrium concept (Pickett, 1980 ; Miller, 1982) operates within a framework of temporal variations in the environment. These variations are brought about by disturbances (cultivation, herbivory, cutting, herbicides) which favour less competitive species, and result in the co-existence of species with different competitive abilities. Another theory (Grime, 1979), explains the greater species diversity observed within stressed compared to fertile environments in terms of reduced competition in stressful environments, whilst other authors (Taylor *et al*, 1990 ; Wilson and Tilman, 1991) argue that plant competition is independent of site fertility.

The concept of balanced competition (Aarssen, 1983, 1989 ; Epp and Aarssen, 1989 ; Goldberg and Werner, 1983) relies on the assumption that competitive abilities converge as a result of natural selection. The regeneration niche concept (Grubb, 1977) states that species with similar ecological characteristics coexist in a limited space through differential regeneration in small gaps which as act as regeneration niches. Shmida and co-workers have stressed the importance of seed migration into plant communities from surrounding habitats. Their seed re-immigration concept (Shmida and Ellner, 1984 ; Shmida and Wilson, 1985) assumes that seed import contributes to species diversity by increasing the relative population sizes of less competitive species. Finally, mention should be given to the species-pool hypothesis of Taylor *et al.* (1990) which claims that the number of species within a community is determined by the commonness of that habitat type and by the geological age of the region in question.

Clearly, the diversity of many natural plant communities, and observed patterns of species co-existence cannot be explained in terms of classical concepts of plant competition alone. Species co-existence is determined by processes which operate over a range of spatial and temporal scales. These may be summarised as ecological, evolutionary and historical (Zobel, 1994). The physiological tolerances which permit species to survive in particular habitats, and individual traits which convey competitive ability are determined evolutionarily. The presence of a species and the number of species present in a species-pool is determined by migratory processes and is ultimately determined by historical factors. Environmental factors which influence habitat conditions operate on an ecological level. The various concepts and hypotheses introduced above reflect all of these, and their relative importance will vary according to particular circumstances and conditions.

To conclude, a statement by Bengtsson *et al.* (1994) neatly summarises the current extent of our understanding of species co-existence in the light of recent advances ;

> "Whereas classical competition theory predicts competitive exclusion of species with similar requirements, recent ideas stress that species diversity may be explained by a multitude of processes acting at different levels, and that similarities in competitive abilities often may facilitate coexistence"

### 5.1.4 Field margins - integrating agriculture and conservation

Field margins and their associated landscape features, have, for the last four decades, occupied a central position in the conflict between intensive agriculture and nature conservation. Representing, as they often do, the interface between the intensively farmed agricultural landscape and the wider countryside, field margins in their various forms, harbour, and act as a reservoir for a diverse range of common and less common plant and animal wildlife. As such they should be viewed as a valuable biological resource on farmland which presents an ideal opportunity for attempts to foster a more harmonious relationship between agricultural production and nature conservation.

The widespread loss of hedgerows from the landscape has been well documented (Barr *et al.*, 1993), however, these alone form only part of the field margin habitat. The 'boundary' encompasses the physical barrier, such as hedge, fence or wall which demarcates the field, and also the hedge bank, if present, and it's associated vegetation together with any water courses including ditches and drains. The 'boundary strip' is the area of ground between the boundary and the crop, it may comprise a farm track, grass strip, or cultivated sterile strip. The 'crop edge' generally includes the headland which is the zone within which agricultural machinery turns (Greig-Smith, 1986).

If managed appropriately, the field margin 'habitat' can act as a refuge for a wide range of plant and animal species including invertebrates (Morris and Webb, 1987 ; Dover, 1994 ; Jepson, 1994), rare arable weeds (Wilson, 1990, 1994 ; Schumacher, 1987), small mammals (Tew, Todd and MacDonald, 1994), birds (O'Connor, 1987 ; Lakhani, 1994), and in particular gamebirds (Sotherton and Rands, 1987 ; Aebischer, Blake and Boatman, 1994).

It is this potential benefit to gamebirds which has stimulated some of the most novel approaches to the management of field margins, which is encompassed in the Game Conservancy's "conservation headland technique" (Boatman and Sotherton, 1988). Many gamebirds nest almost entirely within field boundaries, their chicks preferring to feed within the crop edge or 'headland'. Modified pesticide regimes permit the growth of broadleaved weeds within the outer 6m of arable crops, which in turn encourage the presence of associated insects which are the food source for nesting chicks. The conservation headland technique has not only resulted in consistent increases in the survival of chicks of grey partridge and pheasant (Rands and Sotherton, 1987), but also in considerable benefits to certain groups of insects, and of greater relevance to this study has led to the reappearance of many rare arable weed species (Boatman and Sotherton, 1988).

As a result of these observations the Game Conservancy initiated "the Wildflower Project" (Wilson, 1990, 1992, 1993, 1994) which sought to determine the ecology and conservation biology of these rare arable weeds, and to make recommendations for their conservation. Previous studies have indicated that crop edges are the areas of greatest botanical interest within arable fields (Marshall, 1989), and a survey of the occurrence of emerging seedlings and of the seed content of soil cores by Wilson (1989) confirmed this pattern of distribution for a range of rare arable weeds.

The work reported in this chapter aims to establish management guidelines for the establishment of diverse and persistent communities of rare arable weeds on set-aside land. The widespread decline and current status of these species was discussed in chapter 1, and set-aside land presents an excellent opportunity for their reintroduction, or alternatively for the management of existing populations and communities. This potential has been acknowledged by MAFF in their booklet "How to manage your set-aside land for specific environmental objectives" (MAFF, 1996c).

Set-aside land is subject to a range of management restrictions (MAFF, 1996d, 1997). Where this land is being managed in order to achieve environmental or conservation benefits, certain activities or management practices may be necessary which would not normally be permitted. Where this is the case farmers must apply for a written exemption from their Regional Service Centre. MAFF states that :

> "We will normally expect any request for an exemption for environmental reasons to be supported by a suitable environmental organisation and you will strengthen your case for exemption by seeking professional advice from such an organisation and by demonstrating potential environmental benefits" (MAFF, 1996c)

The range of management practices employed in this trial (section 5.2.3) were, as far as possible, selected in order to avoid this cumbersome procedure.

## 5.2 Materials and Methods

### 5.2.1 The Field Site

The set-aside field trial was conducted on experimental land at the University of Liverpool's Botanic Gardens (Ness, South Wirral). The experimental area was enclosed on three sides by hedgerows, and on the fourth side by a polythene tunnel, resulting in a self-contained and well sheltered field site. Field dimensions were approximately 60 x 55 metres (total area - 3,300m$^2$, 0.33ha). The site has been used to conduct a range of agroecological experimentation over the past 20 years, and as such, has a history of frequent cultivation, crop and weed production and agrochemical and fertiliser application. Immediately prior to the establishment of this trial the field had been idle for a period of 12 months, and vegetation consisted of a dense grass sward.

### 5.2.2 Seed Bed Preparation

In October 1993 standing vegetation was flailed, and the field site was sprayed with a field rate application of glyphosate. Once the existing cover had been destroyed the site was shallow depth ploughed (to a depth of approximately 10cm), and disced to produce a seed bed. Seed bed preparation was completed on 15th November 1993.

### 5.2.3 Experimental Design

The field trial consisted of 108 2m x 2m plots arranged according to a randomised block, split split plot design. The field layout is shown in Figure 5.1. The experimental design comprised three replicate blocks. Main plots (10m x 10m) were cover treatments, these are listed below, and were selected according to set-aside management regulations which require a green cover to have been established by the start of the set-aside year (15th January). This cover may be established through : natural regeneration ; grass cover (including up to 5% leguminous species by weight), wild bird cover, or by sowing a 'non-agricultural crop' (MAFF, 1996d).

1. **(GC1)** Highly competitive grass cover (95% *Lolium perenne*, 5% *Trifolium repens* (by weight)) Sowing rate - 45kg/ha
2. **(GC2)** 'Nurse' crop grass cover (66% *Festuca rubra cv. commutata*, 34% *Agrostis castellana* (by weight)) Sowing rate - 30kg/ha
3. Natural regeneration - no cover sown
4. Winter wheat cv. *riband* Sowing rate - 188kg/ha

Cover treatments were randomly assigned to the four main plots within each block (Figure 5.1). Individual plots were marked using bamboo canes so that 2m 'paths' were left for access between plots.

Sub-plots were annual cultivation regimes and were randomly located within main cover plots :

| | **Year 2 cultivation regime** (October 1994) | **Year 3 cultivation regime** (October 1995) |
|---|---|---|
| 1. | Shallow depth cultivation | Shallow depth cultivation |
| 2. | Shallow depth cultivation and resow rare arable weeds | i) Shallow depth cultivation<br>ii) 2 shallow depth cultivations (autumn and spring) |
| 3. | No cultivation | Shallow depth cultivation |

In year 3, plots assigned to cultivation regime 2 were subject to a further split (see above) to enable a comparison between a single and a double cultivation treatment. This treatment was introduced in an attempt to control population densities of *A. githago* which had become totally dominant by the end of year 2.

Sub sub plots were annual cutting regimes, and these were, once again, randomly located within cultivation sub plots :

| | |
|---|---|
| 1. Early cut | 1st August |
| 2. Late cut | 30th August |
| 3. No cut | |

The early cut treatment occurs within the specified period for the compulsory annual cut on set-aside land (15th July to 15th August). The late cut and no cut regimes would require an exemption from this requirement.

## 5.2.4 Seed sowing

The starting date for the studentship which supported this research (4th October 1993) necessitated that decisions and actions relating to research aims, experimental design, seed stocks and seed bed preparation be made in an extremely short period of time, so that trials could be established before winter, allowing them to run over three growing seasons. This prevented the collection of native seed stocks for rare weed species. Seed sowing was also hampered by very heavy rainfall following seed bed preparation.

### 5.2.4.1 Seed stocks and sowing rates

These are presented in Tables 5.1 a and b below for grass covers and rare arable weed species :

Table 5.1 a and b Seed sowing rates

a) Cover 'crops'

| Species | Sowing rate (Kg/ha) | Seed rate / plot (g) |
|---|---|---|
| *L. perenne* | 42.25 | 16.9 |
| *T. repens* | 2.75 | 1.1 |
| *F. rubra cv. commutata* | 20.0 | 8.0 |
| *A. castellana* | 10.0 | 4.0 |
| *T. aestivum* cv. *Riband* | 188.0 | n/a |

b) Rare arable weed species

| Species | Seed rate (seeds $m^{-2}$) | seeds $g^{-1}$ | seeds/ plot | seed wt/ plot (g) |
|---|---|---|---|---|
| *A. githago* | 250 | 83 | 1000 | 12.05 |
| *C. cyanus* | 250 | 206 | 1000 | 4.84 |
| *C. segetum* | 750 | 1114 | 3000 | 2.69 |
| *P. rhoeas* | 1500 | 7043 | 6000 | 0.85 |
| B. interruptus | 250 | 245 | 1000 | 4.08 |

Winter wheat cover plots (10m x 10m) were marked out and the crop was sown within these areas on 22nd November 1993 using a tractor drawn seed drill. Sub plots were marked using bamboo canes immediately following sowing of the crop, care being taken to walk only on those areas which would subsequently form 'paths' between plots.

Grass covers and introduced weed species were hand sown using a small volume of 5mm sieved peat as a 'carrier' to ensure an even sowing. Constraints of time dictated that it was not possible to conduct tests to determine the initial viabilty of seed stocks, and therefore seed rates given in Table 5.1b are of total rather than live seeds sown per unit area. These species were sown between 23rd and 27th November 1993. These dates were four to six weeks later than optimum sowing dates in an agricultural rotation, however, this could not be avoided due to the problems outlined above.

## 5.2.5 Cutting Treatments

Cutting was carried out on the specified dates. Standing vegetation was cut to a height of approximately 4cm, and cuttings were raked back onto the plots where they were left to decompose *in situ* (Plates 5.1 and 5.2).

## 5.2.6 Cultivation treatments

### 5.2.6.1 Year 2

Prior to the cultivation of randomly selected sub-plots, standing vegetation in the 'no cut' sub sub-plots was flailed. Plots which were subject to a 'no cut and no year 2 cultivation' treatment

Plate 5.1 A grass cover 1 (*Lolium/Trifolium*) plot being cut to an approximate height of 4 inches in August 1994.

Plate 5.2 A cut plot with cuttings left *in situ*

combination remained uncut. Following flailing, all plots which were to be cultivated were cut short to facilitate cultivation (21st October 1994). All cuttings were raked back onto the plots prior to cultivation.

Shallow depth cultivation (10cm) was carried out on 26th October 1994 using a tractor drawn rotovator, which incorporated cut material into the seed bed. Following rotovation, plots were raked to produce a level and relatively homogenous surface for seedling establishment. However, damp soil and the presence of 'turves' from the previous years cover meant that the seed bed was of a reasonably poor quality (see Plate 5.3)

Seed sowing on the cultivation and resow sub-plots was carried out using peat as a carrier on 8th November 1994. Year 2 seed rates are in Table 5.2

Table 5.2 Seed rates for rare arable weed species in year 2

| Species | Live seeds /plot | %viability | total seeds /plot | weight (g) |
|---|---|---|---|---|
| *Agrostemma* | 200 | 100 | 200 | 4.10 |
| *C. cyanus* | 400 | 67 | 596 | 3.78 |
| *C. segetum* | 2000 | 62 | 3226 | 4.74 |
| *P. rhoeas* | 3000 | 50 | 6000 | 0.80 |
| *Binterruptus* | 780 | 64 | 1219 | 5.00 |

5.2.6.2 Year 3

As described for year 2, standing vegetation was flailed and cut as necessary (29th September 1995) and cuttings raked back onto plots. During year 3 all plots were shallow depth cultivated (6th October 1995) as described in section 5.2.6.1 above.

As outlined in section 5.2.3, cultivation regime 2 included a second cultivation in the spring of 1996. Sub-plots assigned to cultivation regime 2 were 'split' and one half of each sub plot was surface cultivated (depth approx 4-6") using a hand held rotovator. Six passes (three in each direction) were made with the rotovator to ensure a thorough disturbance of the soil, and maximum disturbance of established seedlings and covers. This spring cultivation was carried out on 15th February 1996.

### 5.2.7 Terminology.

In the sections which follow, certain terms are frequently used. These are defined below :

The rare arable weed species *A. githago* will be referred to by the generic, *Agrostemma.*

Rare arable 'weeds' are termed rare arable wildflowers to distinguish them from indigenous 'weeds' (those originating from the soil seedbank), which together with sown 'grass cover' species will be referred to as vegetation cover.

Often, the general term 'reproductive structure' is used to describe the seed-bearing organs of rare arable wildflower species. More specifically, these organs are seed capsules for *Agrostemma* and *P. rhoeas*, capitula for *C. cyanus* and *C. segetum* and inflorescences for *B. interruptus.*

Figure 5.1 Scale diagram illustrating the plot layout field trial

Main cover plots are 10m x 10m

Hatched areas are 'paths' between plots (2m width)

Sub-plots are cultivation regimes (randomly assigned) :

Year 2 - lightly cultivate, Year 3 - lightly cultivate

Year 2 - lightly cultivate and resow, Year 3 - lightly cultivate

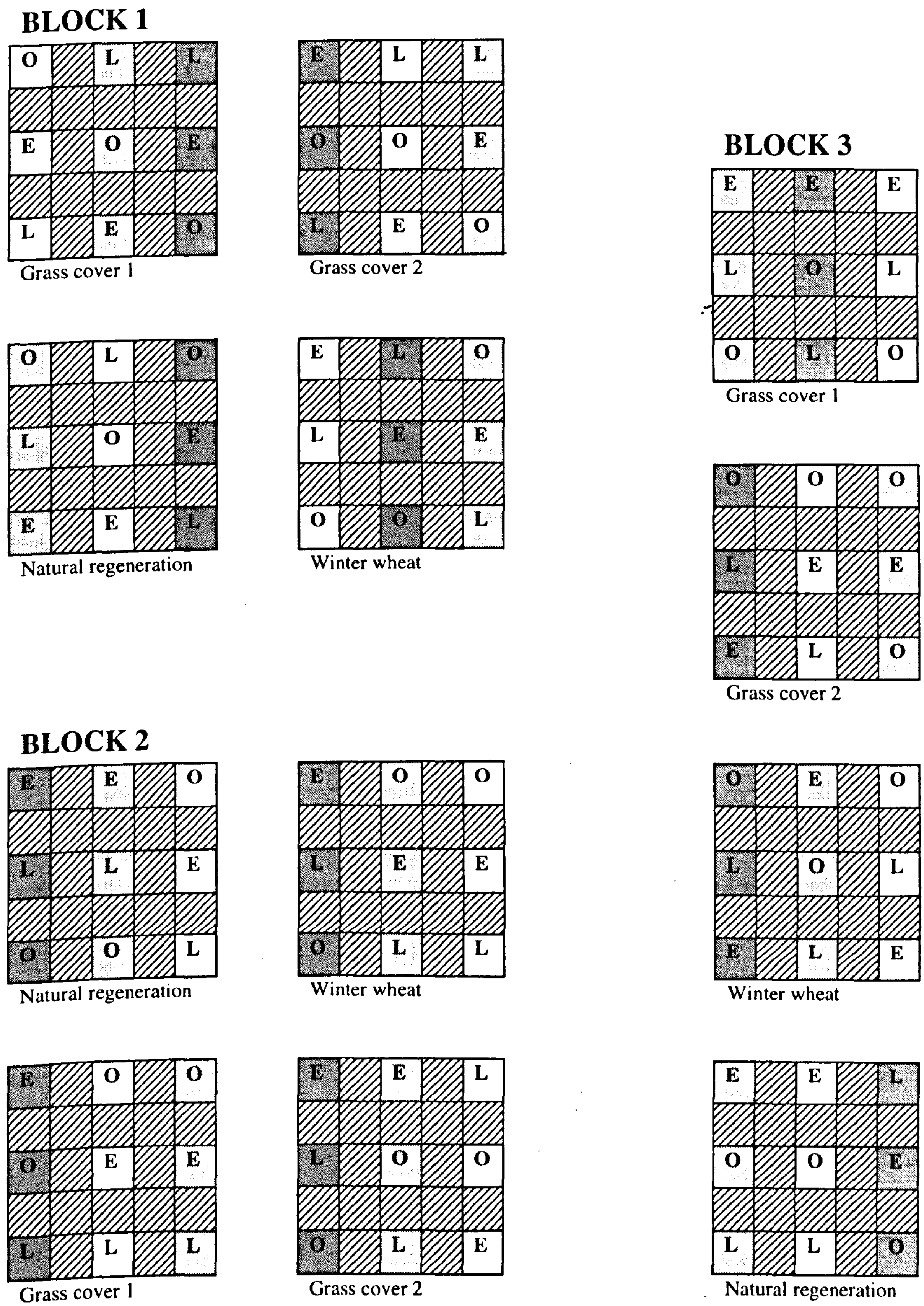
Year 2 - no cultivation, Year 3 (split plots) - lightly cultivate (single and double)

Sub sub-plots are cutting regimes (randomly assigned):

**E** - early cut (1st August)

**L** - late cut (30th August)

**O** - no cut


BLOCK 1
Grass cover 1
Grass cover 2
Natural regeneration
Winter wheat
BLOCK 3
Grass cover 1
Grass cover 2
BLOCK 2
Natural regeneration
Winter wheat
Winter wheat
Grass cover 1
Grass cover 2
Natural regeneration

## 5.3 Monitoring Protocol and Data Analysis

### 5.3.1 Yearly Monitoring Procedures

#### 5.3.1.1 Year 1 - 1993/94

February / March 1994

Four sub-plots from each main plot were randomly selected in each of the three blocks. A 50cm x 50cm quadrat was placed in the centre of each of these and numbers of emerging *Agrostemma* seedlings were counted and recorded. The position of the quadrat was marked using bamboo canes.

May 1994

A 50cm x 50cm quadrat was placed in the centre of all 108 plots (in same location for plots which were sampled in February/March). Counts of established seedlings were made for all rare arable wildflower species. Identification of *B. interruptus* seedlings proved difficult and prohibitively time consuming, and for these reasons this species was excluded from spring census data.

June 1994

Cover abundance of sown grass species was measured using a 50cm x 50cm pin quadrat. The pin frame was placed at random towards the centre of all GC1 and GC2 (competitive and nurse grass cover) sub-plots. The frame consisted of 5 evenly spaced rows, each with 10 'pin holes', to create a grid of 50 holes per frame which was supported on four legs at 50cm above ground level. For each sub-plot 2 to 3 rows were randomly selected, and data recorded for the number of pins which struck sown grasses or clover. This gave 20 or 30 point measurements per sub-plot, which were then summed across main cover plots, so that for each main plot 200 point measurements were taken which could be used to derive a % cover abundance for all sown species on a per main plot basis.

July / August 1994

A 1m x 1m quadrat was marked out in the centre of all plots using four 1m length white painted bamboo canes (by this stage vegetation was too tall and too dense to enable a quadrat frame to be used). The number of surviving *Agrostemma* individuals was counted and recorded within a randomly chosen 50cm x 50cm portion of this quadrat, numbers of all other wildflower species were recorded within the entire quadrat area ($1m^2$). For each of the rare arable wildflower species an assessment of reproductive output was also made. 25 individuals of *Agrostemma* were chosen at random, and the number of seed capsules recorded to enable total numbers of seed capsules per unit area to be calculated on a per plot basis. For all other rare arable wildflower species the total number of seed capsules (*P. rhoeas*), capitula (*C. cyanus, C. segetum*) or inflorescences (*B. interruptus*) per $m^2$ was counted.

The percentage cover of all other indigenous and sown cover species (vegetation cover) was assessed, together with the percentage of bare ground. From these data total cover and species diversity (number of species $m^{-2}$) could be derived on a per plot basis.

5.3.1.2 Year 2 - 1994/95

January / February 1995

Population densities of established seedlings of rare weed species (not *B. interruptus*) were recorded in a 50cm x 50cm quadrat placed in the centre of all 108 plots. The quadrat was strung to produce a grid of 25 10cm x 10cm squares and the position of this quadrat was marked using bamboo canes. Due to the very high densities of *Agrostemma* seedlings, a sub-sample of 5 10cm x 10cm squares was randomly selected and seedling density recorded in these squares only. The position of these squares was noted. All other introduced weed species were recorded within the entire quadrat and an estimate of total percentage cover and percentage cover of wildflower species was made.

July / August / September 1995

A $1m^2$ quadrat was marked out in the centre of all 'early cut' sub sub-plots as described for the summer 1994 census. A random 50cm x 50cm sub-square was selected, and *Agrostemma* individuals were destructively harvested from this area, and numbers were recorded (destructive harvests were performed between 26th and 31st July for 'early cut' plots and between 25th and 30th August for 'late cut' plots to correspond as closely as possible with cutting treatments). Seed capsules were then removed from all individuals, or from a sub-sample of 100 individuals where densities were greater than 100 plants per $0.25m^2$ area, and placed in labelled paper bags. Remaining plant material was returned to harvested plots. Individuals of all other rare arable wildflower species were harvested, counted and recorded within $1m^2$ quadrats, and reproductive structures (seed capsules, capitula or inflorescences) were removed and placed in labelled paper bags. Remaining material was returned to harvested plots.

A random sample of seed capsules and inflorescences was collected for *Agrostemma* and *B. interruptus* respectively from the edge of selected plots in July, prior to seed dispersal. These were used in the derivation of an appropriate calibration, or allometry for mean seed yield per capsule or inflorescence. These calibrations enabled seed yield per unit area to be calculated for each species on a per plot basis. Details of the calibration techniques for each of these species are given below.

*Agrostemma* - A random sub-sample of 100 seed capsules was collected in July 1995 and each of these was individually weighed. Following weighing, each capsule was opened and the number of seeds it contained counted and recorded. A regression analysis was then performed to relate capsule weight and number of seeds. This analysis identified a statistically significant correlation and produced a regression equation from which the number of seeds per capsule could be calculated on the basis of capsule weight. The results from this calibration are presented in section 5.4.

Harvested seed capsule samples from individual plots were then weighed, the total number of capsules counted and a mean weight per capsule derived. The mean number of seeds per capsule was then calculated from the above calibration and multiplied by the total number of seed capsules per $m^2$ to give total seed yield $m^{-2}$. Harvested seeds and capsules were returned to 'early cut' plots on 11th August 1995.

*B. interruptus* - For a random sample (60) of *B. interruptus* inflorescences, the number of seeds per inflorescence was regressed against inflorescence weight and inflorescence length. A statistically significant correlation and associated regression equations were established for both of these parameters (see section 5.4). For the purposes of subsequent calibration, the relationship between inflorescence weight and seed number was used, as measurement of mean inflorescence weight proved less time consuming. Mean seed yield $m^{-2}$ for *B. interruptus* was subsequently calculated from harvested samples as described above for *Agrostemma*. Harvested and weighed inflorescences were returned to early cut plots on 11th August 1995.

*C. cyanus, C. segetum* and *P.rhoeas* - population densities for these species were very low during year 2 of the current trial, and where these species were present reproductive output was expressed as reproductive structures $m^{-2}$.

The monitoring protocol described above was repeated for *Agrostemma* on 'late cut' plots between 25th and 30th August 1995 and harvested seed capsules and inflorescences were 'resown' on 6th September 1995.

The protocol had to be modified for 'no cut' plots as it was not appropriate to destructively harvest (which is analogous to a cutting treatment) these. Numbers of introduced rare arable wildflowers were counted *in situ*, together with total numbers of seed capsules. A random sample of 50 seed capsules for *Agrostemma* was taken from which mean seed yield per capsule could be derived. These seeds were returned to 'no cut' plots on 6th September 1995.

Population censuses of *B. interruptus* on 'late cut' and 'no cut' plots were carried out between 13th and 18th August 1995, and inflorescences were destructively harvested during this period. This early harvest was made necessary by the tendency of this species to disperse its seeds in late summer. Delaying harvesting of inflorescences beyond these dates would have resulted in some seed dissemination, and an underestimation of actual seed yields at harvest time. Harvested inflorescences were returned to the appropriate plots on 26th August 1995.

Percentage cover of the five most abundant indigenous and sown cover species was assessed on all plots, together with an estimation of the percentage bare ground. The presence or absence of all other species was also recorded, enabling overall species diversity to be calculated.

#### 5.3.1.3 Year 3 - 1995/96

One census only, in summer 1996, was conducted during year 3 of this trial. The monitoring protocol was very similar to that described above for the summer 1995 census. As this was the last year of monitoring, cutting treatments were not applied to the plots and it was not necessary to harvest plots to correspond with their assigned cutting regime. The relationships between seed capsule weight and seed number for *Agrostemma*, and between inflorescence weight and seed number for *B. interruptus* were recalibrated for a sample of capsules and inflorescences collected during July 1996.

### 5.3.2 Analysis of results

Data for indigenous and sown weed cover, species diversity, individual rare arable wildflower species densities and reproductive outputs were analysed by analysis of variance, according to a split split-plot design (Snedecor, 1948) using SAS (SAS, 1989). Error terms for main plots, sub plots and sub sub-plots and F-ratios and significance levels were recalculated. Data values were $\log_{10}+1$ transformed for data sets where error variance was not evenly distributed. Tukey's Least Significant difference (LSD) for unplanned comparisons was calculated to enable pairwise comparisons of main treatment effects (cover, cutting and cultivation regimes).

## 5.4 RESULTS

Low soil temperatures (Figure 5.2) following a late sowing (22/11/93) of the winter wheat cover 'crop' during year 1 resulted in very poor germination and establishment for this species (Table 5.4, mean cover - 12.3%). The failure to establish a competitive wheat cover effectively prevented meaningful comparisons of this cover type with others included in the experimental design. For this reason, wheat main cover plots have been excluded from all analyses presented in this chapter.

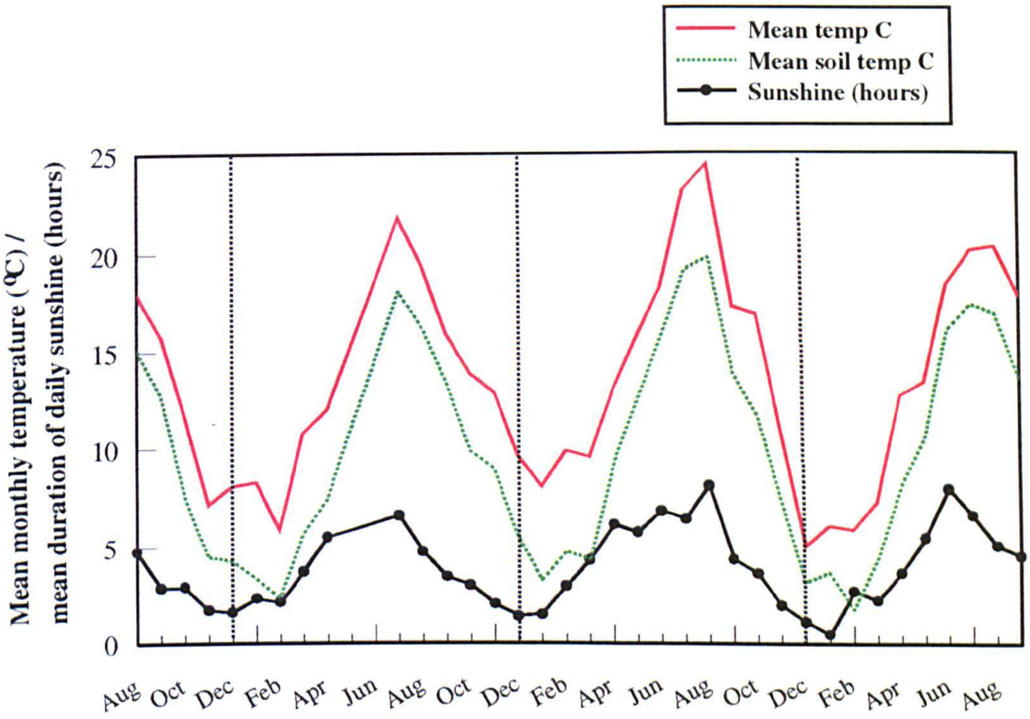
### 5.4.1 Year 1 - 1993/94

#### 5.4.1.1 Year 1 cover establishment

Year 1 treatment effects were restricted to 'cover' crops (GC1, GC2 and natural regeneration). These covers were sown at the same time as rare wildflower seed mixtures, and in common with winter wheat plots, initial (autumn/winter) cover establishment was poor due to low soil temperatures following late autumn sowing. However, subsequent germination and establishment as temperatures rose in spring resulted in dense grass swards on GC1 and GC2 plots, as evidenced by pin quadrat (June 1994) and visual assessments (August 1994) of cover abundance (Table 5.3 and Figure 5.3 respectively). Data from pin quadrats for cover abundance of sown grass species was summed on a per main plot basis (9 sub-plots), and is presented on a per block basis in Table 5.3. The overall density of sown grass swards is very similar for the highly and less competitive (nurse) grass covers, with *L. perenne* and *A. castellana* the respective dominant species.

Results from visual assessments of cover abundances of sown grasses and indigenous weed species are presented in Figure 5.3 a-d. Results from analyses of variance on these data are in Table 5.4. Percentage vegetation cover (excluding sown rare weed species) at harvest, was significantly greater on GC1 and GC2 plots (81 and 74 per cent respectively) compared with the plots where cover developed solely from indigenous seedbank vegetation (natural regeneration) (Figure 5.3a and Table 5.4). The five most abundant species by cover type are shown in Figure 5.3d. Unsurprisingly, on GC1 and GC2 plots the most abundant components of vegetation cover are the sown species, these accounting for the higher overall levels of vegetation cover on these plots. It would have proved too time consuming to attempt to distinguish between individuals of *A. castellana* and *A. capillaris* (the major seedbank component) on GC2 plots, and for this reason the contribution of sown species to overall weed cover may be overestimated. Natural regeneration plots displayed a significantly greater proportion of bare ground than those sown with grass covers (Figure 5.3c).

a) Mean monthly temperature and sunshine hours




b) Monthly rainfall totals

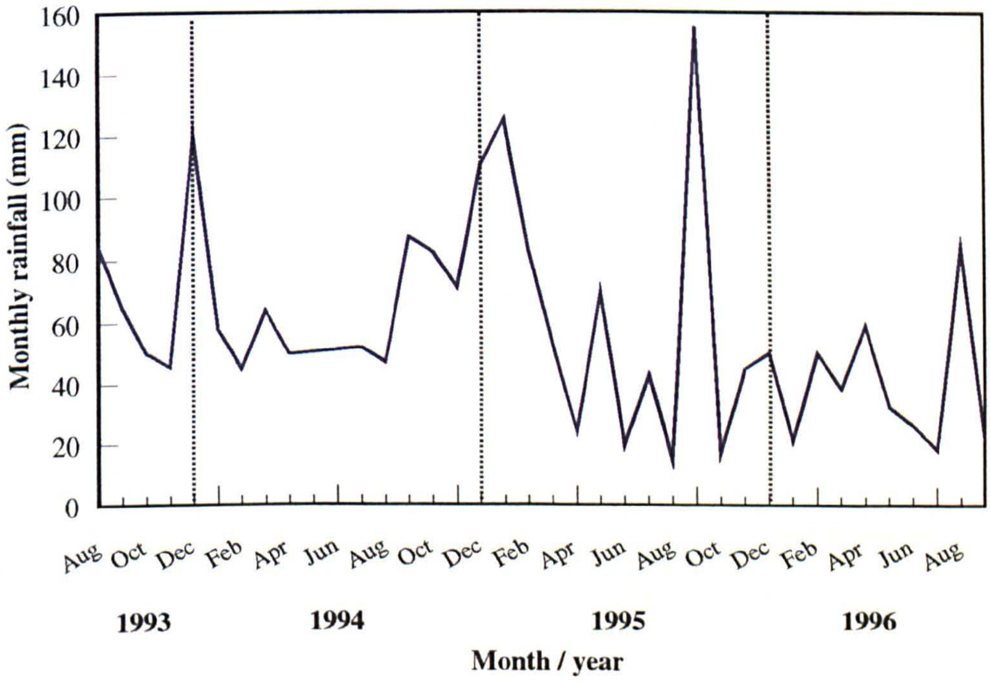
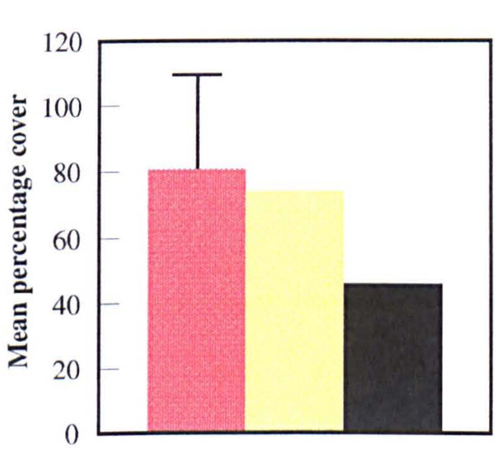
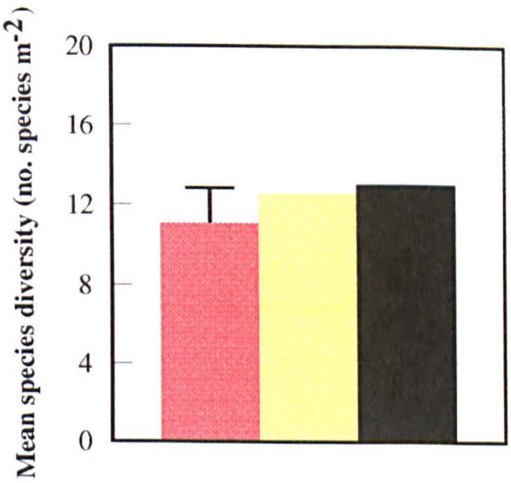



Figure 5.2 a and b Monthly meteorological data recorded at the Ness Garden weather station between August 1993 and September 1996

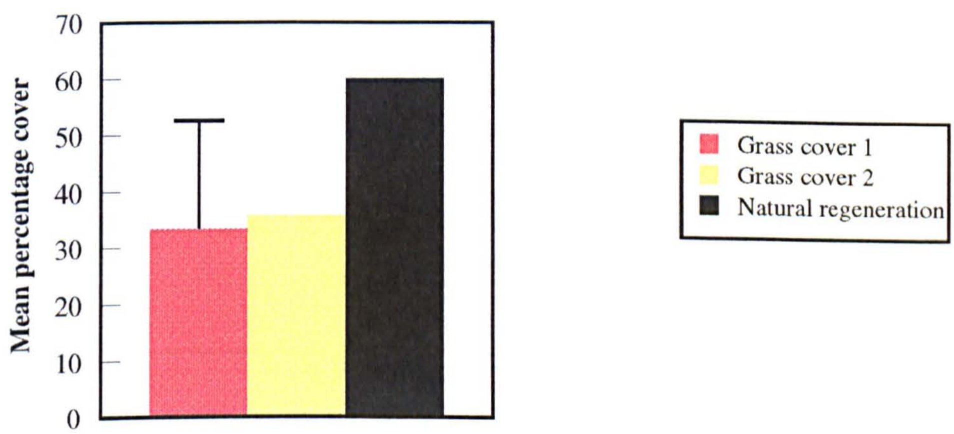
a) % vegetation cover (excluding sown weed species)




b) Species diversity (excluding sown wildflower species)




c) % Bare Ground




d) Five most abundant weed species by COVER TYPE

| Grass cover 1 | Grass cover 2 | Natural regeneration |
|---|---|---|
| *1. Lolium perenne* | *1. Agrostis capillaris* | *1. Agrostis capillaris* |
| *2. Trifoloum repens* | *2. Festuca rubra rubra* | *2. Trifolium repens* |
| *3. Agrostis capillaris* | *3. Trifolium repens* | *3. Tripleurospermum inodorum* |
| *4. T. inodorum* | *4. T. inodorum* | *4. Poa annua* |
| *5. Poa annua* | *5. Poa trivialis* | *5. Poa trivialis* |

Figure 5.3 a - d Year 1 (August 1994) cover abundance, species diversity and percentage bare ground
Error bars are Tukey's LSD (P, 0.05)

Table 5.3 Year 1 (June 1994) percentage cover abundance (pin quadrat data) for sown grass covers (GC1 and GC2). Data are summed on a per main plot basis.

*L.p - L. perenne, T.r - T. repens, A.c - A. castellana, F.r - F. rubra cv. commutata, T.a - T. aestivum*

| | % cover abundance | | | | | | |
|---|---|---|---|---|---|---|---|
| | GC1 | | | GC2 | | | Wheat |
| | *L.p* | *T.r* | Total | *A.c* | *F.r* | Total | *T.a* |
| Block 1 | 64.3 | 8.1 | 72.4 | 48.0 | 29.5 | 77.5 | 10.1 |
| Block 2 | 72.5 | 18.0 | 90.5 | 48.5 | 27.0 | 75.5 | 12.7 |
| Block 3 | 58.4 | 16.1 | 74.5 | 54.0 | 29.0 | 83.0 | 14.0 |
| Mean | **65.1** | **14.1** | **79.2** | **50.2** | **28.5** | **78.7** | **12.3** |

Table 5.4 Analyses of variance on year 1 (August 1994) data for vegetation cover, species diversity and bare ground.

Significance levels (sig) $*P < 0.05$, $**P < 0.01$, $***P < 0.001$

| | **% vegetation cover** | | | **Species diversity** | | | **% bare ground** | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | M sq | $F_{(2,36)}$ | sig | M sq | $F_{(2,36)}$ | sig | M sq | $F_{(2,36)}$ | sig |
| Block | 700.59 | 0.809 | | 26.7 | 3.35 | | 445.6 | 1.38 | |
| Cover | 9318.4 | 10.76 | * | 63.82 | 8.22 | * | 6758.2 | 20.89 | ** |
| Main plot error | 866.1 | | | 7.96 | | | 323.5 | | |

Species diversity (excluding sown rare wildflower species) was greatest on naturally regenerating and GC2 plots (Figure 5.3b), being reduced on GC1 plots by the competitive sward forming sown species. Calculation of Tukey's LSD has illustrated that significant differences in species diversity ($P < 0.05$) existed between naturally regenerating and GC1 plots only.

5.4.1.2 Year 1 sown rare arable wildflower communities.

*Population densities and community structure*

*Agrostemma* was the dominant component of rare arable wildflower communities across all cover treatments and at all census points during year 1 of the trial (Figure 5.4 a-d). Cover treatments had no significant effect on population densities of *Agrostemma* at any of the census points (Table 5.5a). Despite the late sowing date, this species exhibited a flush of synchronous germination shortly after seeds had been sown. Initial autumn germination and establishment (March 1994 census) represented 47.8% of seeds sown, these individuals overwintering as dormant rosettes. A second flush of germination in spring is evidenced by increased population densities in May 1994 for all cover treatments (66.7% of total seeds sown had established to this point, representing a spring germination fraction of 18.9%). *Agrostemma* population densities decline on all covers between the May and final pre-harvest (August 1994) census, suggesting that interference competition during periods of rapid vegetative growth resulted in density dependent mortality of this species. At the final census 51.4% of sown *Agrostemma* seeds had completed their life cycle to produce reproductively mature adult plants.

Other rare arable wildflower species included in the initial seed mixture were represented in year 1 communities at greatly reduced densities compared to *Agrostemma*. *P. rhoeas* was completely absent. The absence of *C. cyanus* and *C. segetum* from the March census suggests that these species were unable to germinate and establish following the late sowing in the previous autumn, and that all representatives of these species in rare wildflower communities were recruited in the following spring. Population densities of *C. cyanus* are not significantly affected by cover (Figure 5.3c, Table 5.5b), although results from the May 1994 census suggest that this species established more readily on the natural regeneration plots where the absence of sown grass species produces more 'safe sites' for germination. In common with *Agrostemma*, population densities decline between May and August, probably as a result of intense interspecific competition from dense populations of rapidly growing *Agrostemma*. At the final August census, 2.4% of *C. cyanus* seeds sown had developed to reproductive maturity (a further 1.8% had germinated but failed to reach maturity), however, unlike *Agrostemma* this species has a persistent seedbank so that ungerminated seeds may survive in the soil forming a reservoir of seeds from which recruitment may occur in subsequent years.

Table 5.5 a-d Analyses of variance on numbers of established seedlings and adult plants of a) *Agrostemma*, b) *C. cyanus*, c) *C. segetum* and d) *B. interruptus* at various census points during year 1 (1993 - 94). Treatment effects are covers.

Significance levels *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

[1] - data were $\log_{10} + 1$ transformed

a) *Agrostemma*

| | Census | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | **March** | | | **May** | | | **August** | | |
| | M sq | $F_{(2,36)}$ | sig | M sq | $F_{(2,36)}$ | sig | M sq | $F_{(2,36)}$ | sig |
| Block | 492.7 | 0.35 | | 4557 | 0.28 | | 818.6 | 0.11 | |
| Cover | 1096.4 | 0.79 | **ns** | 2395 | 0.147 | **ns** | 557.2 | 0.08 | **ns** |
| Main plot error | 1391.2 | | | 16270 | | | 7399.6 | | |

b) *C. cyanus*

| | Census | | | | |
|---|---|---|---|---|---|
| Treatment | **May**[1] | | | **August** | | |
| | M sq | $F_{(2,36)}$ | sig | M sq | $F_{(2,36)}$ | sig |
| Block | 1.036 | 0.83 | | 114.3 | 2.67 | |
| Cover | 0.768 | 0.61 | **ns** | 74.7 | 1.75 | **ns** |
| Main plot error | 1.253 | | | 42.82 | | |

c) *C. segetum*

| | Census | | | | | |
|---|---|---|---|---|---|---|
| Treatment | **May**[1] | | | **August** | | |
| | M sq | $F_{(2,36)}$ | sig | M sq | $F_{(2,36)}$ | sig |
| Block | 0.177 | 0.77 | | 2.70 | 0.45 | |
| Cover | 0.022 | 0.10 | **ns** | 68.11 | 11.28 | * |
| Main plot error | 0.231 | | | 6.04 | | |

d) *B. interruptus*

| Treatment | August | | |
|---|---|---|---|
| | M sq | $F_{(2,36)}$ | sig |
| Block | 15.123 | 1.88 | |
| Cover | 1.83 | 0.23 | **ns** |
| Main plot error | 8.03 | | |

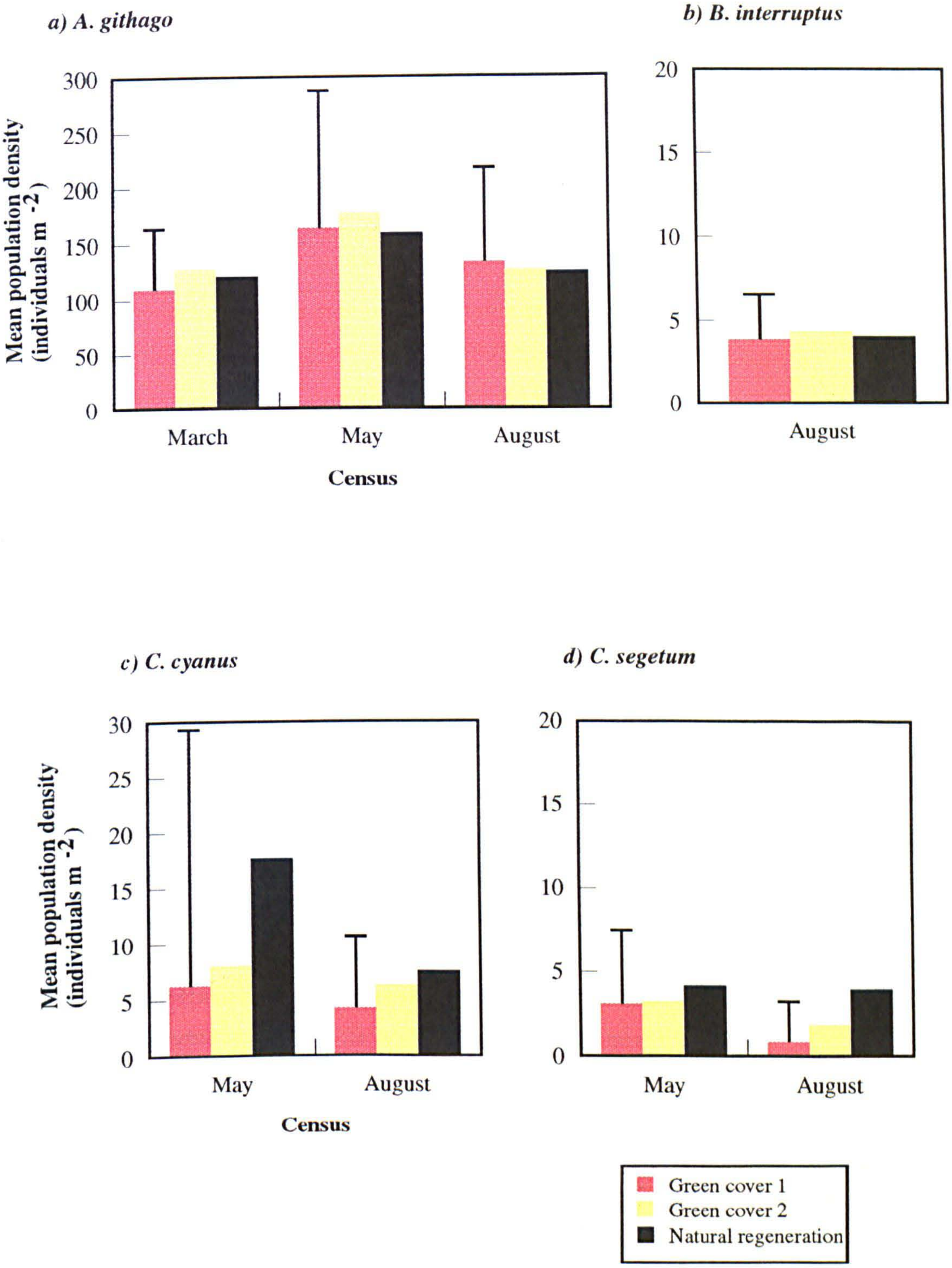



Figure 5.4 a-d Year 1 (1993-94) Rare arable wildflower seedling and adult plant population densities at various development stages (March, May and August censuses)
Error bars are Tukey's LSD (P, 0.05)

Establishment of *C. segetum* was in spring at very low densities (Figure 5.3d) and was not effected by cover type (Table 5.5c). Subsequent mortality between May and August was most pronounced in GC1 plots, so that at the August census the numbers of this species surviving to reproductive maturity was significantly greater ($P < 0.05$) on the natural regeneration plots where competition from sown grass covers was less intense. 0.3% of *C. segetum* seeds sown reached reproductive maturity during year 1 of the trial (a further 0.2% germinated, but failed to reach maturity). This species also possesses a persistent seedbank.

Population densities of *B. interruptus* were assessed at the August census only (Figure 5.3b). These were, once again, very low due to the late sowing date, and were unaffected by cover type (Table 5.5d). This species germinates and establishes entirely in autumn, and as such those individuals which survived to set seed in the following summer must have been recruited in the previous autumn. The absence of data for autumn germination prevents an assessment of subsequent mortality for this species. 1.6% of sown *B. interruptus* seeds developed to reproductive maturity during year 1 of the trial.

*Reproductive output*

During year 1 of the current trial, the reproductive output of rare arable wildflower populations was measured as the number of mature reproductive structures produced per unit area. Results are presented in Table 5.6. In common with results for population density, *C. segetum* was the only species whose reproductive output was significantly effected by cover type ($P < 0.05$), being greater on naturally regenerating plots. However, the lack of statistical significance for *Agrostemma* and *C. cyanus* masks some interesting results which justify discussion (the experimental design means that the main (cover) plot error term in the analyses of variance only has 4 degrees of freedom, considerably reducing the scope for statistical inference from these treatments).

The final densities of populations of *Agrostemma* were lowest on natural regeneration plots (Figure 5.4a). In contrast, the overall reproductive output of these populations was greater than on GC1 and GC2 plots (Table 5.7). It is possible to calculate from these data, values for the mean number of seed capsules produced per plant on a per cover basis : these are 1.86 $m^{-2}$ on GC1, 1.73 $m^{-2}$ on GC2 and 2.23 $m^{-2}$ on natural regeneration. Populations of plants may respond to density dependent competitive effects in two major ways; by regulating population size through density dependent mortality, and by regulating the size and fecundity of individuals within populations as competition for resources becomes more intense. Clearly, in the current trial cover type is exerting it's limited (non-significant) effect on populations of rare wildflowers through regulating individual size and fecundity, rather than by causing mortality of individuals. Similar and more pronounced

Table 5.6 Year 1 (August 1994) mean reproductive outputs (reproductive structures $m^{-2}$) and analyses of variance with cover as treatment effects for *Agrostemma*, *C. cyanus* and *C. segetum*.
Significance levels - *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

| | reproductive structures $m^{-2}$ | | |
|---|---|---|---|
| Cover | *Agrostemma* | *C. cyanus* | *C. segetum* |
| GC1 | 247.7 | 28.1 | 0.96 |
| GC2 | 219.2 | 38.1 | 1.93 |
| NR | 277.9 | 76.3 | 4.70 |
| Tukey's $LSD_{(p, 0.05)}$ | 174.8 | 85.6 | 3.43 |
| Significance level | **ns** | **ns** | * |

trends are evident for *C. cyanus*, this species exhibiting 6.6, 6.1 and 15.4 capitula $m^{-2}$ for GC1, GC2 and natural regeneration plots respectively.

## 5.4.2 Year 2 - 1994/95

### 5.4.2.1 Year 2 cover establishment

Grass cover seed mixtures (GC1 and GC2) were not resown during year 2. Vegetation established on cultivated plots was from soil seedbanks and vegetative fragments from the previous years cover. Whilst shallow depth cultivation successfully destroyed vegetation established during year 1, the aim had not been to produce an agricultural quality seed bed and the resulting seed bed contained many vegetative fragments from which established cover could rapidly regenerate in year 2. Vegetation cover remained undisturbed on 'no cultivation' plots.

Year 2 treatment effects were cover type, cutting regime and cultivation regime and the effect of each of these on percentage vegetation cover and species diversity is summarised in Figures 5.5 and 5.6. Results from split split-plot analyses of variance are presented in Table 5.7. Year 1 cutting treatments and the cover type established during year 1 had no effect on overall percentage vegetation cover recorded in August 1995. The only significant treatment effect ($P < 0.001$) was cultivation regime, overall vegetation cover in year 2 being significantly greater on plots which were not cultivated at the end of the first year. On plots where a grass cover was sown during year 1 (GC1 and GC2), a cultivation resulted in a decrease in percentage vegetation cover (excluding rare arable weed species) in August 1995 compared to August 1994 ; from 81 to 67% on GC1, and from 74 to 61% on GC2. Conversely, where there was no cultivation, vegetation cover increased to 89% on GC1 and to 88% on GC2. On natural regeneration plots which were not cultivated percentage vegetation cover increased from 46% to 79%.

Whilst initial cover type had no effect on overall percentage weed cover by the end of the second year, differences in the species composition of 'indigenous' vegetation communities did exist. Table 5.8 summarises the major components of these communities for the three cover types. The relative abundance of sown cover species on GC1 and GC2 declined during the second year, although these species continued to be amongst the most dominant components of vegetation cover. There was a tendency for all plots to become dominated by a few grass species (*A. capillaris* being the most dominant) at the expense of forbs and this was reflected in a general decline in species diversity (number species $m^{-2}$), from 13.6 species $m^{-2}$ in year 1 to 7.7 species $m^{-2}$ in year 2. The percentage of uncolonised, bare ground declined substantially during year 2. On cultivated plots this was a result

Table 5.7 Analyses of variance on year 2 percentage vegetation cover and species diversity - August 1995. Significance levels - $*P < 0.05$, $**P < 0.01$, $***P < 0.001$

**B - block, COV - cover type, CUT - cutting regime, CULT - cultivation regime**

| Source of | **% vegetation cover** | | | **Species diversity** | | |
|---|---|---|---|---|---|---|
| variation | M square | F | Sig level | M square | F | Sig level |
| Main plot error | 103.15 | | | 6.598 | | |
| B | 323.5 | 3.13 | | 2.323 | 0.504 | |
| COV | 520.39 | 5.04 | ns | 28.622 | 4.340 | ns |
| Sub plot error | 90.25 | | | 4.056 | | |
| CULT | 4886.8 | 54.15 | *** | 22.612 | 5.57 | * |
| COV*CULT | 73.98 | 0.82 | ns | 2.408 | 0.59 | ns |
| Sub sub plot error | 162.04 | | | 2.492 | | |
| CUT | 25.52 | 0.18 | ns | 2.597 | 1.04 | ns |
| COV*CUT | 104.57 | 0.65 | ns | 2.225 | 0.89 | ns |
| CUT*CULT | 298.82 | 1.84 | ns | 1.504 | 0.60 | ns |
| COV*CUT*CULT | 102.08 | 0.63 | ns | 0.856 | 0.34 | ns |

Table 5.8 Major components of plant communities (excluding sown rare weed species) in August 1995 (year 2) on GC1, GC2 and natural regeneration cover plots.

| **GC1** | | **GC2** | | **NR** | |
|---|---|---|---|---|---|
| Species | % | Species | % | Species | % |
| *A. capillaris* | 24.2 | *A. capillaris* | 40.2 | *A. capillaris* | 40.9 |
| *T. repens* | 22.4 | *F. rubra* | 13.4 | *T. repens* | 14.1 |
| *L. perenne* | 21.3 | *T. repens* | 12.2 | *P. trivialis* | 4.0 |
| *Poa trivialis* | 4.5 | *P. trivialis* | 1.7 | *H. lanatus* | 2.1 |
| *Holcus lanatus* | 1.0 | *R. repens* | 0.8 | *T. inodorum* | 1.6 |
| *Raunculus repens* | 0.6 | *T. inodorum* | 0.5 | *R. repens* | 1.1 |
| *T. inodorum* | 0.4 | *H. lanatus* | 0.4 | *A. stolonifera* | 1.0 |
| Bare ground | 7.0 | Bare ground | 12.0 | Bare ground | 15.4 |

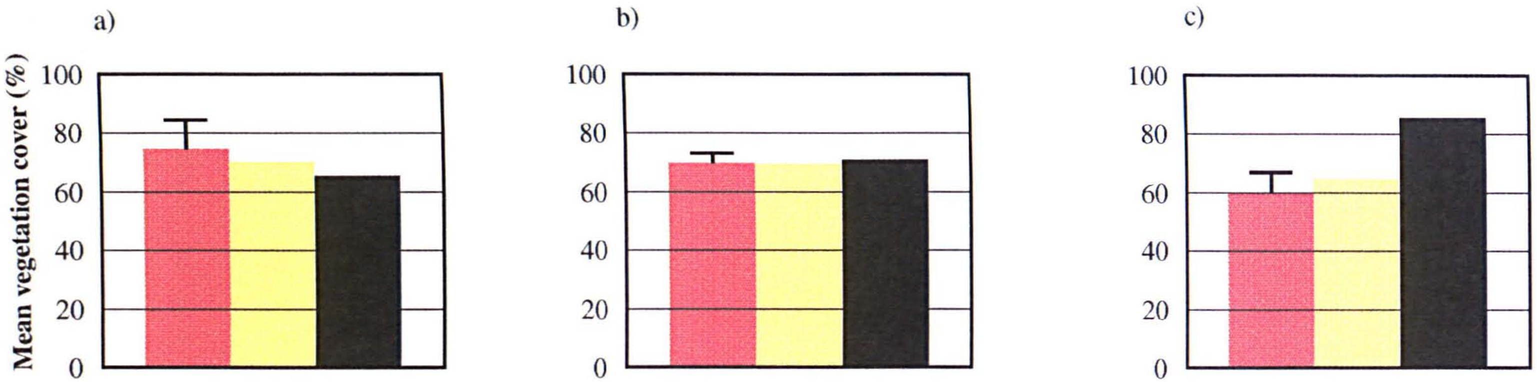



Figure 5.5 a-d Year 2 (1994-95) Mean percentage vegetation cover (excluding sown weed species) in August 1995 under different a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

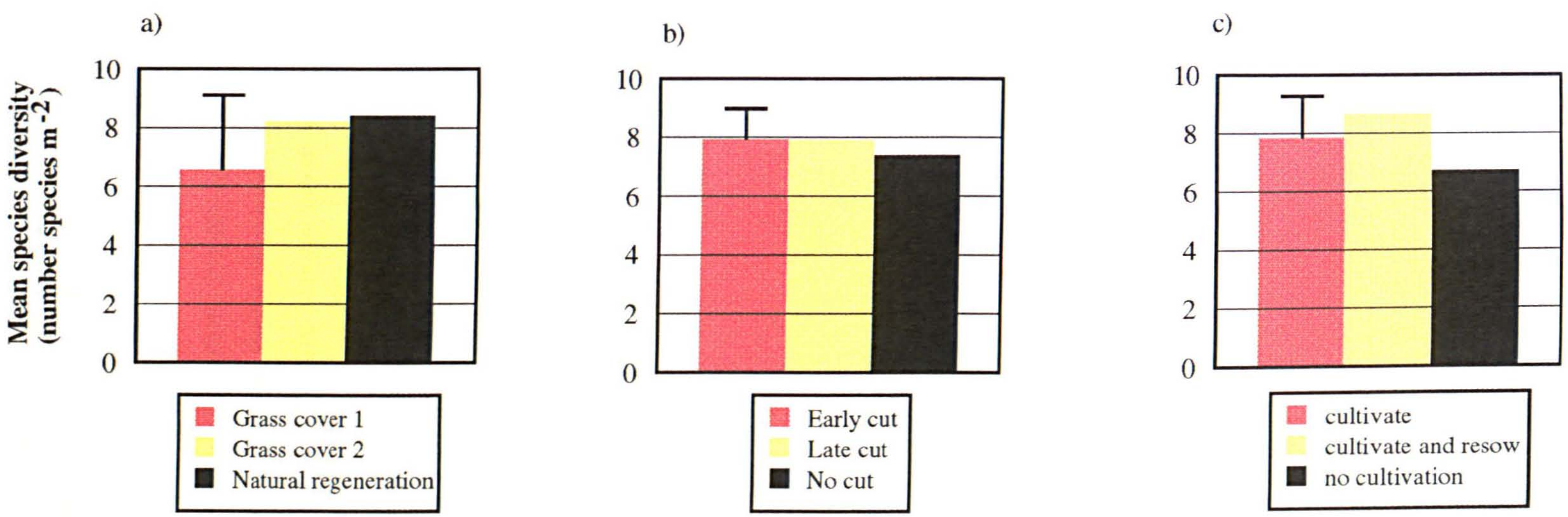



Figure 5.6 a-c Species diversity (excluding sown weed species) at August 1995 under different a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

of increased population densities of rare arable wildflower species and not because of increased cover of 'indigenous' weed species.

Cutting regimes had no effect on subsequent species diversity (Figure 5.6b, Table 5.7). There was a tendency for diversity to be lower during year 2 on GC1 plots (Figure 5.6a), but these differences were not significant. Species diversity on uncultivated plots, where dense grass swards were able to develop excluding forb species, was significantly lower than on cultivated plots (Figure 5.6c, $P < 0.05$).

5.4.2.2 Year 2 sown rare wildflower communities

During year 2 of the trial, rare arable wildflower communities became almost completely dominated by *Agrostemma*. Population densities of the grass species, *B. interruptus* were greater than observed in year 1, whilst *C. cyanus* was only rarely found as an above-ground component of wildflower communities. *C. segetum* and *P. rhoeas* were completely absent from above-ground communities. The following section will consider in turn the above-ground population densities and reproductive outputs of *Agrostemma, B. interruptus* and *C. cyanus* as these were affected by cover type, cutting regime and cultivation regime.

5.4.2.2.1 *Agrostemma githago*

*Population densities*

Data are presented in Figure 5.7 for population densities of *Agrostemma* at two census points during year 2 of the trial, March and August 1995. Analyses of variance were performed on these data on the basis of a split split-plot experimental design. The results of these analyses are in Table 5.9.

Observed changes in population densities for this species between March and August were slight, with a small decline in mean density between the first and second survey. Mean (n = 81 plots) population density (individuals $m^{-2}$) at the March census was 533 and had declined to 498 by August, representing a loss of 6.5%. A similar trend was observed during year 1 and deaths are most likely due to density dependent mortality. The higher population densities observed during year 2 did not increase the magnitude of the mortality event suggesting that population regulation in *Agrostemma* is mediated to a greater extent by plastic vegetative and reproductive growth responses by individual plants. The following discussion of experimental treatment effects on *Agrostemma*

Table 5.9 Analyses of variance on year 2 (1994-95) population densities of *Agrostemma*
Significance levels - $*P < 0.05$, $**P < 0.01$, $***P < 0.001$

| | **Population densities** | | | | | |
|---|---|---|---|---|---|---|
| Source of | **March 1995** | | | **August 1995** | | |
| variation | M square | F | Sig level | M square | F | Sig level |
| Main plot error | 222,702 | | | 304,064 | | |
| B | 37,893 | 0.170 | | 57,714 | 0.190 | |
| COV | 555,974 | 2.496 | ns | 336,254 | 1.106 | ns |
| Sub plot error | 157,154 | | | 110,104 | | |
| CULT | 1,744,045 | 11.10 | ** | 4,090,530 | 37.15 | *** |
| COV*CULT | 162,632 | 1.03 | ns | 133,552 | 1.213 | ns |
| Sub sub plot error | 55,294 | | | 75,804 | | |
| CUT | 607,734 | 10.99 | *** | 411,190 | 5.42 | ** |
| COV*CUT | 34,968 | 0.63 | ns | 61,297 | 0.81 | ns |
| CUT*CULT | 159,159 | 2.88 | * | 217,696 | 2.87 | * |
| COV*CUT*CULT | 60,173 | 1.09 | ns | 39,542 | 0.52 | ns |

Table 5.10 Table of means to illustrate the interaction between cutting and cultivation regimes for March and August population densities of *Agrostemma*

| Cutting regime | Cultivation regime | Mean population density (individuals $m^{-2}$) | |
|---|---|---|---|
| | | March 1995 | August 1995 |
| Early | cultivate | 406.7 | 474.7 |
| Early | cultivate and resow | 513.3 | 549.3 |
| Early | no cultivation | 142.2 | 47.1 |
| Late | cultivate | 766.0 | 817.3 |
| Late | cultivate and resow | 797.8 | 733.8 |
| Late | no cultivation | 333.3 | 107.6 |
| None | cultivate | 942.2 | 1041.8 |
| None | cultivate and resow | 635.6 | 706.7 |
| None | no cultivation | 231.1 | 6.7 |

Table 5.11 Analyses of variance on year 2 (1994-95) seed yields of *Agrostemma* and rates of population increase (1995/1994) Significance levels - $*P < 0.05$, $**P < 0.01$, $***P < 0.001$

| Source of variation | Seed yield (seeds $m^{-2}$) August 1995 M square | F | Sig level | Rate of population increase (λ) M square | F | Sig level |
|---|---|---|---|---|---|---|
| Main plot error | $2.889 \times 10^8$ | | | 6.243 | | |
| B | $4.083 \times 10^7$ | 0.141 | | 11.459 | 1.835 | |
| COV | $8.511 \times 10^7$ | 0.295 | ns | 24.71 | 3.958 | ns |
| Sub plot error | $8.10 \times 10^7$ | | | 6.549 | | |
| CULT | $2.528 \times 10^9$ | 31.21 | *** | 277.02 | 44.37 | *** |
| COV*CULT | $3.846 \times 10^7$ | 0.047 | ns | 12.123 | 1.851 | ns |
| Sub sub plot error | $2.993 \times 10^7$ | | | 5.751 | | |
| CUT | $3.585 \times 10^8$ | 5.99 | ** | 24.688 | 4.29 | ** |
| COV*CUT | $1.558 \times 10^7$ | 0.52 | ns | 8.234 | 1.43 | ns |
| CUT*CULT | $5.055 \times 10^7$ | 1.69 | ns | 14.855 | 2.58 | ns |
| COV*CUT*CULT | $1.527 \times 10^7$ | 0.51 | ns | 6.515 | 1.13 | ns |

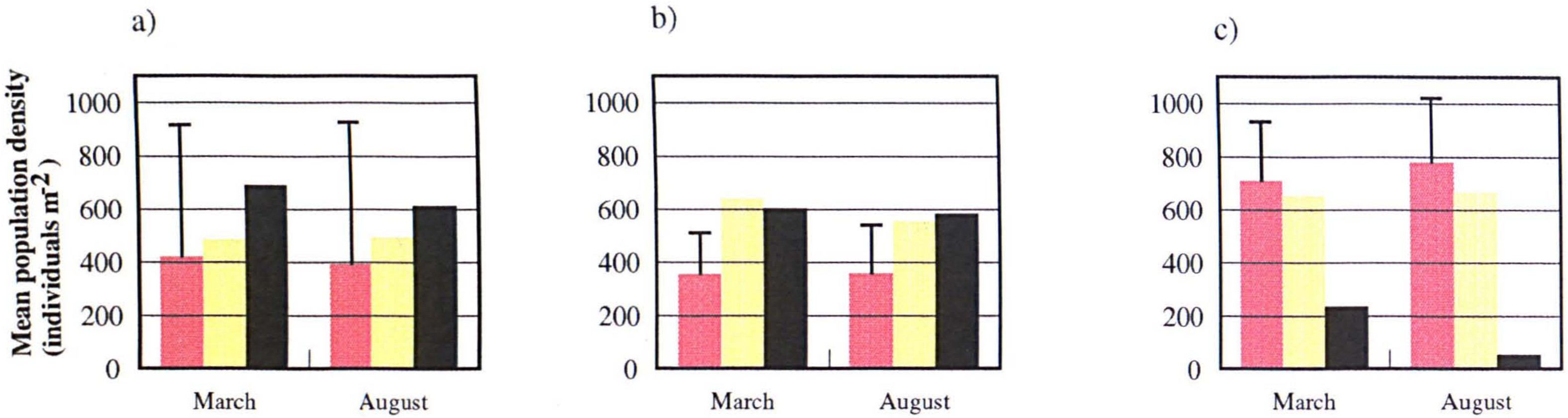



Figure 5.7 a-c Year 2 (1994-95) Mean *A. githago* population densities at March and August censuses under different a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

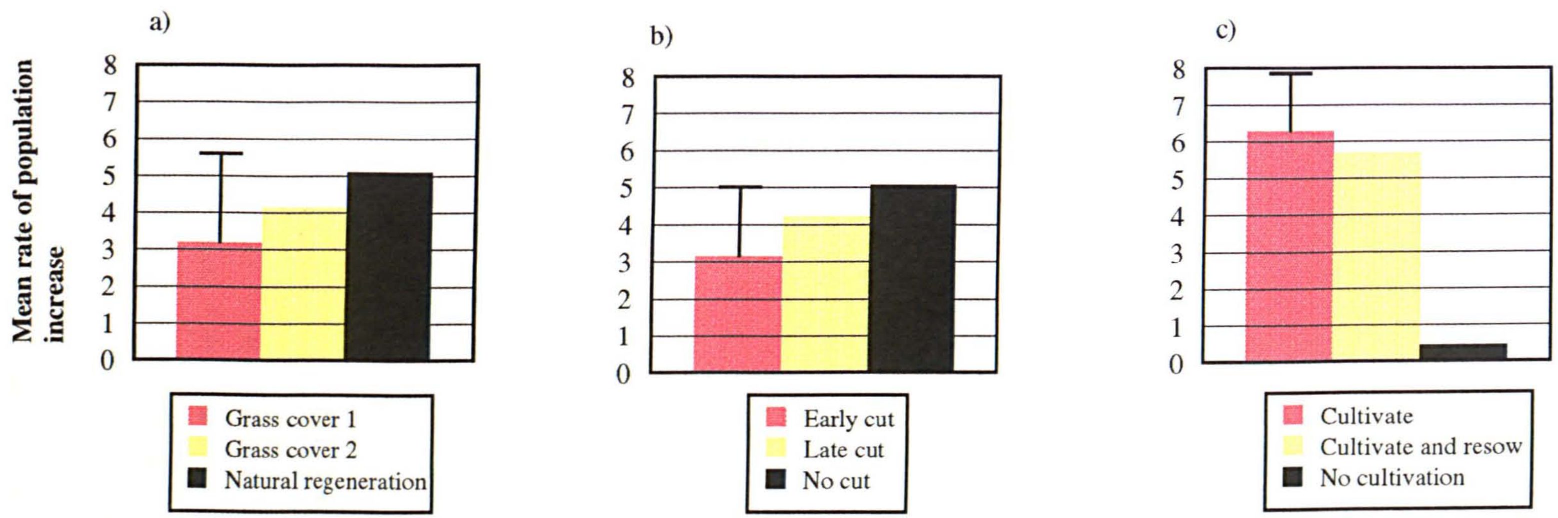



Figure 5.8 a-c Mean rates of population increase (year 1 to year 2) for *A. githago* under different a) COVER TYPES b) CUTTING REGIMES c) CULTIVATIONREGIMES. Error bars are Tukey's LSD (P, 0.05)

populations during year 2 will be restricted to data from August as mortality events were largely independent of these treatments (Figure 5.7).

Whilst not statistically significant, the effect of vegetation cover on populations of *Agrostemma* justifies discussion. Population densities were greatest on natural regeneration plots and lowest on GC1 plots suggesting that safe germination sites are reduced by regenerating sown and indigenous grass species.

An early cutting treatment in the previous year significantly ($P < 0.01$) reduced *Agrostemma* populations in the subsequent growing season (Figure 5.7b). Clearly, cutting on 1st August resulted in the 'dispersal' of a proportion of immature seeds from cut individuals. There was no significant difference in population densities between late and no cut plots.

The absence of an annual autumn cultivation considerably reduced population densities of *Agrostemma* in the following season (Figure 5.7c, $P < 0.001$). The maintenance of a grass sward during the peak autumn germination period limited the availability of safe germination sites, however, despite this constraint a mean of 236 seedlings $m^{-2}$ were recorded at the March census. Subsequent losses during the establishment phase as a result of intense competition from established perennial grass species meant that mean population densities on uncultivated plots at the August census had declined to 54 individuals $m^{-2}$, a rate of loss of 77% compared to the 6.5% decline reported previously across the entire trial. A second sowing of wildflower seed mixtures had no effect on year 2 populations.

The significance of the cutting x cultivation interaction term ($P < 0.05$) is a result of the very low year 2 densities observed under the no cut and no cultivation treatment combination (Table 5.10).

*Rates of population increase*

The rate of increase (λ), or multiplication rate of a population of annual plants, may be calculated as the ratio of population size in successive generations, $N_{t+1} / N_t$ where population sizes are measured at a common point in the life cycle (Mortimer and Cousens, 1995). For species with a persistent seedbank this measure includes an estimation of the buried seedbank component of the population, however, for *Agrostemma* and *B. interruptus* which have no persistence in the soil, population size is measured simply as the number of individuals in the above-ground flora. Consideration of this rate of increase over a number of generations provides a valuable insight into the successional trajectory of weed populations. The rate of increase for populations of *Agrostemma* between year 1 and year 2 in the current trial was calculated as ;

Population density 1995 / Population density 1994

The effect of experimental treatments on λ are illustrated in Figure 5.8, and the results from an analysis of variance on these data is presented in Table 5.11. The analysis of rates of population increase presented in this section has two functions ; firstly it enables consideration of the trajectory of *Agrostemma* populations, and secondly it provides an independent index of the discrete effects of annual management treatments i.e. year 2 population densities are not solely the result of year 1/2 cutting, cultivation and cover regimes but represent the compounded effect of these and factors which determined *Agrostemma* densities prior to their imposition. As such, λ provides a clearer picture of treatment effects.

Comparisons of Figures 5.7 and 5.8, and of the appropriate analyses of variance in Tables 5.9 and 5.11, however, confirm that year 2 population sizes are largely a reflection of rates of increase mediated by year 2 treatment effects. The no cultivation treatment is the only management regime which results in a decline in population size ($\lambda < 1$) from year 1 to year 2. The greatest rate of population increase between year 1 and 2 ($\lambda = 6.26$ ) was observed on plots which were subject to an annual cultivation.

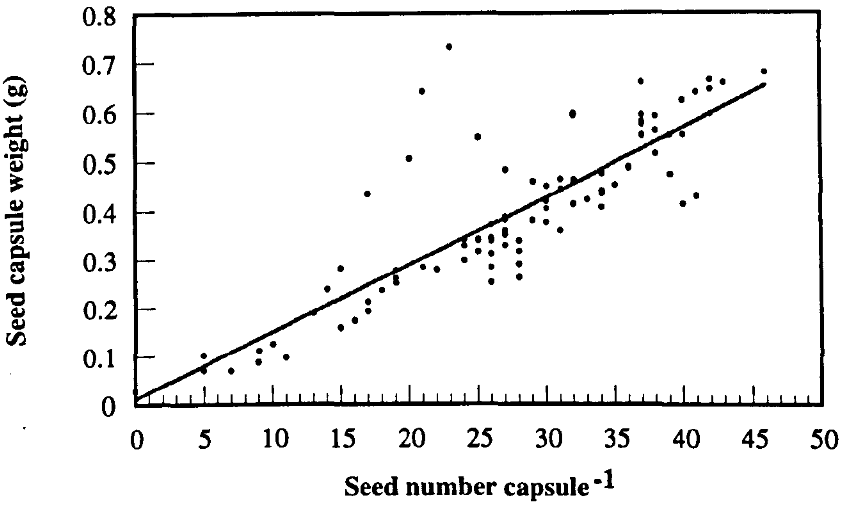
*Reproductive output*

During year 2 reproductive output of *Agrostemma* populations was measured as the total number of seeds produced $m^{-2}$. The method for calibrating seed capsule weight against the number of seeds per capsule was described in section 5.3, and the resulting scatter plot and regression analysis is presented in Figure 5.9a. The correlation between seed capsule weight and number of seeds per capsule was highly significant ($P < 0.001$), providing a sound basis from which to calculate seed yields.

Year 2 seed production $m^{-2}$ for *Agrostemma* populations under different treatment regimes is presented in Figure 5.10, and the results from an analysis of variance on these data are summarised in Table 5.11. Unsurprisingly, patterns of seed production per unit area are closely related to population densities, and the levels of significance of treatment regimes are identical to those reported for population size and rate of increase (λ). However, calculation of mean seed yields per plant show that these tend to increase as population density declines (denisty dependent fecundity) ; for example on GC1 plots where mean population size is 391 plants $m^{-2}$, mean seed

yield per plant was 26.1 whereas on naturally regenerating plots, with a mean density of 613 plants $m^{-2}$ , mean seed yield per plant was only 22.3. This process of density dependent fecundity is resulting in a slight compensation effect on overall levels of seed production.

a) *A. githago*




Regression equation :

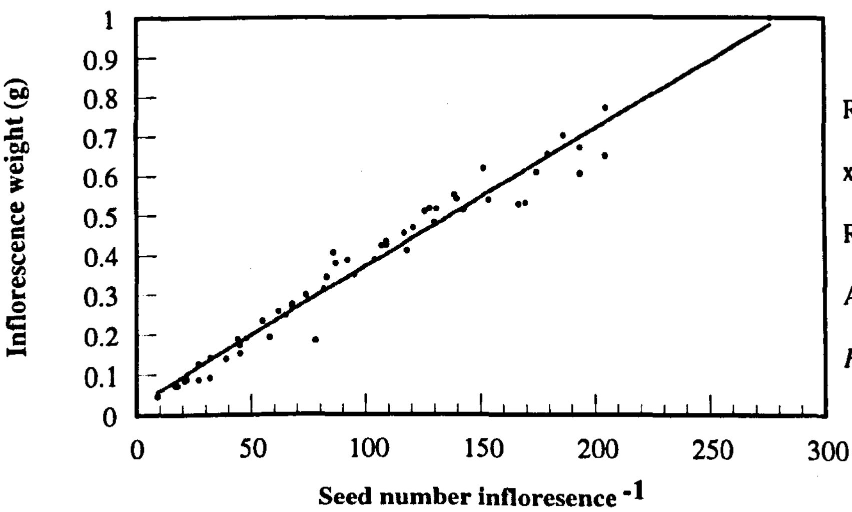
x = 5.73 + 55.4y

R-sq = 0.775

Analysis of variance

$P < 0.001$

b) *B. interruptus*




Regression equation :

x = -4.0 + 280y

R-sq = 0.968

Analysis of variance

$P < 0.001$

Figure 5.9 a and b Year 2 linear regression models for calibration of seed yields
a) *A. githago* - Capsule weight by seed number per capsule
b) *B. interruptus* - Inflorescence weight by seed number per inflorescence

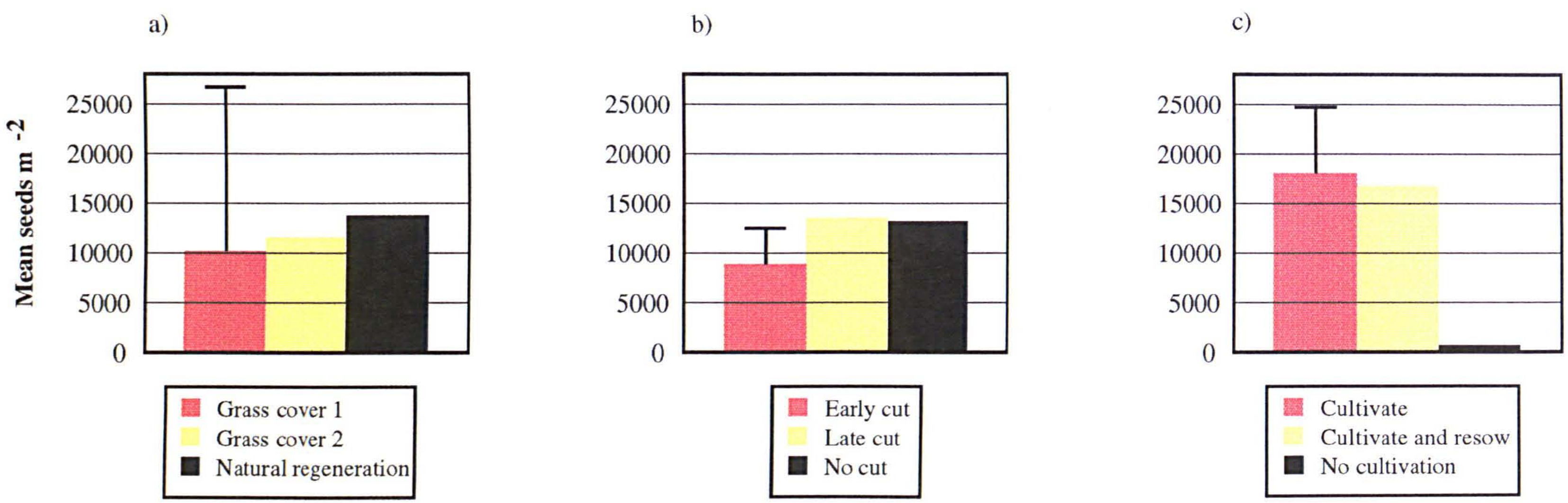



Figure 5.10 a-c Year 2 (1994-95) mean seed production for populations of *A. githago* under different a) COVER TYPES b) CUTTING REGIMES and c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

5.4.2.2.2 *Bromus interruptus*

*Population densities and rates of population increase*

The effects of cover type, cutting regime and cultivation regime on year 2 population densities and rates of population increase (λ) for the grass species, *B. interruptus* are presented in Figures 5.11 and 5.12 respectively. Results from analyses of variance on these data are summarised in Table 5.12. Examination of these data identifies minor variations in response in terms of actual population densities and rates of population increase to different treatment regimes. This is most notable for cutting regimes, where significantly greater population densities on late cut plots (Figure 5.11b) would appear to be the result of intrinsic variability in year 1 establishment on these plots (Figure 5.12b) rather than to specific treatment effects. This observation demonstrates the value of considering rates of increase as well as actual population densities when interpreting dynamic population processes.

Year 2 population densities of *B. interruptus* are significantly greater on natural regeneration plots compared to those where a sown grass cover was established during year 1 (Figure 5.11a, $P < 0.05$). This response is very similar to that observed for *Agrostemma*, and again reflects reduced levels of competition from regenerating grass species.

Cutting and cultivation regimes both have significant effects on year 2 population densities of *B. interruptus*. The apparent disparity between population density and rate of population increase on late cut plots has been discussed, and the major treatment effect is between cut and uncut plots, population densities being significantly reduced (rate of population increase, $P < 0.05$) in the absence of a cut during year 1.

In contrast to *Agrostemma* populations, *B. interruptus* density during year 2 increased on plots which were not cultivated ($P < 0.05$). In the current trial, this tendency probably results from a relative competitive advantage over *Agrostemma* whose establishment on uncultivated plots was significantly reduced, but also demonstrates the ability of *B. interruptus* to germinate and establish successfully within a high density of vegetation cover.

The significance of the cut x cultivation interaction term for population densities ($P < 0.001$) and for rate of population increase ($P < 0.05$) results predominantly from the very low densities observed on plots with a no cut and no cultivation treatment combination (Table 5.13). These are the only plots where population size decreased between year 1 and year 2 ($\lambda < 1$). A similar result was recorded for *Agrostemma* and once again illustrates the importance of a pre-cultivation cut for dispersal of seeds of these species. Analysis also identified a significant interaction between cover and

Table 5.12 Analyses of variance on year 2 (1994-95) population densities and rates of population increase for *B. interruptus*

Significance levels - **P* < 0.05, ***P* < 0.01, ****P* < 0.001

| Source of variation | Population density August 1995 | | | Rates of population increase (λ) | | |
|---|---|---|---|---|---|---|
| | M square | F | Sig level | M square | F | Sig level |
| Main plot error | 186.96 | | | 28.145 | | |
| B | 215.20 | 1.151 | | 12.46 | 0.443 | |
| COV | 1313.53 | 7.026 | * | 95.294 | 3.386 | ns |
| Sub plot error | 204.06 | | | 41.714 | | |
| CULT | 1143.3 | 5.603 | * | 55.956 | 1.341 | ns |
| COV*CULT | 551.05 | 2.700 | ns | 81.324 | 1.950 | ns |
| Sub sub plot error | 135.90 | | | 23.14 | | |
| CUT | 1434.68 | 10.56 | *** | 96.901 | 4.19 | * |
| COV*CUT | 651.55 | 4.79 | ** | 39.202 | 1.65 | ns |
| CUT*CULT | 1733.36 | 12.75 | *** | 118.48 | 5.12 | * |
| COV*CUT*CULT | 213.90 | 1.57 | ns | 29.145 | 1.26 | ns |

Table 5.13 Tables of means to illustrate the interaction between cutting and cultivation regimes for August 1995 population densities and rates of population increase for *B. interruptus*

| Cutting regime | Cultivation regime | Mean population density (individuals $m^{-2}$) | Rate of population increase (λ) |
|---|---|---|---|
| Early | cultivate | 16.56 | 4.393 |
| Early | cultivate and resow | 9.89 | 5.600 |
| Early | no cultivation | 19.67 | 8.603 |
| Late | cultivate | 16.23 | 4.947 |
| Late | cultivate and resow | 7.67 | 1.789 |
| Late | no cultivation | 47.44 | 10.964 |
| None | cultivate | 14.56 | 2.808 |
| None | cultivate and resow | 11.89 | 5.237 |
| None | no cultivation | 1.33 | 0.600 |

Table 5.14 **Tables of means to illustrate the interaction between cover and cutting regimes for August 1995 population densities of *B. interruptus***

| Cutting regime | Cover | Mean population density (individuals $m^{-2}$) |
|---|---|---|
| Early | Grass cover 1 | 9.11 |
| Early | Grass cover 2 | 17.89 |
| Early | Natural regeneration | 19.11 |
| Late | Grass cover 1 | 11.11 |
| Late | Grass cover 2 | 18.33 |
| Late | Natural regeneration | 41.89 |
| None | Grass cover 1 | 9.89 |
| None | Grass cover 2 | 7.67 |
| None | Natural regeneration | 10.22 |

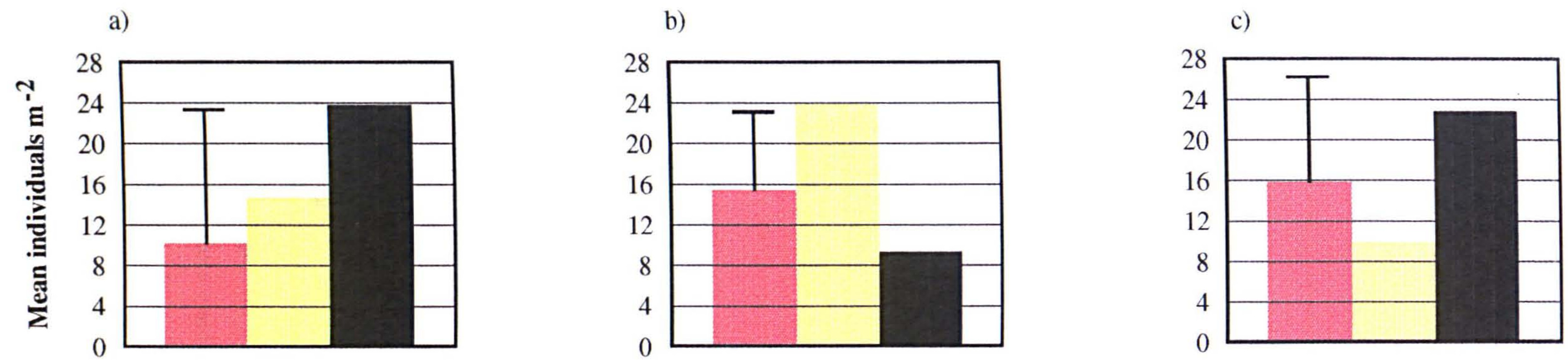



Figure 5.11 a-c Year 2 (1994 - 95) mean population densities of *B.interruptus*at August census under different a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

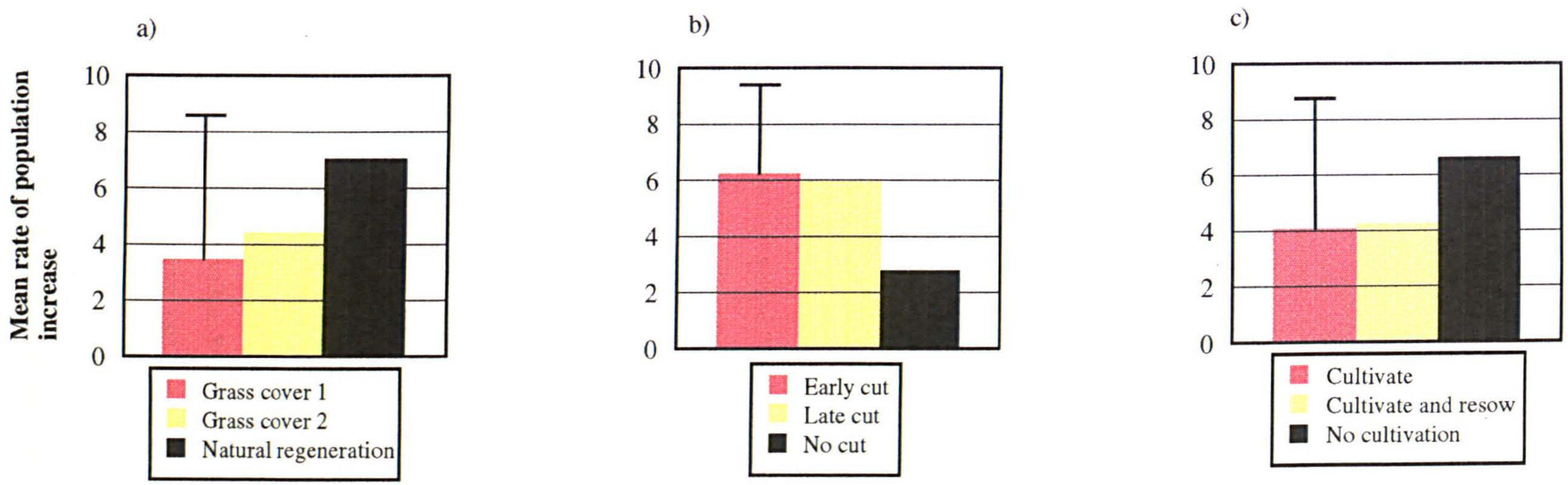



Figure 5.12 a-c Mean rates of population increase (population density 1995 / population density 1994 + 1) for *B. interruptus*under different a) COVERS b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

cutting regime. This is primarily a result of very high densities on the late cut and natural regeneration treatment combination (Table 5.14).

*Reproductive output*

The reproductive output of *B. interruptus* populations was calculated as seed production per unit area according to the method described in section 5.3. A scatter plot and regression analysis for inflorescence weight against number of seeds per inflorescence is presented in Figure 5.9b and illustrates the significant correlation between these two parameters.

Data for seed yield $m^{-2}$ was $log_{10} + 1$ transformed to achieve homogeneity of error variance in the analysis of variance summarised in Table 5.15. $Log_{10} + 1$ mean seed yields are presented in Figure 5.13. Cover type and cutting and cultivation regimes all produced significant differences (Table 5.15) in reproductive output for *B. interruptus* and these are broadly a reflection of differences in population density reported above. However, calculation of mean seed yield per plant does reveal some variations in fecundity as a result of cover and cultivation treatments. Mean seed yield on natural regeneration plots is 42 seeds per plant, compared to 33 and 22 respectively for GC1 and GC2 plots, and 29 on uncultivated plots compared to 39 on plots subject to an autumn cultivation. These results suggest that increased competition from grass cover reduces the number of tillers bearing inflorescences, and the size of these inflorescences within populations of *B. interruptus*.

5.4.2.2.3 *Centaurea cyanus*

*Population densities*

Year 2 population densities for *C. cyanus* at March and August census points are presented in Figure 5.14. Germination and establishment was sporadic, and this species was absent from wildflower communities on many plots during year 2. The resulting data set contained a large proportion of zero values making meaningful statistical analysis impossible. Standard errors of means have been included in Figure 5.14 to provide a measure of sampling variance, and as an aid to comparison of treatment means.

Observed population densities declined between the March and August census points, from a mean of 3.56 individuals $m^{-2}$ in March to 1.19 individuals $m^{-2}$ in August, an overall mortality rate of 67%. Patterns of seedling mortality were largely independent of treatment effects. The mean population density of *C. cyanus* at the August 1994 census was 6.04 individuals $m^{-2}$, population densities recorded at the August 1995 census represent a rate of population increase ($\lambda$) of 0.197,

Table 5.15 Analyses of variance on $\log_{10} + 1$ seed yields for populations of *B. interruptus*
Significance levels - $*P < 0.05$, $**P < 0.01$, $***P < 0.001$

| Source of variation | **$\text{Log}_{10}$ + 1 seed yield $m^{-2}$** M square | F | Sig level |
|---|---|---|---|
| Main plot error | 0.2214 | | |
| B | 0.3916 | 1.769 | |
| COV | 2.4870 | 11.233 | * |
| Sub plot error | 0.3178 | | |
| CULT | 4.4843 | 14.110 | *** |
| COV*CULT | 0.6694 | 2.106 | ns |
| Sub sub plot error | 0.1453 | | |
| CUT | 2.2908 | 4.92 | * |
| COV*CUT | 0.3986 | 0.86 | ns |
| CUT*CULT | 4.8374 | 10.40 | *** |
| COV*CUT*CULT | 0.3456 | 0.74 | ns |

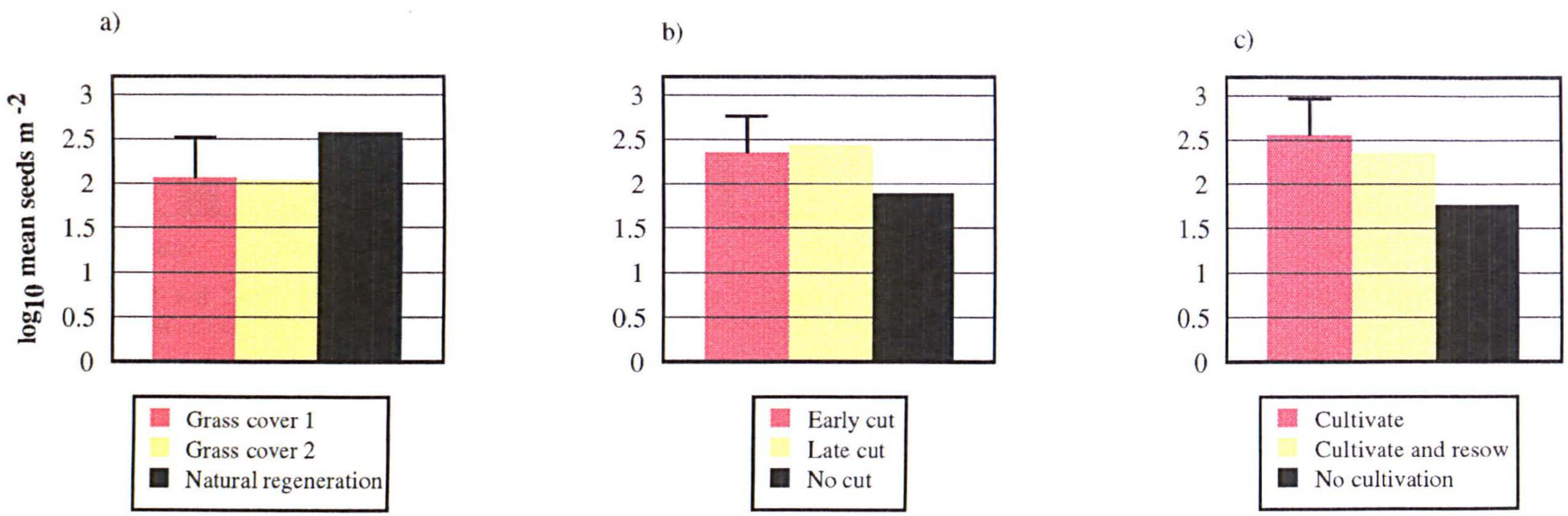



Figure 5.13 a-c Year 2 (1994-95) mean seed production for populations of *B. interruptus* under different a) COVER TYPES b) CUTTING REGIMES and c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

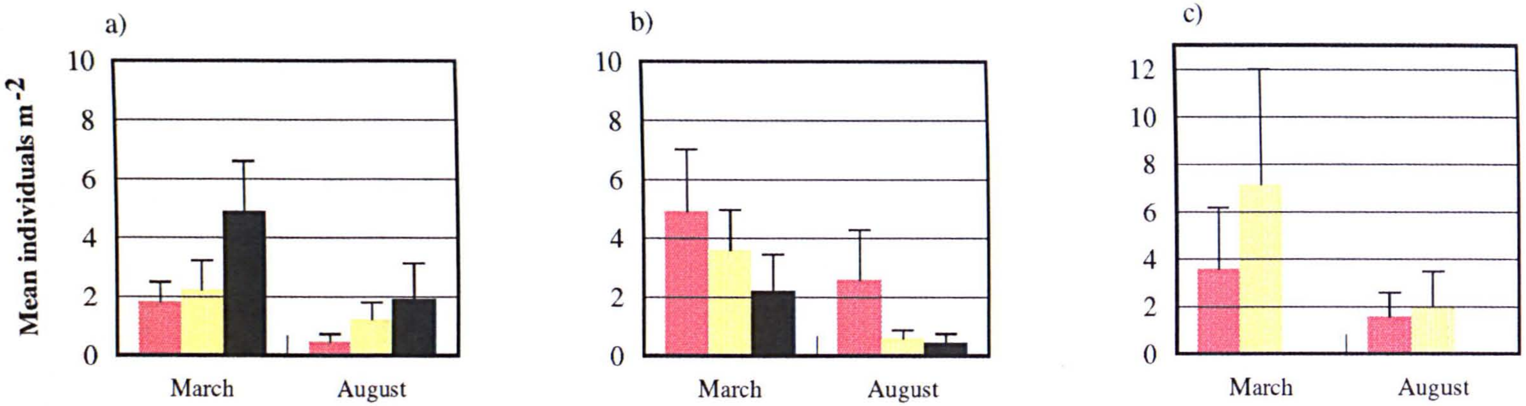



Figure 5.14 a-d Year 2 (1994-95) *C. cyanus* mean population densities at March and August censuses under different: a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are standard errors of the mean

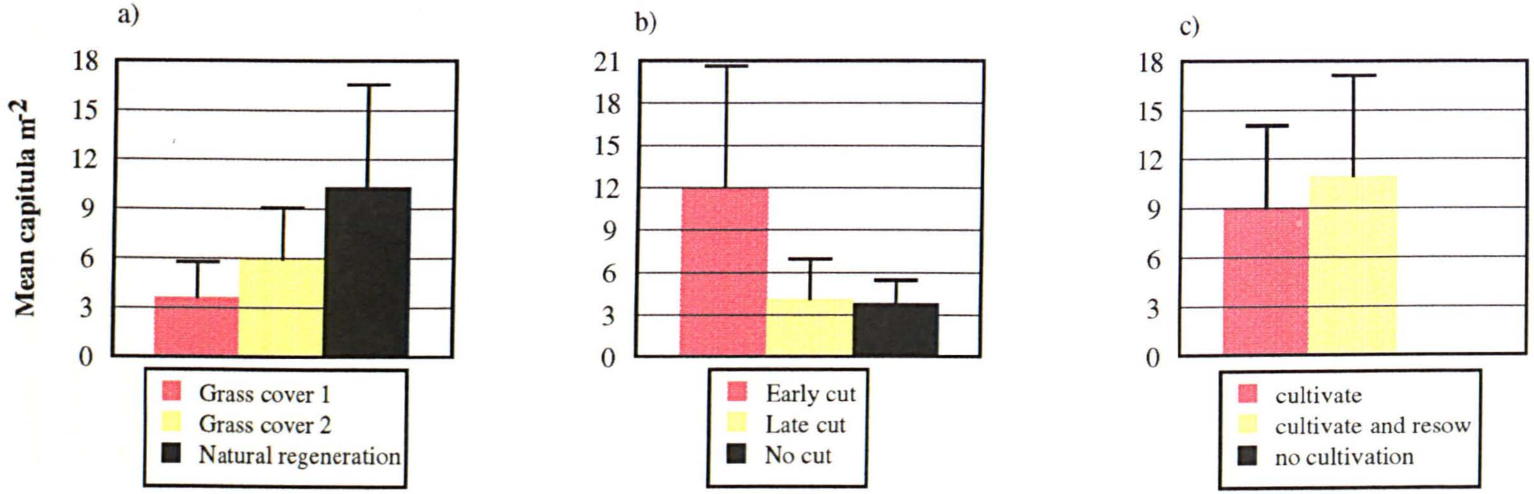



Figure 5.15 a-c Year 2 (1994- 95) *C. cyanus* mean reproductive output at August 1995 under different : a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are standard errors of the mean

indicating that the trajectory of this species is towards relatively rapid exclusion from above-ground rare wildflower communities.

Germination and subsequent establishment of *C. cyanus* was most successful on natural regeneration plots (Figure 5.14a), where competition from regenerating vegetation covers was less intense. This treatment effect was noted for all rare weed species during year 2. *C. cyanus* populations also benefited from an early cut during the previous year (Figure 5.14b), this effect most probably arising as a result of reduced densities of *Agrostemma* on these plots. *C. cyanus* was completely absent from plots which were not cultivated reflecting this species requirement for regular soil disturbance and its apparent inability to germinate and establish within a dense sward.

*Reproductive output*

Reproductive output for populations of *C. cyanus* was measured as number of seed capsules $m^{-2}$. Results are presented in Figure 5.15, together with standard errors of means. Overall capitula production during year 2 for this species is directly proportional to population size with individual populations exhibiting little plasticity in reproductive output.

## 5.4.3 Year 3 - 1995/96

### 5.4.3.1 Year 3 cover establishment

Percentage vegetation cover (excluding rare arable weeds) at the August 1996 census is presented in Figure 5.16 and an analysis of variance on these data is summarised in Table 5.16. Overall, percentage cover of indigenous and sown grass species declined over the course of this trial, from 67% in August 1994 to 34% in August 1996. This decline coincided with increased cover of sown rare wildflower species (predominantly *Agrostemma*), and was accompanied by a reduction in species diversity (number species $m^{-2}$) (Figure 5.17) and increased dominance by grass weeds to the exclusion of herbaceous species.

Cover type, cutting regimes and cultivation regimes all produced significant effects on percentage vegetation cover during year 3 of the trial. Vegetation cover was significantly greater ($P < 0.05$) on GC1 compared to natural regeneration plots, levels on GC2 were intermediate and not significantly different from other cover types. Table 5.17 lists the major component species of indigenous plant communities on these three cover types. As in year 2, *A. capillaris* was the dominant component of plant communities on all covers. The total and relative cover of *T. repens* declined on all plots as did that of the sown grass species *L. perenne* and *F. rubra cv. commutata* on GC1 and

Table 5.16 Analyses of variance on year 3 percentage vegetation cover (excluding rare weed species) and species diversity - August 1996.
Significance levels - $*P < 0.05$, $**P < 0.01$, $***P < 0.001$

| Source of | % vegetation cover | | | Species diversity | | |
|---|---|---|---|---|---|---|
| variation | M square | F | Sig level | M square | F | Sig level |
| Main plot error | 120.55 | | | 5.864 | | |
| B | 356.38 | 2.96 | | 6.864 | 1.171 | |
| COV | 1080.0 | 8.96 | * | 0.901 | 0.154 | ns |
| Sub plot error | 323.5 | | | 7.327 | | |
| CULT | 5461.7 | 16.88 | *** | 127.12 | 17.35 | *** |
| COV*CULT | 133.88 | 0.41 | ns | 5.512 | 0.752 | ns |
| Sub sub plot error | 138.44 | | | 2.868 | | |
| CUT | 492.97 | 3.56 | * | 5.162 | 1.80 | ns |
| COV*CUT | 47.80 | 0.35 | ns | 2.459 | 0.86 | ns |
| CUT*CULT | 27.183 | 0.35 | ns | 5.154 | 1.80 | ns |
| COV*CUT*CULT | 84.283 | 0.61 | ns | 2.496 | 0.87 | ns |

Table 5.17 Major components of plant communities (excluding sown rare weed species) in August 1996 (year 3) on GC1, GC2 and natural regeneration cover plots.

| **GC1** | | **GC2** | | **NR** | |
|---|---|---|---|---|---|
| Species | % | Species | % | Species | % |
| *A. capillaris* | 13.1 | *A. capillaris* | 22.4 | *A. capillaris* | 17.4 |
| *L. perenne* | 12.6 | *P. trivialis* | 4.1 | *T. inodorum* | 3.9 |
| *T. inodorum* | 7.3 | *T.inodorum* | 2.6 | *P. trivialis* | 2.3 |
| *Poa trivialis* | 4.0 | *Avena fatua* | 0.7 | *T. repens* | 1.6 |
| *Agrostis stolonifera* | 1.9 | | | *V. arvensis* | 1.0 |
| *T. repens* | 1.7 | | | | |
| *Viola arvensis* | 1.0 | | | | |
| Bare ground | 15.6 | Bare ground | 18.2 | Bare ground | 24.0 |

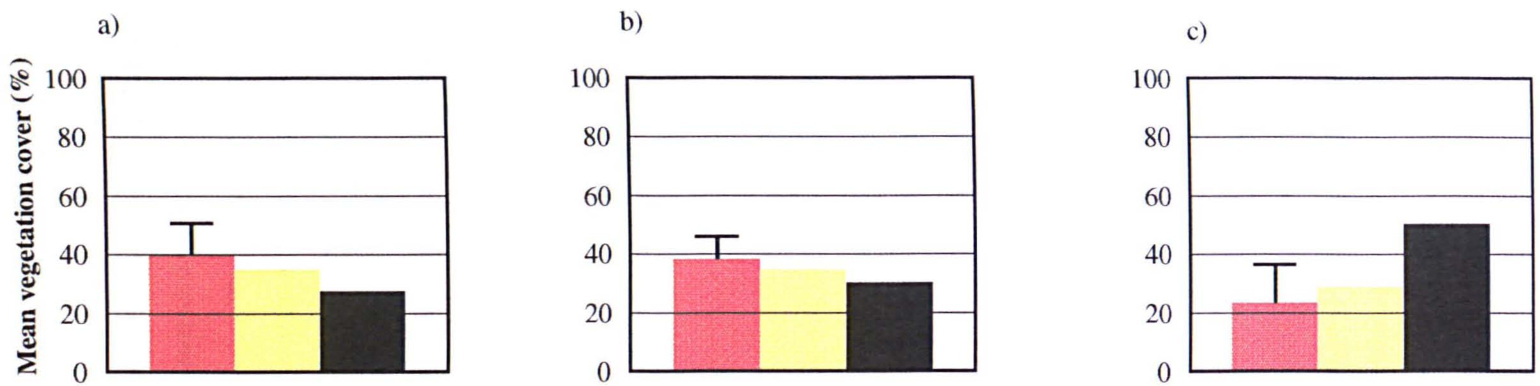



Figure 5.16 a-c Year 3 (1995-96) Mean percentage vegetation cover (excluding sown weed species) in August 1996 under different : a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

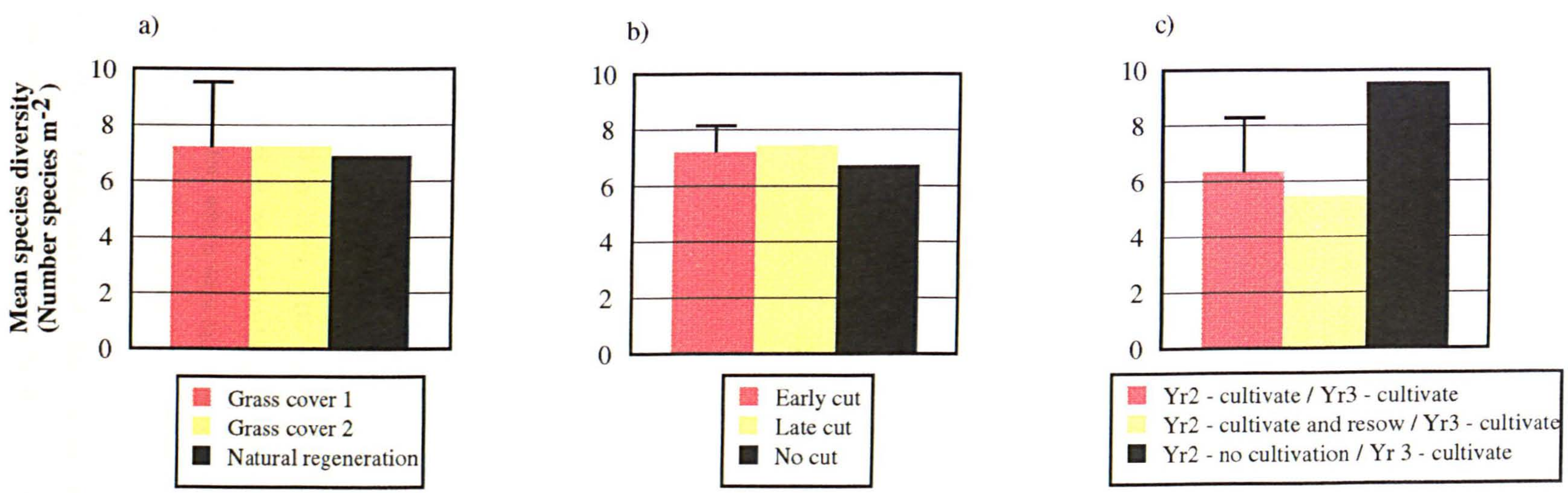



Figure 5.17 a-c Species diversity (excluding sown weed species) at August 1996 under different a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

GC2 plots respectively. Dominance of plots by grass species continued, although *Tripleurospermum inodorum* was a major component of indigenous vegetation on all cover types. Total percentage bare ground followed a similar pattern to previous years, being greatest on natural regeneration and least on GC1 plots, and was slightly greater in year 3 than year 2.

Percentage vegetation cover was significantly greater ($P < 0.05$) on early cut plots than on those that remained uncut during year 2, levels of cover on late cut plots were intermediate and not significantly different from either early or no cut plots. At the beginning of year 3 all plots were lightly cultivated, however, it is the contrast between an annual and biennial cultivation regime which is of relevance to the current years data. Percentage vegetation cover on biennially cultivated plots (year 2 - no cultivation / year 3 - lightly cultivate) was significantly greater than on those which were cultivated during both years.

Figure 5.17 illustrates treatment specific values for species diversity on year 3 plots. Results from an analysis of variance on these results are summarised in Table 5.16. Overall diversity declined from 7.7 species $m^{-2}$ in 1995 to 7.1 species $m^{-2}$ in 1996 continuing the trend of reduced diversity of indigenous plant communities over the course of the experiment. As in year 2, cover type and cutting regime had no effect on species diversity (Figure 5.17 a and b). Species diversity on biennially cultivated plots was significantly greater ($P < 0.001$) than on those which were subject to annual cultivations.

5.4.3.2 Year 3 Rare wildflower communities

5.4.3.2.1 *Agrostemma githago*

*Population densities and rates of population increase*

Year 3 *Agrostemma* population densities are presented in Figure 5.18 a-c, and results from an analysis of variance performed on these data is summarised in Table 5.18. Rates of population increase ($\lambda$) between years 2 and 3 are given in Table 5.19. A second analysis of variance was performed to compare population densities on split split split-plots which were established in year 3 to compare the effects of a single and double cultivation (section 5.2). Results are in Table 5.20.

A mean overall ($n = 81$) rate of population increase during year 3 of 1.48, indicates that, in general, population densities of *Agrostemma* are continuing on an upward trajectory, maintaining and increasing the overwhelming dominance of this species within rare wildflower communities. However, this rate of increase is considerably lower than that observed during year 2 (6.06) suggesting that after three years this species is approaching an equilibrium population, equivalent to the carrying capacity of the experimental habitat. Consideration of this overall level of increase alone masks important variations in rates of increase caused by experimental treatments. These variations will be discussed below with reference to observed population densities of Agrostemma during year 3.

By year 3 of the trial initial cover type and cutting regimes had no significant effect on observed population densities of *Agrostemma* (Figure 5.18, Table 5.18). The mean rate of population increase on GC1 plots during year 3 was 1.73, compared to 1.50 and 1.31 respectively on GC2 and natural regeneration plots. These differences effectively eliminated cover treatment effects observed during year 2. Differential rates of population increase would appear to arise as a result of the diminished ability of year 1 sown covers to suppress germination and establishment of *Agrostemma*.

An early cut (1st August) during year 1 resulted in significantly lower year 2 population densities. This treatment effect was not observed in year 3. Temperatures were higher and rainfall lower (Figure 5.2) during critical periods for seed maturation and ripening in year 2, and as a result the proportion of immature seeds being 'dispersed' following an early cut was probably less than in year 1.

Cultivation regime remained a crucial determinant of *Agrostemma* population density at the final census point in August 1996, with highly significant differences ($P < 0.001$) existing between annually and biennially cultivated plots. The mean rate of population increase following year 3 cultivation of biennially cultivated plots was considerably higher (4.34) than that observed on annually cultivated plots (1.37), but nevertheless, mean population densities remained significantly greater ($P < 0.001$) on annually cultivated plots (Figure 5.18c). A further split was incorporated into the experimental design during year 3 to assess the effect of a double cultivation (autumn and spring) on rare wildflower community structure, and in particular on population densities of *Agrostemma*. *Agrostemma* is an autumn germinating species and it was envisaged that a spring cultivation could potentially eliminate, or at least severely reduce populations of this species, greatly enhancing establishment opportunities for other rare arable wildflower species. Whilst a spring cultivation did significantly reduce *Agrostemma* population density, from 877 individuals $m^{-2}$ to 119 individuals $m^{-2}$ ($P < 0.001$), seedlings showed remarkable resilience to soil disturbance, demonstrating an ability to re-establish and grow to reproductive maturity and *Agrostemma* remained the dominant component of rare arable wildflower communities.

*Reproductive output*

Reproductive output was measured as described in section 5.5.2.2.1. A scatter plot and regression analysis for the current years calibration of seed number per capsule is presented in Figure

Table 5.18 Analyses of variance on year 3 *Agrostemma* population densities (individuals $m^{-2}$) and seed yields (seeds $m^{-2}$) - August 1996.
Significance levels - $*P < 0.05$, $**P < 0.01$, $***P < 0.001$

| Source of variation | population density M square | F | Sig level | seed yield M square | F | Sig level |
|---|---|---|---|---|---|---|
| Main plot error | 351,704 | | | $5.96 \times 10^8$ | | |
| B | 77,200 | 0.220 | | $1.70 \times 10^8$ | 0.286 | |
| COV | 112,111 | 0.319 | ns | $6.353 \times 10^7$ | 0.107 | ns |
| Sub plot error | 149,919 | | | $1.572 \times 10^8$ | | |
| CULT | 5,500,012 | 36.69 | *** | $1.470 \times 10^9$ | 9.35 | ** |
| COV*CULT | 67,36 | 0.449 | ns | $1.368 \times 10^8$ | 0.87 | ns |
| Sub sub plot error | 97,027 | | | $9.823 \times 10^7$ | | |
| CUT | 97,612 | 1.01 | ns | $1.089 \times 10^8$ | 1.11 | ns |
| COV*CUT | 26,897 | 0.89 | ns | $1.686 \times 10^7$ | 0.17 | ns |
| CUT*CULT | 97,895 | 1.01 | ns | $6.672 \times 10^7$ | 0.68 | ns |
| COV*CUT*CULT | 34,472 | 0.36 | ns | $4.524 \times 10^7$ | 0.46 | ns |

Table 5.19 Year 3 rates of population increase (λ) for populations of *Agrostemma* under various management regimes

| Cover | λ | Cutting regime | λ | Cultivation regime[1] | λ |
|---|---|---|---|---|---|
| GC1 | 1.73 | EARLY | 1.87 | CULT 1 | 1.42 |
| GC2 | 1.50 | LATE | 1.38 | CULT 2 | 1.32 |
| NR | 1.31 | NO CUT | 1.33 | CULT 3 | 0.18 |
| | | | | CULT 4 | 4.34 |
| **OVERALL MEAN = 1.48** | | | | | |

[1] - CULT1 - year 2 - cultivate / year 3 - cultivate ; CULT 2 - year 2 - cultivate and resow / year 3 - single cultivation ; CULT 3 - year 2 - cultivate and resow / year 3 - double cultivation ; CULT 4 - year 2 - no cultivation / year 3 - cultivate

Table 5.20 Analyses of variance on year 3 (1995-96) split split split-plot design comparing a single and double cultivation for August 1996 *Agrostemma* census data.
Significance levels - *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

| Source of variation | population density M square | F | Sig level | seed yield M square | F | Sig level |
|---|---|---|---|---|---|---|
| sub plot error | 25,955 | | | $1.160x10^8$ | | |
| CULT2 | 7,767,230 | 299.3 | *** | $3.980x10^9$ | 34.30 | *** |
| COV*CULT2 | 54,245 | 2.09 | ns | $4.615x10^6$ | 0.04 | ns |
| Sub sub plot error | 41,645 | | | $8.683x10^7$ | | |
| CUT*CULT2 | 1508.7 | 0.04 | ns | $1.474x10^8$ | 1.70 | ns |
| COV*CUT*CULT2 | 4,753.2 | 0.11 | ns | $9.293x10^6$ | 0.11 | ns |

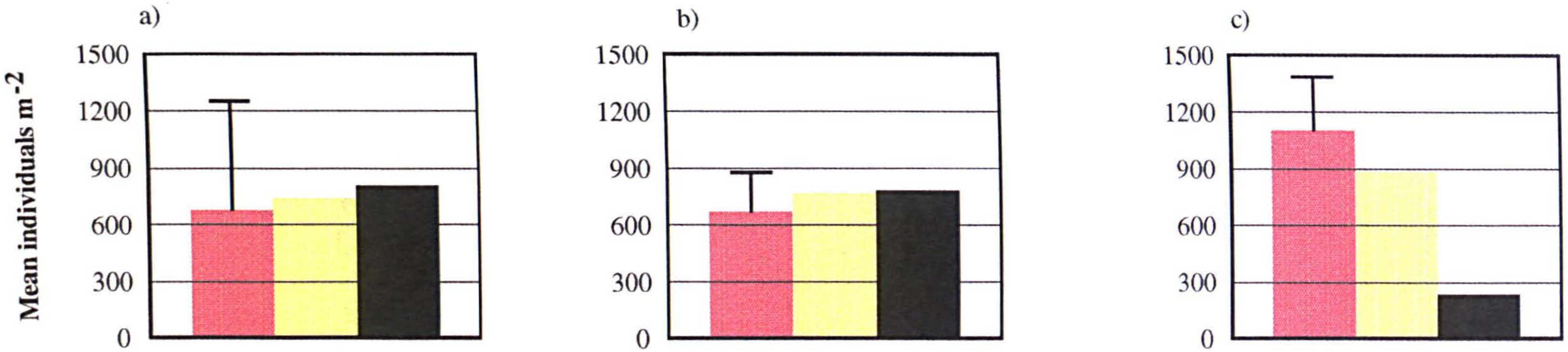



Figure 5.18 a-c Year 3 (1995-96) Mean population densities of *A. githago* under different a) COVER TYPE b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

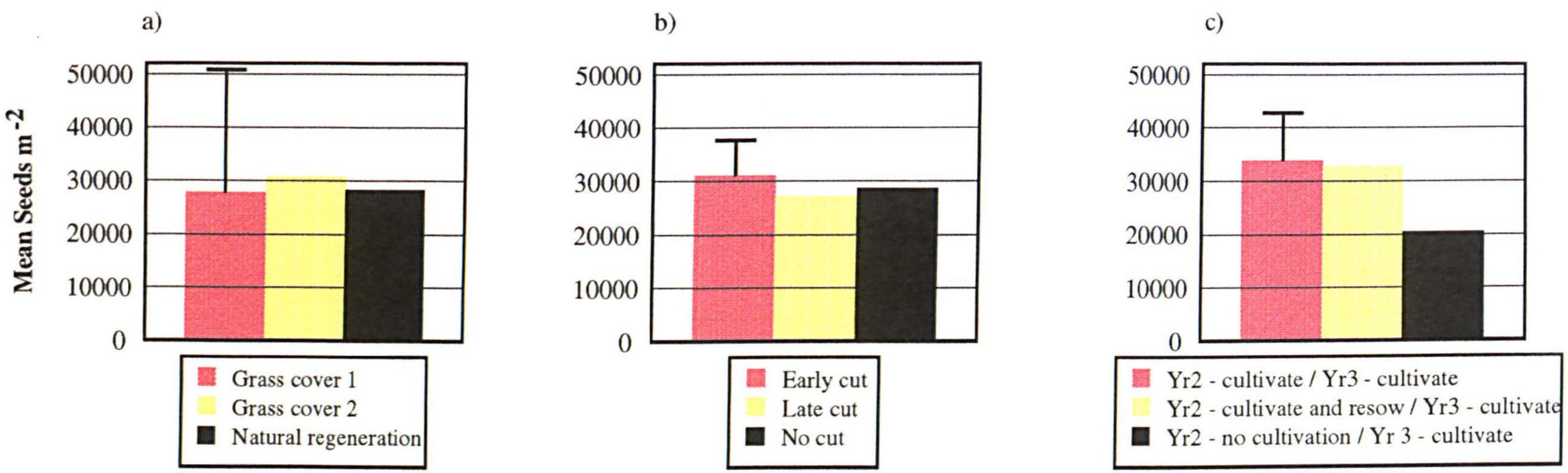
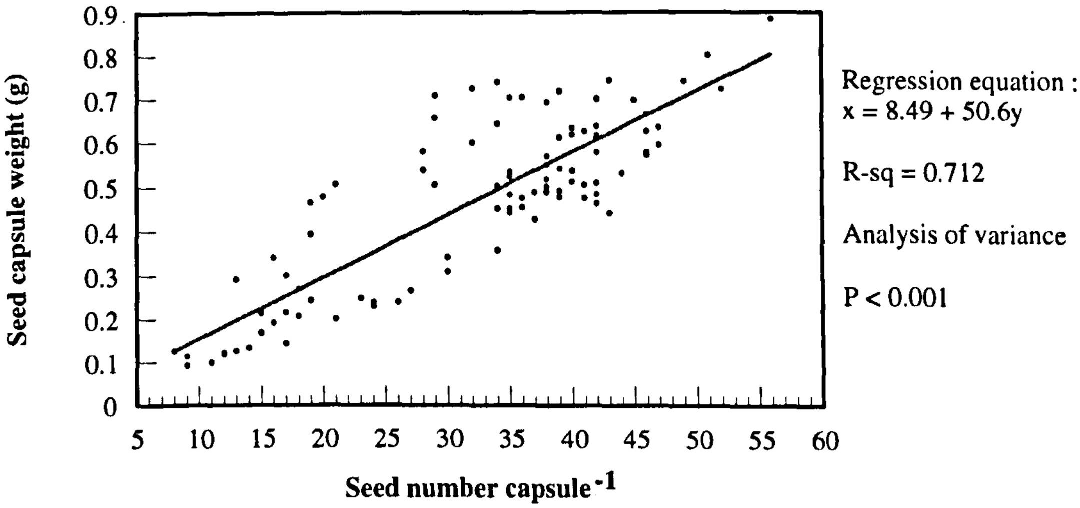



Figure 5.19 a-c Year 3 (1995-96) seed yields of *A. githago* under different a) COVER TYPES b) CUTTING REGIMES and c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

a) *A. githago*




b) *B. interruptus*

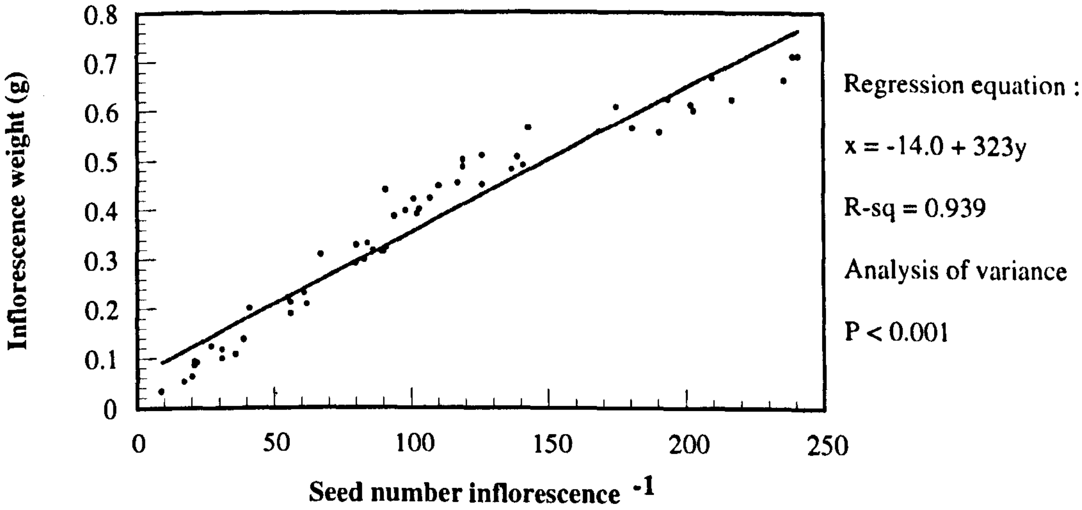



Figure 5.20 a and b Year 3 linear regression models for calibration of seed yields
a) *A. githago* - capsule weight by seed number per capsule
b) *B. interruptus*- inflorescence weight by seed number per inflorescence

5.20. Mean seed yields $m^{-2}$ for *Agrostemma* populations are shown in Figure 5.19 and results from analyses of variance on these data summarised in Tables 5.18 and 5.20.

Mean seed yield at August 1996 was 28,841 seeds $m^{-2}$, representing a rate of increase in seed production (seed yield 1996 / seed yield 1995) of 2.44, compared to a rate of increase in population size ($\lambda$) of only 1.48. Clearly, mean seed yield per individual was considerably greater in year 3 than in year 2. A number of factors may account for this ; competition from indigenous and sown weed cover was less intense during year 3, seed yields were very low in year 2 on plots which were not cultivated (all plots were cultivated in year 3) and the summer months in 1995 were very hot and dry. Regardless of the explanation for these results, they suggest that the upward trajectory of *Agrostemma* populations would have continued if this trial had continued into a fourth year.

In common with population densities, initial cover type and cutting regime did not significantly effect year 3 seed yields (Figure 5.19 a and b) and seed yield on annually cultivated plots is significantly greater ($P < 0.001$) than on those which were cultivated on a biennial basis. Seed yields on double cultivated plots were significantly lower than on split plots which were cultivated in autumn only. Whilst the significance levels of the various treatment variables for population densities and seed yields are identical (Table 5.18 and 5.20), some potentially important differences in seed yields per plant do occur which result in actual differences in seed yield $m^{-2}$ being less pronounced than those between population sizes. Mean seed yield on biennially cultivated plots was 87.2 per plant compared to 33.8 on annually cultivated plots, again demonstrating the considerable ability of this species for plastic growth and density regulated fecundity. On double cultivated plots mean yield per individual was 129 seeds further demonstrating this point and more importantly illustrating the considerable problems associated with attempts at long-term control of this species in order to prevent its complete dominance of rare arable wildflower communities.

5.4.3.2.2 *Bromus interruptus*

*Population densities and rates of population increase*

Year 3 population densities for *B. interruptus* are presented in Figure 5.21 and analyses of variance performed on these data are summarised in Table 5.21. Rates of population increase ($\lambda$) from year 2 to year 3 were calculated and are included in Table 5.22. Like *Agrostemma*, *B. interruptus* is an autumn germinating species, however, in contrast to populations of *Agrostemma* it was completely eliminated from plots subject to a double cultivation during year 3.

Overall, population densities of *B. interruptus* declined considerably during year 3, from a mean of 16.1 individuals $m^{-2}$ in August 1995 to an overall mean density of 2.3 individuals $m^{-2}$ in Table

Table 5.21 Analyses of variance on year 3 *B. interruptus* population densities (individuals $m^{-2}$) and seed yields (seeds $m^{-2}$) - August 1996.

Significance levels - $*P < 0.05$, $**P < 0.01$, $***P < 0.001$

| Source of | **population density** | | | **seed yield** | | |
|---|---|---|---|---|---|---|
| variation | M square | F | Sig level | M square | F | Sig level |
| Main plot error | 5.648 | | | 40,993 | | |
| B | 4.000 | 0.708 | | 79,984 | 1.951 | |
| COV | 45.37 | 8.033 | * | 200,968 | 4.902 | ns |
| Sub plot error | 5.914 | | | 70,195 | | |
| CULT | 10.111 | 1.710 | ns | 6,009 | 0.086 | ns |
| COV*CULT | 2.426 | 0.410 | ns | 25,808 | 0.368 | ns |
| Sub sub plot error | 9.272 | | | 75,647 | | |
| CUT | 32.33 | 3.49 | * | 60,235 | 0.76 | ns |
| COV*CUT | 5.593 | 0.60 | ns | 12004 | 0.16 | ns |
| CUT*CULT | 23.778 | 2.56 | ns | 137,024 | 1.81 | ns |
| COV*CUT*CULT | 3.676 | 0.40 | ns | 61,918 | 0.82 | ns |

Table 5.22 Year 3 rates of population increase ($\lambda$) for populations of *B. interruptus* under various management regimes

| Cover | $\lambda$ | Cutting regime | $\lambda$ | Cultivation regime[1] | $\lambda$ |
|---|---|---|---|---|---|
| GC1 | 0.157 | EARLY | 0.089 | CULT 1 | 0.162 |
| GC2 | 0.116 | LATE | 0.081 | CULT 2 | 0.272 |
| NR | 0.158 | NO CUT | 0.376 | CULT 4 | 0.068 |

**OVERALL MEAN = 0.139**

[1] - CULT1 - year 2 - cultivate / year 3 - cultivate ; CULT 2 - year 2 - cultivate and resow / year 3 - single cultivation ; CULT 4 - year 2 - no cultivation / year 3 - cultivate

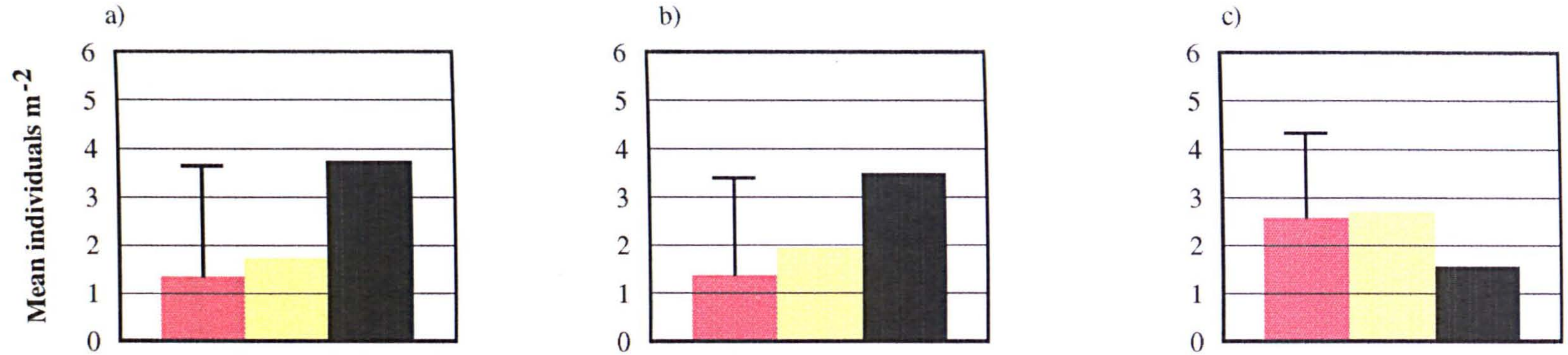



Figure 5.21 a-c Year 3 (1995 96) mean population densities of *B. interruptus* under different a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

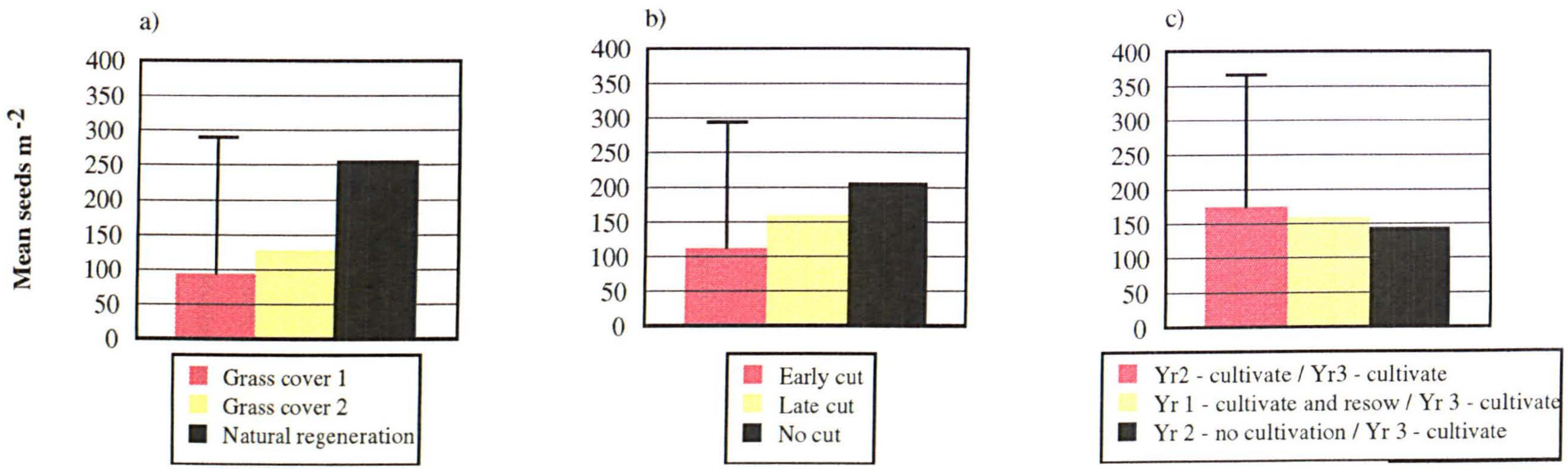



Figure 5.22 a-c Year 3 (1995-96) mean seed yields of *B. interruptus* under different a) COVER TYPES b) CUTTING REGIMES and c) CULTIVATION REGIMES. Error bars are Tukey's LSD (P, 0.05)

August 1996, a rate of population increase (λ) of 0.139. Despite this general decline during year 3, the effect of initial cover type on populations remains the same as observed in year 2 with densities on naturally regenerating plots significantly greater ($P < 0.05$) than on sown grass cover plots (Figure 5.21a). This is not true of cutting regimes. During year 2 population densities were significantly reduced on plots which remained uncut during year 1. Results presented in Figure 5.21b illustrate a starkly different response during year 3, with 'no cut' plots demonstrating significantly higher ( $P < 0.05$) densities than plots which were cut on 1st August 1995, results for late cut plots were intermediate and not significantly different from either early or no cut regimes. These contrasting observations suggest that populations of *B. interruptus* will not respond in a predictable way to various cutting strategies, and that other climatic and biotic factors, and intrinsic population processes may be crucial in determining a populations response to the annual cutting regime.

Over the three year course of this trial no significant difference was observed between *B. interruptus* population densities on annually and biennially cultivated plots (Figure 5.21c).

*Reproductive output*

Reproductive output was measured as described in section 5.5.2.2.2. A scatter plot and regression analysis for the current years calibration of seed number per inflorescence is presented in Figure 5.20b. Mean seed yields $m^{-2}$ for *B. interruptus* populations are shown in Figure 5.22 and results from analyses of variance on these data summarised in Table 5.21.

Seed yields (seeds $m^{-2}$) of *B. interruptus* populations were not significantly effected by any of the experimental treatment variables at the final census point in August 1996 (Figure 5.22, Table 5.21). The mean overall seed yield for year 3 populations was 158.2 seeds $m^{-2}$, compared to 550 seeds $m^{-2}$ in year 2, representing a 71% decline in seed production, and reflecting the decline in population densities discussed above. Only continued monitoring during subsequent years could establish whether the decline in *B. interruptus* populations observed in year 3 would continue, ultimately resulting in the exclusion of this species from arable wildflower communities, or whether these results represent intrinsic fluctuations in populations of this species.

5.4.3.2.3 *Centaurea cyanus*

*Population densities*

Year 3 mean population densities of *C. cyanus* are presented in Figure 5.23. Standard errors of means are included to provide a measure of variability and to aid comparison of treatment means. The absence of this species from weed communities on a large proportion of year 3 plots meant that analysis of variance of the data set was not appropriate.

During year 3 this species persisted at very low densities within above-ground rare weed communities, overall mean population sizes increasing from 1.35 individuals $m^{-2}$ in August 1995 to 2.02 individuals $m^{-2}$ in August 1996. Responses to cover types and cutting regimes (Figure 5.23 a and b) were identical to those reported for year 2 populations. Year 3 cultivation regimes produced the most notable density effects. Population densities of *C. cyanus* were highest on plots which were double cultivated (Figure 5.23c). This species exhibits flushes of germination in autumn and spring and benefited from the spring cultivation which significantly reduced numbers of *Agrostemma* and increased the number of safe sites into which seeds from the persistent seedbank could germinate and establish. The ability of *C. cyanus* to persist as dormant viable seeds within the soil was demonstrated on biennially cultivated plots. During year 2 this species was completely absent from the above-ground flora on uncultivated plots, but following cultivation in year 3 re-emerged as a component of rare wildflower communities on these plots.

*Reproductive outputs*

The reproductive outputs of *C. cyanus* populations were measured as capitula $m^{-2}$. These results are presented in Figure 5.24. The mean number (n = 81) of capitula produced per individual was significantly greater in year 3 compared to year 2 populations. However, reproductive output per individual was independent of management. As such, the response of populations to cover, cutting and cultivation treatments in terms of total seed yield was largely the same as that discussed above for population densities.

5.4.3.2.4 *Papaver rhoeas - Population densities.*

*P. rhoeas*, a component of the original wildflower seed mixture, emerged as a component of rare weed communities during year 3 after being completely absent during the first and second years of the trial. Mean population densities under the various cover, cutting and cultivation regimes are presented in Figure 5.25, together with standard errors of these means. The occurrence of this species

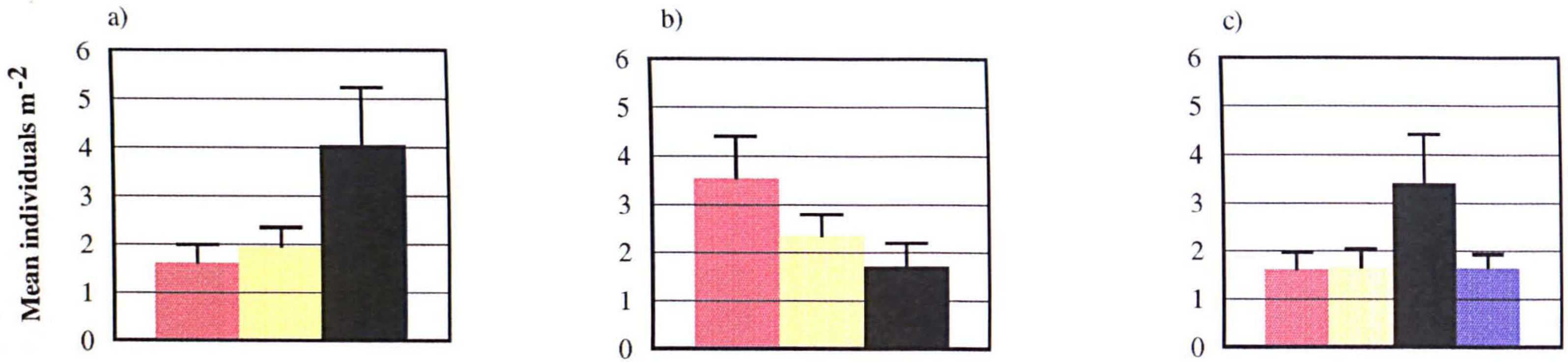



Figure 5.23 a-c Year 3 (1995 96) Mean population densities of *C. cyanus* under different a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES. Error bars are standard errors of the mean

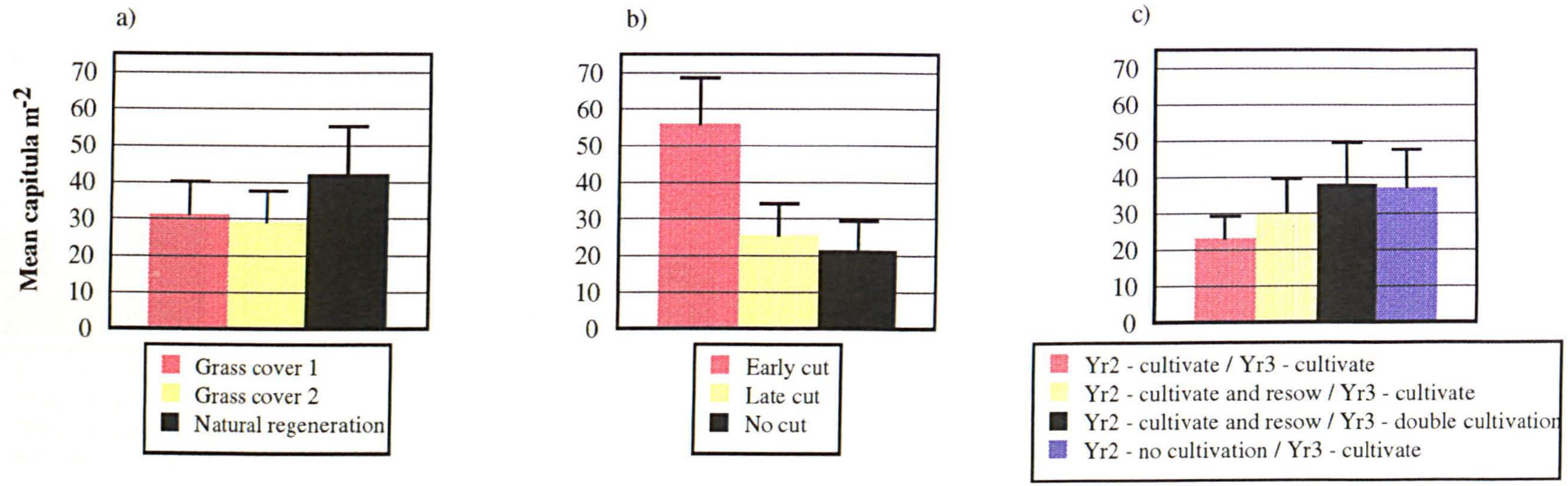



Figure 5.24 a-c Year 3 (1995-96) Mean seed yields of *C. cyanus* under different a) COVER TYPES b) CUTTING REGIMES and c) CULTIVATION REGIMES. Error bars are standard errors of the mean

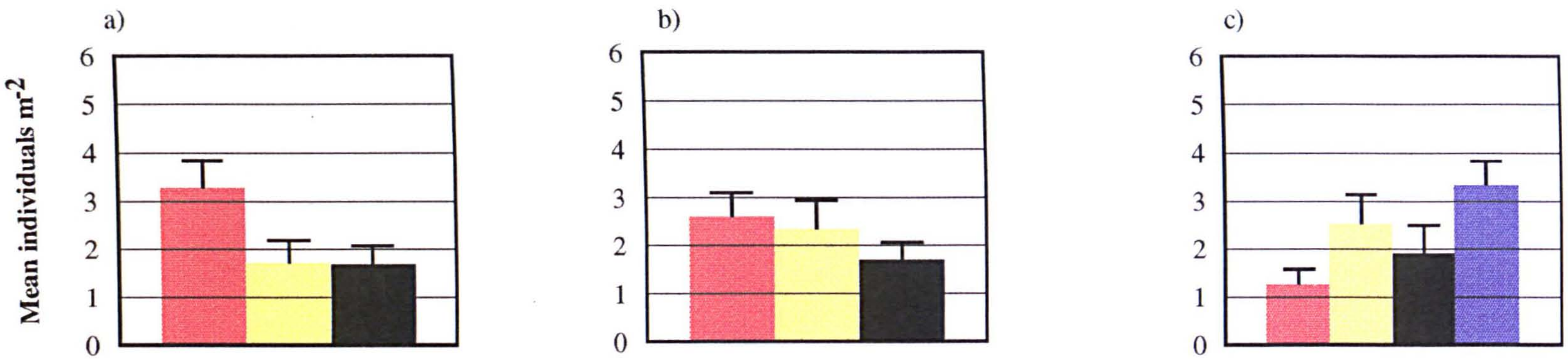



Figure 5.25 a-c Year 3 (1995-96) population densities of *P. rhoeas* under different a) COVER TYPES b) CUTTING REGIMES c) CULTIVATION REGIMES Error bars are standard errors of the mean

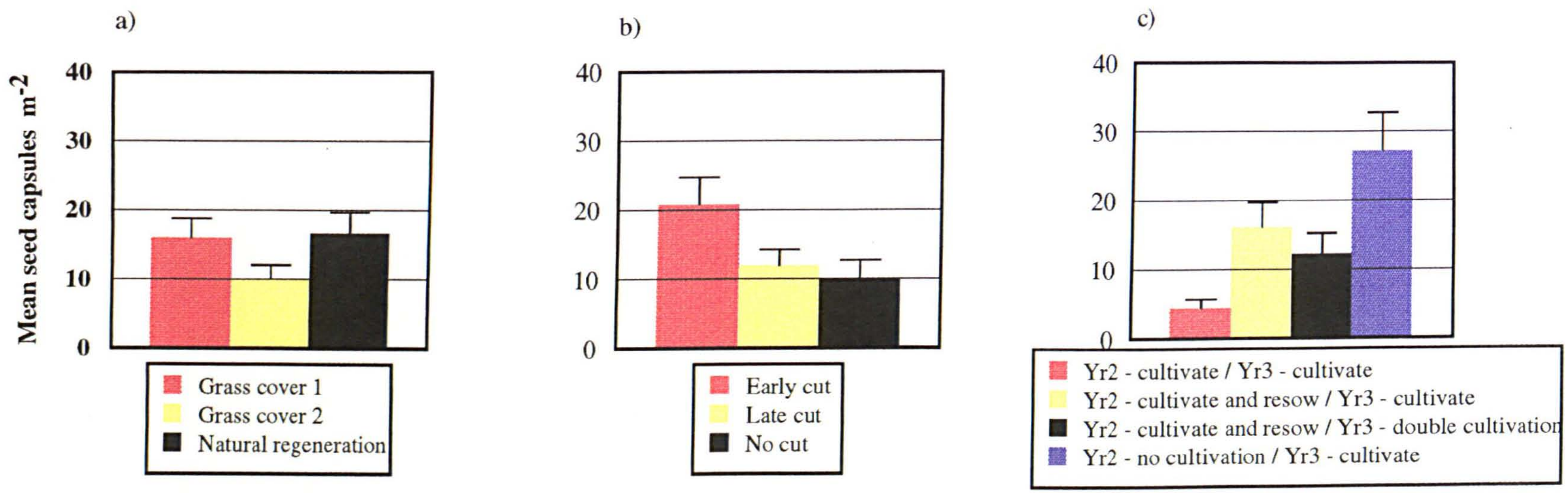



Figure 5.26 a-c Year 3 (1995-96) reproducitve output of *P. rhoeas* under different a) COVER TYPES b) CUTTING REGIMES and c) CULTIVATION REGIMES. Error bars are standard errors of the mean

is sporadic, and the resulting data set which contains large numbers of zero values is not amenable to analysis of variance.

*P. rhoeas* was most abundant on GC1 cover plots (Figure 5.25a) and population densities were largely unaffected by cutting regimes (Figure 5.25b). A comparison of population sizes on annually and biennially cultivated plots suggests that this species was benefited by a biennial cultivation regime (Figure 5.25c). Population densities were reduced on plots which received a double cultivation in year 3.

*Reproductive output*

This was measured as number of seed capsules $m^{-2}$ . Results are presented in Figure 5.26. Whilst actual population densities were greatest on GC1 plots, reproductive output was highest on naturally regenerating plots, apart from this anomaly patterns of reproductive output reflect population densities.

5.4.3.2.5 *Chrysanthemum segetum*

During year 3 this species was only present on plots which received a double cultivation. Mean population density was 6.26 individuals $m^{-2}$.

Plate 5.3 28th October 1994 - A cultivated plot 2 days after cultivation, surviving 'turves' and vegetative fragments from the previous years cover are clearly visible.

Plate 5.4 3rd November 1994 - The same plot 7 days after cultivation. Cover is beginning to regenerate and germinating seedlings of *Agrostemma* are becoming established.

Plate 5.5 7th February 1995 - A typical cultivated plot 3 months after cultivation, dominated by *Agrostemma* seedlings most of which have over-wintered at the 4 leaf stage.

Plate 5.6 August 1995. A typical uncultivated plot, dominated by perennial grasses (predominantly *A. capillaris*). Small flowering individuals of *Agrostemma* are visible at the margins of the plot.

Plate 5.7 August 1995. A typical cultivated plot, dominated by reproductively mature *Agrostemma* individuals.

## 5.5 DISCUSSION

In order to effectively evaluate results from this experiment, in terms of both observed (present) and future community structure, some criteria for defining diverse, persistent and stable communities are outlined. One of the fundamental features of plant communities is their tendency towards change, and it can be argued that the completely stable plant community does not exist. Dodd *et al.* (1995), when considering patterns of community stability on the Park Grass experimental plots commented that "change is the prevailing state of plant communities in the long term". When considering processes of community change and stability, it is the time scale over which change occurs which is of over-riding importance. There are two types of temporal change in plant communities, directional changes which occur over ecological and geological time scales, and are termed succession, and non-directional changes which are cyclic and occur from generation to generation (Krebs, 1985).

The weed communities of arable land have one universally common feature ; they are subject to regular 'catastrophic' seasonal disturbance which precludes the survival of above-ground biomass. As a consequence, species must persist as underground perennating organs, or as seed, and the majority of arable weeds display an annual life-cycle. These regular and severe disturbances preclude large scale and long-term successional change, but nevertheless these communities may change on a smaller scale, in terms of both species composition and relative abundance. These processes are referred to as community dynamics. Long-term studies of community dynamics and community change within grasslands have been widely reported (Bradshaw, 1981 ; Watt, 1981 ; Davy and Jefferies, 1981 ; Dodd *et al*, 1995 ; Wilson *et al*, 1996). However, similar studies for arable weed communities are rare, and where large-scale studies have been attempted, results have been purely descriptive (Chancellor, 1977 ; Chancellor and Froud-Williams, 1984 ; Mutkula *et al*, 1969), or have been oriented primarily towards the development of 'tactical' and 'strategic' weed control programs to eradicate or control arable weed communities.

Results presented in this chapter will be discussed, in the first instance, on the basis of the effects of various management regimes on the establishment of rare wildflower communities. This is followed by consideration of the dynamic community processes which are observed as a result of, and independently of these management factors. The trajectory of individual weed populations is considered, together with the implications of autecological and seedbank characteristics determined in chapter 4. In conjunction, dynamic processes above-ground, and within the soil seedbank are discussed to determine if stable, diverse and persistent communities of the five sown species have been, or can be (over a longer time scale) attained on set-aside land, or if, alternatively, these communities will ultimately become dominated by *Agrostemma* to the detriment of overall community diversity.

## 5.5.1 The development of plant cover on set-aside land

Current regulations require a green cover to be established on set-aside land before the start of the set-aside season (15 January). MAFF (1996d) presents a number of options via which this may be achieved, two of which are to allow natural regeneration from the soil seedbank, or to sow a grass/legume cover crop (legumes may account for up to 5% by weight of the seed mixture). There has been a wealth of literature investigating the effects of cover type on the composition and diversity of weed communities on set-aside land. Much of this has focused on preventing injurious weed populations from escalating to levels which may impact on subsequent and adjacent crop yields (Clarke, 1992, 1995 ; Jones and Naylor, 1992 ; Lechner, Hurle and Zwerger, 1992 ; Davies, Fisher and Atkinson, 1992). Others have considered the potential benefits to wildlife from increased botanical diversity on set-aside land (Wilson, 1992 ; Smith and MacDonald, 1992). Taken together with surveys which have characterised the botanical composition of set-aside fields (Fisher et al, 1992 ; Poulton and Swash, 1992) and existing literature on 'old-field' succession (Gibson and Brown, 1991 ; Schmidt, 1988) this work provides a substantial literature on processes of succession on set-aside land.

The main purpose of including the three cover types in the experimental design was to compare their effects on the establishment and maintenance of rare wildflower communities. However, before these are discussed, consideration is given to changing patterns of species composition of indigenous and sown weed communities on the three cover types.

### 5.5.1.1 Changes in the composition of indigenous and sown weed communities - succession on set-aside land.

Two major patterns emerge over the three year course of the trial regardless of cover type ; mean species diversity (number species $m^{-2}$) declines from 13.6 during year 1 to 7.1 during year 3, and at the same time, indigenous plant communities become increasingly dominated by perennial grasses which exclude many of the annual species observed during year 1. Botanical diversity is significantly greater during year 1 of the trial on natural regeneration compared to GC1 plots. Diversity is intermediate on GC2 plots. These results are not surprising given the highly competitive nature of the GC1 species, and similar results have been reported elsewhere (Fisher *et al.*, 1992 ; Wilson, 1992 ; Lechner, Hurle and Zwerger, 1992 ; Clarke, 1992). Depending on emphasis these have been variously discussed in terms of their potential for decreasing weed infestations in subsequent crops, or conversely in recognition of their wildlife and nature conservation benefits. Similar, though not statistically significant, trends emerged during year 2, but by year 3 initial cover establishment had no effect on species diversity.

The tendency for weed communities to be dominated by annual species during the first year of cover development on set-aside land, and the trend towards increasing dominance by perennials in subsequent years has been widely reported (Fisher *et al*, 1992 ; Wilson, 1992 ; Clarke, 1992 ; Lawson *et al*, 1992 ; Shield and Godwin, 1992) and is a characteristic pattern in 'old-field' successions (Schmidt, 1988 ; Gibson and Brown, 1991). During the first year of the current trial, particularly on natural regeneration plots, a large number of typical annual arable weeds, some frequent and others more sporadic, established from the existing indigenous seedbank population. Most common amongst these were *Tripleurospermum inodorum, Viola arvensis, Poa annua, Anagallis arvensis, Aphanes arvensis, Myosotis arvensis, Polygonum aviculare, Stellaria media,* and *Cerastium fontanum*. During years 2 and 3 these were progressively excluded, or their relative abundances were greatly reduced by perennial grass species of which *A. capillaris* was the most abundant. By year 3 *A. capillaris* was the dominant species on plots which were initially sown with a grass cover. In a survey by Poulton and Swash (1992) *A. capillaris* was reported as the most frequently occurring species on set-aside fields in England. Other common perennial species were *Poa trivialis, Trifolium repens, Holcus lanatus* and *Agrostis stolonifera*.

Cutting regimes had no effect on the species diversity or composition of indigenous and sown vegetation cover at any stage during the trial. Cutting is a form of disturbance, and as such is often employed as a management tool to encourage diversity in grass swards. On set-aside land the frequency and timing of annual cuts will ultimately be determined by the nature of the weed flora, and the goals which are being sought (weed control or nature conservation) (Smith and MacDonald, 1992). Early and frequent cutting will prevent seeding of dominant weed species and remove a disproportionate amount of their biomass, and is often encouraged where weed control is sought. It may also create gaps into which other species may establish. In the current trial the 'early' cutting time was designated to coincide with the compulsory annual cut on set-aside land (between 15th July and 15th August). The late cut was two weeks after this period. It was anticipated that earlier and more frequent cutting would prevent seed production in arable wildflowers, and result in their eradication from subsequent communities. In light of this, differences between cutting regimes are minor, and their effects are expected to interact with the individual phenology of rare arable wildflowers, rather than cause widespread changes in species composition and diversity of indigenous weed populations.

An annual cultivation destroys all green cover, and as such is a more radical form of disturbance than cutting. Much of the previous work reporting successional changes in species diversity and composition on set-aside land has been carried out on fields which have remained uncultivated. In the current trial it might be expected that cultivations would remove the tendency for weed cover to become dominated by relatively few species. Comparisons of species diversity on cultivated and uncultivated plots at the end of year 2 identifies a tendency towards reduced diversity in the absence of cultivation. Whilst annual cultivations may, in many instances, promote or maintain species diversity, their effect in the current trial was to result in rapidly increasing population densities of *Agrostemma.* Dominance of vegetation cover by *Agrostemma* was the primary reason for the observed losses in diversity, and for the overall reduction in levels of indigenous and sown weed cover in this trial.

5.5.1.2 *The effect of sown cover on rare weed community structure*

Regardless of management, the nature of the initial 'cover' type had a relatively minor effect on rare wildflower community structure, and in particular, on the population densities of *Agrostemma.* The initial success of *Agrostemma* in terms of establishment, and ultimately 'space capture' (Harper, 1977) during year 1 of the trial had much to do with the ability of this species to germinate and become established in late November and early December following late seed sowing. Establishment of sown grasses and legumes over the same period was very poor and was completely absent for other sown wildflower species, with the possible exception of *B. interruptus.* As a consequence of the almost complete absence of competition during the establishment phase for *Agrostemma*, cover type had no effect on seedling, and ultimately adult population densities during the first year of the trial.

Subsequent germination and establishment of sown grasses on GC1 and GC2 plots in spring 1994 resulted in the formation of dense swards, considerably reducing the occurrence of 'safe sites' for spring germination of rare wildflower species. This is reflected in observed population densities of *C. cyanus* and *C. segetum* which were greatest on natural regeneration plots and least on the competitive grass (GC1) plots (these differences were significant for *C. segetum* only). Previous studies have demonstrated the tendency for uncompetitive grass cultivars such as *A. castellana* and *F. rubra cv. commutata* to act as 'nurse crops' during the establishment phase for heathland and grassland vegetation in restoration schemes (Wells *et al.*, 1981 ; Wells, 1983). These species create favourable microsites for germination in the early stages of restoration, and due to their uncompetitive nature do not become pernicious weeds in subsequent communities. Such a 'nurse' effect is not evident in the current trial ; slightly greater (though non-significant) mean population densities for *C. cyanus* and *C. segetum* on GC2 plots are more likely a consequence of the reduced competitiveness of sown grasses on these plots.

Subsequent regeneration of 'sown' covers following cultivation in years 2 and 3 is predominantly from vegetative fragments in the soil (Plate 5.3 and 5.4), and evidence has been presented of a gradual replacement of sown species by indigenous seedbank species, amongst which *A. capillaris* is the dominant. At the final summer census (August 1995) during year 2 there were no significant differences in overall levels of sown and indigenous weed cover between the three cover regimes. Nevertheless, similar (though once again non-significant) patterns emerged for *Agrostemma*, this species being most abundant and exhibiting the greatest rate of population increase on natural regeneration plots. This observation may in part be due to the reduced competitiveness of the cover on natural regeneration plots, but also to the greater reproductive output observed for this species on these plots during year 1.

Despite higher densities of *Agrostemma*, rates of population increase (λ), and actual population sizes for *B. interruptus* were significantly greater on natural regeneration plots during year 2 than on other cover types. Like *Agrostemma*, *B. interruptus* is an autumn germinating species which exhibits no innate dormancy (see chapter 4 and Howard, 1991), and as such is liable to germinate soon after cultivation. At this stage in cover development, suitable sites for germination are abundant and early germinating species or individuals are able to pre-empt resources through 'space capture'. Competition for these 'regeneration niches' (Grubb, 1977) with *Agrostemma* seedlings does not appear to be a limiting factor on *B. interruptus* population density during year 2.

By year 3 of the trial, sown grass covers were being progressively replaced by indigenous species, and no significant differences in overall vegetation cover were measured. Observed cover treatment effects arise from differential seed production by rare arable wildflowers as a consequence of competition from sown cover during years 1 and 2, and do not reflect competitive effects from cover during year 3.

Grass cover treatments were incorporated into the experimental design to i) assess their ability to suppress potential infestations of pernicious weeds arising from the soil seedbank (GC1), and ii) to determine if uncompetitive grass mixtures exhibit any capacity to act as 'nurse' cover to establishing arable wildflower species (GC2). Pernicious weed problems were not encountered, and *Agrostis / Festuca* cover did not exhibit any 'nurse effect'. Sown grass covers exhibited a very slight, though non-significant, capacity to reduce population densities of *Agrostemma*, but regardless of this, all rare wildflower communities remained dominated by this species. Other sown wildlower species were benefited by the absence of a sown cover. Given these observations, particularly in the light of the additional expense of sown cover, natural regeneration emerges as the most suitable method of cover establishment on set-aside land where creation of diverse communities of arable wildflowers is the primary management objective.

### 5.5.2 The influence of cutting regime on rare wildflower community structure

Over the course of the trial, in common with cover type, the presence or absence, and timing of the annual cut had a relatively minor influence on wildflower community structure and composition (*Agrostemma* remained the dominant species regardless of all treatment variables). Significant differences were observed in the population densities of individual species but these treatment effects were not constant from year to year, suggesting that the influence of cutting regimes interacts with seasonal variables such as climate and the timing of cultivation to produce observed effects.

In the results section the influence of year 1 and year 2 cutting regimes was presented in relation to observed population densities in years 2 and 3 respectively. To ensure maximum production of mature, viable seeds cutting should be carefully timed to coincide with completion of the annual life cycle for sown wildflower species. In an experiment which investigated the effects of herbicide application and cutting treatments on the species composition of sown field margin strips, Marshall and Nowakowski (1994) showed that the cover of sown annual species was considerably reduced by early (April, May, June) and frequent cutting in the year of cutting and in subsequent years. This was particularly true for *Agrostemma* and *C. cyanus* which showed little capacity for regeneration once cut. Cover of *P. rhoeas*, on the other hand, was promoted by mowing in April or May. In the current trial the 'early' cut was completed towards the end of the growing season, subsequent regeneration of annual species did not occur and thus, did not contribute to total seed production. Observed differences in population densities in the following year are the result of subtle interactions between the phenology of individual species and the timing of cuts.

During year 2 population densities of *Agrostemma* were significantly increased on plots which were cut late or not cut in year 1, this effect was not evident in year 3. These observations demonstrate the impracticability of attempts to prescribe fixed cutting dates for these species and communities, and provides evidence for the interaction between seasonal variables, species phenology and cutting times. Reduced population densities on early cut plots in year 2 resulted from the lower yield of mature, viable seeds in year 1, suggesting that not all individuals of *Agrostemma* had reached full reproductive maturity before the imposition of the early cutting regime. This was not the case for year 2 populations. Whilst it is not possible to prove without further experimentation, the late cultivation and sowing date in year 1, together with lower temperatures and increased rainfall during critical periods for seed maturation, meant that a proportion of seeds were 'shed' before they were fully mature. In year 2 an earlier cultivation and higher summer temperatures ensured that all *Agrostemma* seeds were fully mature by 1st August.

In common with *Agrostemma*, responses of *B. interruptus* to cutting treatments varied from year to year. During year 2, population densities were lowest on uncut plots. In contrast, during year 3, densities were significantly greater on uncut compared to early cut plots. The comparison between early and late cut plots is straightforward and suggests that this species is consistently favoured by the later cutting regime. The apparent contradiction between year 2 and year 3 responses to the no cut regime require some further explanation which is provided by examination of the interaction between cutting and cultivation regimes for year 2 data. Analysis of variance has identified a significant interaction between these factors, and consideration of treatment means for these interactions provides a more rigorous analysis. The low mean population density on no cut plots during year 2 is entirely a result of very low densities within the no cut / no cultivation treatment combination (this is the only treatment combination which results in a decrease in population size compared to year 1). These are the only plots which remain completely uncut (no cut plots which are subsequently cultivated are flailed immediately prior to cultivation), and as such seed dissemination is not facilitated by cutting. Observations in the field showed that, for many individuals, seed was retained on the senescent parent plant until late autumn and sometimes beyond, and that cutting treatments were effectively promoting the dissemination of seed and enabling germination and 'space capture' by this species in early autumn. A very similar observation was made for *Agrostemma*, seeds of which are naturally shed mostly in October and November (Firbank, 1988) and together these clearly demonstrate how the life history characteristics of these species have evolved to mimic crop plants to the extent that in the past they have relied for their persistence on being harvested and resown with grain crops (Firbank and Watkinson, 1986). In the current trial cutting regimes and the maintenance of cuttings *in situ* mimic the annual harvest on arable land.

Responses of *C. cyanus* to cutting regimes indicate that this species is benefited by an early cut. However, this observation is probably a reflection of greater opportunities for germination and establishment on these plots where population densities of *Agrostemma* and *B. interruptus* are reduced.

Late cut and no cut regimes ensure that annual species are able to complete their life-cycles and produce the maximum quantity of viable seed. However, the aim of this trial was not to maximise the population densities of the most successful species, but to establish diverse populations of rare arable weed species, and a cutting regime is sought which best achieves this goal. None of the regimes imposed in this trial reduced the density of *Agrostemma* sufficiently to greatly increase the overall diversity of rare wildflower communities. The observed interaction of cutting time with extrinsic seasonal variables and species phenology makes it difficult to prescribe recommended cutting times which should be 'set in stone'. Instead the timing of the annual cut should be decided, in the light of seasonal factors to coincide with the completion of the life cycle of an optimum number of species during that year. In the absence of an annual cultivation the no cut treatment is not recommended as many annual arable weed species have evolved to take advantage of the annual harvest as an aid to seed dissemination. In the absence of this 'disturbance' seeds are retained on the senescent parent plants well into the autumn months.

### 5.5.3 The influence of annual and biennial cultivation regimes on rare weed population densities and community structure.

Cultivation regimes, which were imposed in the autumn of year 2, were chosen after consideration of results obtained during the first year of the trial. It was immediately apparent that in order to achieve the stated objective of persistent and diverse rare weed communities, measures were necessary to reduce population densities of *Agrostemma.* The principle comparison which is considered in this section is between an annual and a biennial cultivation regime. The third regime encompassed a light cultivation followed by resowing of wildflower seed mixtures. This treatment provided a 'control' for the hypothesis that the failure to germinate and establish of a number of seeds during year 1 was a consequence of the late sowing date, and that these species, due to death, decay and the loss of viability of seeds would, at this stage, be poorly represented in the seedbank. This assumption was made without the detailed knowledge of the autecological and seedbank dynamics of these species which was gained from subsequent glasshouse and field trials and is discussed in chapter 4. No significant differences in population densities or community structure were observed between plots which were resown and those which were not, and this regime will not be discussed further.

Annual weeds of arable land are, by nature, pioneer ruderal species of disturbed land, and as such, require regular soil cultivation if they are to persist from year to year without being succeeded by more competitive species. The purpose of the biennial cultivation regime in the current trial was to assess if the absence of cultivation during year 2 would significantly reduce the population density of *Agrostemma*, and more importantly, by doing so, confer a competitive advantage to other rare arable wildflowers during that, and in subsequent growing seasons.

Unsurprisingly, population densities of *Agrostemma* were significantly reduced on uncultivated plots during year 2 reflecting the paucity of suitable safe sites for germination within an established grass sward. Population densities of *B. interruptus* were greater on these plots, demonstrating the ability of this grass species to germination and become established within a dense sward, however, their reproductive output was significantly reduced compared to cultivated plots. This observation demonstrates the importance of pre-emptive competition for resources in determining the outcome of density dependent effects on the fecundity of individuals. Other rare weed species were completely absent from uncultivated plots.

During year 3, following cultivation of 'biennial' plots, population densities of *Agrostemma* remain significantly lower than on annually cultivated plots. Nevertheless, rare wildflower communities remain dominated by this species, and no benefits in terms of increased diversity are observed. More importantly, the mean seed yield per plant on these plots is considerably higher, resulting in less pronounced (though still significant) differences in reproductive output. In conclusion, whilst exhibiting some capacity to prevent plots from becoming dominated by *Agrostemma*, biennial cultivations do nothing to increase the overall diversity of rare wildflower communities.

5.5.3.1 The effect of a double cultivation on *Agrostemma* population densities and rare weed community structure.

*Agrostemma* exhibits synchronous autumn germination forming a dense carpet of seedlings (Plate 5.5) which greatly reduces opportunities for germination and establishment of other rare wildflower species. During year 3 of the trial, an additional cultivation regime, described in section 5.2, was incorporated into the experimental design. This double cultivation was designed to eradicate or greatly reduce the density of autumn germinating seedlings of *Agrostemma*, creating opportunities for spring germination of other wildflower species. Young adult individuals of *Agrostemma* displayed considerable resilience even under this severe management regime. A spring cultivation completely inverted established cover which was dominated by *Agrostemma*. Nevertheless, where individuals remained intact, albeit completely uprooted, they demonstrated an ability to become re-established through fresh root growth, and subsequently to resume growth. As a result, whilst population densities of *Agrostemma* were significantly reduced in the following summer (August 1996 census), this species remained the dominant component of rare weed communities.

Spring cultivation, which resulted in reduced densities of *Agrostemma* and an increased occurrence of 'safe' sites for germination, favoured establishment of seedlings of the spring germinating species, *C. cyanus* and *C. segetum*. The emergence of *C. segetum*, which was completely absent from all autumn cultivated plots, demonstrates the ability of this species to survive in the soil as viable, ungerminated seed. The appearance of *C. cyanus* and *C. segetum* in above-ground communities considerably increases their diversity and visual amenity. Population densities of *P. rhoeas* were unaffected by this regime.

*B. interruptus*, an autumn germinating species did not demonstrate the same capacity as *Agrostemma* for re-establishment following the spring cultivation, and was completely eradicated from subsequent communities. This observation demonstrates the extreme difficulty which is encountered when attempting to determine management regimes which will benefit all sown species in the current trial, and thereby ensure optimal species diversity. Some of the ecological principles of plant community dynamics which underpin these limitations are explored in the next section of this discussion.

## 5.5.4 Rare weed community dynamics

Previous discussion has focused on the effect of various management variables on the population dynamics of component species within rare weed communities, and recommendations have been made for the establishment of diverse communities based on these observations. A more holistic approach to plant community dynamics and community theory is required to determine if the stated objective of this trial, to establish diverse, persistent and stable rare weed communities has been achieved, or is capable of being achieved over the longer term. A theoretical framework is proposed which defines diverse, persistent and stable plant communities. In principle, stable communities will persist in the environment, however, this statement requires qualification. All communities of plants are, to a greater or lesser extent, unstable. The key to attainment of long-term stability lies in the nature of short-term (season to season) fluctuations in community structure. Where these occur about a mean, community change may be said to be cyclical, and long term stability is secured. Conversely, where communities change from season to season along a continuum, change is directional and succession rather than stability is the long-term outcome (Krebs, 1985).

Even the most diverse plant communities are very commonly dominated in terms of cover by a very few species, amongst which a long list of rare species persists (Grubb *et al*, 1982). Talbot *et al.* (1939) found 109 species of annual plant in an area of 583ha in California, but also noted that over a three year period, three species only, accounted for the majority of plant cover. These observations and reflections illustrate that even in the most diverse communities, dominance by a few species is maintained.

These principles and definitions are now applied to the data observed in the current trial. The main feature of established communities was their overwhelming dominance by *Agrostemma*, and the key to determining the long-term stability, or otherwise, of these communities rests in a consideration of observed population trajectories for this species. For management regimes including an annual cultivation, population densities of *Agrostemma* continued to increase throughout the three years of the trial, and there is every indication that this trend would be continued until the maximum population density/biomass for this species had been reached, ensuring it's total dominance to the exclusion of all other wildflower species. This situation had almost been reached by the end of the trial, *C. segetum* was completely absent from communities subject to annual cultivation and where present *B. interruptus*, *C. cyanus* and *P. rhoeas* were observed at very low population densities. We may conclude that on annually cultivated plots, communities were unstable and rapidly moving towards complete domination by *Agrostemma.*

The biennial cultivation regime effectively reduced population densities of *Agrostemma* during years when plots remained uncultivated, but produced no overall long-term benefits in terms of community stability or diversity.

The most diverse rare weed communities observed during the trial resulted from the double cultivation regime. Unfortunately, only one years data is available for communities managed under this regime, and, as a consequence, it is difficult to make inferences about the longer term stability of these communities. Nevertheless, a valuable insight into the community dynamics of rare weed species is provided. In many ways, this regime is analogous to a single spring cultivation. However, the unforeseen ability of autumn germinating *Agrostemma* individuals to regenerate after cultivation produced benefits in terms of overall diversity which may not have been envisaged. Subsequent communities may continue to be dominated by *Agrostemma*, albeit at significantly lower densities, which permit the establishment of spring germinating species. Continued domination by *Agrostemma* is not problematical, provided some means of keeping a check on the population trajectory of this species is incorporated into the management regime. Indeed, in many ways this situation is desirable ; as discussed previously in this section, even the most diverse communities have dominant components, and in this experiment domination of plots by *Agrostemma* is preferable to potential problems caused by pernicious and undesirable weed species. An alternative to this form of management would be to remove *Agrostemma* from the initial seed mixture.

Perhaps the most crucial determinant of arable weed community dynamics to have emerged from the work described in the last two chapters is the distinction between species which possess a persistent seedbank and those which do not. This distinction reveals vital differences in the life history strategies of arable weeds which are key determinants of community structure and the long-term persistence of weed species. Most weeds of arable land possess mechanisms of dormancy which enable them to survive in the soil as viable but ungerminated seeds over long periods. *Agrostemma* and *B. interruptus* exhibit no such dormancy, and as a result all seeds either germinate, or lose their viability shortly after dispersal from the parent plant (a few seeds may survive until the following spring or autumn). These characteristics endow weed species with a life history strategy, whereby, under favourable conditions they are able to rapidly colonise and become dominant on recently disturbed soil. This strategy has obvious advantages as demonstrated in the current trial, but in the case of *Agrostemma* and *B. interruptus* may also have been a major contributor to their decline and disappearance from the native flora. Their predictable life histories and the lack of a persistent soil seedbank means that they can be eradicated from arable weed communities in a single season by preventing seed return to the soil.

The historical success of *Agrostemma* as a weed has been well documented (Salisbury, 1961) and was commented on by Shakespeare (c 1609 after Firbank, 1988) who described it as "the cockle of rebellion, insolence and sedition which we ourselves have plough'd for, sow'd and scatter'd". This success relied upon continuous reintroductions from contaminated grain (Thompson, 1973) and the subsequent decline of *Agrostemma* was entirely due to improved seed cleaning techniques which were developed early in the 20th century. *Agrostemma* ceased to be recognised as a major impurity of British cereal seed during the 1950's (Broad, 1952 ; Tonkin, 1968).

*C. cyanus*, *C. segetum* and *P. rhoeas* possess persistent seedbanks. They have more exacting requirements for germination, display distinct seasonal peaks, or flushes of germination behaviour (periodicity) and, even when conditions for germination are apparently ideal, a proportion of seeds remain dormant and ungerminated - so called 'fractional germination'. Grubb *et al.* (1982) discussed species co-existence and relative abundance within plant communities in terms of the regeneration niche, defined as a microsite which is suitable for the establishment of a plant species. In summary, Grubb *et al.* (1982) state that "if a species is persistently found at a relatively low level of abundance it must be that either the microsites suitable for it's establishment are less common than those that are suitable for more abundant species, or that it is less capable of occupying all micro-sites suitable for it". Results from the current trial may be interpreted on this basis.

Rapid germination and establishment in autumn by *Agrostemma* and regenerating grass covers at the high densities observed, results in the occupation of a large proportion of potential regeneration niches soon after cultivation (on uncultivated plots these are occupied by perennial cover from the previous season). Subsequent germination and establishment by other rare wildflower species depends on their seeds not only occupying a suitable regeneration niche but also on this seed being in germinable condition. Added to this, and of particular importance to *C. segetum* and *P. rhoeas* is the depth at which the seed is buried. Seeds of these two species have been shown to be incapable of emergence from depths of 50mm (see chapter 4), and even the shallow depth (c. 100mm) cultivation practiced in this trial can be expected to result in the burial of at least 50% of seed at depths in excess of this.

The colonisation of recently cultivated arable land by weed species is the first stage in a succession towards plant communities which are at equilibrium with the prevailing climatic and soil conditions (Holt, 1988). These communities are largely composed of annual pioneer species, and as such they are dynamic in nature and far from any apparent equilibrium (Streibig and Andreasen, 1993). Frequent and catastrophic disturbances on arable land mean that, unlike in more stable habitats, it is difficult to characterise distinct plant (weed) communities. Many of the theories of plant community assemblage presented in the introduction to this chapter were conceptualised with respect to more stable habitats (grassland and woodland) which are not subject to frequent and catastrophic disturbances. They act to determine community structure over a number of seasons and are not applicable to rare arable weed communities. Others, such as the species-pool hypothesis may be important for determining the diversity of arable weeds which occur throughout Britain, but do nothing to explain patterns of community structure observed in the current trial.

The concept of the regeneration niche (Grubb, 1977) is perhaps the most amenable to the analysis of the dynamics of rare weed communities, and arable weed communities in general. Regular cultivation events completely destroy plant cover, producing an abundance of regeneration niches for weed (and crop) species at distinct periods during the growing season. The ability of sown or seedbank species to exploit these is dependent upon cultivation events interacting with, seasonal patterns of seed dormancy, depth of seed burial and prevailing climatic conditions. The ability of seeds to 'detect' these gaps in the vegetation is also important. A covering of vegetation acts as a very effective temperature buffer insulating the soil from diurnal fluctuations and one of the most effective methods of restricting germination to gaps in vegetation is for seeds to possess a requirement for fluctuating temperature to break their dormancy (Thompson et al., 1977 ; Thompson and Grime, 1983). Other species are able detect these gaps by differentiating between the quality of light in gaps and beneath a vegetation cover (Gorski *et al.*, 1977 : Dickie, 1977).

In the current trial, the course of subsequent competition is determined entirely by the ability of species to germinate and become established immediately following cultivation. Initial advantage in terms of space or resource capture is of over-riding importance to subsequent competition within plant communities, and ultimately determines the communities structure.

To conclude, *Agrostemma* was able to dominate plots in the current trial because ;

i) early and synchronous autumn germination enables it to occupy a large proportion of regeneration niches, excluding other rare weed species
ii) early germination (initial advantage) ensures resource capture, so that *Agrostemma* individuals are larger than competing species at critical periods of interference. These size differences become compounded by asymmetric competition

" Among plants, asymmetry in competition for nutrients and light is mainly a result of size differences, because acquisition of these resources usually depends more on plant size, than on species identity" (Bengtsson, Fagerstrom and Rydin, 1994)

### 5.5.5 The actual potential of set-aside land for the conservation of rare arable weeds - a review of findings

The last 10 to 15 years has witnessed a growing realisation amongst conservationists that measures are required to protect components of the arable flora if certain characteristic, and once common species are not to be lost. The decline of many of these species has been well documented (Salisbury, 1961 ; Fryer and Chancellor, 1970). The first attempts to preserve these species and communities *in situ* were reported in Germany (Eggers, 1984 ; Schumacher, 1987). Smith (1986) included arable weeds in her study of endangered species of disturbed habitats in the UK, but the first pro-active approach to the conservation of these species in the UK arose from observations made on field margins managed according to the Game Conservancy's "Conservation headland technique" (Boatman and Sotherton, 1988). These observations gave rise to the "Wildflower project" (Wilson, 1990, 1992, 1993, 1994), which has done much to raise the profile of these species, determine causes for their decline and establish guidelines for their conservation. Work described in this chapter recognises the potential of set-aside land as a vehicle for the re-introduction of communities of these species into the arable ecosytem.

'Semi-natural' plant communities, such as calcareous grassland or lowland heath exist in a state of arrested succession, and are described as plagioclimax communities. As such, their species composition can be defined within a set of boundaries. Arable weed communities are less distinct, their species composition the result of chance introductions as well as past and present management practices. As such, it is not possible to define or parameterize their community structure. In the current trial this has been set by the seed mixture which is sown. To this end, management guidelines for the establishment of the communities will be specific to the initial seed mix, and also to the nature of the indigenous weed flora.

Nevertheless, some general principles have emerged. Uncompetitive grass cover (GC2) produced no benefits in terms of a 'nurse' effect, and in the absence of pernicious indigenous weed populations, natural regeneration of cover appears to be the optimal strategy for establishment of rare weed communities. Annual weeds tend to have poor regenerative capacity after cutting, and for this reason a single annual cut towards the end of the growing season is recommended. The precise timing of this cut depends on individual species phenology and seasonal effects and should be determined accordingly at an appropriate time.

In the current trial, the ability of a species to secure an initial advantage through germination and 'space capture' shortly after cultivation or seed dissemination was the over-riding determinant of subsequent community structure. In view of this, the timing of cultivations should be carefully considered in relation to the dormancy characteristics and periodicities of rare weed species. This highlights the importance of a thorough comprehension of the autecological and seedbank characteristics of sown species.

In the experiment reported in this chapter two species which exhibited similar periodicities of seedling emergence and life history strategies (*Agrostemma* and *B. interruptus*) were the dominant components of established rare arable wildflower communities. These species, which exhibited rapid, synchronous autumn germination shortly after cultivation were able to pre-empt resources through space capture. Very dense covers of establishing *Agrostemma* seedlings and regenerating grass species in autumn greatly reduced the occurrence of 'regeneration niches' into which spring germinating rare species could germinate and establish and the overall result was low species diversity within wildflower communities.

It is suggested that the coexistence and persistence of arable weed species depends on spatial and temporal variabilty in the field and niche differentiation between species. Spatial heterogeneity may arise from a wide range of abiotic and biotic factors. Variations in the temporal recruitment of new individuals into a community are important in promoting stable coexistence. Two criteria (Warner and Chesson, 1985) must be satisfied to promote coexistence : environmental fluctuations must be such that each species has periods of strong recruitment when it at low density ; and generations must be overlapping. Life history characteristics such as persistent seedbanks (generation overlap), plasticity in growth form and polycarpy (high reproductive output) are species attributes which may contribute to such stability. Many of these conditions are satisfied by the mixture of species sown in this experiment. Chapter 4 has identified considerable variations in the periods of peak seedling recruitment for the five species sown and these could realistically be expected to promote species coexistence. However, autumn establishment of indigenous and sown species (predominantly *Agrostemma*) is at high densities which significantly reduce the availability of suitable regeneration niches to spring germinating species during potential periods of strong recruitment for these species. A number of alternatives emerge for increasing community diversity :

i) remove *Agrostemma* from the seed mixture
ii) determine management practices which will effectively keep 'in check' the population trajectory of *Agrostemma* (spring or double cultivation was the most effective regime to emerge from this experiment), permitting greater opportunity for spring recruitment
iii) include only autumn germinating species in the initial seed mixture

The work described in this chapter has gone some way to determining management strategies for rare arable weeds on set-aside land. However, these may vary considerably depending on the species sown. A great deal of further research is necessary, both at the autecological and the community level, and it is envisaged that this will demonstrate the need for more carefully considered seed mixtures. Requirements for further research will be explored in greater detail in chapter 6, together with an analysis of the wider implications of the work described.

# *Chapter 6*

## *General Discussion*

## 6.1 Introduction

The study reported in this thesis has adopted an integrated (socio-economic and ecological) approach to evaluate the **actual, perceived** and **realised** wildlife conservation potential of arable land, set-aside under the Arable Area Payments Scheme. Both of these approaches are considered. Firstly, to report the way in which set-aside land is being managed, and to appraise current constraints on the uptake of conservation-oriented management. Future developments which might ensure that set-aside land is able to occupy an appropriate position within a conservation framework for agricultural land within the UK are also considered. Ecological field experiments which examined the actual conservation potential of set-aside land, have, by necessity, focused on a small group of species (rare arable weeds). An appraisal is made of the feasibility of this approach, together with the wider implications of reintroducing 'weed' species to arable land and requirements for further research.

## 6.2 Farm-based questionnaire surveys : A behavioural analysis of farmers' attitudes and decision-making with respect to set-aside land.

The questionnaire surveys reported in chapters 2 and 3 have clearly identified a gulf between farmers' attitudes towards nature conservation, and their actions with respect to these on set-aside land. Ninety per cent of farmers from the initial baseline survey indicated that they were interested in wildlife on their farms ; motivations for this interest ranged from 'personal pleasure' to 'sporting interests.' Few perceived nature conservation and environmental protection as even a secondary objective of the Arable Area Payments Scheme. Nevertheless, a significant minority (40%) acknowledged the conservation potential of set-aside land, and 35% indicated that they believed that MAFF had done too little to incorporate this potential into set-aside policy. Further evidence of farmers' willingness to embrace the conservation interest was provided by the second survey in which farmers acknowledged their dual role in the countryside, and agreed that agricultural intensification in the post-war era had eroded the concept of 'stewardship' resulting in considerable environmental degradation. 72% of surveyed farmers supported calls for a greater degree of integration between agricultural (food production) and environmental policies.

Despite these observations, which identify a favourable disposition to the conservation interest amongst a significant proportion of the arable farming community, the observed uptake of conservation-oriented management on set-aside land was dismally low. Similar discrepancies between conservation attitudes and behaviour have been reported by others (Newby et al., 1977 ; Carr and Tait, 1991 ; Morris, 1993), and responses to attitude statements relating to nature conservation, reported in chapter 3, give some indication of the reasons for this discrepancy. 72% of surveyed farmers indicated that they believed wildlife habitats should be viewed as agricultural products attracting appropriate payments, 83% felt that current incentives in this respect were inadequate, and 58% that nature conservation was a luxury which they were unable to afford.

### 6.2.1 Attitudes to land diversion.

Whilst few arable farmers who responded to the survey were wholly opposed to the outcome of the 1992 CAP reform, there was widespread dislike of set-aside as a policy instrument. Clearly, these negative attitudes are unlikely to engender a positive or pro-active outlook when farmers consider management options for their set-aside obligation. Over 60% of farmers felt that set-aside was a temporary solution to the problem of over-production ; a perception which must reduce their inclination to commit to conservation-oriented management on this land. A sizeable minority (particularly smaller farmers) felt that set-aside was unfair and discriminated against small producers. The major concerns arose, however, from farmers' perceptions of the way in which the public viewed set-aside, and from a deep-seated reluctance to leave productive land idle. These concerns may be easily addressed if farmers embrace the concept of 'conservation set-aside'. The impression created by set-aside, that farmers are 'being paid to do nothing', could be dispelled if set-aside was used to 'open up the countryside', create visual amenity and conserve rare and endangered species. At the same time, the impression of a neglected and idle countryside would be overcome.

In the eyes of the arable farming community, however, one factor above all others precludes any attempts to create a 'conservation reserve' on set-aside land ; the complete absence of any system of financial incentives above the basic set-aside premium to reward positive conservation actions. In short, farmers who chose to practice conservation-oriented management on their set-aside land must absorb any extra costs that this incurs. This factor alone may account for the almost complete absence of pro-active conservation-based management and explain the observed discrepancy between conservation attitudes and behaviour on set-aside land.

### 6.2.2 Conservation set-aside : Financial incentives or cross-compliance ?

A number of options exist for increasing the realisation of the conservation potential of set-aside land. Some of these were reviewed in Chapter 1 and discussed further at the end of Chapter 3. Broadly speaking, two mechanisms are considered : financial incentives and 'environmental' cross-compliance.

A system of **financial incentives** requires recognition by MAFF and the EU that nature conservation, recreational and amenity resources are countryside products for which farmers have a right to be paid. As such, a prerequisite for these measures will be budgetary support from the EU, and, or MAFF.

The simplest and most easily administered system would encompass a series of **'top-up'** payments in excess of the basic set-aside premium. The level of these payments could be varied according to the objectives of the option, and the degree of management required. In the survey described in Chapter 3 such a scheme was proposed, and farmers were asked to indicate a level of payment which would encourage them to enter land into each of the MAFF-directed options for 'achieving environmental objectives on set-aside land' (Table 3.13). Whilst a number of these 'bids' were clearly excessive, results were encouraging, with a significant proportion of respondents indicating that they would enter land at payment rates of below £100/hectare. Given the set-aside payment rate for 1998 of £326, this does not seem excessive if the acknowledgement by MAFF and the EU of the conservation potential of set-aside land is more than mere rhetoric.

Traditionally, management agreements between farmers and conservation or government agencies have paid the farmer to follow a set of management prescriptions which it is hoped will produce the desired results in terms of habitat creation, maintenance or enhancement. Currently ESAs and the Countryside Stewardship Scheme encompass this approach. A novel approach has been proposed by the Countryside Commission, **'payment for products'** whereby farmers are paid according to their success in achieving prescribed goals (payment for outputs as opposed to inputs) . Such a system could be applied to set-aside payments for conservation-oriented management. The benefits of such a system are discussed in section 1.9.2, potential obstacles would include increased administrative costs.

A system of bidding for conservation payments on set-aside land may also be considered (Potter, 1987 ; Countryside Commission, 1992). Farmers could be invited to propose their own management strategies with clearly defined goals, together with **'bids'** for the payment rate they required to carry out this management. These proposals could be assessed by the relevant bodies, and management agreements awarded where it is envisaged that the greatest 'value for money' would be achieved.

Finally, in recognition of the limited amount of resources which would be likely to be made available, financial incentives could be offered only in **'target'** areas, where it is envisaged that they would achieve the greatest environmental benefit (Burnham *et al.*, 1987 ; Potter *et al.*, 1993). These areas could be selected in accordance with the criteria outlined by Burnham *et al.* (1987) (section 1.10.2). It is well known that the poorest quality agricultural land often has the greatest nature conservation potential, and by ensuring that these 'top-up' payments were primarily available on the most marginal land where profit-margins are lowest, such a targeted scheme could encompass a social as well as an environmental dimension. The surveys reported have identified the south-eastern region as an ideal candidate for such a scheme.

The alternative to a system of financial incentives is one which requires **'environmental cross-compliance'**. To date, the EU and MAFF have maintained clearly defined boundaries between production and conservation-oriented policies, resisting persistent calls for closer integration. In the case of set-aside policy, cross-compliance has the potential advantage of enabling environmental gains to be made without increased expenditure. The simplest way to achieve this would be to make qualification for set-aside payments conditional on the attainment of clearly defined environmental and conservation standards on set-aside land. However, this would prove difficult to police, considerably adding to the overall cost of the scheme, and could realistically only be expected to produce modest environmental gains compared to a scheme which was targeted at the most suitable land, and at those farmers who expressed an interest in nature conservation.

A more flexible approach, combining aspects of both the financial incentive and cross-compliance options could involve a system of 'menus' similar to those provided for the Countryside Stewardship Scheme (MAFF, 1996b). Farmers who did not wish to manage their set-aside land according to environmental or conservation-oriented guidelines would qualify for the 'basic' set-aside premium (this could be reduced from the current level to encourage compliance, and to offset the cost of increased payments on conservation set-aside). Farmers wishing to enhance the wildlife potential of their set-aside land could chose the most appropriate options to follow. Menus could be devised on a regional basis, according to local priorities and the quality of agricultural land, with payment rates set according to management requirements.

The range of options discussed above has attempted to address the most critical limiting factor on the uptake of conservation-oriented management on set-aside land ; the lack of financial incentives or inducements. Without these, the full conservation potential of set-aside land will remain largely unrealised and underexploited. If, in the future, the political will exists to establish appropriate incentives, other factors will continue to restrict uptake, these have been discussed in depth in Chapter 3, and are summarised in Figure 3.8. One of the initial aims of the farm-based surveys was to establish a 'participation spectrum' (Morris and Potter, 1995) for the adoption of MAFF-directed options for '*managing set-aside land for specific environmental objectives*'. These secondary 'structural' and 'attitudinal' factors (Figure 3.8) will determine the patterns of adoption and non-adoption which will ultimately define this 'participation spectrum' once (and if) financial incentives are in place.

In 1997, MAFF set out proposals for an Arable Stewardship Scheme whose objective was to provide "incentive payments to farmers, designed to test means of improving biodiversity on arable farmland" (MAFF, 1997b). Initially this scheme will operate as a pilot in two agricultural areas : East

Anglia (south Cambridgeshire, west Suffolk, north Essex and north Hertfordshire) and the west Midlands (Shropshire/Staffordshire border). The stated aims of the pilot scheme are :

i) to evaluate the effectiveness of a range of management prescriptions in producing conditions suitable for a suite of threatened farmland plants and animals ;

ii) to evaluate its uptake amongst farmers within specified areas and to identify factors which influence participation ;

iii) to assess how effective participating farmers are in implementing the prescriptions and to identify factors that constrain or enhance such implementation (MAFF, 1997b)

Participating farmers are able to select appropriate options from a menu of management prescriptions (Table 6.1). Payment rates vary according to management requirements, and potential losses in yielding capacity

These payments are available on set-aside land, with participants receiving Arable Stewardship payments in addition to basic set-aside payments, and as such create a system whereby financial inducements become available to farmers wishing to manage their set-aside land for conservation objectives. Payment rates exceed those 'requested' by a significant proportion of surveyed farmers. Results from farmer surveys suggest that this scheme will prove popular among the farming community, and has considerable scope for increasing the realisation of conservation potential on set-aside land. If the current pilot scheme is successful and Arable Stewardship becomes widely available it will greatly enhance the potential for nature conservation and biodiversity on set-aside and productive arable land.

One further factor must be considered ; what is the future for set-aside policy within the EU ? Many farmers and commentators alike, perceive set-aside to be a temporary solution to the longer term problem of over-production. Inevitably, this influences farmers' decision-making processes with respect to set-aside and may forestall any attempts to establish a long-term strategy for conservation on set-aside land.

Table 6.1 Management prescriptions for pilot Arable Stewardship Scheme

| Option | Supplements | Payment (£/ha) |
|---|---|---|
| **1. Overwintered stubbles** | | 55 |
| | a) Restricted herbicide in previous crop | 25 |
| | b) Spring cultivation - spring/summer fallow | 485 |
| | c) Followed by spring crop | 35 |
| **2. Undersown spring cereal** | | 180 |
| | a) preceded by overwintered stubble | 20 |
| | b) ley retained for further year | 420 |
| **3. Conservation headland** | | 20 |
| | a) herbicide use restricted | 80 |
| | b) herbicide use restricted and fertiliser prohibited | 130 |
| **4. Uncropped wildlife strip** | | 500 |
| **5. Grass margin** | | 450 |
| | a) sown establishment | 100 |
| | b) field centre beetle bank | 200 |
| **6. Wildlife seed mixture** | | based on cost |

## 6.2.2 Set-aside : An uncertain policy future

There is an increasing realisation amongst the farming community, the agricultural lobby and agricultural commentators alike, that further reform of the EU's Common Agricultural Policy is inevitable. Pressure is being applied from all sides for a European agricultural policy which is more closely oriented to prevailing market conditions, and this is likely to spell the end for set-aside. The next ten years will see the CAP face its biggest challenge to date, as the EU moves towards enlargement to include ten eastern European countries. The importance of the agricultural industry to eastern Europe is reflected in its 9.5 million farmers (20% of the workforce, compared to 6% in western Europe) and extension of the current support regime to these countries would cost billions, ultimately crippling the EU budget.

At the same time, internal pressures continue to mount, consumers are paying for the system twice over ; in high taxation and artificially inflated food prices, and all of this is being achieved against a backdrop of increasingly unacceptable environmental damage and degradation. Finally, and perhaps most pressing from the political perspective, there are increasing calls for liberalisation of world trade in agricultural commodities. The next round of GATT negotiations is due to commence in 1999 and these are likely to bring considerable pressure to bear on EU agriculture to reduce agricultural subsidies, and bring European agricultural more in line with the world market. Clearly, further reform of the CAP is unavoidable.

It is beyond the scope of this discussion to consider what form further reforms may take. The main aim has been to illustrate the long-term untenability of set-aside policy. Current discussions suggest a brighter future for environmental and conservation concerns within a reformed CAP, with calls for EU agricultural funds to be channelled to support non-farming activities such as tourism, recreation and amenity within a vibrant and evolving rural economy. Buckwell (from Warman, Observer, 09/02/97) has called for 'transitional adjustment payments' which will reward farmers for meeting environmental and rural development targets in a less production-oriented agricultural economy.

Regardless of the nature of the reformed CAP in the next century, a less intensive agricultural industry should increase the potential for re-introducing the concept of 'stewardship' on arable and other agricultural land.

## 6.3 The conservation of rare arable weeds - a 'case study' on set-aside land.

Chapters 2 and 3 of the thesis and the preceding sections of this discussion have presented an evaluation of the **perceived** and **realised** nature conservation potential of set-aside land, and discussed these in the light of future policy developments. The remainder of this discussion will focus on its **actual** conservation potential, considering future research requirements together with the wider implications of the work described in Chapters 4 and 5. Clearly, set-aside land presents a range of opportunities for enhancing the wildlife potential of arable land (Table 1.3). These range from longer term attempts to recreate valuable wildlife habitat, to the creation of transient habitats for declining, rare or endangered species. It would have been impossible in the present study to investigate all of these, and a group of species, characteristic of arable land, whose abundance and distribution have declined considerably as a result of modern intensive agricultural methods, were chosen - rare arable weeds.

### 6.3.1 The nature of arable weed communities

Unlike more stable plant communities such as deciduous woodland or calcareous grassland, the structure of arable weed communities is not easily defined (Streibig and Andreasen, 1993). Arable weeds are opportunistic, and the co-existence of assemblages of these species is the result of chance introductions, and past and present cropping practices rather than successional processes which are predictable over the long-term and mediated by local soil and climatic characteristics. In this sense, the diverse, stable and persistent communities which were sought in chapter 5 are artificial, inherently dynamic and, in the absence of regular disturbance, far from any apparent equilibrium.

As a result, 'natural' rare weed communities which can be used as a 'template' against which the success of these attempts can be measured, do not exist, and the desired end result must be defined purely in terms of the initial seed mixture. This observation necessitates an approach which concerns itself primarily with the population dynamics of individual species, ensuring that the trajectory of single species are such that they do not compromise overall species diversity within rare weed 'communities'.

### 6.3.2 Rare Arable Weeds : Management guidelines for set-aside land

Specific management guidelines for the establishment of rare weed communities on set-aside land will depend, to a large extent, on the autecological characteristics of the species included in the initial seed mixture. Results reported in Chapter 5 have demonstrated clearly the value of this knowledge in advance of the formulation of this mixture. However, general principles have been established. Broad distinctions are able to be made between arable weed species on the basis of their life-history strategies ; primarily between predominantly autumn and predominantly spring germinating species and between those species which exhibit a persistent soil seed bank and those which do not.

In the trial described in chapter 5 the seed mixture had representatives of all of these groups. Of apparent over-riding importance was the relationship between the timing of annual cultivations and the periodicity of emergence of individual species. Species which were able to germinate and become established shortly after autumn cultivation (*A. githago, B. interruptus*, and to a lesser extent *C. cyanus*) were able to 'pre-empt' resources, an advantage which was a critical determinant of the course of subsequent competition. At the same time, those species which did not possess mechanisms of seed dormancy and hence, did not exhibit 'fractional germination' were able to occupy a large proportion of available 'regeneration niches' (Grubb, 1977) (*A. githago* and *B. interruptus*). The occurrence of spring germinating species was severely limited by the scarcity of these niches during the spring months, and the likelihood of those species exhibiting a persistent seed bank finding a suitable regeneration niche was reduced by their 'fractional germination'.

The conclusions from this trial are that seed mixtures should be composed of groups of species which exhibit similar autecological requirements in relation to regeneration niche occupancy (periodicity of emergence). Alternatively, where the initial seed mixture contains a range of species which exhibit temporally discrete peak recruitment periods, that management should ensure the persistence of a relatively open community structure so that species exhibiting a range of germination periodicities are able to co-exist. In the current trial this was not the case as rapid synchronous germination by *A. githago* resulted in occupancy of a large proportion of potential regeneration niches before periods of peak recruitment for spring germinating species. A double (autumn and spring) cultivation overcame this constraint on species diversity in this experiment.

The approach adopted in this study has presupposed that rare arable wildflowers will be reintroduced to set-aside land as seed. Where remnant populations of these species exist in fields diverted from arable production, this need not be the case, and appropriate management may ensure their survival. However, for the rarest and nationally extinct species (*Bromus interruptus* and *Agrostemma githago*) this is not possible, and reintroduction as seed is necessary. Regardless of the approach taken, general management guidelines will be as outlined above, whilst more specific prescriptions will depend on the species sown, or those which are present within the soil seedbank.

### 6.3.3 Rare arable weeds : Set-aside, conservation headlands and the Arable Stewardship Scheme.

As discussed earlier in this chapter, the future of set-aside as an agricultural policy instrument is far from certain. Nevertheless, the profile of rare arable weeds has now been raised, largely as a result of the work of Wilson ( 1990, 1992, 1993, 1994) and the Game Conservancy (Boatman and Sotherton, 1988), and the work described in chapters 4 and 5 is not solely applicable to set-aside land.

Whilst the set-aside obligation remains, diverted arable land may be used as a vehicle for the reintroduction of rare weed species, or, alternatively for the management of existing populations and communities. Two options are proposed :

i) Field margins may be set-aside on a **rotational** basis, rare weed seed mixtures sown and communities established during the set-aside year. On return to cropping, these field margins should be managed according to the conservation headland technique (with fertiliser use prohibited). If the Arable Stewardship Scheme becomes permanent incentives payments will be available for appropriate management. In the absence of Arable Stewardship, the motivation to establish rare weed communities on arable land will be largely dependent on the game rearing interest

ii) Rare weed communities may be established on **non-rotational** set-aside land. The pilot Arable Stewardship Scheme proposes payments for wildlife seed mixtures and uncropped wildlife strips for a five year period. Non -rotational set-aside combined with a stewardship management agreement provides a financially attractive option for the conservation of rare arable weeds in the future. In the absence of these incentives, uptake on set-aside and other arable land is likely to remain very low.

## 6.4 Concluding Remarks

The field experiment reported in Chapter 5 has clearly demonstrated the requirement for an understanding of the autecological characteristics of individual rare weed species before seed mixtures are selected. Further research in this direction will enable mixtures of species with similar phenological characteristics to be developed so that management requirements can be tailored to ensure the creation and persistence of diverse and stable rare weed communities.

The work reported in this thesis has not considered the ability of rare arable weeds to persist in crops which follow set-aside, nor the potential effects of these weeds on crop yield. Cousens *et al.* (1985) suggested that weeds could reduce profit in cereal fields in three ways : reduction in yield, interference with harvesting operations and contamination of grain. Boatman and Sotherton (1988) in their review of the agronomic costs of managing field margins for game and wildlife added to these, reduction in grain quality and increased grain moisture content. As part of the current study a second large-scale field trial was established to determine the persistence and yield reduction effects of communities of rare arable weeds managed under a range of management options in a winter wheat crop following rotational set-aside. These results will be published separately. Major findings were that populations of *Agrostemma* establishing at high densities in subsequent crops had considerable potential for interference with the crop, and consequently yield reduction. These could be effectively controlled by herbicide application, but resulted in the complete eradication of this species from subsequent communities due to its lack of a persistent seed bank. On the whole, species which exhibit persistent seed banks may be more suitable candidates for reintroduction to arable land. Where these species establish at densities in subsequent crops which threaten yielding potential, they may be controlled by herbicide application without the threat of completely eradicating these species from subsequent communities.

Farm-based questionnaire surveys have demonstrated that a significant proportion of farmers are willing to acknowledge a dual role in the countryside, both as producers of food and as 'guardians' of the land, and that given appropriate incentives and long-term policy assurances they would be prepared to integrate nature conservation into farm management. Many arable producers agree that set-aside provides an excellent opportunity to enhance the wildlife interest of their land, however, favourable attitudes and perceptions are not being reflected in the management of set-aside land. Reasons for this have been presented, amongst which the lack of financial incentives or even compensation for the extra expenditure incurred, and uncertainty over future policy developments are the most critical determinants of non-participation. If set-aside is to achieve its full conservation potential, an aspect of which has been demonstrated in large-scale ecological field trials with rare arable weeds, these concerns must be addressed in the future.

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*Appendices*

## *Appendix 1*

*Questionnaire : Attitudes towards set-aside, nature conservation and changing agricultural policy*

***A baseline survey***

A QUESTIONNAIRE SURVEY

# ATTITUDES TOWARDS SET-ASIDE, NATURE CONSERVATION AND CHANGING AGRICULTURAL POLICY

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The research aims and background to this project are explained in the accompanying brochure.

Confidentiality : All information provided will be held in the strictest confidence and used solely for the purposes of this research project. We undertake not to identify individual names or opinions at any time during this research.

## 1. *THE 1992 COMMON AGRICULTURAL POLICY (CAP) SETTLEMENT.*

**1.1 In general, were you satisfied with the 1992 CAP reform settlement ?**

(Please tick appropriate box)

| | | | |
|---|---|---|---|
| Very satisfied | ❑ | Quite opposed | ❑ |
| Quite satisfied | ❑ | Strongly opposed | ❑ |
| Neutral | ❑ | | |

**1.2 Do you agree that set-aside is "a step in the right direction" towards reform of the arable sector ?**

YES ❑ NO ❑

**1.3 Which of the following do you perceive to be the <u>most important</u> objective of the *arable area payments scheme* ?**

(Please tick <u>one box</u> only)

| | |
|---|---|
| To balance supply and demand for certain surplus products | ❑ |
| To reduce overall expenditure on agricultural support | ❑ |
| To achieve environmental benefits | ❑ |
| To provide welfare payments for particular groups of farmers | ❑ |
| Don't know | ❑ |
| Other (please give details below) | ❑ |

..........................................................................................

..........................................................................................

..........................................................................................

## 2. *SET-ASIDE ON YOUR HOLDING*

### A) VOLUNTARY 5 YEAR SCHEME [1]

**2.1 Did you participate in the previous voluntary 5 year set-aside scheme ?**

YES ☐ NO ☐

(If NO please go to question 2.5)

**2.2 What *area* of land did you enrol under this scheme ?**

..........................................................................................(ha/acres)*

* delete as appropriate.

**2.3 Under which *option* did you manage this land ?**

(Please tick appropriate boxes and indicate the area of land under each option)

| | | Area(ha/acres)* <br>* delete as appropriate |
|---|---|---|
| Permanent fallow | ☐ | .............................. |
| Rotational fallow | ☐ | .............................. |
| Grazed fallow | ☐ | .............................. |
| Woodland | ☐ | .............................. |
| Non-agricultural use | ☐ | .............................. |
| Other (please give details below) | ☐ | .............................. |

..........................................................................................................................

..........................................................................................................................

**2.4 Is this land still managed under the voluntary scheme ?**

| | |
|---|---|
| YES | ☐ |
| NO, now set-aside under arable area payments scheme | ☐ |
| NO, now in agricultural production | ☐ |

1 See definitions in accompanying explanatory brochure.

## B) THE ARABLE AREA PAYMENTS SCHEME

**2.5 How much land do you have eligible for *arable area payments* ?**

..................................................................(ha/acres)

**2.6 Is this area currently registered under the *arable area payments* scheme ?**

YES, under the MAIN SCHEME ☐

YES, under the SIMPLIFIED SCHEME ☐

NO ☐

**If answer to above is NO, please go to question 3.1**

**2.7 If you are registered under the main scheme, please state the percentage and total area of land which you have set-aside ?**

............................ % ..............................(ha/acres)

Delete as appropriate

**2.8 What percentage of your set-aside area is under**

a) the rotational option ........................................%

b) the non-rotational option ..................................%

**2.9 Have you set-aside land as ;**

| | | Approx area (ha/acres) Delete as appropriate |
|---|---|---|
| a) Whole fields | ☐ | ......................................... |
| b) Part fields | ☐ | ......................................... |
| c) Strips within fields | ☐ | ......................................... |
| d) Field margins | ☐ | ......................................... |

**2.10 Please rank the following considerations *in order of importance* when deciding which land to set-aside on your holding.**

(1 = most important, 5 = least important)

Poor agricultural land ☐

Land which was difficult to access ☐

Land with perceived conservation value ☐

Land which would benefit from resting ☐

Land with trespass or public access problems ☐

Other (please give details below) ☐

..........................................................................................................................

..........................................................................................................................

**2.11 Do you envisage an increase in production/output on areas not set-aside ?**

YES ☐ NO ☐

**2.12 How are you managing your set-aside area ?**

(Please tick accordingly and indicate the area managed under each option)

| **a) ROTATIONAL** | | **Area (ha/acres)*** | **b) NON ROTATIONAL** | | **Area (ha/acres)*** |
|---|---|---|---|---|---|
| Natural regeneration | ☐ | .................... | Natural regeneration | ☐ | .................... |
| Sown grass cover | ☐ | .................... | Sown grass cover | ☐ | .................... |
| Non agricultural use | ☐ | .................... | Non agricultural use | ☐ | .................... |
| Wild bird/Game cover | ☐ | .................... | Wild bird/Game cover | ☐ | .................... |
| Other | ☐ | .................... | Field margins / Boundary strips | ☐ | .................... |
| | | | Other | ☐ | .................... |

* delete as appropriate.

If other please give details below

.................................................................... ....................................................................

.................................................................... ....................................................................

**2.13a Have you any marginal land or grassland which you are considering converting to arable production in the near future ?**

YES ☐ NO ☐

**2.13b If YES, what is the nature of this land ?**

Improved grassland ☐ Scrub ☐

Unimproved grassland ☐ Semi-natural habitat ☐

Rough grazing ☐

Other ☐

Please give details below

..............................................................................................................................

..............................................................................................................................

**2.14 If YES to 2.13a above, was *your decision* influenced by the introduction of set-aside ?**

YES ☐ NO ☐

**2.15 How has setting aside land affected the amount of time spent managing/maintaining this land ?**

Reduced ☐ Same ☐ Increased ☐

**2.16 Do you believe that the *introduction of set-aside* has been beneficial or harmful to your farm business ?**

(Please tick one box for each of a, b and c)

| | Beneficial | No difference | Harmful |
|---|---|---|---|
| a) FINANCIALLY | ☐ | ☐ | ☐ |
| b) AGRICULTURALLY | ☐ | ☐ | ☐ |
| c) ENVIRONMENTALLY | ☐ | ☐ | ☐ |

## 3. *CONSERVATION ON YOUR HOLDING*

**3.1a Would you consider yourself to be generally *interested in, and sympathetic towards wildlife*[2] on your farm ?**

Very interested ❑ Quite uninterested ❑

Quite interested ❑ Very uninterested ❑

Indifferent ❑

**3.1b If interested, what are your reasons for this interest ?**

(Please tick as appropriate)

Sporting interests ❑ The 'balance of nature' ❑

Personal pleasure ❑ Other, please specify ❑

..................................................................

..................................................................

**3.2 Do you have any contacts with conservationists or conservation organisations ?**

YES ❑ NO ❑

If **YES** please specify which organisations and the nature of your association.

..........................................................................................................................

..........................................................................................................................

**3.3 Do you have any of the following *semi-natural habitat types* on your farm ?**

Coniferous woodland ❑ Scrub ❑

Broadleaf woodland ❑ Hedgerows ❑

Rough pasture / unimproved grassland ❑ Open water ❑

Marshy land ❑

Other ❑

If other please give details below

..........................................................................................................................

2 See definitions in accompanying explanatory brochure

**3.4 Do you *actively manage* these areas ?**

YES ☐ NO ☐

**3.5 Are you at present, or have you in the last 5 years been in receipt of any of the following *conservation management agreements ?***

(Please leave blank if not)

| | Date of entry | Duration of agreement |
|---|---|---|
| SSSI management agreement . | .................... | .......................... |
| ESA management agreement | ..................... | ......................... |
| Farm woodland schemes | .................... | ......................... |
| MAFF conservation grants | .................... | .......................... |
| Hedgerow incentive scheme | .................... | .......................... |
| Countryside stewardship | .................... | .......................... |
| Nitrate sensitive areas scheme | .................... | .......................... |

**3.6 Do you practice any of the following forms of *conservation headland* or *field margin management* ?**

(Leave blank if not)

Reduced spraying of crop headland ☐

Sterile strip between field margin and crop ☐

Hedgerow management ☐

Sown grassland field margin ☐

Others ☐

If other please give details below

..............................................................................................................................

..............................................................................................................................

## 4. *CONSERVATION AND AGRICULTURAL POLICY.*

### A) SET-ASIDE

**4.1 Do you agree that set-aside is an effective policy for enhancing the conservation and wildlife potential of agricultural land ?**

Strongly agree ☐ Disagree ☐

Agree ☐ Strongly disagree ☐

Do not agree or disagree ☐

**4.2 Have you noticed any *specific wildlife benefits* on your set-aside land ?**

YES ☐ NO ☐ If yes, please briefly describe these.

........................................................................................................................................

........................................................................................................................................

**4.3 Do you think that MAFF has done enough to *incorporate conservation objectives* into set-aside policy ?**

Enough ☐ Too little ☐ Too much ☐ No view ☐

**4.4 How would you view managing some of your land for *conservation objectives* as opposed to managing it for agricultural production ?**

More satisfying ☐ Less satisfying ☐

Equally satisfying ☐ Would not consider ☐

**4.5a Are you aware of the MAFF guidelines for the 'management of set-aside land for environmental objectives '?**

YES ☐ NO ☐

**4.5b If YES, are you at present managing your set-aside land under any of the following suggested regimes ?**

Minimal cultivation for rare weeds ☐ Otter havens ☐

Sites for ground nesting birds ☐ Pasture for wildfowl ☐

Restoration of sandy grassland ☐ Wild bird cover ☐

Restoration of damp lowland grassland ☐

Field boundary set-aside ☐

**4.7 Would you be prepared to enter your land into *long term set-aside* (20 years) considering that this would be a voluntary scheme ?**

YES, if set-aside payments were guaranteed for full Period ☐

YES, but only at an increased payment rate ☐

Not at present, will await policy developments ☐

Fundamentally opposed ☐

## B) AGRI - ENVIRONMENT PROPOSALS

**4.8 Are you aware of the *'agri-environment' regulation*[3] which formed part of the 1992 CAP reform ?**

YES ☐ NO ☐

**4.9 Are you aware of the following schemes which have been proposed by the U.K. as part of the *'agri-environment' regulation ?***

(Please tick one box for each scheme)

| | Never heard of | Heard of but no detailed knowledge | Heard of, and some knowledge |
|---|---|---|---|
| New nitrate sensitive areas | ☐ | ☐ | ☐ |
| New ESA designations | ☐ | ☐ | ☐ |
| Moorland scheme | ☐ | ☐ | ☐ |
| Habitat scheme | ☐ | ☐ | ☐ |
| Organic aid scheme | ☐ | ☐ | ☐ |
| Countryside access scheme | ☐ | ☐ | ☐ |

**4.10 Subject to the announcement of payment rates, and detailed guidelines would you be inclined to join any of these schemes, where appropriate ?**

YES ☐ NO ☐

If yes, which ?

.............................................................................................................................

3 See definitions in accompanying explanatory brochure

## 5. *PERSONAL DETAILS*

**5.1 How long have you been farming ?**

..................................................................

**5.2 How long have you been farming this holding ?**

..........................................

**5.3 Are you an *owner/occupier* or a *tenant* ?**

.........................................................

**5.4 What is the total size of your holding ?**

.................................................................

**5.5 In which of the following age groups are you ?**

UNDER 30 ❑ 30-40 ❑ 40-55 ❑ OVER 55 ❑

**5.6 Which of the following activities do you practice on your holding ?**

| | | | | | |
|---|---|---|---|---|---|
| Cereal production | ❑ | Protein crops | ❑ | Oil seed crops | ❑ |
| Vegetable crops | ❑ | Fruit crops | ❑ | Commercial woodland | ❑ |
| Dairy | ❑ | Pig farming | ❑ | Beef production | ❑ |
| Sheep rearing | ❑ | Poultry | ❑ | Other | ❑ |

If other please give details below

.........................................................................................................................

.........................................................................................................................

**5.7 Indicate the area of your holding under each of the following crops at time of survey**

| | Approximate Area (hectares/acres)* |
|---|---|
| Cereals | ............................... |
| Protein crops | ............................... |
| Oil seed crops | ............................... |
| Improved grassland | ............................... |
| Unimproved grassland | ............................... |
| Orchard | ............................... |
| Commercial woodland | ............................... |
| Semi-natural habitat | ............................... |
| Derelict/abandoned land. | ............................... |
| Open water | ............................... |
| Set-aside | ............................... |

* delete as appropriate

**5.8 How would you describe the profitability of your farm business since the CAP reform of 1992 ?**

Decreasing ☐ Static ☐ Increasing ☐

6.0

**Would you be prepared to grant me a personal interview to discuss your views further, at your convenience ?**

**YES** ☐ **NO** ☐

**If YES please give a telephone number or address at which you may be contacted**

**If you know of any colleagues *who would* be interested in receiving this questionnaire, please give *names and* addresses below.**

**Thank you for your time and assistance in completing this questionnaire.**

# *Appendix 2*

## *Questionnaire : Attitudes towards set-aside, nature conservation and changing agricultural policy*

### ***The 'follow-up' questionnaire***

**The Agricultural Policy Research Unit**
**University of Liverpool.**

# Attitudes towards CAP reform, nature conservation and changing agricultural policy in the U.K .

(Tick as appropriate)

1. Do you have any set-aside land on your holding ?

Yes ☐ No ☐

2. In general, were you satisfied with the 1992 CAP Reform settlement ?

Very satisfed ☐ Quite opposed ☐
Quite satisfied ☐ Very opposed ☐
Indifferent ☐

3. Do you consider set-aside to be a "step in the right direction" towards reform of the arable sector ?

Yes ☐ No ☐

4. Would you consider youself to be generally interested in, and sympathetic towards wildlife on your farm ?

Very interested ☐ Quite uninterested ☐
Quite interested ☐ Very uninterested ☐
Indifferent ☐

5. How would you view managing some of your land for conservation objectives as opposed to managing it for agricultural production ?

More satisfying ☐ Less satisfying ☐
Equally satisfying ☐ Would not consider ☐

6. Do you think that MAFF has done enough to incorporate conservation objectives into set-aside policy ?

Enough ☐ Too little ☐ Too much ☐ No view ☐

ALL REPLIES WILL BE CONFIDENTIAL

## *Appendix 3*

*Questionnaire : Attitudes towards set-aside, nature conservation and changing agricultural policy*

***An exploration of further issues***

A QUESTIONNAIRE SURVEY

# ATTITUDES TOWARDS SET-ASIDE, NATURE CONSERVATION AND CHANGING AGRICULTURAL POLICY : an exploration of further issues

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The research aims and background to this project are explained in the accompanying brochure.

Confidentiality : All information provided will be held in the strictest confidence and used solely for the purposes of this research project. We undertake not to identify individual names or opinions at any time during this research.

# SECTION 1 - Set-aside on your holding

1.1 What is the total area of your holding eligible for payments under the **Arable Area Payments Scheme ?**

..........................................................ha/acres
(delete as appropriate)

1.2 Have you set-aside some of your cropped area within this scheme ?
(Please tick appropriate box)

YES ☐ NO ☐

If yes, what area ............................................ha/acres

1.3 Which of the following options is your land set-aside under ?

ROTATIONAL ☐

FLEXIBLE ☐

GUARANTEED ☐

ADDITIONAL VOLUNTARY ☐

1.4 What area of your set-aside land is

a) rotated around the farm ..........................ha/acres

b) maintained within the non-rotational option ..........................ha/acres

1.5 Are you **actively managing** any of your set-aside area for nature conservation objectives ?

YES ☐ NO ☐

If yes, how much land ............................................ha/acres

Briefly describe this management

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# SECTION 2 - Attitudes towards set-aside policy

Below are a set of statements relating to set-aside policy. Please indicate by ticking the **most appropriate box** (one box only) whether you agree or disagree with each of the statements.

| | Strongly agree | Agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| Set-aside is the **most effective** policy for reducing over-production of surplus arable crops | | | | | |
| **Less intensive production** across the **entire** cropped area would be a **more effective** means of reducing production | | | | | |
| Set-aside should be **targeted** towards the **least productive** arable land | | | | | |
| Set-aside policy is an attempt at a **temporary solution** to the longer-term problem of over-production | | | | | |
| Set-aside policy **will achieve** the desired **reduction in total crop yields** within the European Community | | | | | |
| Set-aside land appears to be **untidy** and **unkempt** giving an impression of neglect to the public | | | | | |
| Set-aside land increases **pest and disease problems** across the whole farm and in subsequent crops | | | | | |
| Reducing the area of land in intensive arable production enables **more precise timing of operations** on the remaining cropped area | | | | | |
| Set-aside is a **fair policy** and does not discriminate on the basis of farm size | | | | | |
| Set-aside **reduces farm labour costs** resulting in increased profits per unit of production | | | | | |
| Set-aside is viewed by the public as **'paying farmers to do nothing'** | | | | | |
| Surplus arable land should be diverted to production of **alternative** and, or **industrial crops**, rather than set aside | | | | | |
| **Nature conservation** would be a **more appropriate** use for set-aside land | | | | | |
| Overall, I believe the introduction of **set-aside** has been **beneficial to the arable sector** | | | | | |

# SECTION 3 - Attitudes towards nature conservation

3.1 Would you consider yourself to be interested in, and sympathetic towards wildlife on your farm ?

Very interested ☐ Quite uninterested ☐

Quite interested ☐ Very uninterested ☐

Neutral ☐

3.2 Would you agree that setting aside arable land results in considerable **environmental and wildlife benefits** ?

Strongly agree ☐ Disagree ☐

Agree ☐ Strongly disagree ☐

Neutral ☐

3.3 Do you have any contact with conservationists or conservation organisations ?

Yes ☐ No ☐

If yes, please give brief details of these contacts (i.e FWAG, RSPB etc)

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3.4 Do you **actively manage** any areas on your holding for **nature conservation** objectives ?

Yes ☐ No ☐

Below are a set of statements relating to nature conservation on farmland. Please indicate by ticking **the most appropriate box** (tick one box only) whether you agree or disagree with each statement.

| | Strongly agree | Agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| Farmers should be viewed solely as **producers of food** | | | | | |
| Farmers should be viewed as **'guardians of the land'** and as such their activities should reflect a **range of land-use objectives** | | | | | |
| The goals of intensive **agricultural production** and **nature conservation** are **entirely incompatible** | | | | | |
| A return to more **traditional** (less intensive) **farming** systems will achieve considerable **environmental** and ***wildlife benefits*** | | | | | |
| **Agricultural policy** should include both **production** and **environmental goals** | | | | | |
| The authorities have done **too little** to incorporate **environmental** and **wildlife** concerns into agricultural policy | | | | | |
| **Wildlife habitats** should be viewed as agricultual products, and as such farmers should be **paid** for their **creation** and **maintenance** | | | | | |
| Intensive farming systems have **no harmful effects** on semi-natural habitats and, or farm wildlife | | | | | |
| **Managing land for conservation** objectives is equally as **satisfying** as managing land to maximise crop yields | | | | | |
| **Nature conservation** is a **luxury** which many farmers are not able to afford | | | | | |
| Current **financial incentives** for farmers to incorporate nature conservation into farm management are inadequate | | | | | |
| **Conservationists fail to understand** modern farming systems | | | | | |
| Wildlife on farms maintains **'the balance of nature'** | | | | | |
| The **role of farmers** should be redefined to encompass nature conservation as well as food production | | | | | |

# SECTION 4 - Awareness and uptake of conservation management on set-aside land

4.1 Are you **aware** of the following **MAFF directed** conservation oriented management guidelines for set-aside land ?

| | YES | NO |
|---|---|---|
| Rotational set-aside for birds | ❑ | ❑ |
| Rotational set-aside for rare arable weeds | ❑ | ❑ |
| Non-rotational Brent geese pasture | ❑ | ❑ |
| Non-rotational Stone Curlew meadow | ❑ | ❑ |
| Field margin set-aside for woodland edge and hedgerow | ❑ | ❑ |
| Field margin set-aside for meadow strips | ❑ | ❑ |
| Long-term set-aside (20 year habitat scheme) for habitat restoration | ❑ | ❑ |
| Set-aside for woodland establishment | ❑ | ❑ |

Are you managing any of your set-aside area in accordance with these guidelines ?

Yes ❑ No ❑

If yes, which guidelines are you following ?

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4.2 Our initial survey indicated that the uptake of these conservation schemes on set-aside land has been very poor. Which of the following factors do you believe are the most important in accounting for this **(Please rank in order of importance i.e 1 = most important, 5 = least important)**

| | |
|---|---|
| Set-aside is an **unpopular policy** with many farmers | ☐ |
| Farmers are **not interested** in **nature conservation** | ☐ |
| A lack of **awareness** of these opportunities | ☐ |
| A **lack of financial reward** for the extra expenditure incurred | ☐ |
| A lack of available **advice** on management of set-aside land for conservation objectives | ☐ |

4.3 For each of the schemes indicate what you believe would be an appropriate additional payment (added to basic set-aside premium) to make them financially viable

| | **£/ha** |
|---|---|
| Rotational set-aside for birds | .......... |
| Rotational set-aside for rare arable weeds | .......... |
| Non-rotational Brent geese pasture | .......... |
| Non-rotational Stone curlew meadow | .......... |
| Field margin set-aside for woodland edge and hedgerow | .......... |
| Field margin set-aside for meadow strips | .......... |
| Long-term set-aside (20 year habitat scheme) for habitat restoration | .......... |
| Set-aside for woodland establishment | .......... |

# SECTION 5 - Farm and farmer details

5.1 What is the total size of your holding ?

................................ha/acres

5.2 What is the total area of your holding currently in agricultural production (including set-aside) ?

................................ha/acres

5.3 Do you have any areas of semi-natural habitat on your holding ?

Yes ☐ No ☐

If yes, briefly describe these areas

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5.4 Are you an owner/occupier ☐

a tenant ☐

5.5 In which of the following age groups are you ?

20-20 ☐ 30-40 ☐ 40-55 ☐ over 55 ☐

5.6 Prior to the 1992 CAP reform settlement would you describe the profitibility of your farm as

Increasing ☐

Static ☐

Decreasing ☐

5.7 Has the introduction of the Arable Area Payments Scheme made your business

More profitable ☐

Less profitable ☐

No different ☐

Following completion and analysis of this questionnaire, we hope to conduct a small number of personal interviews by telephone. The purpose of these interviews will be to enable farmers to express in person their views towards set-aside and the wider issues of nature conservation on farmland and to raise any points which have not been covered by this questionnaire.

If you would be prepared to grant us a personal interview, at your convenience, please give your name, address and telephone number in the space below, together with convenient times to call.

If there are any further points you would like to make regarding issues raised by this questionnaire please do so in the space provided below, or on a separate sheet of paper.

**The members of the Agricultural Policy Research Unit (A.P.R.U) would like to thank you for your time and assistance in completing this questionnaire.**