ENGLISH NATURE

A summary review of information on the autecology and control of six grassland weed species

No. 44 - English Nature Research Reports

working today
for nature tomorrow

ENGLISH NATURE

English Nature Research Report

Number 44
A Summary review of information on the autecology and control of six grassland weed species

N A Simpson

ADAS, Huntingdon

Final report (Contract F72-08-14)

Nominated Officer: Dr R G Jefferson

Further copies of this report are available from the nominated officer at English Nature, Northminster House, Peterborough PE1 1UA

ISSN 0967-876X

English Nature Research Reports

NCC CONTRACT NUMBER F72-08-14

A SUMMARY REVIEW OF INFORMATION ON THE AUTECOLOGY AND CONTROL OF SIX GRASSLAND WEED SPECIES

Creeping Thistle *(Cirsium arvense)*,
Spear Thistle *(C. vulgare)*,
Broad-leaved Dock *(Rumex obtusifolius)*
Curled Dock *(R. crispus)*.
Common Ragwort *(Senecio jacobaea)*,
Marsh Ragwort *(S. aquaticus)*,

Report by: N. A. Simpson
ADAS Huntingdon
Chequers Court
Huntingdon
Cambs
PE18 6LT

Final Report: 12 March 1993

A SUMMARY REVIEW OF INFORMATION ON THE AUTECOLOGY AND CONTROL OF SIX GRASSLAND WEED SPECIES - Creeping Thistle *(Cirsium arvense)*, Spear Thistle *(C. vulgare)*, Broad-leaved Dock *(Rumex obtusifolius)*, Curled Dock *(R. crispus)*, Common Ragwort *(Senecio jacobaea)*, and Marsh Ragwort *(S. aquaticus)*.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to the many members of English Nature, ADAS colleagues and research workers who without exception were very helpful, bound together by a common desire to share what they knew on the subject for the benefit of you the reader. If the author has not fairly or accurately represented the views of those quoted in this report then he apologises, and would be pleased to make ammends where possible.

CAUTIONARY NOTE

In places conflicts of opinion do exist. The author has corrected mis-information where he was aware of it. The author aims to guide the reader, but the resolution of conflicts of opinion or conflicting experimental results must be a priority for further research. This report has been written to give guidance on the ecology of individual 'weed' species and to inform the reader of possible means of control.

For specific site recommendations the reader should consult the Science Directorate of English Nature before attempting any control of the species covered by this report.

A SUMMARY REVIEW OF INFORMATION ON THE AUTECOLOGY AND CONTROL OF SIX GRASSLAND WEED SPECIES - Creeping Thistle *(Cirsium arvense)*, Spear Thistle *(C. vulgare)*, Broad-leaved Dock *(Rumex obtusifolius)*, Curled Dock *(R. crispus)*, Common Ragwort *(Senecio jacobaea)*, and Marsh Ragwort *(S. aquaticus)*.

CONTENTS

PART II - BROAD AND CURLED DOCK AUTECOLOGY AND CONTROL

Page No.

PART III - COMMON AND MARSH RAGWORT AUTECOLOGY AND CONTROL

FOREWORD

This report written primarily for the site managers of the 37 lowland grass National Nature Reserves (NNRs) currently managed by English Nature, otherwise known as the Nature Conservancy Council for England, and conservation advisers with English Nature and the voluntary conservation sector (R. Jefferson, personal communication). It is also applicable to many more lowland pasture Sites of Special Scientific Interest and nature reserves managed by other wildlife conservation bodies.

It contains information on current agricultural practice to enable the reader to compare a modern farmers' approach with what is recommended for semi-natural grasslands of high conservation value.

The species covered by this report often do not present a problem to conservationists until concern is expressed by neighbours or licencees of grazing or hay meadows or other site occupiers who are able to cite the Weeds Act, 1959, as grounds for action being taken. Thus, site managers become involved and then the following species are labelled as a 'weed problem':

Creeping Thistle *(Cirsium arvense)*, Spear Thistle *(C.vulgare)*, Broad-leaved Dock *(Rumex obtusifolius)*, Curled Dock *(R. crispus)*, Common Ragwort *(Senecio jacobaea)*, and Marsh Ragwort *(S. aquaticus)*.

However, any of these species can be a problem to conservationists, as well as farmers, given their capacity to dominate an area, smother desirable species, and interfere with the of grassland for stock feeding, whether by grazing, cutting for hay or silage, or feeding.

Control and not elimination is the prime objective of the recommendations given in this report. This is both practical and sensible advice because elimination is rarely possible with the weed species studied and the fact that all of the 'problem species' covered by this report are desirable for invertebrates, and it would be foolish to reduce the diversity of a nature reserve or SSSI where such problem species are under control.

To exacerbate the difficulty of controlling these species it is said that a thin, short sward is essential for achieving a highly diverse flora (Haggar, undated). These very conditions make it easier for the problem species to invade, establish and multiply through provision of establishment sites and lack of competition. Similarly Haggars' suggested means of producing such a thin, short sward - by grazing, mowing, burning or the use of chemical growth retardants at key times of the year, usually after flowering and seed setting, can all increase the populations of these highly-competitive, undesirable species at the expense of those which a manager may wish to encourage.

This report aims to help managers recognise the conditions which may tip the balance in favour of the undesirable weed species. This report also aims to help managers achieve their goals in preventing the introduction of such species where they are currently absent, reduce their spread where they are present in low numbers or try to reduce their dominance where they have been unsuccessfully controlled in the past.

Cooke (1986, 1991) has outlined English Nature's policy and guidelines on the use of pesticides on NNRs. One of the central recommendations is that the control of unwanted plant species should be achieved by methods other than herbicides, wherever this is practicable. The most specific method of eliminating undesirable plants is by removing each individual by hand or machine. Such thinking is not new, it is one of the methods of suppression listed in the Board of Agriculture and Fisheries Leaflet No.112 first published in 1904 (Anon, 1913). This also lists:

- prevention of seeding,
- care in disposal of hayloft sweepings,
- judicious cutting with spade, hoe or scythe,
- close feeding with sheep to check certain plants and prevent them seeding, as for example with ragwort
- spraying with chemical substances.

This leaflet also lists techniques open to the farmer but rarely applicable to site managers. Besides use of appropriate rotations, these guidelines include avoidance of:-

uncleaned or weed-infested seed when reseeding, deep ploughing, fallowing, draining, liming, fertilising, use of organic manures, and avoiding use of broad-spectrum sprays.

Where numerous individual plants/weeds have to be controlled on grassland of high conservation value then regular cutting, grazing, or burning may provide the solution or at least reduce the problem. However, in some situations, these methods may be unsuccessful or impracticable, they may also be expensive, particularly when extensive hand labour is needed. In such situations and where further inaction would lead to a loss of conservation interest, then herbicide use is viewed as an option, by most English Nature staff. This is achieved by using relatively selective herbicides (eg clopyralid) or reasonably precise placement techniques which minimise the toxic impact of a pesticide on the community being invaded.

Cooke (1991) states that 'a herbicide should not be used to tackle the proximate cause of a problem without the ultimate cause also being tackled, if this is feasible'. This logical approach is environmentally desirable, and will often make economic sense for a site manager; but may cause inconvenience, if not loss, to a grazier. Thus if a thistle problem stems from poaching caused by over-stocking in the early spring and lax grazing later in the year, the stocking rate should be corrected in order to reduce the need to re-spray the thistles in subsequent years. Cooke (1991) regarded any herbicide usage as a 'one-off' management exercise to aid habitat restoration. However, re-spraying may be necessary where extensive creeping root systems occur, where there is a high level of seed reserves in the soil, where weeds in neighbouring land are uncontrolled resulting in re-invasion, especially if the number of germination sites is increased by any adverse climatic factors (eg drought) or management influences (eg poaching, or feeding infested hay on pastures) aside from any poor control that may result from adverse environmental conditions at the time of spraying or spray misses.

For control of perennial weeds, repeated use of herbicides will often be necessary if these weeds are to be eliminated. If complete control is not required, depending on the situation, one herbicide application may be sufficient for a number of years - the period of control depending on the ecology of the species concerned, the environmental and management factors relevant to the site and alternative control techniques which may be tried after the initial spraying.

None of the weeds studied are easy to control, that is why they were chosen for this study.

Cavers (1985) said that intractable weed species are characterised by great intraspecific variation and this must be considered in control measures. Variation occurs in respect of resistance to herbicides, susceptibility to pathogens and parasites, seed dormancy and longevity, phenology and life-span and the structure and function of vegetative reproductive organs. This is why the autecology of the individual species is reviewed in this report.

Biological survival and success depend upon competitive advantage. All the species covered by this report have advantages over other species present in the sward, to the point where they can dominate. For example, all the species covered by this report are capable of regenerating from roots, although it is rarer from Spear Thistle and Curled Dock than with the other species. These roots are often sufficiently large and nutrient-filled to enable regrowth after many attempts at control. New individuals arising from such roots can be much more vigorous than a seedling of the same species. Vegetative reproduction and regeneration can occur even when flowering is prevented, or at times of the year when flowering and seed set do not occur, as in the autumn, so utilising resources which might not be utilised if such growth did not occur. Vegetative reproduction enables a population to spread within a local area that is favourable for such a species. If a plant which is capable of vegetative reproduction is damaged or endures conditions which are unfavourable, it is capable of regenerating when conditions are favourable (Cavers, 1985).

There are no easy answers - if there were then these species would not be a continuing problem. However, each species can be controlled provided that sufficient priority and resources are given to tackling the problem by site managers. It is generally easier to prevent these weeds becoming a problem than curing the problem later.

Weeds sometimes do cause a problem, this may be due to factors beyond a manager's control, concentration on other priorities, or inadvertent error. If this happens, it should be understood that there are compromises to be made, that there will be continual need to be vigilant and to 'blitz' problem weeds when they get out of control.

BACKGROUND

English Nature and the Royal Society for Nature Conservation aim to produce a Grassland Management Handbook, which will be published early in 1993.

One sub-section of the book will cover methods of control of problem species in lowland grassland, with emphasis on control in permanent pastures of high conservation value. Botanically-rich pastures and pastures which have desirable invertebrate species may also contain plant species which are regarded as "weeds". These plants are regarded as weeds because of their actual or potential dominance of the sward which can reduce botanic diversity, their interference with the management of farm livestock, their association with "bad farming" or aesthetic reasons.

The main problem species in grassland for conservationists and farmers in order of occurrence nationally are Creeping Thistle *(Cirsium arvense)*, Broad-leaved Dock *(Rumex obtusifolius)* and Curled Dock *(R. crispus)*, Spear Thistle *(Cirsium vulgare)*, Common Ragwort *(Senecio jacobaea)*, and Marsh Ragwort *(Senecio aquaticus)*.

Locally any of these species may be dominant in a sward or geographic area. Examples of dominant ragwort infestations have been studied by Forbes (1974 and 1976), Davies (1953), and McClements (1992). Creeping Thistle poses particular problems for many English Nature managers (John Bacon, Maurice Massey, Paul Toynton, Tony Smith, Graham Bellamy, Keith Payne, David Hinchelwood, and Malcolm Whitmore, personal communications). Docks have been identified as a particular problem by English Nature managers (Keith Payne, John Bacon, personal communications). Finally Marsh Ragwort has been cited as a particular problem by Tim Dixon, English Nature Site Manager at the Lower Derwent Valley NNR, in North Yorkshire and North Humberside.

Thus a need was identified for the collation of existing information on the autecology, control and management of specified weed species in lowland grassland.

Control of the main problem weed, Creeping Thistle, has proved difficult on some of English Nature's National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs). As a precursor to commissioning research into the control of Creeping Thistle in semi-natural grasslands, existing knowledge and ideas for further investigation needed elucidation.

All the weeds studied in this report have similarities, and differences, thus one report was required; but it was felt that the most appropriate layout of the report would be three sections each covering the main weed types - thistles, docks and ragworts. This was to enable easy selection of the parts of the report most relevant to the individual reader; however, to avoid excessive repetition, each part contains comments and ideas which may be relevant to a weed more fully covered in another section. Given the ability of these species to occur in mixed populations or for one infestation to succeed another the whole report is commended to the reader.

AIMS AND OBJECTIVES OF THIS REPORT

1 To produce a summary review of information on the ecology and control of the six weed species identified above in various lowland grasslands -including improved and semi-natural swards, and those cut for hay or silage as well as grazing pastures.

2 To assess the practicality and effectiveness of current control methods in semi-natural grasslands of high conservation value (ie NNRs and SSSIs). To contact a range of English Nature's site managers to provide additional information to that in the published literature.

3 To assess other potential methods of control or elimination.

4 To produce an action calendar, which will guide site managers and others on prevention and control of Injurious Weeds throughout the year.

5 To briefly assess the likely future research requirements for control of individual species.

6 To produce a bibliography of information sources including scientific papers, reports, etc.

REFERENCES GIVEN IN CONTENTS SECTION

Anon, (1913), Weeds and their suppression, Leaflet 112, (Fourth Edition), Board of Agriculture and Fisheries, London.

Bacon, J., personal communication.

Bellamy, G. personal communication.

Cavers, P.B. (1985) Intractable Weeds - intraspecific variations must be considered in control measures, 1985 British Crop Protection Conference -Weeds, 1, pp 367-376.

Cooke, A.S., (1986)The use of herbicides on nature reserves, Focus on Nature Conservation No. 14, Nature Conservancy Council, Peterborough, 80 pp.

Cooke, A.S., (1991) The use of herbicides on Nature Reserves, Brighton Crop Protection Conference - Weeds, 2, pp 619-626.

Davies, A.J., (1953) The ragwort problem in Wales, Proceedings of the 1st British Weed Control Conference, pp 204-210.

Dixon, T., personal communication.

Forbes, J.C., (1974) A survey of ragwort in Orkney, British Crop Protection Council Monograph No 9, pp 115-120.

Forbes, J.C., (1976) Influence of management and environmental factors on the distribution of the marsh ragwort (*Senecio aquaticus* Huds.) in agricultural grassland in Orkney, Journal of Applied Ecology, 13 (3), pp 985-990.

Haggar, undated, Conserving the native flora on grassland farms, in Science, Agriculture and the Environment, Agricultural and Food Research Council, 106 Great Portland St, London W1N 6DT, pp 24-25.

Hinchelwood, D., personal communication.

Massey, M. personal communication.

McClements, I., (1992) Farm Survey, PhD Thesis, Queens' University, Belfast, Chapter 2.

Payne, K., personal communication.

Smith, A., personal communication.

Toynton, P., personal communcation.

Whitmore, M.,personal communication.

PART I - CREEPING AND SPEAR THISTLE AUTECOLOGY AND CONTROL

1.0 Introduction

1.1 The main problem species in grassland for conservationists and farmers is Creeping Thistle *(Cirsium arvense)*. Nationally Spear Thistle *(Cirsium vulgare)* is regarded as less of a problem than Creeping Thistle but it may be locally important.

1.2 One complication for nature reserve managers, which tends to be ignored by most farmers, is the need to conserve the rarer species, including other thistles, related to the two problem weeds considered here. These rarer native thistle species are often confined to smaller geographic areas and include:-

Carline Thistle *(Carlina vulgaris)*,
Marsh Thistle (*Cirsium palustre/Carduus palustris)*
Meadow Thistle *(Cirsium dissectum)*
Stemless or Dwarf Thistle *(Cirsium acaule/acaulon)*,
Tuberous Thistle *(Cirsium tuberosum)*, and
Woolly Thistle *(Cirsium eriophorum)*.

There are also other native thistle species of the Carduus genus, which would be susceptible to the same control techniques, these include:-

Musk or Nodding Thistle *(Carduus nutans)*
Plymouth Thistle *(Carduus pycnocephalus)*
Slender Thistle (*Carduus tenufolius)*
Welted Thistle (*Carduus crispus)*

Yet more native species are relatives within the tribe *Cynareae* in the Compositae Family. These include:-

Lesser Burdock (*Arctium minus*)
Greater Burdock (*Arctium lappa*)
Milk-Thistle (*Silybum marianum*)
Cotton Thistle (*Onophordum acanthium*)
Alpine Saw-wort (*Saussurea alpina*) - an upland species
Knapweeds (*Centaurea spp.*)
Saw-wort (*Serratula tinctoria*)

1.3 Many of the above species are often associated with lowland grassland and their conservation will inhibit the range of weed control measures capable of adoption.

1.4 Creeping Thistle poses particular problems for many English Nature managers (J.Bacon, M.Massey, P.Toynton, A.Smith, G.Bellamy, K.Payne, D.Hinchelwood and M.Whitmore, personal communications) and a mowing regime to reduce the dominance of this weed in pasture may not be compatible with control of Spear Thistle or may reduce the competitiveness of other desirable broad-leaved species.

1.5 Control of Creeping Thistle has proved difficult on some of English Nature's National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs). As a precursor to commissioning research into the control of Creeping Thistle in semi-natural grasslands, existing knowledge is reviewed here and ideas for further investigation are suggested.

2.0 Creeping Thistle Biology and Ecology

2.1 English Common names: Creeping or Field Thistle in the UK, Canada/Canadian Thistle (in N. America), Californian Thistle (in New Zealand), Small-flowered Thistle, Perennial Thistle and Green Thistle. French common names exist, listed by Ferron et Cayouette (1971) - the most common of which is chardon des champs.

2.2 Latin Names: *Cirsium arvense* (L) Scop, *C. argenteum* Peyer, *C. horridum* (Wimmer & Grab.) Stankov, *Serratula arvensis* L., *Carduus arvensis* L. Hill with a host of sub-species (varieties) eg var *setosum* C.A. Mey, var. *mite* Wimm. & Grab., and occasionally another variety found in Britain but more often in Southern Europe var. *incaum* (Fisch.) Ledeb. (Clapham, Tutin and Warburg, 1962; Hanff, 1983). Moore and Frankton (1974) produced a key to separate four varieties - var. *vestum* Wimm. & Grab., var. *integrifolium* Wimm. & Grab., var. *arvense*, var. *horridum* Wimm. & Grab. These varieties are interfertile and do not breed true, Detmers (1927) found that the variety *vestum* produced seedlings of all varieties.

2.3 Main attributes: Creeping Thistle is the most widespread, troublesome and difficult to control of all weeds occurring in UK grassland (Haggar, Oswald and Richardson, 1986). It is a perennial occurring on most soils in Britain up to an altitude of 640 m (2100 feet), but is not common above 360 m (1180 ft). It has been introduced to N. America and New Zealand, and is found across Europe, Scandinavia, Asia, Minor, Afghanistan, Asia, South Africa, N. Africa, Japan, and south-eastern Australia. It is vigorous, aggressive and will quickly dominate either cultivated or waste ground if left unchecked.

2.4 Its growth habit, and root system, varies according to plant age, soil, site, climate, and management. This with varietal differences and intermediate forms may explain differential and variable levels of control from certain herbicides. Selected ecotypes show differences in phenology and photoperiodism, vigour and growth habit, stomatal frequency and response to herbicides, seed dormancy and germination (Moore, 1975). Some plants escape herbicide damage because their excessive hairness prevents herbicide contact with sensitive tissues (P. Marriage, personal communication to Cavers, 1985) whereas in other species the difference in herbicide response is found at the cellular or sub-cellular level.

2.5 The stems and leaves, both of mature plants and seedlings, are sensitive to hard frost. The first frosts kill off all the green parts above ground, but the buds below ground are uninjured, and is from these that the plant is chiefly propagated (Anon, 1906). Thus any attempt at control in the autumn is a waste of time, because the plant is already prepared to cope with frosts. Similarly any accurate assessment of level of thistle infestation after such frosts is not possible.

2.6 Height is generally 30-90 cm but plants may reach up to 1.5 m.

2.7 Means of spread: The most usual means of spread is by creeping roots which rapidly colonise an area. A single small cutting of creeping root has been recorded as producing in two years a patch 60 ft across (Gill and Vear, 1958). Abundant reproduction and spread also occurs by either fragmentation of the roots during ditch work, winter or spring poaching, or disturbance of the soil. However, repeated cultivation at 10 cm at three week intervals in a bare fallow can exhaust roots over time (Ivens, 1978). Spread may also occur because some roots are also said to be brittle and to be broken by frost-heaving (Donald, 1992: Hamdoun, 1972). Rogers (1928) found that individual roots live only for about 2 years, and are then replaced by new roots which develop from the old.

2.8 The underground system is complex, consisting of three types of organ:

a) **thin vertical feeding/storage roots**

b) thicker, over 1.3 cm diameter (Donald, 1992) **lateral secondary roots** creep horizontally, growing by 1.25 -12.2 metres per year (Chancellor, 1970; Courtney, 1973; Ivens, 1978); although the rate of spread is reduced to as little as 0.04-3.41 metres as stocking rate is increased (Amor and Harris, 1975). Most vegetative growth occurs in the spring (Amor and Harris, 1975) and, in spring the secondary roots produce c):-

c) **vertical sub-terranean shoots with scale leaves** (Sagar and Rawson, 1964), otherwise known as **adventitious buds** (Prentiss 1889; Anon,1906; Hayden 1934: Hodgson, 1970; Hamdoun 1972). Such shoots last longer than one year and develop aerial leaves once they appear above the soil surface (Chancellor, 1970), which can grow up to 3 cm per day (Hodgson, 1968a). After producing these vertical shoots, the creeping roots turn downwards and produce more of a) the vertical roots. The more often the shoots above ground are cut down the more root buds develop into new stems (Anon, P51, 1987). It is reported that mowing only once or twice for one season seems to produce no reduction of infestation the following season (Malcolm Whitmore, personal communication), but cutting each time the plants reach flower bud stage, if continued over three years, will eventually exhaust the food supply in the roots (Gill and Vear, 1958). Disturbed whole or fragmented root (as short as 2.5 cm - Ivens, 1978) quickly produce new shoots (Hamdoun, 1972). One bud, normally the apical bud, has an inhibiting effect on the growth of others along the root. This apical dominance which keeps these lateral buds dormant is broken by fragmentation, which results in the buds along the root fragments growing readily; there tends to be an inverse relationship between the length of a root and the number of buds that sprout (Lampkin, 1990). The buds are 2.5-3 cm apart. Prentiss (1889) found that each 12 mm length of root fragment with a cross-section of 3-6 mm has 100% probability of producing shoots, and 14% of 8 mm root fragments of similar diameter could produce shoots. Only towards the end of flowering are the roots so weakened that only 5-10% of the pieces can grow into a new plant should the occasion arise (Lampkin, 1990). Rogers (1928) states that a root fragment which is more than 6 weeks old and less than 2 years old can regenerate an entire plant.

2.9 Roots can remain dormant for long periods, possibly several years, in adverse conditions awaiting more favourable conditions to produce shoots (Bates, 1935). Shoots emerge after soil and air temperatures have warmed. Hodgson (1968a) found that emergence began when the weekly average temperature reached 5°C, and was best when temperatures exceeded 8°C. Adverse conditions, such as 24 hours exposure on the soil surface can reduce root viability (Ivens, 1978). Flooding also appears to kill perennial root-stocks (Gill and Vear 1958).

2.10 Propagation is mainly by the roots which are generally 0.5 m deep but can reach depths of 2-4.5 m (6-15 ft), more rarely from seed.

2.11 Daylength, temperature and rosette size are important determinants of time of flowering and subsequent seed production (Link and Kommedahl, 1958; Leeuwen, 1983). Creeping Thistle is a long-day plant, flowers generally open in July and may be seen until after the first frosts up to October/November. The entire stem dies back in late autumn to just below the soil surface.

2.12 Plants are almost always dioecious ie male and female flowers on separate plants (the other sex characteristics are developed but rudimentary or abort) - male plants have perfect pollen-bearing anthers on small flowers - female plant flowers are ovoid, have a honey/vanilla like scent but male flowers may be almost scentless. Male plants are commonest and hermaphrodite plants are rare (Salisbury, unknown publication date). Distinct colonies of each gender arise from their underground roots. Both due to their colour and scent flowers are freely visited by a great variety of insects. To produce viable seed by wind pollination female plants have to have a male plant within 50 m. (Ivens, 1978) or 400 m (Amor and Harris, 1974): but insect pollination over much greater distances cannot be ruled out. Detmers (1927) stated that honey bees were the chief agent of pollination. However, the greater the separation of male and female plants, the lower the seed set, whatever the means of pollination.

2.13 Seeds 4 mm, olive green/brown, smooth with a soft silky pappus 20-30 mm long, feathery as in all Cirsium species - seeds can be dispersed by wind up to 1 mile (Courtney, 1973). The fruit weighs 0.00096-0.0018 gm but poses little danger of spread (Anon, P51, 1987; Chancellor, 1970). This is because of low seed viability and the pappus often becomes separated from the seed limiting wind dispersal. Bakker (1960) observed that at a distance of 1 km only 0.2% of floating plumes had a seed attached. Not all the seeds produced by a plant are likely to be released but this might equate to 11 seeds out of the the entire production of a shoot. Long distance spread by water is possible, Bruns and Rasmussen (1957) reported 70% germination after 6 months submergence in water, and Hope (1927) found *C. arvense* seeds in irrigation water.

2.14 The seed germinates best at a very shallow depth, 0.5-1 cm (Amor and Harris, 1975) or 1-2 cm (Ivens, 1978). Kolk (1947) found a few seeds will emerge from depths of up to 6 cm, which was the maximum tested. The viability of spread seed is generally low even if a suitable germination site is found (Ref Chancellor, 1970). Eggers (1978) found only 3.7% of Creeping Thistle seed, from various German sources, germinated in the laboratory under optimal laboratory conditions (25-30°C); but in New Zealand 44% germination has been recorded (Thompson, 1983). Amor and Harris (1974) found that samples of seed from 37 sites in Australia, stored for 6 months at 20°C, produced 52-97% germination (average 78%). Genetic variation, weather and seed-borne diseases eg Alternaria spp. often cause variation in viability of other seeds, and may explain local variation. Cavers (1974) observed that greater variability or intermittency in seed germination often improves a weed population's success, since each time that a stand of seedlings or older plants is destroyed, a new stand will soon arise from the seed bank to take its place. Seed germination may help thistle spread but vegetative spread of creeping thistle is more common.

2.15 It is worth remembering that owing to the unisexual character of the plant and the fact that large areas are often infested by the vegetative offspring of a single individual, examination of the the fluffy-fruit heads reveals no fertile fruits whatever. Diurnal temperature fluctuation is often important in seed germination (Salisbury, unknown publication date), so laboratory conditions may need to mimic this. Whatever the seed viability, radial extension by the creeping roots makes this one of the commonest and most pernicious of pasture weeds and so research should concentrate on limiting vegetative spread.

2.16 True seedlings, which are difficult to distinguish from those of other thistles are seldom seen, Anon, P51 (1987), and true seedlings can only be distinguished by their cotyledons from new shoots arising from the roots. However, large numbers of seeds are produced, approx 1,500-40,000 are given as the average number of seeds per female plant. These figures may be mis-leading, because rarely can one ascertain how many shoots make up a plant, so it is better to concentrate on seed production per shoot. Various references (Detmers,1927; Hayden, 1934; Bakker, 1960) give the average floret number as 100, range 84-132. Detmers (1927) observed that one vigorous shoot may bear 100 heads in a season and Bakker (1960) found 32-69 heads per shoot in favourable growing conditions. This gives a theoretical maximum of about 10,000 seeds produced per female flowering shoot. Hay (1937) reports that one 'plant' may produce up to 5,300 seeds, but the average production was 1,530.

2.17 Occasionally a functional male plant may develop a few seeds but commonly either male or female plants growing alone are sterile. New plants can be produced from seed, particularly where conditions are favourable - ie bare ground after tillage, or poaching, ditch clearance, fire sites, and scrub clearance by mechanical means, burning, or use of non-selective and non-persistent chemicals. Seeds only germinate in gaps in a thin sward, either in the year in which they are produced or the following spring (Anon, L166, 1906) although once they are buried they can survive in soil for 6-10 years (Courtney, 1973) or at least 20 years (Bakker, 1960). Toole and Brown (1946) looked at percent germination of seed stored at different depths, from 20-105 cm, for differing periods of time, up to 39 years. No germination was recorded after 30 years; but after 21 years 1% germination was found at 20 and 55 cm depths, with 5% from seed buried 105 cm. Amor and Harris (1975) showed a peak of seedling emergence in the spring from an autumn sowing at 0.5-1.0 cm into bare ground - working in Victoria, Australia - at one site the peak occurred in their September, equivalent to our month of March, with a substantial decline over the following two months, with less than 0.1% or no seedling emergence at other times of the year; at the other site establishment occurred on bare soil from the equivalent of our months of November to February. Neither was there any emergence when seed was artificially spread onto two pastures. When the seed was spread on bare soil lower seedling emergence was recorded, and at one of the two sites no establishment occurred from seeds on the surface. However, where Creeping Thistle plants do establish they can produce phytotoxins which may hinder the establishment of other species. Bendall (1975) has reported that water and alcohol extracts of roots and foliage of *C. arvense* inhibit the germination of its own seed and that of clovers and inhibit the growth of other seedlings. This may have important implications in a nature reserve.

2.18 Obvious seeding of Creeping Thistle causes offence to many neighbours of infested land, and given the ability to spread locally from the creeping roots it is listed as an Injurious Weed under the Weeds Act, 1959. Measures to prevent the spread of this species (as with all others covered by this report) may be required if there is a threat to agricultural production. Complaints are addressed to one of the Executive Officers (Field) at the local Regional Service Centre of the Ministry of Agriculture, Fisheries and Food (MAFF). These officers can supply a leaflet on control of all injurious weeds to interested parties, addresses are given at the back of this report. Set-aside land is not exempt from the provision of the Weeds Act 1959.

2.19 Where there is a threat to agricultural land or production from injurious weeds on roadside verges or railways, the highway authority or British Rail should be contacted. On Ministry of Defence land, either the Defence Lands Service or the occupier, if different, may be subject to remedial action. On common land, the occupier is responsible, if the land is unoccupied the person who has a right to occupy may be subject to action.

2.20 When Agriculture Departments are notified of Injurious Weeds on NNRs or SSSIs then English Nature, Scottish Natural Heritage or the Countryside Council for Wales will be contacted. On local authority reserves the local authority will be contacted. Appropriate action will then be determined as a result of consultation. Spread to domestic gardens, horse paddocks and allotments is primarily a matter for local authority bye-laws or Public Health Acts. Occupiers of such land have recourse to civil action.

3.0 Spear Thistle Biology and Ecology

3.1 Common names: Spear Thistle, Bull Thistle, Bell Thistle, and 10 other local names are listed in The Englishman's Flora by G. Grigson, (1955).

3.2 Latin Names: *Cirsium vulgare* (Savi) Ten., *C. lanceolatum* (L.) Scop., *C. lanceolatus* L., *C. crinitum* Boiss., *C. microcephalum sensu* Lange, *C. strigosum* Hoffmans & Link Coutinho. The variety *hypoleucum* (D.C.) Clapham *(Cirsium nemorale* Rchb.) is a form of uncertain taxonomic status.

3.3 Main attributes: Spear Thistle can become a serious weed of grassland and waste places, occurring in Britain to a height of 2050 ft (Clapham, Tutin and Warburg, 1962). It is usually a biennial with a deep tap root which descends to 30 cm (Anon, 1906). However, it must be stressed that Randall (1990) reported that rosettes can survive up to four years without bolting, so may require many years of clearing efforts, especially if seeds blow in from distant locations. Spear Thistle only spreads by seed (Anon, 1987). Ordinarily if placed in suitable soil the seed germinates within 2-3 days (Anon, 1906) and in the first season of growth produces a compact rosette close to the ground. In the second year a central stem is sent up, which branches and bears flower heads in which seeds are produced. After the latter are ripe the plant dies. As is common with annuals and biennials density estimates vary widely from year to year.

3.4 A plant can bear one or two adventitious lateral roots, produced near the soil surface. The essential control measure is to prevent it seeding. The seeds are borne away from the parent plant by means of the feathery pappus (= "down"). The soil seed bank of *C. vulgare* has been estimated to range from 1480-26371 m^{-2} in different years within infested areas (Forcella and Wood, 1986).

3.5 The distance the seed is carried is usually less than 30-40 metres, but it varies with the state of the weather. On hot, dry days the seed separates or dries off the pappus almost as soon as it escapes from the flower-head and drops close to its parent, the pappus floating away without it load. Most of the thistle down seen on windy days bears no seed (Anon, 1906).

3.6 A dense sward helps prevent further germination. Silvertown and Smith (1989) reported that in their experiments germination was generally poor but significantly more seedlings emerge in gaps 10-20 cm diameter than 5 cm gaps. Poor or variable germination may actually help spread. Cavers (1974) observed that greater variability or intermittency in seed germination often improves a weed population's success, since each time that a stand of seedlings or older plants is destroyed, a new stand will soon arise from the seed bank to take its place. Spear thistle spreads mainly from seed and few would say it is uncommon, so providing evidence which supports Cavers' observation.

3.7 Spear Thistle occurs on most soils in Britain. It has been introduced to N. America and Chile, is found throughout Europe, in Scandinavia, N. Africa and W. Asia. It is sturdier than Creeping Thistle.

3.8 Spear Thistle rosettes seem more tolerant of cold and frosts than Creeping Thistle. However, stems and leaves of plants which have flowered are sensitive to frost.

3.9 Height is generally 30-100 cm but plants may reach up to 150 cm or more.

3.10 Flowers generally open in July and may be seen until after the first frosts up to October. Both due to their colour and scent flowers are freely visited by a great variety of insects. The entire stem dies after flowering. Seeds are 3.5-6mm long, olive green, smooth and bear a parachute of hairs otherwise described as a soft silky pappus 20-30 mm long, feathery as in all *Cirsium* species. Seeds can be dispersed by wind, the seed only weighing 0.002 gm but much of the thistle down which is seen blowing from infested areas, particularly if carried over distances greater than 40m, is pappus which has become separated from the seed, and poses less danger of spread than is generally believed (Anon, P51 1987). However, Klinkhamer, de Jong and van der Meijden (1988) reported 10% of seeds could travel over 32 metres. In addition, because the distance wind-dispersed seeds travel is positively correlated with the height they are released (Harper, 1977; Sheldon and Burrows, 1973) taller plants especially at high altitude on exposed sites may be able to spread their seed over considerable distances.

3.11 The viability of spread seed is said to be generally low even if a suitable germination site is found (Silvertown and Smith, 1989). However, seeds of *C. vulgare* buried at 0-2, 5 or 20 cm, when collected and germinated 3 years later had percentage viabilities of 1.4, 30.9 and 50.5% respectively (Anon, 1986). Disturbance of the soil has been shown to advance the germination of *C. vulgare* (Klinkhamer and de Jong, 1988).

3.12 Seeds produced per plant may vary from 1600 (de Jong et al, (1987) to 8400 seeds per plant (Forcella and Wood, 1986); but are said to average about 4000 per plant (Salisbury, unknown publication date). On average about 100 seeds are produced per flower; but up to 340 have been recorded (Salisbury, unknown publication date). *C. vulgare* can produce seeds over a long period, and the amount of seed is affected by spring and summer rainfall patterns, which can than affect the size of subsequent plant populations (Sindell, 1991). The large numbers of seeds can result in new plants arising from seed, particularly where conditions are favourable. Seeds are less likely to germinate in dense swards (Anon, P51, 1987). Sindell (1991) states that "the essential principle of any thistle control programme must be the provision of a dense, vigorous and competitive pasture, particularly during the autumn period which coincides with thistle germination and establishment. In general, thistles are weakest or most susceptible to control when at the early seedling stage or when passing from the seedling to rosette stage." For example, the percentage of *C. vulgare* seedlings that survived through to the rosette stage was only 1% under grazed conditions and 0.2% in ungrazed pastures (Forcella and Wood, 1986). Forcella and Wood (1986) found that sheep grazing by reducing the competition from neighbouring plants increased the survival of C. vulgare seedlings, as well as increasing their growth, flowering and seed production. This partly explains the association of thistles with sheep grazing.

3.13 Obvious seeding of Spear Thistle causes offence to many neighbours of infested land, hence it is listed as an Injurious Weed under the Weeds Act, 1959. Measures to prevent the spread of this species (as with all others covered by this report) may be required if there is a threat to agricultural production. Complaints are addressed to one of the Executive Officers (Field) at the local Regional Service Centre of the Ministry of Agriculture, Fisheries and Food (MAFF). These officers can supply a leaflet on control of all Injurious Weeds to interested parties, addresses are given at the back of this report. Set-aside land is not exempt from the provision of the Weeds Act 1959.

3.14 Where there is a threat to agricultural land or production from injurious weeds on roadside verges or railways, the highway authority or British Rail should be contacted. On Ministry of Defence land, either the Defence Lands Service or the occupier, if different, may be subject to remedial action. On common land, the occupier is responsible, if the land is unoccupied the person who has a right to occupy may be subject to action.

3.15 When Agriculture Departments are notified of Injurious Weeds on NNRs or SSSIs then English Nature, Scottish Natural Heritage or the Countryside Council for Wales will be contacted. On local authority reserves the local authority will be contacted. Appropriate action will then be determined as a result of consultation. Spread to domestic gardens, horse paddocks and allotments is primarily a matter for local authority bye-laws or Public Health Acts. Occupiers of such land have recourse to civil action.

4.0 Incidence of Creeping and Spear Thistles

4.1 In the past (1970-72) it was reckoned that about one million hectares or 22% of grassland in England and Wales was infested or partially infested with thistles mainly *C.arvense* (Peel and Hopkins ,1980) as a result of surveys by Forbes *et al.* (1980) and Green (1982). Additionally, in eastern Scotland, Swift *et al.* (1983) found 27% of pastures infested with thistles and *C.arvense* was recorded as being a problem on 20% of the grassland surveyed in N.Ireland in 1969 (Courtney, 1973).

4.2 Perrott (1987) reported 1.13 million ha out of a total of 6.29 million ha (18%) of grassland in Great Britain to be infested with thistles in 1982; but only 13% or 710,000 ha of the total area of 5.47 million ha in 1986. As is common with such surveys individual species are not reported.

4.3 Survey data from eight English Nature managers for this report showed that *C.arvense* is the most common and most serious weed problem on English Natures' NNRs. Appendix 1 gives the names of the managers consulted and the sites discussed with each, to identify the locations and scale of the weed problems covered by this report. The identities of two sites are deliberately suppressed, to conform with the managers' wishes.

4.4 Cautionary note: The survey should not be taken as representative of all English Nature reserves, nor the results extrapolated beyond the sites concerned. By surveying only managers who were regarded as having problems and after being asked to identify these problems a unrepresentative selection of reserves may have been made - the results can only indicate the relative scale of the weed problems as perceived by the managers covered by this survey in this report.

4.5 Of 29 sites discussed, which included some SSSIs, 23 sites were reported as having problems with *C. arvense* - of these 21 were reported as having widespread problems.

4.6 Of the 21 sites with a widespread problem with *C. arvense*, *C. vulgare* was not regarded as a problem on 7 of the sites, only a localised problem on 4 of the 21 sites, but both *C. arvense* and *C. vulgare* were a serious problem on 10 sites. Of the other two sites with localised problems - on one site *C. arvense* was regarded as less of a problem than *C. vulgare* and on the other site problems existed in places with *C. arvensis* but *C. vulgare* was not regarded as a problem.

4.7 Sixteen of the 29 sites discussed were reported as having problems with *C. vulgare*, of these on 12 sites the problem was regarded as serious. Only on one site - Knocking Hoe was *C. vulgare* the sole thistle problem, on the 15 other sites *C.arvensis* was also a problem.

5.0 Effect of Environmental Factors - which predispose an area to infestation by Creeping Thistle

5.1 Bare ground or gappy swards are particularly favourable to the spread of Creeping Thistle. Similarly low fertility, particularly low nitrogen and phosphate levels, weakens the competitive effect of vigorous grasses such as *Lolium perenne*. Drought and soils of low available water capacity can also mean greater spread by reducing competitiveness of other species - Creeping Thistle with its extensive root system to draw moisture and storage reserves can exploit such opportunities. However, high populations of Creeping Thistle may be reduced through intra-specific competition when moisture and temperature stress occurs (Donald, 1992).

5.2 Surveys (Swift *et al.*, 1983; Hopkins *et al.*, 1985) have found Creeping Thistle infestations are often related to sward age, particularly those over 10 years old were heavily infested ie more than one plant per 16 m^2, and partial infestations also increase with sward age. In the uplands Hopkins *et al.* (1988) found it occurred in swards over 20 years of age and particularly where slopes were greater than 8.5°. This is almost certainly due to management difficulties on such slopes, but may also be linked to sward damage providing germination sites as animals, vehicles and man try to traverse such slopes, yet given the steepness of the slope drainage is not a problem producing conditions the thistle can exploit. They also found a link with little or no fertiliser application, and again the steeper the slope the less fertiliser it is likely to receive.

5.3 From another survey (ADAS-GRI National Farm Study reported in Hopkins and Green, 1979) Creeping Thistle is said to be associated with soils low in phosphorus and high in potash and high pH. However, with regard to pH, 12.6% seedling emergence was recorded by Amor and Harris (1975) at pH 5.2, which is regarded as low in UK mineral soils.

Soil indices are a measure of the availability of particular plant nutrients (P,K, Mg). 0 is the lowest possible index; 9 is the highest. In UK grassland, values are generally 3 or below. See Appendix XI to equate the soil indices given below with actual levels of nutrients available in the soil.

Infestations were recorded when at least one plant was found per 3.3 m^2; this survey found:-

23% of pastures were infested at P Index = 0,
15% at P Index = 1,
12% at P Index 2 and
8% at P Index 3 and over.

7% of swards were infested at K Index 0,
11% at K Index 1,
13% at K Index 2 and
22% at K Index 3 and over.

6% of swards were infested at pH 5.4 or less,
12% at pH 5.5-5.9,
13% at pH 6.0-6.4 and
15% at pH 6.5 and over.

5.4 Keith Payne (1992), Conservation Officer for Oxfordshire, observes in notes relating to Port Meadow SSSI, that *Cirsium arvense* is most common in fields of Bents and Ryegrasses (*Agrostis/Lolium* spp). He reports that it does not do well in wet soils, and seedlings germinate most readily in late May. The latter coincides with the seedlings requirement for limited competition and high light intensity (Moore, 1975)

5.5 Hopkins (1986) associates various management and soil factors to *Lolium*, *Agrostis* and *Cirsium arvense* associations - these include use of low level of nitrogen fertiliser (60-80 kg/ha), intensive spring grazing with either a rest or lax summer grazing by sheep and cattle or sheep or horses only, never mown, with an overall stocking rate of 300-400 grazing livestock unit days per hectare, swards which are not poorly drained, nor on dairy farms. Grazing livestock units are otherwise known as cow equivalent units (Forbes *et al.*, 1980) see Appendix VII; definitions of the other characters are to be found elsewhere in the same reference). A mid-summer rest seems crucial in permitting *C. arvense* to spread (Peel and Hopkins, 1980) Infestations were almost absent from fields mown more than once per year. There were also less thistles in grassland receiving organic manures (Hopkins *et al.*, 1985).

5.6 From the survey above one can see that calcareous potash-releasing clay soils provide conditions which also favour *Agrostis* and *Lolium* grasses; and without phosphatic fertilisers may be more prone to Creeping Thistle infestation.

5.7 The above values do not exclude this species from sites with different characteristics but are meant to exemplify those associated with infestation. Jones (1933a, b and c) showed that excessive emphasis on the influence of the soil is quite wrong.

5.8 Although edaphic (ie soil) factors play their part in regard to the botanical composition and nutritive value of a pasture, actually **environmental factors are of secondary importance, and quite subservient to the biotic factor ie the way the management of the grazing is carried out by Man.** It is possible, under a wide range of soil and climatic conditions, to control the botanical composition of the sward according to the way it is grazed.

5.9 Moreover, the effect of frequency and timing of grazing or cutting does not end in the season of treatment, it is carried forward into the next season when the first growth in spring is particularly influenced by previous management (Jones 1933a; Jones and Jones, 1930).

6.0 Effect of Environmental Factors - which predispose an area to infestation by Spear Thistle

6.1 Surveys have generally not named Spear Thistle separately from other *Cirsium* species and given Creeping Thistles' dominance any such results should be treated with extreme caution. Peel *et al.* (1985) found *Cirsium* spp infestations are more common as sward age increases. Pastures over 10 years old were more commonly heavily infested ie more than one plant per 16 m^2, similarly partial infestations are also more frequent as sward age increases.

6.2 Peel *et al.* (1985) report that *Cirsium* spp infestations were less common in the early 1980's compared to the early 1970's. This means that managers may now be less able to point the finger at other farmers with similar problems than previously and chances of spread from agricultural land to nature reserves is probably less. More importantly, when infestations do occur on nature reserves given their comparative rarity on agricultural land, farmers are more likely to draw managers attention to the infestation. However, variation between years, localities and individual circumstances will often make such generalisations invalid in a particular situation.

7.0 Effect of Environmental Factors - which reduce or inhibit thistle infestation

7.1 Thistles are generally reported as being frost-susceptible, and less common under wet conditions or poor drainage ie on soils which show distinct gleying above 30 cm. Hodgson (1968a) found deep, well-aerated soils produce good growth whereas poorly aerated soils or high water tables limit growth.

7.2 Creeping Thistle is less common in vigorous dense grass swards, but the root system is able to remain viable but dormant under such swards. It can then emerge and produce shoots at a later date when conditions are favourable. (Courtney 1973).

7.3 Jones (1933a) also found that during winter grazing, grasses try to maintain a constant top to root ratio, even though the temperature falls below that required for normal growth, which he took as 5.55°C (42°F). This dormant season growth is made at the expense of the whole grass plant as shown by weaker than normal growth the following spring. He showed ryegrass is a less efficient competitor if weakened by heavy grazing in winter and early spring. Given the additional effect of poaching that may occur from such grazing, Jones (1933b) showed over-grazing in winter if combined with under-grazing in summer and autumn increases thistles.

7.4 Claims are made that set-stocking or continuous stocking reduce the chances of spread; but others, including Jones (1933b), claim rotational grazing will reduce infestations. The truth is that stocking should be **adjusted** and then either continuous or rotational systems can reduce infestations, but adjustment is easier under rotational grazing, and vigorous grasses (like Perennial Ryegrass) when given suitable rests (particularly over winter and in early spring, and during the growing season), as in rotational grazing can compete more effectively with thistles.

7.5 The reasons put for set-stocking rely on the generation of dense relatively weed-free swards, and avoidance of poaching; but these conditions can also occur under rotational grazing. Proponents of rotational grazing claim it is easier to avoid under or over-grazing by adjustment of the frequency of grazing or substitution with cutting should growth be excessive. Certainly adjustment of stock numbers can be more difficult in set-stocking systems but beef cattle growth rates are often better when they are infrequently disturbed.

7.6 Perennial Ryegrass has been shown to be the most successful grass species in checking the incursion of Creeping Thistle into a sward, when compared to Rough Meadow Grass or Crested Dogstail, and also a more successful competitor than Wild White Clover (Jones, 1933a):-

Table 1: The number of Creeping Thistles per 20 quadrats, each of 4 feet^2 (ie total 80 ft^2= 7.44 m^2) in July 1932, three years after sowing:-

Plots with grass and clover mixture	15
Plots of Perennial Ryegrass	22
Rough Meadow Grass	351
Crested Dogstail	360
Wild White Clover	143

(Jones, 1933a)

7.7 The success of the ryegrass in checking the thistle was no doubt due to the earlier growth in the spring, the ryegrass being well away before the thistle made an appearance in the spring. Whereas the later more prostrate growing plants allowed the thistle better opportunity during the more difficult stage of establishing sub-aerial growth (Jones, 1933a). Evidence in support of this view is supplied by the fact that where the ryegrass was weakened by heavy grazing of the winter and early spring, it was not so efficient in its competition with the thistle, as where the ryegrass was strong in the spring after rest in winter and early spring.

8.0 Losses and Harmful Effects due to Creeping and Spear Thistles

8.1 Economic losses from thistles are difficult to quantify; but they are likely to arise from three sources:-

- direct competition with the surrounding herbage, including secretion of chemicals which suppress the growth of surrounding vegetation - initial results comparing no infestation with up to 9 plants m^{-2} on grass at Weed Research Organisation did not support this (Oswald, 1985).

- by interference with grazing, or feeding on conserved forage, particularly hay. As stock try to avoid thistles they do not eat so much of the herbage that does grow; so a reduction in animal production may result (Hartley and James, 1979; Hartley and Thompson, 1981; Oswald, 1985)

- costs of control including diversion of resources from other priorities

8.2 Additionally Creeping and Spear Thistles are obvious because of their height above surrounding vegetation as single plants or canopy stands which can be aesthetically displeasing, by competing with other species they may alter the 'natural scene' and pose a real or potential threat to surrounding land. This includes acting as a host for the black bean aphid *Aphis fabae* Scop.

8.3 In short, thistles cannot be ignored. A manager may wish to ignore them or leave them alone but that is as deliberate a strategy as attempts at control.

8.4 When established thistles compete strongly for nitrogen and water, Creeping Thistles, at a density of 30 plants m^{-2}, have reduced yields of wheat by 60%. In glasshouse trials, extracts of roots or foliage have been found to reduce the growth of numerous crop plants (Ivens, 1978). Jeater (1958) found grass production was inversely related to the quantity of *Cirsium arvense*.

8.5 The prickly nature of mature plants prevent stock from eating close to the base of isolated plants and they may be excluded entirely from patches of ground occupied by colonies (Bates,1955). Contact can result in painful skin eruptions on the mouth and lips (Oswald, 1985). Oswald (1985) included a graph showing that in a pasture grazed by beef animals grass height increased the closer one got to an individual thistle or patch, and the bigger the patch, the taller was the closer grass.

9.0 Beneficial Effects of Creeping and Spear Thistles

9.1 Thistles are mainly beneficial as nectar sources to feeding bees, hover-flies, butterflies, and other insects however, specific records of such visits are scarce. One author states High Brown Fritillary butterflies *(Fabriciana adippe)* are especially attracted to flowering thistles in woodland rides and clearings (Newman, 1977). Moore (1975) states that larvae of the Painted Lady butterfly (*Cynthia cardui* (L.) defoliate the thistle. There are many more invertebrate species which visit thistles, these have been comprehensively reviewed by Margaret Redfern (1983) in her Naturalist Handbook entitled 'Insects and Thistles'.

9.2 Most invertebrate species dependent on thistles are herbivores. Most are restricted to particular microhabitats on the thistle and there are distinct groups of insects associated with different parts of the plant. The flower heads, the insides of the stems, roots, and leaves carry characteristic concealed fauna of gall-inducers, borers and miners, apart from the more conspicuous insects which feed on the outside of the plant - visiting flowers, browsing leaves, or sucking sap. Within each group there are differences in timing of life cycle, methods of feedingand causes of mortality which may minimise competition. Some species are monophagous, but others feed on many species of plant. (Redfern, 1983)

9.3 Thistles contain a number of independent communities, connected only by their common dependence on the plant and by relatively few roving predators which wander all over the plant.(Redfern, 1983)

9.4 Flower heads of thistles contain the most varied, specific and well-known insect fauna of any part of the plant. They are a rich source of food, packed with achenes, and their inhabitants are protercted from vertebrate predators by the tough spiny bracts, especially in Spear Thistle. The larvae of several herbivorous groups live here - flies, mites and moths - together with their parasites, and later detritivores.

9.5 A gall-fly Urophora stylata is the commonest galling species and the one which has the greatest effect both on the thistle and the associated fauna. It is usually associated with Spear Thistles. Another Tephritid (picture-winged) fly is highly specific to Creeping Thistle - this is *Tephritis cometa*, but this is not gall-forming. *Terrellia serratulae* is the commonest non-galling tephritid (Redfern, 1983). These in turn support parasites and predators, including various moth caterpillars, which may be therefore indirectly dependent on the thistles and related species.

9.6 Stem gall-inducing and mining fly larvae live inside thistle stems - these include *Urophora cardui* and *Melanagromyza aeneoventris*. Leaf mining and web-spinning caterpillars exist, but their biology is not well known. A lot of what is known is reviewed by Redfern (1983). Aphids and lacebugs feed on thistle sap and there are a number of leaf beetles commonly found on thistles, particularly C. arvense.

9.7 For the reader who wishes to know more than can be presented in the limited space here Margaret Redfern's book (1983) entitled 'Insects and Thistles' is invaluable.

9.8 Weed species when eaten may provide stock with vitamins and minerals. In samples of *C. arvense* and *C. vulgare* taken in late May early June (Barber, 1985) reported the following major and minor trace element values on a dry matter basis:- (Grass values for comparison taken from Anon (1986) - but obviously vary with species, site, soil availability/pH, time of cutting, etc.

Table 2: Mineral Contents of Creeping and Spear Thistles compared to grass

	%				mg/kg			
	Ca	P	Mg	Na	Mn	Zn	Cu	Co
C. arvense	2.13	0.51	0.24	0.27	59	-	29	0.06
C. vulgare	1.84	0.40	0.20	0.35	36	-	24	0.15
Fresh Grass	0.46-0.53	0.25-0.32	0.12-0.15	0.17-0.28	16-314	15-60	3.4-23	0.06-0.2

Trace element values (ie Mn, Zn, Cu, Co) taken from Spedding and Diekmahns (1972).

9.9 Both the above species have been reported (Fairburn and Thomas, 1959) to have high protein and copper contents, up to 300g/kg DM and 30 mg/kg DM respectively. These values may explain why Creeping Thistle is claimed to be of value when ensiled in grass (Anon, P3243, 1990). Creeping Thistle plants are also said to be palatable or browsed to an extent in their earlier stages of growth; but more freely when they are cut and wilted, especially by horses. Goats readily graze Creeping Thistles (Anon, P3243, 1990). However, in a mature state they are spinous. Spear Thistle is a very prickly plant and of limited acceptability to stock except goats (Crouchley, G. 1983).

9.10 Calcium content is very high in both species. This could cause problems if intakes were high, as it would be very difficult to create a mineral balance (Barber, 1985); but high intakes are unlikely.

9.11 Thistle Broomrape (*Orobanche reticulata* Wallr. = *O. pallidiflora* Wimmer and Graeb.) is a parasitic plant on a range of *Cirsium* and *Carduus* thistle species, including Creeping Thistle. However, the plant is rare according to the British Red Data Book (Perring and Farrell, 1983), and it is an offence under the Wildlife and Countryside Act 1981 to destroy it. There are only 17 known sites, including one SSSI, where Thistle Broomrape occurs (Farrell, personal communication) - mainly in N.Yorkshire on magnesian limestone. However, it is also found occasionally on opportunistic, open sites on river shingles and gravels on the River Ouse and River Ure (Jefferson, personal communication). Rumsey and Jury (1991) also state that Thistle Broomrape occurs on unimproved pasture, roadsides, waste places, and grassland overlying limestone. The plant is rarely perennial, and the numbers flowering in June to August fluctuate widely between years at its few British sites. Before starting thistle control on sites in Yorkshire farmers are advised to consult their local ADAS Agricultural Consultant and the local office of English Nature in York.

9.12 Dodder (*Cuscuta* spp.) has been reported on *Cirsium arvense* in New York State (USDA, 1960).

10.0 Current Thistle Control Techniques on National Nature Reserves

10.1 Because vegetative propagation from adventitious root buds allow persistence of Creeping Thistle after establishment, control measures must be directed at killing perennial roots in order to achieve long term control (Donald, 1990).

10.2 For both thistles prevention of seeding and exhaustion of root reserves should minimise spread; but in the short term due to seed and root reserves, little evidence of control is often seen. Lee (1952) stated that 'no single treatment, regardless of practice can be relied upon to produce a complete kill' of *C. arvense*. This is still true today. Strand (1982) summarised the United States extension service's opinion that integrated control programmes for *Cirsium* require 5 to 10 years effort, and observed that *C. arvense* control is not a 'one shot' treatment. A series of well-calculated and timely operations are essential for successful results. It is also clear that any lapse in such efforts is likely to be severely punished as these weeds are capable of rapid re-establishment.

11.0 Cultural Control by Management - Effect of Grazing

11.1 Rotational grazing by cattle, and on non-nature reserves cutting for silage, combined with an increase in fertiliser nitrogen, can usually reduce an infestation, but frequent topping seldom eradicates the weed (Williams, 1984). Rotational grazing rather than set-stocking should be practised (Oswald, 1985). Jones (1934) was able, by grazing according to the amount of growth available, to keep a sward practically free from Creeping Thistle. Uniform stocking throughout the year however led to an increase in Creeping Thistle, *Agrostis* spp and Yorkshire fog. (Jones 1933b). On a poor old pasture controlled grazing was effective in reducing the proportion of undesirable plants. Grazing too early will retard grass growth and allow thistles to take a strong hold (Jones 1933a, b and c).

11.2 Given the chance livestock will eat the most nutritious and palatable herbage in the sward and reject the rest. This will happen at low stocking rates and will encourage such species as Creeping Thistle. At higher levels of stocking animals will be less selective, and in general a more productive sward will result. However, this approach cannot be taken too far otherwise individual animal performance will suffer. Cattle tend to be less selective than sheep, horses are particularly discriminating. There are therefore advantages in mixed or alternate stocking (Williams, 1984) especially when horses graze pastures (Armstrong 1948).

11.3 Mixed grazing by beef and sheep can increase animal output (Nolan and Connolly, 1977) and increase herbage utilisation. In areas where thistles are more common controlled grazing may be beneficial, but may involve expense in terms of fencing, watering and management to be able to move stock. More intensive grazing (but avoidance of poaching) until the end of May with sheep, and grazing with the less selective beef animals in June may be practical in some cases. This would be expected to reduce plant size and numbers, reduce thistle seeding and be environmentally friendly. However, this is likely to increase the content of the more vigorous grasses in the sward at the expense of the other broad-leaved species (Jones, 1933; Jones, 1934), so may only be appropriate on solely agricultural holdings.

11.4 Courtney (1973) states over-grazing early in the year will weaken grass competition of grass against Creeping Thistle. Others (Fryer and Makepeace, 1978; Jones, 1933a) suggest avoidance of over-grazing in winter and spring. Since Creeping Thistle does not make much growth before May, early over-grazing will allow it to spread. Changing the system of management so that grass growth is vigorous during May, will aid control. However, this may reduce the frequency of other desirable plants in nature reserves which are conserved for their flora (Haggar, undated).

11.5 Managers may be understandably reluctant to deliberately change grazing or cutting regimes, but for us to understand why they have a problem, it is worth asking if such management changes have been made inadvertently. If they can change their management to help control a localised problem (without detriment to other areas), or if they can introduce other control measures (which are adequately selective) then there is some hope for the future. If not, then increased problems can be expected in future.

11.6 Current English Nature guidelines on stocking based on timing of cutting or grazing and specification of cattle or sheep grazing weeks may need modification to indicate when stock numbers need to be adjusted. For example, at present 30 cattle grazing weeks or 120 sheep grazing weeks per hectare are commonly given as annual guidelines in SSSI Section 15 agreements on calcareous grassland (Tony Smith, personal communication). Other guidelines may be used elsewhere (Maurice Massey, personal communication). 30 cattle grazing weeks or 120 sheep grazing weeks roughly equates to 160 grazing livestock unit days per hectare per year. Whilst this maximum annual stocking rate target may not need to change, it could change depending on site fertility and the carrying capacity of the sward, another measure based on grass heights at particular times of the year can be used to indicate under or over-grazing (Jones 1934, Lowman, Swift and Grant, 1984). Whilst grass height is relatively simple to assess using a 'sward stick', it seems labour intensive, and a visual assessment using a welly-boot may be more 'user-friendly'- see Appendix VI (Wilkinson, 1983). However, a record of the observations must be made. The more sites that a manager has to look after and the greater the capacity for adjustment of stocking or supplementary feeding, the better the records should be. With one site and experience a mental record may be adequate, but it must then be used to make decisions. Written records have the advantage of being able to be used by others, and to review past practice. Grass growth varies between seasons and sites according to rainfall and other factors so sward height measurements could enable targets to be used meaningfully.

11.7 ADAS targets for maximum animal production may not be appropriate, where deliberate over or under-grazing occurs to conserve particular species. Maurice Massey (personal communication) aims for a turf height of 10-12.5 cm (4-5") and tussocky growth in spring where insects are to be conserved; and tightly grazed open turf to enable flowering of the Pasque Flower (*Pulsatilla vulgaris*) on chalk grasslands. At Barnack Hills the aim is for 70% of the site to be tightly grazed where the main interest is botany, and 30% to have height or 'structure'. On marshy ground or wetland bird reserves it is common to aim for taller, structured growth. Nests of ground-nesting birds can be trampled by stock, and some nests are more likely to be trampled than others (Reyrink, 1985). Consequently each area of a nature reserve may need specified targets which recognise the requirements of the flora and fauna present as well as that of any grazing animals, and also recognise when rabbits or other mammals are having an impact.

11.8 Typical target sward heights to maximise livestock production per hectare were given in an East of Scotland College of Agriculture Note (Lowman, Swift and Grant, 1984), if sward height fall below the targets given below individual animal performance suffers, if the sward height is significantly higher ie more than 2 cm than the targets under-grazing is occurring, and total output per hectare falls :-

Table 3: Typical target sward heights to maximise livestock production per hectare

	Sheep	Beef	Dairy
Continuous grazing - residual height (cm)			
Spring	4	5	6
Summer - fattening/milk systems	5	7	8
- store systems	4	6	-
Autumn	7	8	10
Rotational grazing			
Stubble height after grazing	6	8	9

WINTER KILL: frosts can kill grass, to minimise the risk of this, graze to below 5 cm before the winter starts.

BARE GROUND: little bare ground can be seen if it represents 10% or less of the ground cover; however, for grazed swards with more bare ground the target heights given above should be increased by 1-2 cm.

11.9 Thus it can be seen for sheep the target grass height is 4-6 cm for the main part of the growing season, sheep do not grow any faster when sward height exceeds 6 cm. Thistles are commonly associated with lax sheep or cattle and sheep grazing during this period, under-grazing should not be practised unless it is a deliberate policy. Hartley, Lytle and Popay (1984) showed lax spring and summer grazing can lead to increased *C. arvense* numbers.

11.10 The above has been further refined by Lowman (1987) and in ADAS Grassland Management Calendars for the above types of stock, indicating level of supplementary feeding and target stocking rates on a month by month basis. (Anon, 1991). However, when over-grazing occurs the reduction in stocking rate be too small for a nature reserve applying little or no nitrogen to a sward not dominated by *Lolium* species. Individual managers need to produce their own targets, using the published data and their own observations.

11.11 **Table 4:** Target sward heights for continuous grazing systems (Lowman, 1987)

	cm
Ewes and lambs - store lamb production	4-5
- grass finishing	5-6
Flushing ewes	6-8
Store cattle/dry cows	6-8
Finishing cattle/Lactating cows	8-10

11.12 The above guidelines can be used to assess appropriate stocking rates to minimise other weeds. Silvertown and Smith (1989) reported in their experiments on Spear Thistle that germination was generally poor but significantly more seedlings emerge in gaps 10-20 cm diameter than 5 cm gaps. They suggested that control strategies based on grazing management should be aimed at reducing suitable establishment sites in the spring to be most effective. Their experimental work was carried out at Little Wittenham Nature Reserve, Oxon. It showed that Spear Thistle rosettes were less common when intensive sheep grazing occurred in the spring compared to ungrazed plots. This may have been due to trampling or grazing of the rosettes killing young plants. Given the dislike of thistles to competition from more vigorous swards it is also possible that spring grazing encouraged tillering of the grass and this reduced the survival of Spear Thistle seedlings. Sindell (1991) recommends that "because thistle seedlings are vulnerable to competition soon after the autumn rains, stock should be removed from infested paddocks in order to increase thistle mortality." This is an ideal but impractical in many situations. However, an experiment could be establish the effect of removing stock in early September from densely infested areas of thistles, <u>to compare</u> with Silvertown and Smith's (1989) results.

12.0 Effect of Cutting

12.1 <u>For Creeping Thistle control</u>: In agricultural situations, cutting for silage, combined with an increase in fertiliser nitrogen, can usually reduce an infestation, but frequent topping seldom eradicates the weed (Williams, 1984). Williams also states Creeping Thistle needs to be cut quite close to the ground and preferably twice per year. Anecdotal evidence suggests heavy rain falling on a cut stem will prevent regrowth (T. Overbury, personal communication). It is suggested that if the cut stem is filled with water regrowth is unlikely. This may be due to a water-soluble hormone which stimulates regrowth being leached out. Research into cutting and following with a watering can or boom sprayer fitted with flood jets could prove or disprove this, and further guidance might then be issued on time of cutting.

12.2 <u>For Spear Thistle control</u>: Introduction of mowing for hay or topping, if not already practised, may still be appropriate in certain areas to keep populations under control. Low mowing (or topping above the sward height at 20 cm could still reduce adult seeding) just before the first flower buds open can be practised, to try to reduce root reserves and subsequent seeding but it is likely to result in shorter regrowth which then attempts to flower (Randall, 1990). Harris and Wilkinson (1984) stated that Spear Thistle can be controlled effectively by mowing shortly before the plants flower, but cautioned that they will re-flower if mown too early in the season.

12.3 There is an old country saying:-

'Cut a thistle in June, it's a month too soon ;
Cut a thistle in July , it will surely die '

This applies particularly to Spear Thistle; but early repeated cutting is recommended for Creeping Thistle. Cut back each successive growth of stem either with the scythe or mower. The cutting should begin early in the season when the stem is only a few inches high and should be repeated as often as the plant reappears (Armstrong, 1948). However, Plakolm (1984) indicates this can in the short term increase the above ground shoot number, due to removal of apical dominance stimulating new buds to grow. Salisbury (Unknown publication date) states that to achieve any appreciable diminution the cutting must be repeatedly carried out over three or more years. He believed that cutting should be performed just before the flower heads show colour, when underground root reserves are at their lowest, having been largely used in the formation of reproductive organs.

12.4 Mowing is impractical in many nature reserves due to slopes or the uneven nature of the terrain. Tractors may also damage a vulnerable sward and exacerbate the problem by increasing the number of potential germination sites for seeds from outside or from the seed bank.

12.5 Randall (1990) reports work parties can cut Spear Thistles at the root crown rather than pulling or digging them out as practised in places in the past. Cutting is quicker and causes less disturbance than pulling or digging. If cut plants fail to re-sprout it is an efficient way of killing them. Thistle establishment is promoted by removal of vegetation cover and further promoted by soil disturbance.

12.6 Randall (1990) found that from cutting adult Spear Thistles in July 1988 at a height of 20 cm - 3 out of 30 re-sprouted, at 5 or 10 cm - 1 re-sprouted, and if cut or spudded at ground level no Spear Thistle re-sprouted. In September, re-sprouts were shorter (54.6 cm) compared with adults in control plots (128.4 cm) and produced fewer inflorescences (4) than controls (20.2). Numbers of thistles were not significantly different in the autumn (1988), in the same year as cutting. This was apparently because rosettes which were not cut far outnumbered the adult plants. However, by the spring of 1989 and spring 1990 numbers of thistles in manual control plots were significantly lower, primarily due to significantly lower seed input. He concludes cutting Spear Thistle near its root crown proved effective in reducing populations. Effective control of thistles will probably require many years of clearing efforts because rosettes can survive up to four years without bolting and seed may blow in from distant locations.

12.7 Surprisingly in another experiment, Randall found after cutting Spear Thistles, at the soil surface using hand clippers or machete, the date of cutting at fortnightly intervals between late June and mid-August had no significant effect on re-sprouting, when measured in mid-September. Nor did he find any significant effect on the height of re-sprouts or number of inflorescences per re-sprout, whatever the cutting date. However control (uncut) plots had 2.6 adults m^{-2} compared with less than 2% re-sprouting of the adult thistles in the cut-and-remove plots while slightly more than 5% re-sprouted in the cut-and-leave plots. This may be due to cut-and-leave plants obscuring others from cutting so they escape. Alternatively one could postulate that cut flowering stems contain a hormone which leaches out onto the cut tap root and stimulates re-sprouting if cut stems are not removed. The differences between treatments was significant ($p<0.01$), so it is suggested later in this report that mascerated stem solution is applied to cut tap roots and compared with water applications to see if the hormonal regeneration theory can be proven, and the hormone identified. This work also emphasises the need to be thorough given a researcher using small plots is less likely to miss thistles than a work party. The mean number of adult thistles in all the cut plots was 0.25 m^{-2}, so a very significant reduction (over 90%) in adult thistle populations can be achieved without herbicides or other control strategies by using the very selective and laborious technique of cutting by hand. In this experiment, re-sprouts were shorter (44 cm) compared with adults in control plots (85 cm) and produced fewer inflorescences (3.7) than controls (15.8).

12.8 Beware of cutting after flowering because viable seed is set within 6 days of flowering and may even be set on stems cut 5-10 days after anthesis (Randall, 1990). Randall's work shows that late cutting will still reduce adult plant numbers; but note it is too late to stop seeding. So apart from aesthetic reasons, it is advisable to remove cut stems, and arrangements need to be made for disposal before cutting. Given the prolific capacity of this species to produce seed, even a few seeding plants might find germination sites, especially if recent disturbance by cutting has occurred, so cutting adult Spear Thistle just before flowering is still recommended. However, there is little evidence of a Spear Thistle seed bank in the soil (Klinkhamer and de Jong, 1988; Roberts and Chancellor, 1979).

12.9 Rosettes are usually far more numerous than adults but attempts to cut them would be extremely inefficient and probably lead to extensive damage of the remaining vegetation. However, spudding out below ground when in the young or rosette stage is a means of preventing seeding (Anon, L51, 1976). Salisbury (Unknown publication date) stated unequivocally that "spudding out in the young rosette stage is the best method of control where the plants are widely scattered," recommending herbicides in denser colonies.

12.10 Due to the uneven maturation of thistle stands more than one treatment per season will be required, to hit each plant just before flowering, and sound grazing management is still required to minimise germination and establishment of seed (Roberts, 1982). Randall (1990) suggests a second sweep one month after the first cutting could probably be done rapidly and result in the elimination of most of the remaining flowering plants. A machete is the best tool for cutting adult Spear Thistles (Randall, 1990).

12.11 To summarise, mechanical or chemical means of selective control of the thistles may be something which managers need to adopt regularly to preserve their desired balance of species in their reserves, combined with a grazing regime which favours those species tipping the balance against Creeping Thistle and other pasture weeds.

13.0 Effect of Organic Manures

13.1 Creeping Thistle was more frequent where little or no fertiliser is applied in a survey by Hopkins *et al.* (1988), but this result may be linked to sward age, and gradient as older and steeper swards were less commonly fertilised.

13.2 Weed ecology and the use or avoidance of organic manures has not been compared in any experiments to the knowledge of the author. From personal observation, sward density generally increases with appropriate grazing and earlier growth can occur with fertiliser usage, so avoiding use of organic manures may result in a sward less dense and more prone to poaching damage, but dung applications can kill some plants and in spreading on wet soils can cause severe sward damage. Thus generally manurial applications should be lightly spread, using low ground pressure tyres and applied when the ground is dry.

13.3 Unfertilised grass is likely to take longer to recover from animal poaching or human trampling and this increases the likelihood of thistle establishment but the balance may be tipped in favour of other species with appropriate management. This was shown by Jones (1933a, b and c). Jones (1933a) showed that the proportions of the major herbage species in a sown sward did not alter appreciably with manuring, but slower establishment of the sown species as a pure stand or slower invasion by other species did occur in some cases. Jones (1933b) shows that management is much more potent than manuring in governing the botanical composition of sown species. The NCC view expressed by Dick Hornby at a seminar in 1983 (Russell and Way, 1983) is that a single application of fertiliser will affect the composition of a herb-rich sward by reducing the frequency of the most sensitive species. These are the ones that cannot cope with the competition, require a nutrient poor, thin soil and have become rare. The loss of such species is important to nature conservation and may pass unnoticed by non-botanists. Bryn Green from Wye College at the same seminar referred to the Park Grass Experiment at Rothamsted which showed that any increase in soil fertility lowers species diversity once a low threshold representing the minimal needs of most of the dwarf downland herbs have been met (Russell and Way, 1983).

13.4 From farm surveys, thistles tend not to be a problem associated with the high use of organic manures or fertilisers (Hopkins *et al.*, 1988). On such farms intensive management is linked to frequent and heavy cutting and grazing, the inputs being necessary for adequate production, and this intensity of farming reduces the likelihood of thistles being present.

13.5 On sites covered by management agreements, organic manures are rarely allowed, but if thistles become established, the current small applications of organic manures is unlikely to add significantly to thistle control in the short-term. Indeed, Spear Thistle has been found to achieve maximum relative yield at high nutrient concentrations (Austin et al., 1985).

13.6 However, in the longer term, if organic manures are used to help to produce a denser, more vigorous sward with appropriate cutting and grazing management this may reduce infestations.

13.7 If current practice is to use, or avoid, organic manures then the presence of thistles does not necessitate a change in manuring policy. Other changes should be considered first.

13.8 Having thought about these other changes where organic manures are not presently used but could be used, consider whether manure would help, in the individual circumstance. Bear in mind the need to avoid damaging the sward at the time of application and the likely effects on sward composition and the need to use the extra growth produced without lax grazing.

13.9 <u>Warning</u>: cattle farm yard manure is higher in potash than any other nutrient. It was shown earlier that thistle infestations tend to be more common in high potash soils, so any build-up in the fertility of a site may make it more prone to later infestation by thistles or other weeds, particularly docks, if it is mis-managed, and will certainly change the balance of species in the sward. However, the balance of species in a sward is never static and a more desirable equilibrium than currently exists may be appropriate - particularly if thistles or docks are already a problem.

14.0 Chemical Control of Thistles using Herbicides

14.1 On a NNR the usual aim of applying a herbicide is to control a single species invading a plant community. The aim in conventional agriculture is often the reverse, ie to control a weed community in a single crop. In neither is complete eradication necessary or cost-effective; but management control is required.

14.2 Herbicides may be cost-effective management tools in the hands of the farmer or site manager. Unlike hand treatments which can give selective control of individual species, no specific herbicide is available for only thistle control, and even if it were available it would damage rarer thistle species. The most specific herbicide currently available for thistle control is Dow Shield (clopyralid). Other materials with varying effect on non-target species may be used through weed-wiper, knapsack sprayer or tractor mounted boom sprayer, depending on the individual circumstances. The most specific means of application are either by weed-wiper or a knapsack to give a spot-spray.

14.3 Herbicidal drift or accidental scorch is to be avoided wherever possible on farms or sites managed for conservation. The drift of herbicides has been studied (Davies *et al.*, 1992; Elliot and Wilson, 1983). The side-effects of herbicides, which have or may be used, on conservation sites will never be given as much publicity as their effects on the main target species. Agrochemical companies and others have such data but it can be difficult to obtain. Such information or references available to the author at the time of writing is included where relevant.

14.4 There are published guidelines and legislation governing the use of herbicides on farms (eg Code of Good Agricultural Practice, Food and Environmental Protection Act 1985, Wildlife and Countryside Act, 1981) and on conservation sites (Cooke, 1986; Cooke 1991; English Nature Pollution News No.2). The last reference includes the following guidelines:-

a) Non-chemical methods are preferred whenever possible;

b) A herbicide should not be used to deal with the symptom of a problem without the ultimate cause being tackled if this is feasible;

c) Only a few listed herbicides (Cooke, 1986 and in an English Nature Circular written by Cooke dated 4.12.91) may be used without prior consultation with the Science Directorate of English Nature.

14.5 The list in Cooke (1986) only includes one herbicide which would have any significant effect on thistles - glyphosate. Glyphosate is not as effective on broad-leaved species as on grasses. As with all herbicides sufficient material needs to be applied for control and no specific reference is made by Cooke to use of glyphosate for thistle control. Asulam is cited with Cirsium susceptibilities but unless spot-treating with a knapsack sprayer poor control would usually result. Even when using high concentrations of asulam through a knapsack sprayer *Cirsium* species are only rated moderately susceptible.

14.6 Thompson (1983) in New Zealand found glyphosate applied through a rope wick applicator at full flower reduced the number of flowering stems (to 0.8 m^{-2}), more than treatment at the bolting stage(3.2 m^{-2}), compared to 8.4 m^{-2} on untreated plots. It also reduced seed viability from 44% to 0.3% when applied at flowering. However, Creeping Thistles extensive root system constantly produces new aerial shoots so any reduction in infestation is usually temporary. Particularly where weeds are dense, or travelling speed is too high, one pass of a weed-wiper is unlikely to transfer sufficient chemical. The seed head is not very good at translocation, and once weeds start to flower downward translocation is poorer (Cromack, personal comm.). However, this is contradicted by Harrington and Ivens (1983) who state that destruction of Creeping Thistle roots occurred more consistently following post-flowering applications of glyphosate, probably because herbicide translocation was predominantly to the roots at this time. At earlier timings, most glyphosate appeared to move towards developing daughter shoots. More root damage occurred when glyphosate was applied to the lower rather than upper parts of the stem. Applications to the stem or leaves were equally effective.

14.7 This contradiction is possibly explained by the height of application using a rope wick. Assimilates, and thus phloem-mobile herbicides like glyphosate, move predominantly towards the stem apex from leaves growing on the upper part of the plant but to the roots from basal leaves. As glyphosate is mainly applied on to the upper leaves, translocation could be less than if lower leaves were treated (Harrington and Ivens, 1983). Research may be worthwhile in determining the movement of glyphosate from the site of application to the roots or other above ground parts, in the field, at different plant growth stages under differing water regimes.

14.8 ADAS results 1981-2, (Anon, 1981, 1982) have been summarised in the table below:-

Table 5: ADAS Results - 1981-2 - AG 06561

	Percentage reduction of initial populations of Creeping Thistles (ie actual kill)		
	After 3 weeks	After 1 yr	After treatment repeated a 2nd time
1 pass glyphosate Hectaspan MKI	18	54	70
2 pass glyphosate Hectaspan MKI	55	33	85

14.9 ADAS results 1982-3, (Anon, 1982, 1983) have been summarised in the table below:- (where Creeping Thistle numbers on treated plots increased nil control is recorded, where not tested a dash is given)

Table 6: ADAS Results using various weed wipers and herbicides - 1981 to 1983 - AG06502 - assessed one year after treatment

	Percentage Creeping Thistle Control	
	In very dense stands of *C. arvense* (12-32 m^{-2})	Less dense stands of *C. arvense* (3.6-10 m^{-2})
Wiper set above sward height:-		
1 pass glyphosate Hectaspan MKI	64	-
2 pass glyphosate Hectaspan MKI	78	-
1 pass 2,4 D Hectaspan MKI	58	-
2 pass 2,4 D Hectaspan MKI	65	-
1 pass glyphosate Hectaspan MKII	Nil	Nil
2 pass glyphosate Hectaspan MKII	16.7	24
Wiper set at average sward height (5-7 cm):-		
1 pass dicamba Hectaspan MKII	21.4	52
2 pass dicamba Hectaspan MKII	33.3	-
1 pass picloram Hectaspan MKII	Nil	63
2 pass picloram Hectaspan MKII	20.0	-

14.10 A herbicide added to the list by Cooke (1987) is 'Broadshot' (dicamba, triclopyr and 2,4 D) which has good activity against thistles, but given its broad spectrum (hence the name) weed-wiper application would generally be required. 5 l/ha is reported as giving 82% control (Bird 1985) and weed-wiper applications using a 1:3 dilution in 2 passes checked thistles and gave up to 78% control when assessed 3 months later.

14.9 Dicamba as 'Tracker' applied through a weed-wiper would control thistles and can be used without specific permission from English Natures' Science Directorate (Cooke, 1989); similarly clopyralid can be used via a rope wick applicator to specifically control thistles in grassland (Cooke, 1991).

14.10 'Grazon 90' (clopyralid + triclopyr) is believed to have been used on various English Nature sites as a knapsack spot spray (Malcolm Whitmore, personal communication); but this should not be used without permission from the Science Directorate.

14.11 There are many other products which could be considered for thistle control on agricultural holdings or conservation sites - these are given at Appendices III, and V with their spectrum of activity. **None should be used without permission from the Science Directorate, some are particularly inappropriate on botanically rich sites, especially through a tractor mounted hydraulic boom sprayer.** A farmer may use the broad-spectrum products through a boom sprayer and will principally choose a material which controls the species required in the relevant crop at the time required at the least cost with minimum management difficulty. Both farmers and site managers should remember their responsibilities under the Control of Substances Hazardous to Health (COSHH) and the need to select the least hazardous product which is suitable.

14.12 A herbicide product label should always be read, prior to purchase, or use, and the user should comply with the statutory conditions of use. The label rates given should not be exceeded but lower rates may be appropriate. For some uses a specific numbered off-label use is allowed eg clopyralid through a weed wiper (Off-label No. 0662/92). Local MAFF or ADAS offices should be asked to supply the relevant literature before such a use is undertaken. Other off-label uses may be available to an individual farmer or site manager through the long term off-label arrangements which apply until 1 January 1994 (Anon, 1992, Ivens, 1992).

15.0 Factors which Influence Control

15.1 The timing and period of herbicide applications has been studied but opinions still vary on optimum timing for different treatments. Whatever the species, plant growth habit, and root system, varies according to plant age, soil, site, climate, and management. This with varietal differences and intermediate forms may explain differential and variable levels of control from certain herbicides. Selected ecotypes show differences in phenology and photoperiodism, vigour and growth habit, stomatal frequency and response to herbicides, seed dormancy and germination (Moore, 1975). Some *C.arvense* plants escape herbicide damage because their excessive hairness prevents herbicide contact with sensitive tissues, (P. Marriage, personal communication to Cavers, 1985) whereas in other species the difference in herbicide response is found at the cellular or sub-cellular level.

15.2 Cutting is often said to be best timed just before flowering when root reserves are at their lowest, (Anon, 1976) and certainly this will prevent seeding which is an important factor in long-term thistle control. Repeated cutting may "wear down" an infestation but must be continued for several years to succeed (Cooper, Personal communication).

15.3 For Creeping Thistle control, MCPA applied during the early bud stage will kill the aerial parts, but repeat applications the following year may be necessary for complete control (Cooper, personal communication). Ivens (1978) states that by using MCPB Creeping Thistle can be greatly reduced by spraying at the rosette stage in the spring and again in the autumn but at least 3 years treatment are likely to be needed for effective control. Others state that the best time to spray hormonal herbicides is in early summer up to the time when most flower buds are well developed but not yet open (Anon 1976). Salisbury (Unknown publication date) says the best time to spray or cut out is just before the flowerheads show colour, for at this period the food reserves in the underground parts are at their minimum, having largely been used in the formation of the reproductive organs, but also adding some races are more resistant than others. Research maybe needed to clarify optimum spray timing.

15.4 However, one of the most effective and selective materials clopyralid (Singh and Malik, 1992) is recommended at an earlier timing - best applied when active growth occurring but before the flowering spikes are 15 cm (6") high (Thompson and Goodliffe 1985). If the grass has been cut for hay or silage the treatment should be delayed for 2-3 weeks until sufficient regrowth has occurred. One application of clopyralid , is normally sufficient to achieve an acceptable level of control.

15.5 Cromack (personal communication) suggests that when weed wiping one should aim at start of shooting to maximise downward translocation, and exploit the thistle-sward height differential. However, Harrington and Ivens (1983) state glyphosate applied near the base of the Creeping Thistle is best timed post-flowering.

15.6 For Spear Thistle control using hormonal herbicides, for best results treat at the seedling or young plant stage. Latest application should be made before flowering when active growth is occurring (Cooper, personal communication).

15.7 Most often herbicides effects on top-growth has been examined, over varying periods. However, the effectiveness of multi-year herbicide treatments for the control or eradication of *C. arvense* roots has seldom been studied (Carlson & Donald, 1988). Control of Creeping Thistle roots is essential.

16.0 **Choice of Herbicide**

16.1 Herbicides are approved for use in a particular crop or situation. They mainly vary in their spectrum, efficacy, timing, hazard to health, cost, availability and ease of application. Decisions on product choice may be influenced by other factors - past experience, available knowledge, and the alternatives available. With certain products there is a need to exclude stock from treated pastures, which can also occur when herbicides are used on pastures containing poisonous weeds like ragwort.

16.2 Conservation site managers may need to consider constraints such a need for permission to use certain products. Products may be selected for thistle control from Appendix III.

17.0 **Herbicidal Control Strategy for Thistles - see Appendix III**

17.1 Spraying can reduce infestations by altering the competitive balance in favour of the grasses which can then cover the area more densely and keep the remaining Creeping Thistle roots dormant (Oswald, 1985).

17.2 Creeping Thistle shoots are readily killed by growth regulator herbicides but the long term effect is variable. Products approved for use in established grassland with activity against these thistles include:-

benazolin + 2,4 DB + MCPA (Legumex Extra, Setter 33)
clopyralid (Dow Shield)
clopyralid + triclopyr (Grazon 90)
clopyralid + mecoprop (not currently marketed)
2,4 D (eg BASF 2,4 D Ester, Campbells Destox, Campbell Bioweed)
dicamba (Tracker)
dicamba + MCPA + mecoprop (eg Campbells Grassland Herbicide, Docklene, Hysward)
dicamba + mecoprop (eg Di-Farmon, Farmon Condox, Hygrass)
dicamba + mecoprop + triclopyr (Fettel)
dicamba + triclopyr + 2,4 D (Broadshot)
glyphosate* (Roundup - approved in grassland for use either prior to sward destruction or as a selective application through a weed-wiper; but not approved in grassland through a knapsack sprayer - this approval relates to forestry, non-crop areas, aquatic situations and top-fruit orchards)
MCPA (eg BASF MCPA Amine 50, Phenoxylene)
MCPA + MCPB (eg MSS MCPB + MCPA, Trifolex-tra, Tropotox-Plus)
mecoprop (=CMPP) and the mecoprop-p isomer (the latter is now more commonly available and recommended to reduce the risk of contamination of water)
triclopyr (Garlon 2)

Note: Muster is a glyphosate formulation but it is only approved for sward destruction. It is not approved for use through a weed-wiper, nor for the selective control of grassland weeds by knapsack - spraying.

17.3 Old literature includes dichlorprop but it is not currently approved for use as a 'straight' in grassland, and can only be used in some mixtures on grass seed crops and then off-label. Similarly 2,4 DB is not approved for use in grass as such but grass undersown in cereals (where clover important- plants should have at least 1 trifoliate leaf).

Old literature (Williams 1984) gives moderately susceptible ratings for:

2,4 DB + 2,4 D + MCPA;
asulam + mecoprop + MCPA;
dicamba + mecoprop + 2,4,5-T;
2,4,5-T +2,4 D =/- dicamba;
2,3,6 TBA + dicamba + MCPA

<u>None</u> of the immediately above quoted by Williams are currently approved as formulated products in the UK.

17.4 MCPB is approved for leys - where clover important- plants should have at least one trifoliate leaf. Ivens (1978) states that at least 3 years treatment are likely to be needed for effective control. Ivens suggests that if a certain amount of clover damage is acceptable MCPA can be used to speed up this process.

17.5 Research papers (Haggar, Oswald and Richardson, 1986; Oswald 1985, West and Richardson 1985) include references to use of the following in established grassland, but those below are not approved for use in grassland in the UK, and many of the straight products were either not sufficiently damaging to thistles, too expensive or damaged grass or clovers:-

bentazone
bentazone + triclopyr
bentazone + triclopyr + clopyralid
bentazone + MCPB
clopyralid + dicamba
clopyralid + triclopyr + fluroxypyr
fluroxypyr
picloram
triclopyr

17.6 Other products can be used in newly sown grassland:-

bentazone + cyanazine + 2,4 DB
bentazone + MCPA + MCPB

17.7 Using weed-wipers and glyphosate ADAS results gave 40-80% control of thistles with better control from using dicamba or clopyralid , 2,4 D gave 58-65% control with one and two passes respectively. Two passes were generally superior to one pass, (Anon, 1981; Anon 1982; Anon 1983) indicating the need for maximum transference of chemical. A common problem with glyphosate through a weed-wiper is poor flow through being sticky and oily. The recommended dilution for use in aweed-wiper is one part glyphosate to one part water; but for hot dry conditions one part glyphosate to two parts water is recommended (F. B. Cooper, personal communication). Surfactants used with the material in spraying have not been tried to improve flow or effect.

17.8 Where clover damaging MCPA is to be used hard grazing prior to spraying will reduce clover leaf area and so reduce uptake (Ivens 1978). Whilst too weak a solution is ineffective, too strong a solution kill the overground shoots too quickly to permit nay appreciable translocation of the herbicide to the underground parts, according to Salisbury (Unknown publication date).

17.9 Good results have been obtained from autumn spraying before the first frosts (Anon, L51, 1976). Dry drought conditions may reduce the effect of herbicides. Long-term control is easier in arable land or newly sown leys where the roots have been broken by cultivation, than in old grassland which have colonies with extensive root systems. This reduces the effectiveness of translocated herbicides (Oswald, 1985)

17.10 One spray treatment seldom eradicates Creeping Thistle from permanent pasture - therefore if at first you do not succeed, do not give up. It is emphasised that a change in management to improve the competition from herbage plants may be essential for lasting control (Anon, L51, 1976). Haggar *et al.*, (1984) stated repeat spraying was necessary, coupled with improved sward management.

17.11 The Weed Research Organisation (now defunct) played an important role in developing the technique of smearing translocated herbicides (eg glyphosate) on tall growing perennial weeds, including Creeping Thistle (Oswald, 1982). Useful control of shoot numbers - up to 72% control (without grass damage) has been achieved using dicamba applied through a rope wick-applicator especially when lowered into the grass canopy to 20 cm (8") (Oswald 1985). Further trials with this material are recommended.

17.12 Hard grazing may help to increase the height differential between sward and weeds to improve efficacy of rope wick applicators.

17.13 In grassland, **Spear Thistle** is susceptible (Anon, L51, 1976) to treatment with:-

clopyralid (Dow Shield)- best applied when active growth occurring but before the flowering spikes are 15 cm (6") high
(Thompson and Goodliffe (1985)
2,4 D (eg BASF 2,4 D Ester, Campbells Destox, Campbell Dioweed)
MCPA (eg BASF MCPA Amine 50, Phenoxylene)
MCPA + MCPB (eg MSS MCPB + MCPA, Trifolex-tra, Tropotox-Plus)

17.14 2,4 DB is not approved for use in grassland but grass undersown in cereals (where clover important- plants should have at least 1 trifoliate leaf).

17.15 MCPB is approved for leys - where clover important- plants should have at least one trifoliate leaf.

17.16 It is not known why some of the following which would be expected to kill Spear Thistles are not also listed in ADAS Pamphlet P51 (1987):-

clopyralid + triclopyr (Grazon 90)
dicamba (Tracker)
dicamba + MCPA + mecoprop (eg Campbell's Grassland Herbicide, Docklene, Hysward)
dicamba + mecoprop (eg Di-Farmon, Farmon Condox, Hygrass)
dicamba + mecoprop + triclopyr (Fettel)
dicamba + triclopyr + 2,4 D (Broadshot)
mecoprop (=CMPP) and the mecoprop-p isomer (the latter is now more commonly available and recommended to reduce the risk of contamination of water)

17.17 Spraying should take place when the plant is growing strongly.

18.0 Appropriate Application Technique

18.1 For useful control of an undesirable species and the minimum environmental damage there is a need for correct choice of application method and careful application of a weed-killer.

18.2 Application techniques to be considered are:-

a) Boom spraying - few conservation sites allow such application, but it is the most common method of applying herbicides on farms, being the least labour intensive, quickest, and cheapest method of weed control in many agricultural situations.

b) Knapsack spraying for spot-treatment - appropriate where small areas require spraying but the saving in chemical cost and minimisation of usage can be out-weighed by labour costs.

c) Weed-wiping - in the past poor control has often resulted from use of weed wipers; but this report will indicate that new machinery is being developed which combined with relatively recently developed herbicides may mean greater success and usage of this technique in future.

The reasons for past poor control include too rapid a forward speed through the sward, lack of height differential, irregular terrain, and a desire to obtain effective control in one pass with herbicides which needed two passes (Anon, 1984; Garstang, 1985). One may add at too great a height resulting in insufficient weed coverage with herbicide. The errors of history are for our instruction! Any new machine will have to used appropriately.

d) Hand-applied granules to individual plants or tap roots after cutting or spudding. This technique was used in the past with sodium chlorate or sulphate of ammonia (a fertiliser with herbicidal properties when applied in this way) and has been used on an experimental basis more recently to apply picloram. However, this technique has not generally been used on a field-scale recently, and given the laborious work involved in application and the persistency of these materials they are not to be recommended.

18.3 Whatever the application technique employed, when using dicamba or other relatively broad-spectrum herbicides, it is advisable to concentrate on weed infested areas. These same areas are likely to be the least botanically rich, due to weed competition. Such selective application will minimise the damage, and it is far better to do this than, say, raise the height of weed-wiper wicks, which would just reduce the effectiveness of the operation, costing the same if not more than selective area application, in terms of labour, time and machinery. However, reducing wick height will greatly increase chemical cost, due to the resultant higher flow rate.

18.4 Whatever the application technique requires concentration, skill and expertise.

18.5 Operators for successful herbicide usage must ensure:-

careful application,
avoidance of misses, overlaps, drift, and
use of the correct volume at the correct pressure and dilution
when necessary making adjustments and
always checking the equipment is functioning correctly

18.6 Problems occur when there is a lack of care, and this need for care puts off many site managers or their staff from use of herbicides. It cannot be ignored if the task is delegated to a contractor. Whenever communications are involved there is a need for clearly written instructions from someone who knows what is to be done to someone who will read and follow them.

18.7 This may all seem obvious but the frequency of problems and the errors that do occur are usually due to operator or communication error. Poor control from a herbicide, assuming it was initially chosen correctly, is usually due to mis-application.

18.8 Product labels may not always be sufficiently detailed for an individual users' requirement, this can be particularly true for the manager of a nature reserve. Garstang (1985) states the techniques currently available for the control of perennial weeds lend themselves to development of control strategies (presumably because no single technique is effective alone). However, label recommendations are complex enough as it is, and it would seem unlikely that it will ever be possible to encapsulate such strategies for perennial weed control on product labels.

19.0 Biological Control of Thistles

19.1 Alone biological control is likely to be impractical, and given the potential damage to rarer species caution is advised. Research screening followed by licensing is essential before release of non-native species. However, usually biological control agents need help from low doses of herbicide or favourable weather, to help give control. If the assistance required can be controlled and targeted biological control techniques may have a place, but prudence would suggest that we do not use non-native control agents in Britain.

19.2 Biological Control of Thistles - Invertebrate

In Europe, many insects feed on thistles (Zwölfer, 1965) and help to reduce the size of thistle populations naturally. In N.America most of these invertebrate herbivores are missing so that thistle populations can become very large. However Moore (1975) does list species which infest Creeping Thistle and states none of the native North American species cause sufficient damage to control this thistle. Two species of insect have been used as biological control agents for Spear Thistles a gall-forming fly *Urophyra stylata* F. and *Rhinocyllus conicus* Froel. On Creeping Thistle studies on the efficacy of a weevil and a gall fly *Urophyra stylata* F. (Harris and Wilkinson 1984; Peschken, Finnamore and Watson 1982) has been carried out in the USA and Canada. These species attack the flowering head. *Urophora stylata* is almost confined to Spear Thistle, so it is unlikely to infest economically useful plants and it is surprising that it has been deliberately released on to Creeping Thistle.

19.3 These insects are not listed as invertebrates of economic importance in Britain (Seymour, 1989); but they are native to the UK (Redfern, 1983). *C. vulgare* reproduces exclusively by seed, and in galled heads the number of viable seeds is significantly reduced - roughly by 20 to 80% (Redfern, 1968; Zwölfer, 1972). In addition galled heads produce swollen achenes which fail to germinate.

19.4 Preliminary studies indicate that *Urophora carduii*, another Tephritid fly, reduces the vigour of Creeping Thistle, in the laboratory (Redfern, 1983). It is specific to this thistle and may help to control it. Redfern (1983) suggests that it may be worth introducing *Urophora carduii* to uninfested Creeping Thistle in southern England to attempt to control it.

19.5 Other insect herbivores which feed on thistles include weevil larvae of *Ceutorhynchus litura*, which could be useful in reducing the spread of canopy Creeping Thistles, and reduce its seeding. No studies have been done on the effects of the commoner weevils *Apion carduorum* and *Apion onopordi*, and Redfern (1983) suggested that their potential for biological control may be greater. For individuals who are interested in phytophagous invertebrate the Institute of Terrestrial Ecology at Monks Wood has a relevant databank.

19.6 Leaf-feeding tortoise beetles *Cassida rubiginosa* and *Cassida vibex* prefer *C. arvense* to other *Cynareae* according to Zwölfer and Eichhorn (1966). However, there is the possibility of their becoming pests of crop plants such as artichokes. *Cassida rubiginosa* has been accidentally introduced into E. Canada and the USA where it is quite common on *Cirsium arvense* and, so far, has not been noticed spreading to other potential host plants (Zwölfer and Eichhorn ,1966). High populations of tortoise beetle adults and larvae can occur on *C. arvense*, but their effect on the growth of this species is not known (Redfern, 1983).

19.7 In England in 1969 there was a release of the non-native European beetle *Altica (=Haltica) carduorum*, whose larvae feed on the roots of *Cirsium arvense*. Colonisation was hampered by intense predation and low temperature (Baker, Blackman and Claridge, 1972). This was more of an experiment than a real attempt at biological control. The beetle appears restricted to areas where the temperatures do not fall below 20°C for several months of the year (Williams, 1984). Any records of other *Altica* spp on thistles would be of interest.

19.8 Biological Control of Thistles - Fungal Pathogens

Sedlar *et al.*, (1983) lists 17 species of fungi, other than rust fungi, associated with *Cirsium* species. At the Weed Research Organisation, a study was started on the effect of the indigenous rust fungus *Puccinia punctiformis* on Creeping Thistle. Under normal circumstances the pathogen does not kill its host but inundative inoculation (ie with repeated mass produced inoculum) may increase its effect (Haggar, Oswald and Richardson, 1986). Preliminary investigations suggested a combination of the pathogen and a low dose of 2,4 D could produce severe effects on the host, indicating the possibility of economic and lasting control (Oswald, 1985). Moore (1975) lists a number of fungi and viruses which attack *C. arvense* but states they do not seriously harm it and have not been considered for biological control. Before any further research is started it might be worth referring to a paper on specific weed control with mycoherbicides which was given by Templeton (1985).

19.9 Biological Control of Thistles - Feeding by wild mammals and birds

If this were to be significant then thistle problems would be controlled naturally. However, apart from being eaten by wild goats and horses, thistles are unlikely to be eaten by many mammals.

19.10 Birds eat thistle seed. The American Goldfinch (*Spinus tristis*) eats *Cirsium arvense* seed according to Moore (1975). Anecdotal evidence in Britain indicates goldfinches and linnets feed on thistle heads. Some of the seed-eating birds have declined in numbers in recent years - possibly this is linked to weed control (Jefferson, personal communication).

19.11 Biological Control of Thistles - Integrated Control Measures

In North America a number of thistle eating insects have been released to complement low doses of 2,4 D herbicide (Trumble and Kok, 1982). Moore (1975) comments that increased incidence of rust (*Puccinia punctiformis*) may have contributed to the control given by a deliberately released colony of *Ceutorhynchus litura* at one site in Ontario, reported by Peschken and Beecher (1973).

20.0 Suggestions for Further Research

20.1 It is recommended that there is liaison with research workers and conservation bodies in New Zealand, Australia, Canada, Holland and the United States, who often have similar problems. It is suggested that continued monitoring of the literature on a regular basis is necessary and that this will enable experimentation on new control techniques to begin in Britain as early as possible.

20.2 Anecdotal evidence suggests heavy rain falling on a cut stem will prevent regrowth (T. Overbury, personal communication). It is suggested that if the cut stem is filled with water regrowth is unlikely. This may be due to a water-soluble hormone which stimulates regrowth being leached out. Research into cutting and following with a watering can or boom sprayer fitted with flood jets could prove or disprove this, and further guidance might then be issued on time of cutting.

20.3 Research maybe needed to clarify optimum spray timing, particularly when using non-selective materials like glyphosate, combined with a study of the effect of site of application. Possibly the effect of subsequent cutting at different intervals could be examined.

20.4 Biological control by inundative releases, may reduce thistle infestations, but commercial production of such biological control agents is unlikely unless they had some use on commercial crops. Further research may therefore be both uneconomic and adoption impractical; but if PhD students wanted an interesting topic to study they might identify possible biological control agents for thistles, and they might identify the conditions under which these organisms would have maximum effect. This may then enable anyone who could identify, capture and sustain a high naturally occurring population of successful biological control agents to release these organisms at sites where they are less common, possibly on the same nature reserve. As examples one might suggest for further study the effects of the relatively common weevils *Apion carduorum* and *Apion onopordi*. It is not known if recent work has been or is being done on these species, but none had been done up to 1983, and Redfern (1983) suggested that their potential for biological control may be greater than some other weevil larvae.

20.5 A trials programme might be devised to follow up some of the following ideas:-

a) The height of application using a rope wick is critical. Photosynthetic assimilates, and thus phloem-mobile herbicides like glyphosate, move predominantly towards the stem apex from leaves growing on the upper part of the plant but to the roots from basal leaves. As glyphosate is mainly applied on to the upper leaves, translocation could be less than if lower leaves were treated. Research may be worthwhile in determining the movement of glyphosate and other herbicides from the site of application to the roots or other above ground parts, in the field, at different plant growth stages/timings under differing water regimes.

b) Investigation of the grazing habits of different ages, sexes and breeds of animal may be worthwhile, for example, anecdotal evidence suggests that goats eat thistles more readily than other stock, Beulah sheep are useful in controlling scrub, and so on. This may be linked to examples of grazing management, such as folding at Martin Down NNR, mixed grazing as at Wylye Down NNR, flexible mixed grazing at Parsonage Down NNR and natural grazing, for example by rabbits and deer at Porton Down.

c) Herbicide effects may be enhanced by cutting at an appropriate interval after spraying, the interval depending on the time of year and the product applied (Courtney and Johnston, 1974). For thistles no relevant cutting interval with particular spray timings has yet been identified, nor the effect on total herbage yield. This could be researched.

20.6 It is important that Injurious weeds are looked at in context, as part of the ecosystem of each site. At a FWAG/NCC Seminar on 10 August 1983 to discuss topics relevant to understanding herb-rich chalk swards linked to Parsonage Down NNR, Roger Haggar (now at IGER Aberystwyth) suggested the following (Russell and Way, 1983):-

a) to measure the growth curves of the major indigenous grasses which are likely to differ substantially from the seasonal growth curve of a heavily fertilised, perennial ryegrass ley. The data would enable optimum stocking rates to be worked out for particular livestock systems at different sites;

b) to demonstrate the adverse effect of fertiliser nitrogen on species diversity and to see if this adverse effect could be lessened by increasing stocking density at key times of the year.

c) to measure the benefits to animal production of having a range of herbs to choose from compared with a monoculture of perennial ryegrass;

d) to monitor which plant species animals select at different times of the year;

e) to review the literature on the nutritive value of different species;

f) to devise a two paddock grazing system to more fully utilise banks at Parsonage Down where most of the relic chalk grassland lies;

g) to see if plant growth regulators can be used to maintain high species diversity, even in the absence of grazing. (This latter point maybe useful on railways and next to roads which constitute large areas on which nature conservation is possible.)

20.7 Alan Adamson (NCC) at the same seminar (Russell and Way, 1983) agreed with a) and e) above and added research was needed on nutritive values. Roger Haggar added research was needed to indicate which livestock consumed which plants, to indicate the species on which nutritional information is required, and this may vary between sites, ages and breeds of stock, and seasons.

Alan Adamson also commented that supplementary feeding at critical times of the year could increase animal production and stocking rates.

20.8 Peter Schofield (NCC) and Jack Rossiter (GRI) suggested that research could be undertaken on herb-rich swards - yield, composition, ground cover, animal consumption, forage quality, and animal production. At present English Nature does have a contract with the Department of the Environment and the Ministry of Agriculture, Fisheries and Food which is examining the effect of fertilisers on animal liveweight gain, herbage yields, sward digestibilities as the season progresses and botanical composition on the Somerset Levels (Jefferson, personal communication). This research might be repeated elsewhere. Research could also be undertaken on resting swards at different times, length of growing season and for individual species - period of production, pattern of production, ability to withstand drought, mineral balances, and palatability (Russell and Way, 1983).

20.9 Norman Moore (FWAG) suggested research on the interaction of rabbit and sheep and/or cattle grazing, on flora and fauna (Russell and Way, 1983).

20.10 Tom Bryson and Bryn Green of Wye College suggested that the effect of agistment (winter out-grazing by sheep) and burning in the absence of regular grazing should be investigated. This would cover the effects on the sward, and invertebrates. Research could be undertaken into different burning strategies and timings (Russell and Way, 1983).

20.11 Johnny Johnson (Rothamsted) questioned the effect of low levels of nitrogen, phosphate and potash, given that dung contains these nutrients, and wondered how variation in nutrient content in small areas varied, over (say) a 1 metre square grid, and could this be linked to variation in flora (Russell and Way, 1983).

20.12 Peter Schofield (NCC) asked "Does the typical pattern of grass growth match the grass and herb growth curve" at a particular site? "If not, should animal husbandry be altered to match ewe and lamb needs with sward growth? Should NCC produce grass and herb growth curves" (for different species)? There is a need to know how each herb species reacts to the minerals in fertiliser application, its role as a provider of trace elements particularly selenium and copper (to grazing animals), its ability to withstand competition and its productivity curve (Russell and Way, 1983).

It is suggested that NNRs and SSSIs may offer facilities for research.

20.13 Some of the above suggestions are contentious; however, they do indicate gaps in our knowledge and would help quantify effects of certain management practices, and may point the way forward to strategies for the future. Such research would be useful in managing Environmentally Sensitive Areas (ESAs) and Set-Aside land in a manner sympathetic to the environment, so link funding with various organisations including MAFF could be considered.

NB Because of the biennial nature of Spear Thistle, whatever control techniques are investigated, (hand-pulling, herbicidal or biological or use of grazing animals), it is important that the degree of control which results from treatment is monitored for <u>at least</u> the two following seasons after treatment. Due to the perennial nature of Creeping Thistle it is important that the degree of control is monitored over <u>at least</u> three seasons.

21.0 Recommendations

These fall in to two categories, i) those to be applied to all sites and ii) those which may be relevant in a particular situation, or need modification to individual circumstances. However, it should be appreciated that once a thistle infestation exists an integrated approach to control is required, no single technique is sufficient. The first priority must be to produce as dense and competitive sward as the site allows, but this may take longer to produce than the benefits of other control measures. Also, when considering alternatives, methods of control in one habitat may be entirely inappropriate in another habitat.

21.1 **Avoid poaching or damage to the sward**, particularly in wet conditions when such damage is more likely to occur, from the following:-

- vehicles
- ditching/ hedging/ river bank maintenance
- frequent animal movement
- animals congregating regularly in one area (unless a deliberate 'sacrifice area' is a practical necessity)
- if stock feeding or chain harrowing is allowed on a particular site, it should be restricted to areas of low conservation value

21.2 **Prevent thistle seeding or Creeping Thistle root spread** by appropriate techniques. It is important that the chosen method of control allows minimal provision of new invasion sites. Possible control techniques include the following (which may not be relevant in every situation):-

a) hand-control techniques, such as cutting with a machete, or scythe as low as possible; or spudding with a spade at ground level; or hand-pulling - whichever technique is used preferably remove the weeds and burn them.

b) weed-wipe when maximum weed growth is occurring - this will tend to be when the rosette is sending up a flowering shoot. Minimise the damage to the grass and other flora.

If possible, use the most selective herbicide available (in the case of thistles, this is clopyralid) although other herbicides can be considered (e.g. dicamba) where a mixture of Injurious Weeds exists. Preferably use the prototype weed-wiper devised by the Royal Agricultural College (RAC) at a wick-height of 10 cm. This is likely to result in the best control of the target species.

A second-best alternative to a selective herbicide is to use a relatively non-selective herbicide once a sufficient height differential exists between the sward and the target weeds, and to set the wick height just above the sward canopy. This technique is only really suitable on level ground.

Whatever type of herbicide is used aim to maximise chemical transfer, by driving at the correct speed, ensuring adequate flow rate, the optimum height and making two passes instead of one, not missing any infested areas, and so on.

c) top or cut infested areas with a mower, as low as possible, just before flowering when the thistle plant has expended its maximum energy reserves, but the flower buds have not opened, and repeat one month later. By concentrating on the worst infestations which have little botanical diversity, it is possible to minimise damage to the sward and other flora.

d) on hay meadows, take a hay cut just before the target weeds flowers open, rather than after flowering, if possible. The seed bank will maintain most species for a varying period according to their seed dormancy and longevity; but beware of losing late flowering annuals. Do not cut too low, else sward regrowth will be poor, similarly allow aftermath grazing once sward about 2 cm above target height as given in Table 3 on page 18.

Early hay cutting regimes tend to be infrequently associated with high dock populations. However, early cutting may not always be desirable from a nature conservation point of view. This may be due to the botanical need to allow annuals like Yellow Rattle (*Rhinanthus minor*) to flower and set seed, or to allow ground-nesting birds to rear their young, particularly breeding waders in wet grassland.

21.3 **If early control to prevent seeding is missed: apply herbicide through a weed-wiper in August or later in the autumn before the first frosts**, as low as the terrain and chemical chosen allows without causing sward damage to maximise herbicide transfer to the targets. This may still reduce seed viability and late seeding with all thistle species and given that the primary objective of control of Creeping Thistle is to kill the creeping roots a translocated material such as clopyralid or glyphosate should be used. The earlier this herbicide is applied the better, to maximise effect.

21.4 **Use grazing livestock to perform controlled grazing to create a denser, thicker sward where possible. Avoid under or over-grazing, or erosion on slopes, particularly when herbage is slow growing.** Ensure stock levels are regularly adjusted according to the amount of grazing available and the ground conditions. Provide adequate fencing, water, or supplementary feeding or move stock off vulnerable areas.

If it is deliberate policy to practice lax grazing (ie allowing grass to exceed target heights) at critical times of the year, be prepared to adopt other thistle control techniques.

21.5 **Avoid burning or any other operation which results in bare ground** anywhere. If it is unavoidable, have cleaned seed (free from 'weeds') ready to sow over such areas, these seeds should have been taken at different harvest dates from the reserve previously, and be prepared to control weeds during the establishment phase. Natural regeneration without over-sowing should rarely be used.

21.6 **Try to alternate cutting or grazing regimes** to intensify utilisation to try to produce a thicker sward, or use grazing with different types of livestock either by mixed grazing or use various livestock alternately. Beware of changing sward composition and losing desirable species.

21.7 **As a last resort, spot or boom spray when and where necessary, if it is practical.** Avoid herbicide drift, ensure timing of operations is ideal for both the particular weed target and the chemical chosen to be used. Choose a material from Appendices II-V consistent with the site objectives .

22.0 **Action Calendar for Botanically-rich Grassland**

This calendar sets out an ideal strategy for control of ragwort, and other weeds that exploit bare ground due to poaching or over-grazing. It is not practical to follow it in all circumstances, and it will not acceptable on all sites every year, each site needs to be managed according to its individual objectives and resources. However, the following general principles can be followed in most circumstances:-

- avoid fertiliser use,
- avoid application of stored organic manures where possible,
- avoid cutting of botanically-rich grassland before mid-July
- avoid or minimise poaching or damage to the sward, particularly in wet conditions when such damage is more likely to occur, from the following:-

- vehicles
- ditching/ hedging/ river bank maintenance
- frequent animal movement
- animals congregating regularly in one area (unless a deliberate 'sacrifice area' is a practical necessity)
- if feeding is allowed on a particular site, it should either be supplementary concentrates free of viable seeds or forage free of thistles, docks and ragworts and restricted to areas of low conservation value.

The following management guidelines, will reduce the risk of weed infestation and help to prevent spread of weeds when inadvertent invasion occurs:-

January Where possible, remove any sheep which are grazing on fields which are later to be grazed, give priority to fields needed soon after lambing, (or exceptionally, where a very early silage cut is to be taken - to reduce the risk of poaching or leptospirosis) and maximise grass growth before turnout. Consider away- wintering, housing or use of a sacrifice area; if sheep out-wintering is unavoidable do not graze below 3 cm.

Do not allow cattle grazing in winter, on botanically-rich sites.

February If sheep are grazing on fields which are to be cut for hay, (or silage) remove them. Check/repair fencing and water supply. Do not allow sheep grazing on swards below 3 cm height.

March	Turn out ewes with lambs on to areas which have not been grazed recently.
	Before cattle turnout, start measuring sward height on or soon after March 10; once a week if cold, twice a week if warm.
	Aim to turnout when ground is dry and for set-stocked areas sward height is 1 cm above the height given in Table 3 (Part 1: Section 11.8 on page 19) and height is increasing. For rotationally grazed areas sward height at turnout can be up to 5 cm above the targets given in Table 3. If grass exceeds 5 cm above the target height, use an electric fence to strip graze. Subsequently target heights up to 2 cm above can be allowed before under-grazing occurs; if sward height falls close to, or below, the values given in Table 3, over-grazing is occurring. Increase or reduce stock numbers to maintain target sward height. Alternatively use an electric fence to adjust grazing area; check fences regularly, and close off parts of fields to prevent excessive damage or over-grazing. If necessary supplementary feed with concentrates, particularly if animals have recently given birth, and grass is limited ie close to the target given in Table 3 (Part 1: Section 11.8 on page 19).
	If applying organic manures to cutting fields apply no later than mid-March; spread thinly to reduce contamination of fodder and minimise sward damage; if not applied now, store until after cutting. If muck-spreading or chain harrowing is allowed it should be restricted to areas of low conservation value.
April	Only continue to feed sheep supplements if sward height is less than 4 cm and not increasing. Do not be afraid to graze at 7 ewes or more to the acre, to avoid grass exceeding 5 cm height, provided that grass was not over-grazed earlier, and poaching or over-grazing (ie grass height below 4 cm) can be avoided.
May	Your most important month. Stocking density should be at its peak in late May. Do not allow grass height to be more than 2 cm above target, as given in Table 3 (Part 1: Section 11.8 on page 19); if necessary, stock heavily, strip graze and fence off an area for fodder conservation. Once thistles are slightly above the rest of the sward consider use of herbicide preferably applied by a weed-wiper at 10 cm above ground.
June	If the sward becomes stemmy, and if this is undesirable, an area may be closed up for hay, possibly using an electric fence, or try to increase stock numbers. However, gradually allow sward height to increase, particularly on drought-prone sites.
	Once thistles are slightly above the rest of the sward consider weed-wiping, particularly for Creeping Thistle to minimise root spread. Use weed-wiper when maximum weed growth is occurring - this will tend to be when the rosette is sending up a flowering shoot. Use a selective herbicide, (in the case of thistles, this is clopyralid) although other herbicides can be considered (e.g. dicamba) where a mixture of Injurious Weeds exists, preferably applied by a weed-wiper at 10 cm above ground to minimise the damage to the grass and other flora. See Section 21.2 b) above.

July — Ensure that swards are not over-grazed, see Table 3, (Part 1: Section 11.8 on page 19) add 1-2 cm to target heights if on droughty sites, and try to maintain sward density. If areas become thin, reduce grazing pressure to allow self-seeding, to thicken sward later.

Cut thistles just before flower buds open, as low as possible, and remove them to minimise risk of seeding. Prevent weed seeding and spread of creeping Thistle roots by appropriate techniques - see Section 21.2. above.

August — Graze hay/big bale silage aftermaths once regrowth reaches about 2 cm above target sward heights given in Table 3 (Part 1: Section 11.8 on page 19) ; but if grazing area includes previously uncut areas you may graze earlier than this.

If dense weed patches are controlled, consider sowing seed from other parts of the site (which is 'weed'-free) on bare or thin patches.

Cut thistles again if necessary as low as possible. If earlier control to prevent seeding was missed: apply a herbicide through a weed-wiper in August or later in the autumn before the first frosts, as low as the terrain and chemical chosen allows without causing sward damage to maximise herbicide transfer to the targets. This may still reduce seed viability and late seeding with all thistle species and given that the primary objective of control of Creeping Thistle is to kill the creeping roots a translocated material such as clopyralid or glyphosate should be used. The earlier this herbicide is applied the better, to maximise effect.

September — If earlier control to prevent seeding was missed: apply a herbicide through a weed-wiper before the first frosts, as low as the terrain and chemical chosen allows without causing sward damage to maximise herbicide transfer to the targets. This may still reduce seed viability and late seeding with all thistle species and given that the primary objective of control of Creeping Thistle is to kill the creeping roots a translocated material such as clopyralid or glyphosate should be used. The earlier this herbicide is applied the better, to maximise effect.

October — House cattle, including calves before a reduction in their performance and serious poaching occurs. Wean spring born suckler calves prior to housing. Only allow stock to stay out if dry conditions allow minimal poaching. <u>Avoid poaching or damage to the sward</u>, particularly in wet conditions when such damage is more likely to occur.

November — Consider allowing sheep to graze down to 4-5 cm, after cattle housing, to remove surplus grass and minimise frost-kill. Such grazing may be an extra source of income, as well as increasing sward density; but avoid over-grazing or poaching, to minimise weed invasion sites. Continue measuring sward once a fortnight through the winter.

December — Do not allow sheep to graze below 3 cm, and do not allow poaching of the sward.

23.0 Conclusions

23.1 Understanding the biology of weed species is helpful in devising control strategies and it helps to indicate suitable timings, reasons why a particular technique succeeds or fails, and promising avenues for research in to control techniques.

23.2 Control is possible if sufficient effort can be justified and sustained. However, as is often the case, prevention is better than cure, and avoidance of poaching, bare ground, under-grazing or over-grazing should be the aims of all site managers.

24.0 References

Anon (1906) Leaflet 166 - Some Common Thistles, Board of Agriculture and Fisheries, Whitehall, London, pp 1-11.

Anon (1976), Leaflet 51 - Thistles, ADAS/MAFF, Pinner, Middlesex.

Anon (1981) AG06561 Grassland - control of thistles by selective application of herbicides, ADAS Research and Development Reports, Reference Book 227 (81), Grassland and Fodder Conservation Crops 1980, ADAS/MAFF.

Anon (1982) AG06502 Broad-leaved weed control in established swards, ADAS Research and Development Reports, Reference Book 227 (82), Grassland and Fodder Conservation Crops 1981, ADAS/MAFF.

Anon (1983) AG06502 Broad-leaved weed control in established swards, ADAS Research and Development Reports, Reference Book 227 (83), Grassland and Fodder Conservation Crops 1982, ADAS/MAFF.

Anon, (1986) Deep weeds lasting longer, New Zealand Agrichemical Manual Update, 1 (4), 12.

Anon (1987), Pamphlet 51 - Thistles, ADAS/MAFF, Alnwick, Northumberland, 3 pp.

Anon (1990), Pamphlet 3243 - Nutritive value of broad-leaved weeds and forage herbs in grassland. ADAS London, 4 pp.

Anon (1991) Grassland Management Calendar 1991 - Dairy Cows,
- Beef Cattle
- Lowland Sheep, ADAS.

Amor, R.L.,and Harris, R.V.,(1974) Distribution and seed production of *Cirsium arvense* (L.) Scop. in Victoria, Australia. Weed Research, 14, pp 317-323, Australia.

Amor, R.L. and Harris, R.V. (1975) Seedling establishment and vegetative spread of *Cirsium arvense*(L.) Scop. in Victoria, Australia. Weed Research, 15, pp 407-411. Australia.

Armstrong, S.F. (1948) British grasses and their employment in agriculture. University Press, Cambridge, UK, pp 274-285.

Austin M.P., Groves, R.H., Fresco, L.M.F., and Kaye, P.E., (1985) Relative growth of six thistle species along a nutrient gradient with multispecies competition, Journal of Ecology, 73, pp 667-684.

Bacon, J., personal communication.

Baker, C.R.B., Blackman, R.L., and Claridge, M.F., (1972) Studies on *Altica carduorum*, an alien beetle released in Britain as a contribution to the biological control of creeping thistle (*Cirsium arvense* L. Scop.), Journal of Applied Ecology, 9, pp 819-830.

Bakker, D (1960) A comparative life-history of *Cirsium arvense* (L.) and *Tussilago farfara* L., the most troublesome weeds of the newly reclaimed polders of the former Zuiderzee. In Symposium on the Biology of Weeds, British Ecological Society, (Ed. by J.L. Harper), Blackwell Scientific Publications, Oxford, pp 205-222.

Barber, W.P. (1985) The Nutrition Value of Common Weeds. British Grassland Society Occasional Symposium No. 18. Edited by Brockman, J.S. British Crop Protection Council Monograph No. 29, pp 104-111.

Bates, G.H., (1935) Journal of Ecology, 23, pp 470-487.

Bates, G.H., (1955) Weed control. London. Farmer and Stock Breeder Ltd.

Bellamy, G., personal communication.

Bendall, G.M., (1975) The allelopathic activity of Californian Thistle (*Cirsium arvense* (L.) Scop) in Tasmania. Weed Research, 15: pp 77-81.

Bird, D.P., (1985) Optimising the control of perennial broad-leaved and woody weeds in established grassland with Broadshot using conventional and novel applicators. British Grassland Society Occasional Symposium No. 18, Edited by J.S. Brockman, British Crop Protection Council Monograph No. 29, pp 273-4.

Bruns, V.F. and Rasmussen, L.W. (1957) The effects of fresh water storage on the germination of certain weed seeds II. White Top, Russian Knapweed, Canada Thistle, Morning Glory and Poverty Weed. Weeds 5: pp 20-24.

Carlson, S.J. and Donald, W.W. (1988) Fall-applied glyphosatre for Canada thistle (*Cirsium arvense*) in spring wheat (*Triticum aestivum*) Weed Technology, 2, pp 445-455.

Cavers, P.B. (1974) Germination polymorphism in *Rumex crispus*. The effects of different storage conditions on germination responses of seeds collected from individual plants. Canadian Journal of Botany, 52, pp 575-583.

Chancellor, R.J. (1970) Biological background to the control of three perennial broad-leaved weeds. Proceedings 10th British Weed Control Conference, 3, pp 1114-1120.

Clapham, A.R. Tutin, T.G. and Warburg, E.F., (1962) Flora of the British Isles, University Press, Cambridge, pp 867-869. UK.

Cooke, A.S. (1986) The use of herbicides on nature reserves. Focus on Nature Conservation 14, Peterborough.

Cooke A.S., (1987) Regional Circular, English nature, Peterborough, dated 15.5.87.

Cooke A.S.,(1989) Regional Circular, English nature, Peterborough, dated 23.2.89.

Cooke, A.S. (1991) The use of herbicides on NNRs, English Nature Circular dated 4.12.91. English Nature, Peterborough

Cooke, A.S. (1991) The use of herbicides on nature reserves, Brighton Crop Protection Conference - Weeds, pp 619-626

Cooke, A.S. (1992) Pollution News No. 2, English Nature, Peterborough, pp 4.

F. B. Cooper, ADAS Wolverhampton, personal communication.

Courtney, A.D. (1973) Noxious weeds in grassland - docks, thistles and ragwort. Agriculture in Northern Ireland 48, pp 22-25.

Courtney, A.D. (1974) Herbicides for weed control in grassland. Agriculture in Northern Ireland, 49 (1), pp 11-14.

Courtney, A.D. and Johnston, R.T. (1974) Time of herbicide application for the control of docks (*Rumex obtusifolus*) in a grassland conservation system, Proceedings 12th British Weed Control Conference, pp 751-760.

Cromack, H.T.H. personal communication.

Crouchley, G. (1983) Blackberry control in Hawkes Bay, Proceedings Ruakura Farmers Conference, pp 63-64.

Davies B.N.K.(Ed.), Marrs, R.H., Brown, M.J., Frost, A.J., Lakhani, K.H., Luniss, P., Plant, R., Yates, T.J., Pinder L.C.V., House, W.A., Farr, I.S., Bass, J.A.B., Breeze, V.G., Simmons, J.C., and Roberts, M.O., (1992) Environmental Impact of Pesticide Drift, Institute of Terrestrial Ecology (National Environment Research Council) and others, Appendix 2, pp 1-19.

Detmers, F., (1927) Canada thistle (*Cirsium arvense*) Tourn. Ohio Agricultural Experiment Station Bulletin 414, 45 pp.

Dixon, T., personal communication.

Donald, W.W. (1990) Management and control of Canada thistle. Reviews of Weed Science, 5, pp 193-250.

Donald, W.W. (1992) Herbicidal control of *Cirsium arvense*(L.) Scop. roots and shoots in no-till spring wheat (*Triticum aestivum L.*) Weed Research, 32, pp 259-266.

Elliot, J.G. and Wilson, B.J. (Editors) (1983) The influence of weather on the efficiency and safety of pesticide application. The drift of herbicides. Occasional Publication No. 3, British Crop Protection Council, 135 pp

Eggers, T. (1978) Biology and ecology of economically important weed species. German Federal Republic, Biologische Bundesanstalt für Land - und Forstunirtschaft, Annual Report 1978, 50.

Fairburn, C.B. and Thomas, B. (1959) The potential nutritive value of some weeds common to north-eastern England. Journal of the British Grassland Society, 14, 36-46.

Farrell, (1991) personal communication,

Ferron, M., and Cayouette, R., (1971) Noms des mauvaises herbes du Québec, Ministry of Agriculture Colonisation du Québec. Publ. 288, 133 pp.

Forbes, J.C., Dibb, C., Green, J.O., Hopkins A., and Peel, S., (1980) Factors affecting the productivity of permanent grassland, Joint ADAS-GRI Permanent Pasture Group, Hurley, 141 pp.

Forbes, J.C., Kilgour, D.W. and Carnegie, H.M. (1980) Some causes of poor control of *Senecio jacobaea* L. by herbicides. Proceedings 1980 British Crop Protection Conference - Weeds, pp 461-468.

Forcella F. and Wood H., 1986, Demography and control of *Cirsium vulgare* (Savi) Ten. in relation to grazing, Weed Research, 26, pp 199-206

Fryer, J.D. and Makepeace, R.J. (1978) Weed Control Handbook, Volume II - Recommendations. British Crop Protection Council, published by Blackwell Scientific Publications. pp 233-390.

Garstang, J.R., (1985) An advisory view, British Grassland Society Occasional Symposium No. 18. Edited by Brockman, J.S. British Crop Protection Council Monograph No. 29, pp 234-242.

Gill, N.T. and Vear, K.C. (1958) Agricultural Botany. Gerald Duckworth and Co. Ltd, London, 636 pp.

Green, J.O. (1982) A Sample Survey of Grassland in England and Wales 1970-1972. The Grassland Research Institute, Hurley, 39 pp

Grigson, G. (1955) The Englishman's Flora, J.M. Dent and Sons Ltd, London, pp 386-387.

Haggar, R.J. (1980) Survey of the incidence of docks *(Rumex* spp.) in grassland in ten districts in the UK in 1972. ADAS Quarterly Review 39, pp 256-270.

Haggar, R.J., Oswald, A.K. Richardson, W.G. (1984) Importance and control of creeping thistle in grassland Crop Protection, 5, (1), Butterworths, Guildford, pp 73-76.

Haggar, R.J. Oswald, A.K. and Richardson, W.G. (1986) A review of the impact and control creeping thistle in grassland. Crop Protection 5 (1), Butterworths, Guildford, pp 73-76

Hamdoun, A.M. (1972) Regenerative capacity of root fragments of *Cirsium arvense* (L.) Scop. Weed Research, 12, pp 128-136.

Hanf, M. (1983) The arable weeds of Europe with their seedlings and seeds. BASF United Kingdom Limited, 494 pp.

Hartley, M.J. and James, T.K. (1979) Cost benefit of selective control of Californian thistle in pasture. Proceedings 32nd New Zealand Weed and Pest Control Conference.

Harper, J.L., (1977) Population biology of Plants, Academic Press, New York.

Harris, P., and Wilkinson, A.T.S., (1984) *Cirsium vulgare* (Savi.) Ten., bull thistle (*Compositae*) (edited by J.S. Kelleher and M.A. Hulme), Biological control programmes against insects and weeds in Canada 1969-1980, Commonwealth Agrricultural Bureau, Farnham Royal, UK, pp 147-153.

Hartley, M.J. Lyttle, L.A. and Popay, A.I. (1984) Control of Californian Thistle by Grazing Management. Proceedings 37th New Zealand Agricultural Weeds and Pest Control Conference, pp 24-27.

Hartley, M.J. and Thompson, N.A. (1981) Effect and control of California thistle in dairy pasture. Proceedings Grassland Association, 43, pp 104-107.

Hay, W.D. (1937) Canada thistle seed production and its occurrence in Montana seeds. Seed World, March 26, pp 6-7.

Hayden A (1934) Distribution and reproduction of Canada thistle in Iowa. American Journal of Botany, 21, pp 355-373.

Hinchelwood, D., personal communication.

Hodgson, J.M. (1968a) The nature, ecology and control of Canada thistle. United States Department of Agriculture Technical Bulletin No. 1386. 32 pp.

Hodgson, J.M. (1968b) Canada thistle and its control. US Department of Agriculture Leaflet No. 523, 8 pp.

Hodgson, J.M. (1970) The response of Canada thistle ecotypes to 2, 4 D, amitrole and intensive cultivation, Weed Science, 18, pp 253-255.

Hope, A. (1927) The dissemination of weed seeds by irrigation water in Alberta. Scientific Agriculture 7, pp 268-276.

Hopkins, A. (1986) Botanical composition of permanent grassland in England and Wales in relation to soil, environment and management factors. Grass and Forage Science 41, pp 237-246.

Hopkins A. and Peel, S. (1985) Incidence of Weeds in Permanent Grassland. British Grassland Society Occasional Symposium No. 18. Edited by Brockman, J.S. British Crop Protection Council Monograph No. 29, pp 93-103.

Hopkins, A., Wainwright, Joanne, Murray, P.J., Bowling, P.J. and Webb, Morag (1988) 1986 survey of upland grassland in England and Wales: changes in age structure and botanical composition since 1970-72 in relation to grassland management and physical features, Grass and Forage Science, 43, pp 185-198.

Ivens, G.W. (1978) Californian thistle, New Zealand Journal of Agriculture, 137 (11), pp 13-14

Ivens, G.W.(1992) The UK Pesticide Guide 1992, Commonwealth Agricultural Bureau International and British Crop Protection Council, pp 581.

Jeater, R.S.L., (1958) The effect of MCPA, MCPB, and 2,4 DB on the productivity and botanical composition of permanent pasture, Proceedings 4th British Weed Control Conference, pp 11-14.

Jefferson, R., personal communication.

Jones, M.G. (1933a) Grassland management and its influence on the sward. The Empire Journal of Experimental Agriculture, 1, pp 43-57.

Jones, M.G. (1933b) Grassland management and its influence on the sward - II. The management of a clovery sward and its effects. Empire Journal of Agriculture, 1, pp 123-128.

Jones, M.G. (1933c) Grassland management and its influence on the sward III. The management of a grassy sward and its effects. Empire Journal of Experimental Agriculture, 1, pp 223-234.

Jones, Martin, (1934) Report 3rd Grassland Conference, Zurich, pp 221-230.

Jones, M.G. and Jones, W.I. (1930) The effects of varying the periods of rest in rotational grazing. Welsh Plant Breeding Station, Bull. II, pp 11.

de Jong, T.J., Klinkhamer P.G.L., Nell, H.W., & Troelstra S.R. (1987), Growth and nutrient accummulation of the biennials *C. vulgare* and *Cynoglossum officinale* under nutrient-rich conditions, OIKOS, 48, 62-72.

Klinkhamer P.G.L.and de Jong, T.J, (1988) The importance of small-scale disturbance for seedling establishment in *Cirsium vulgare* and *Cynoglossum officinale*, Journal of Ecology, 76, 383-392.

Klinkhammer, P.G.L., De Jong, T.J., and Van Der Meijden, E. (1988) Production, dispersal and predation of seeds in the biennial *Cirsium vulgare*, Journal of Ecology, 76, pp 403-414.

Kolk, H (1947) Studies on germination biology of weeds (in Swedish) Publ. Inst. Plant Husbandry R. Agric. Coll. of Sweden No. 2, pp 108-167.

Lampkin, N. (1990) Organic Farming. Farming Press, London, pp 170-211.

Lee, O.C. (1952) Canada thistle control. Purdue University Agricultural Extension Service Leaflet No. 345.

Leeuwen, B.H., (1983) The consequences of predation in the population biology of the monocarpic species *Cirsium palustre* and *Cirsium vulgare*, Oecologica, 58, pp 178-187.

Link, A.J. and Kommedahl, T. (1958) Canada Thistle - spotlight on a troublesome weed. Minn. Farm Home Science 15, pp 21-22.

Lowman, B.G. (1987) Day to Day Grassland Management. Condensed from a paper given at the 1986 Winter Meeting. Grass Farmer, No 26., p 3-11.

Lowman, B.G.,Swift, G., and Grant, S.A., (1984) Grass height - a guide to grassland management, Edinburgh School of Agriculture, Technical Note No. 345, May 1984.

P. Marriage, personal communication to Cavers, 1985, Intractable Weeds- intraspecific variation must be considered in formulating control measures, British Crop Protection Conference - Weeds, pp 367-376.

Massey, M., personal communication.

McClements I. (1992) Marsh ragwort (*Senecio aquaticus*) biology and control, PhD Thesis, Queens' University, Belfast.

Moore R.J., (1975) The biology of Canadian weeds, 13, *Cirsium arvense* (L.) Canadian Journal of Plant Science, 55, pp 1033-1048.

Moore, R.J. and Frankton, C. (1974) The thistles of Canada. Canadian Department of Agriculture Monograph No. 10, Ottawa, Ontario.

Newman, L. Hugh (1977) Looking at Butterflies, Collins, London, 144 pp.

Nolan, T. and Connolly, J.(1977) Mixed stocking by sheep and steers, a review. Herbage Abstracts, 47, pp 367-374.

Oswald, A.K. (1985) Impact and control of thistles in grassland British Grassland Society Occasional Symposium No. 18. Edited by Brockman, J.S. British Crop Protection Council Monograph No. 29, pp 128-136.

Oswald, A.K. (1985) The height directed application of dicamba for controllling *Rumex obtusifolius* and *Cirsium arvense* in grassland, 1985 British Crop Protection Council Monograph No. 28, Symposium on Application and Biology, Edited by Southcombe, E.S.E., British Crop Protection Council, Croydon, UK, pp 55-61.

Overbury, T., personal communication.

Payne, K., personal communication.

Payne, K. (1992) Port Meadow SSSI. Notes on *Cirsium arvense, Senecio jacobaea* and the response of swards to heavy grazing, SP40. KRP/PW, dated 11 May 1992.

Peel, S., Matkin, Elizabeth A., Ellis, Julia A., and Hopkins, A. (1985) South-West England Grassland Survey 1983, 2. Trends in cropping pattern, reseeding and sward composition 1970-83. Grass and Forage Science, 40, pp 467-472.

Peel, S. and Hopkins, A. (1980) The incidence of weeds in grassland. Proceedings of the 15th British Crop Protection Conference - Weeds 1980, pp 877-890.

Perring, F.H. and Farrell, L., (1983) British red data books 1. Vascular Plants, 2nd Edition, Lincoln, UK.

Perrott, T. (1987) Weed control in grassland. Grass Farmer No. 26, pp 12-13.

Peschken, D.P. and Beecher, R.W. (1973) *Centorhychus litera (Coleoptera: Curculioridae*): biology and first releases for biological control of the weed Canada thistle (*Cirsium arvense*) in Ontario, Canada. Canadian Entomolist 105, pp 1489-1494.

Peschken, D.P., Finnamore, D.B. and Watson, A.K. (1982) Biocontrol of the weed Canada thistle (*Cirsium arvense*) in Canada. Canadian Entomology, 114, pp 349-357.

Prentiss, A.N. (1889) On root propagation of Canada thistle Cornell University Agricultural Experiment Station. Bulletin 15, pp 190-192.

Randall, J.M., (1990) personal communication to Dr. A.S. Cooke, entitled 'Manual control of spear thistle (*Cirsium vulgare*), an alien biennial in Yosemite National Park, California', talk given to Biology and Control of Invasive Plants Conference organised by the Industrial Ecology Group of the British Ecological Society, Sept. 1990. (unpublished)

Redfern, M. (1983) Naturalist Handbook, 'Insects and Thistles', Cambridge University Press, UK, 64 pp.

Reyrink, L.A.F. (1985) Bird protection in grassland in the Netherlands in Environmental Management in Agriculture - European perspectives. Edited by Park, J.R. Bellhaven Press, London, pp 159-169.

Roberts, H.A. and Chancellor, R.J. (1979) Periodicity of seedling emergence and achene survival in some species of *Carduus, Cirsium* and *Onopordum*. Journal of Applied Ecology 16, pp 641-647.

Roberts, H.A. (1982) Weed Control Handbook Volume 1: Principles. Blackwell Scientific Publications, Oxford:

Rogers, C.F. (1928) Canada Thistle and Russian Knapweed and their control. Colorado Agricultural Experimental Station Bulletin 434, 44 pp.

Rumsey, F.J. and Jury, S.L. (1991) An account of *Orobanche* L. in Britain and Ireland Watsonia, February 1991, Vol. 18, Part 3, pp 257-295.

Russell, R. and Way (1983) The Management of Chalk Grassland for Agriculture and Conservation. FWAG/NCC Seminar, 1983, 19 pp..

Sagar, G.R. and Rawson, H.M. (1964) The biology of *Cirsium arvense* (L.) Scop. Proceedings 7th British Weed Control Conference, 2, pp 553-562.

Salisbury, Sir Edward, (Unknown date of publication) Weeds and Aliens, Collins - The New Naturalist Series, London, pp 213-217.

Sedlar L., Vonmoos, R., Defago, G., and Kern, H. (1983) Fungi occurring on selected weeds - a compilation of literature data, Institute fur Phytomedzin, ETH-Zentrum, Zurich, Switzerland, 99 pp.

Sheldon, J.C. and Burrows, F.M. (1973) The dispersal effectiveness of the achene-pappus units of selected *Compositae* in steady winds with convection. New Pathologist 72, pp 665-675.

Silvertown, J. and Smith, R.(1989) Germination and population structure of spear thistle, *Cirsium vulgare*, in relation to experimentally controlled sheep grazing. Oecologicia, 81, pp 369-373.

Sindell, B.M., (1991) A review of the ecology and control of thistles in Australia, Weed Research, 31, pp 189-201.

Singh, S. and Malik, R.K. (1992) Evaluation of clopyralid against *Cirsium arvense*. Test of Agrochemicals and Cultivars 13, Annals of Applied Biology 120 (Supplement), pp 46-47.

Smith, A., personal communication.

Spedding, C.R.W. and Diekmahns, E.C. (1972) Grasses and Legumes in British Agriculture. Commonwealth Agricultural Bureaux Bulletin 49, Farnham Royal, Bucks, UK, 511 pp.

Strand, O.E. (1982) Proceedings of the North Central Weed Control Conference, 37, pp 113-114.

Swift, G., Holmes, J.C., Cleland, A.T., Fortune, D. and Wood, J. (1983) The grassland of east Scotland - a survey 1976-79. Bulletin No. 29. Edinburgh: East of Scotland College of Agriculture, 43 pp.

Toynton, P., personal communication.

Templeton, G.E., (1985). Specific weed control with mycoherbicides, 1985 British Crop Protection Conference - Weeds, 2, pp 601-607.

Thompson, A. (1983) Pasture weed control by rope wick applicator. Proceedings of the 36th New Zealand Weed and Pest Control Conference (Edited by Hartley, M.J., and Popay, A.J.), pp 96-98.

Thompson, A.R. and Goodliffe, J.P. (1985) Practical pest and weed control in grassland British Grassland Society Occasional Symposium No. 18. Edited by Brockman, J.S. British Crop Protection Council No. 29, pp 293-294.

Toole, E.H. and Brown, E. (1946) Final results of the Duval buried seed experiment. Journal of Agricultural Research 72: pp 201-210.

Trumble, J.T. and Kok, L.T. (1982) Integrated pest management techniques in thistle suppression in pastures of North America. Weed Research, 22, pp 345-359.

USDA (1960) Index of Plant Diseases in the United States, Agricultural Handbook 165, USDA-ARS, Washingtron D.C.

West, T.M. and Richardson, W.G. (1985) Pot experiments to assess herbicides for selective control of established thistle in perennial ryegrass. British Grassland Society Occasional Symposium No. 18. Edited by Brockman, J.S. BCPC Monograph No. 29, pp 271-272.

Whitmore, M., personal communication

Wilkinson, M. (1983) Put your foot in it - do the wellie boot test. Farmers Weekly. Reed Publishing, Sutton, UK, July 8, 1983, pp 101-104.

Williams, R.D. (Editor) (1984) Crop protection handbook - Grass and clover swards. British Crop Protection Council, 104 pp.

Zwölfer, H. (1965) Preliminary list of phytophagous insects attacking wild *Cynareae* (Composite) in Europe. Commonwealth Inst. Biol. Control Tech. Bulletin No. 6, pp 81-154.

Zwölfer H. and Eichhorn, O., (1966) The host ranges of *Cassida* spp. (*Col. Chrysomelidae*) attacking *Cynareae (Compositae)* in Europe, Zeitschrift für angewandte Entomologie, 58, pp 384-397.

PART II - BROAD AND CURLED DOCK AUTECOLOGY AND CONTROL

1.0 Introduction

1.1 Docks (*Rumex* species) form a group of species which occur in a wide range of habitats. Several species may be locally troublesome, but only two are of widespread concern. These are the Broad-leaved Dock (*Rumex obtusifolius)* and the Curled Dock (*Rumex crispus*). Both are listed under the Weeds Act 1959 as injurious weeds, and this requires land occupiers to control these weeds on their land if there is a threat to agricultural production. In agriculture true weeds are plants which reduce the profitability of an enterprise (Hance and Holly, 1990).

1.2 Weeds are characterised by their ability to persist in the face of repeated habitat disturbance and periodic and near total destruction of the above ground biomass. Survival and persistence of docks are linked to four main factors (Whytock, Davies and Younie, 1987):

- ability to grow in a wide range of habitats, according to species, from woodland to wet fields and marsh. They thrive in a range of climates across Scandinavia, Europe, most of Africa, the Azores and SW Asia, and can withstand extremes of moisture and temperature.

- prolific seed production

- longevity and dormancy of seed

- ability to regenerate vegetatively, either if leaves are removed from the tap root or by breaking up or damage of the root stock by trampling or cultivation. The thick fleshy tap root has considerable resistance to drying when exposed. The roots may also contain chemicals that resist the growth of some fungi, bacteria and other plants which can cause decay, so the dock roots can more easily re-sprout than some other plants (Kasai *et al*, 1982). There are no mycorrhizal fungi associated with dock roots (Cavers and Harper, 1962).

1.3 These properties make them particularly difficult to control by non-chemical means.

1.4 In surveys docks are reckoned to be present in significant numbers on about 10% of UK grassland. They are capable of being eaten by stock, particularly cattle, and are quite nutritious; but have a lower energy value than grass. Docks replace grass production directly, and consequently energy production per hectare. Docks also usually, but not always, reduce total herbage dry matter yields (Courtney, 1985; Whytock, Davies, and Younie, 1987).

1.5 Dock control in agriculture is often for cosmetic rather than economic reasons but this is not criticised as uncontrolled dock problems do get progressively worse, and can spread to non-infested areas. In conservation sites, dock infestations can reduce botanical diversity. In hay, dock seed can be spread after passing through livestock or directly when fed outdoors. Docks growing near stores of organic manures should be controlled to prevent further contamination of the manure.

1.6 In the British Isles, 51 species are members of the Polygonaceae, belonging to 10 genera, are native or well established. Another 29 species have occurred as casual adventives ((Lousley and Kent, 1981). Besides Broad-leaved and Curled Docks, the other dock species found in Britain include:-

Clustered or Sharp Dock (*R. conglomeratus)*
Common Sorrel (*R. acetosa)*
Fiddle Dock (*R. pulcher)*
Golden dock (*R. maritimus)*
Great Water Dock (*R. hydrolapathum)* - commonly found near water.
Marsh Dock (*R. palustris)*
Monks Rhubarb (*R. alpinus)* - introduced species
Mountain Sorrel (*Oxyria digyna)*
Patience Dock (*R. patientia)* - introduced species
Rumex thyrsifolius
Scottish Dock (*R. aquaticus)* - rare and restricted to Britain
Sheeps Sorrel (*R. acetosella)*
Shore Dock (*R. rupestris)* - quite rare and restricted to Britain
Wood Dock or Red-veined Dock (*R. sanguineus)*

1.7 Measures described here will help control all of the above, but some insect species are host specific therefore care may need to be exercised in identification and application of control techniques, indeed English Nature would not wish to control some species eg Great Water Dock (Jefferson, personal communication). No single means of control is perfect and a combination of control methods is usually needed.

2.0 Dock Biology and Ecology

2.1 Common names: Broad-leaved Dock or Common Dock is known as Broad-leaf Dock in the USA. Grigson (1955) gives 16 local names used in the UK, plus three more names which fit any *Rumex* species.

2.2 Latin name: *Rumex obtusifolius* ssp. *obtusifolius*, this is the only sub-species native to the UK (Clapham, Tutin and Warburg, 1962). Other sub-species occur rarely as aliens eg ssp. *transiens* (Simonk.) Rech. F and *sylvestris* (Wallr.) Rech. particularly near London. Hybridisation occurs with *R. crispus, R. aquaticus, R. hydrolapathum, R. cristatus, R. patienia, R. sanguineus, R. pulcher, R. maritimus, R. longifolius, R. conglomeratus* and *R. palustris* (Lousley and Kent, 1981).

2.3 Common names: Curled Dock is known as Curly Leaf Dock in the USA.

2.4 Latin names: *Rumex crispus, R. elongatus* Guss. One variety recognised is var. *uliginosus* Le Gall, others include var. *littoreus* Hardy, (including var. *trigranulatus* Syme), var. *planifolius* Schur., *R. elongatus* auct. brit. non Guss. Hume L. and Cavers P.B., (1982a, 1982b, 1983a, 1983b) examined populations of *R. crispus* from a wide range of habitats, across a gradient of latitudes and climates within North America. They found that most of the variation between plants could be attributed to phenotypic (rather than genetic) plasticity and within population variation (Hume and Cavers, 1982a). Hybridisation occurs with *R. obtusifolius, R. aquaticus, R. hydrolapathum, R. cristatus, R. patienia, R. sanguineus, R. rupestris, R. ovatus* and *R. palustris* (Lousley and Kent, 1981).

2.5 Main attributes: Docks are perennial members of the *Polygonaceae* family, occurring almost anywhere - arable land, pastures, waste ground, ditches, path and field margins, dune slacks, shingle beaches, in thickets and hedgerows.

2.6 Docks prefer organically rich loamy or clay soils, rich in phosphate, and above all nitrogenous (Peel and Hopkins, 1980). Docks are indicators of such soils. (Hanff, 1983). Strangely Peel and Hopkins (1980) and the GRI-ADAS National Farm Study (Hopkins and Green 1979) found tendency for infestations to be more common on low potash soils. This is surprising as clay soils are often naturally high in potash and organic manures are also high in potash. Curled Dock is usually absent from shady places, acid moorland or heath.

2.7 Cavers and Harper (1964) are said to give the most complete description of each species (Foster, 1989); although 'Docks and Knotweeds of the British Isles', BSBI Handbook No.3 by Lousley and Kent 1981 is an authoritative work, giving many relevant references.

2.8 Broad-leaved Dock is an erect plant, leaves growing in rosettes from crown buds from a long, strong tapering tap-root, which is often branched. It produces a stout flowering stem commonly 30-90 cm tall; but up to 150 cm.

2.9 Curled Dock is also an erect plant which produces a stout stem usually 30-90 cm tall, but up to 150 cm. It has a long tapering tap-root, which is less branched than Broad-leaved Dock. Leaves have a more distinctly wavy margin, and as one might expect, are narrower than the Broad-leaved Dock. Clapham, Tutin and Warburg (1962) and Lousley and Kent (1981) claim that Curled Dock is the commonest British dock species.

2.10 Flowering

R. obtusifolius seldom flowers until the second year (needing vernalisation of a sufficiently large rosette?) but will continue to flower for 5 years or more if allowed to do so (Anon, 1970). However, according to Whytock, Davies and Younie (1987) Broad-leaved Docks can set seed in their seedling year. Foster (1989) from his reading suggests this only occurs occasionally.

2.11 *R. crispus* often flowers in its first year, and then normally dies (Anon, 1970). *R. crispus* is capable of producing a flowering stem 9 weeks after emergence and may behave as an annual or biennial under arable conditions including grass seed crops (Anon, 1970). Foster (1989), from his reading, presumably of Cavers and Harper (1964), does not distinguish between the two species regarding timing of seed set, stating this is not usually until the second year and that the tendency for plants to die after seeding is merely more marked in *R. crispus*.

2.12 Flowers can appear from late June and continue to the onset of winter if earlier growth has been checked by mowing or grazing. Shooting of the stem occurs roughly a month before flowering. When in flower the panicle has a reddish-brown tinge. Seeds are formed soon after the start of flowering and are viable from an early stage of development. The fruit often remains in clusters on the stems.

2.13 Curled Dock flowering stems appear earlier than those of Broad-leaved Dock in May and flowering begins in early June and continues to October.

2.14 Foster (1989) claims from his reading that a large dock plant can produce seed twice in one season, the first flowers appearing in May-June (maybe later) with a second flowering occurring in August-September. This second flowering occurs less often with *R.crispus* than with *R. obtusifolius.*

2.15 The flowers have no nectar and are mainly wind pollinated. Most plants are highly self-fertile although variation exists.

2.16 Seeds - Dispersal

All dock species are profuse seeders and the seeds retain their viability for many years, especially when buried; they germinate and establish vigorously under suitable conditions of light and space. With their corky tubercle surrounding the perianth segments and ability to remain dormant in the absence of light and aeration, they are well adapted to spread by water, (Gill and Vear, 1958) slurry or farm yard manure. Seeds may occur as contaminants in agricultural seeds but the problem is less today than in the past. Potential to spread in hay means that restriction of hay feeding on conservation sites should continue. Similarly where organic manures are allowed to be spread, the potential for docks to be introduced or encouraged must be recognised. Spread can also occur in straw, or by farm implements or livestock, especially if moved from infested to non-infested pastures. Spines on the fruits of *R. obtusifolius* facilitate livestock dispersal. Prevention of seeding of all dock species wherever they occur, is clearly the best means of preventing spread. This is particularly true for Curled Dock, where plants only persist for a few years if regularly prevented from ripening seed (Anon, 1970; Anon, 1987).

2.17 Large plants of Broad-leaved Dock are said to be capable of producing in excess of 60,000 seeds of which 80% may be viable (Anon, 1970). Hanff (1983) suggests an average 7000 seeds are produced per plant, and Foster (1989) suggests a minimum of less than 100.

2.18 Over 40,000 seeds per plant has been recorded from *R. crispus* (Anon, 1970). Seeds of hybrids are generally of low viability, usually less than 1% - Foster (1989), so they are restricted to patches between clumps of parent species. The hybrids probably have greater powers of vegetative regrowth than either of the parent species (Foster, 1989).

2.19 Foster (1989) states that the fruit achieves more than 75% of its mature weight within 3-4 weeks of the flower opening. Stalks that are cut down just after flowering produce viable but very light seed. The fruits can be blown considerable distances by the wind. Nonetheless many fruits simply fall to the ground and germinate in clusters around the parent plant.

2.20 Obvious seeding of dock causes offence to many neighbours of infested land, and it is listed as an Injurious Weed under the Weeds Act, 1959. Measures to prevent the spread of this species (as with all others covered by this report) may be required if there is a threat to agricultural production. Complaints are addressed to one of the Executive Officers (Field) at the local Regional Service Centre of the Ministry of Agriculture, Fisheries and Food (MAFF). These officers can supply a leaflet on control of all Injurious Weeds to interested parties, addresses are given at the back of this report. Set-aside land is not exempt from the provision of the Weeds Act 1959.

2.21 Where there is a threat to agricultural land or production from injurious weeds on roadside verges or railways, the highway authority or British Rail should be contacted. On Ministry of Defence land, either the Defence Lands Service or the occupier, if different, may be subject to remedial action. On common land, the occupier is normally responsible for control but if the land is unoccupied the person who has a right to occupy may be subject to action.

2.22 When Agriculture Departments are notified of Injurious Weeds on NNRs or SSSIs English Nature, Scottish Natural Heritage or the Countryside Council for Wales will be contacted. On local authority reserves the local authority will be contacted. Appropriate action will then be determined as a result of consultation. Spread to domestic gardens, horse paddocks and allotments is primarily a matter for local authority bye-laws or Public Health Acts. Occupiers of such land have recourse to civil action.

2.23 <u>Seed dormancy and longevity</u>

Very variable dormancy has been recorded, variation even occurring between seeds from different parts of the same plant. Dormancy may last for several months - particularly if unripe, but some seeds are capable of germination soon after falling from their parent. Dock seeds are capable of living for many years buried in the soil, high orders of viability being recorded in seeds buried for 30-40 years. Consequently some seeds when buried at 56 or 107 cm may be viable for over 40 years (Toole, 1946) and up to 80 years (Whytock, Davies and Younie, 1987). Variable germination may actually help spread. Cavers (1974) observed that greater variability or intermittency in seed germination often improves a weed population's success, since each time that a stand of seedlings or older plants is destroyed, a new stand will soon arise from the seed bank to take its place. Docks are mainly spread from seed and docks provided the example species on which Cavers based his observation.

2.24 <u>Germination and Establishment</u>

Seedlings of both species most commonly "flush" in March/April or September/October. The seed is light sensitive and normally only germinates at or near the soil surface. Seed buried deeper than 10 cm (4") rarely germinates (Anon, 1970). Seedlings are not very competitive with grass until the tap root begins to swell or until they produce leaves capable of shading the surrounding sward.

2.25 Germination of docks has been reviewed by Roberts and Totterell (1981). From this work, it is surmised that winter disturbance of the soil does not stimulate dock seeds to germinate because day time temperatures rarely reach 15°C, germination is suppressed by a leaf canopy which suppresses the amount of red light reaching the seed, yet increases the proportion of far red light, as well as reducing the diurnal fluctuation in temperature compared with an open bare surface (Foster, 1989). More recent work by Jeangros and Nösberger (1992) showed pre-germinated dock seedlings were less sensitive than perennial ryegrass to reductions in light intensity. They concluded establishment of *R. obtusifolius* seedlings cannot be prevented by the shade of an established sward. This indicates why prevention of poaching and sward damage is so important in grassland to reduce germination, because once it occurs, the docks can compete more effectively than even a vigorous species like perennial ryegrass.

2.26 Regeneration from Root Fragments

Cultivation or stock trampling may break off root or stem fragments which are capable of producing new plants. Some experimenters have found that any part of the root can produce new plants whilst others have found it is only the top 10 cm (4") which has this capability. It seems the time of year when fragmentation occurs is important. Regeneration is more likely from deeper root portions when fragmentation occurs in the spring compared with other times of the year (Anon, 1970).

2.27 When whole root stocks are buried by cultivation they are capable of regeneration even if buried by more than 40 cm of soil (Anon, 1970).

3.0 Incidence of Broad-leaved and Curled Docks

3.1 Opinions differ as to the commonest British dock species; however Clapham, Tutin and Warburg (1962) and Louseley and Dent (1981) claim that Curled Dock (Rumex crispus) is the most common. The broad leaved dock (*Rumex obtusifolius*) is stated (Anon, 1970) as the commonest dock of grassland, followed by the Curled Dock (*Rumex crispus*). Less fertile, not sterile, hybrids of the two can sometimes be found (Anon, 1970). In arable situations *R. crispus* is more commonly found to be troublesome and a maritime form of this species exists in coastal situations (Anon, 1970).

3.2 In grassland, docks are mainly associated with frequently cut fields - especially multi-cut silage. Of those fields containing docks the highest incidence is associated with dairy cattle (Hopkins, Matkin and Peel, 1985), this is probably due to the following main factors - dung pats and slurry provide opportunities for seed germination, heavy stock and frequent movement also commonly cause poaching and dairying is more common in the wetter west of Britain making poaching more likely. Silage and high levels of fertiliser are more commonly used on dairy farms compared with those farms with non-dairy livestock.

3.3 Docks are associated with higher levels of fertiliser nitrogen or areas of high fertility. The latter commonly receive high organic manure applications, particularly slurry, (Courtney, 1973; Haggar, 1980; Hopkins, 1982; Hopkins *et al.*, 1985). It is said that nitrogen applied to grass conservation fields results in more open swards, which allows docks to establish (Hance and Holly, 1990). Courtney (1983) reports that advisory staff in Northern Ireland suggest that dock control with herbicides is less effective in a herbage conservation system. He says that this may simply reflect the higher initial levels present, or perhaps that a system which favours dock development may also favour dock recovery from treatment.

Hopkins and Peel (1979) showed docks grow in cutting fields in association with *Poa trivialis, Lolium* spp. and *Dactylis glomerata*. Generally the sward is less than 20 years old (Hopkins *et al.*, 1985). Intensification of grassland management is suggested as producing conditions more favourable to docks (Anon, 1970) so unlike many other weeds which can be removed by intensification docks are more likely to be a problem in such situations.

3.4 Survey information needs to be interpreted with care; because experimental work quoted later (Courtney, 1985), showed ryegrass to be more responsive to nitrogen than docks, in terms of dry matter production. High nitrogen use is almost always linked to intensive management to utilise the herbage produced.

Heavy application of organic manures is also generally linked to intensive production. Intensive management is likely to increase damage to swards (not generally a problem in experimental plots just looking at nitrogen and cutting interactions). Thus it may be said that trampling, vehicle traffic and poaching of swards is what is being indicated by the farm surveys rather than an association with nitrogen. Surveys have only quantified intensity of utilisation by recording nitrogen use, rather than measuring sward damage directly.

3.5 In the past (1970-78) it was reckoned that between 8-13% of grassland in England and Wales was infested or partially infested with docks (Hopkins and Peel, 1985) as a result of surveys by Forbes *et al.* (1980) and Green (1982). Additionally, in eastern Scotland, Swift *et al.* (1983) found 5% of pastures infested with docks in 1976-78 and they were recorded as being a problem on 11% of the grassland surveyed in N.Ireland in 1969 (Courtney, 1973). In south west England in 1983 a higher incidence of 18% of swards were partially (12% of swards) or highly infested (6% of swards) with docks.

3.6 Perrott (1987) reported 652,000 ha out of a total of 6.29 million ha (10.3%) of grassland in Great Britain to be infested with docks in 1982; but only 9% or 490,000 ha of the total area of 5.47 million ha in 1986. As is common with such surveys individual species are not reported.

3.7 Survey data from eight English Nature managers for this report showed that docks are a common weed problem on English Natures' NNRs. Appendix 1 gives the names of the managers consulted and the sites discussed with each, to identify the locations and scale of the weed problems covered by this report. The identities of certain sites are deliberately suppressed, to conform with the managers' wishes.

3.8 **Cautionary note:** The survey should not be taken as representative of all English Nature reserves, nor the results extrapolated beyond the sites concerned. An unrepresentative selection of reserves may have been made; because only managers who were regarded as having problems were surveyed and then they were asked to identify their problems. The results can only indicate the relative scale of the weed problems as perceived by the managers covered by this survey in this report.

3.9 Of 29 sites discussed, which included some SSSIs, 9 sites were reported as having problems with docks - of these 6 were reported as having widespread problems. At three sites localised problems exist. On one of these sites at Ashford Hill in Oxfordshire the main problem was Broad-leaved Dock.

3.10 Of the 6 sites with a widespread problem with docks, at one site i.e. North Meadow NNR the main problem was with Curled Dock, on the rest of the 6 sites the dock species present were not identified. On two of the sites with localised problems the main species was *R. obtusifolius*.

4.0 Effect of Environmental Factors

4.1 <u>Environmental factors - which predispose an area to infestation</u>

Most dock infestations arise from seeds already present in the soil, which germinate when brought to the surface by treading or cultivation. Consolidation may also help establishment. Once established docks easily withstand quite severe trampling although flowering may be inhibited (Cavers and Harper, 1964).

4.2 The best means of control is to eliminate these seedling plants, although prevention of seeding and avoidance of poaching should be attempted wherever possible. Older plants are remarkably hardy and will regenerate vigorously - even from pieces of root.

4.3 Intensively used areas are more commonly infested with docks. A high nitrogen environment, combined with open swards and heavy pressure of trampling by stock are favourable to dock establishment and growth. Hence the association with cutting, and cattle grazing. The uneven or excessive use of slurry can smother grass and leave bare patches which are ideal for dock colonisation. In other crops regular soil cultivation and routine herbicide spraying tend to control these weeds at the seedling stage (Whytock, Davies and Younie, 1987).

4.4 Bare ground or gappy swards are particularly favourable to the spread of docks.

4.5 From the ADAS-GRI National Farm Study (Hopkins and Green, 1979) docks are said to be associated with soils high in phosphates and low in potash; but infestations occur across most of the pH range.

Soil indices are a measure of the availability of particular plant nutrients (P,K, Mg). 0 is the lowest possible index; 9 is the highest. In UK grassland, values are generally 3 or below. See Appendix XI to equate the soil indices given below with actual levels of nutrients available in the soil.

Infestations were recorded when at least one plant was found per 3.3 m^2; this survey found:-

1% of pastures were infested at P Index = 0,
4% at P Index = 1,
4% at P Index 2 and
5% at P Index 3 and over.

8% of swards were infested at K Index 0,
6% at K Index 1,
4% at K Index 2 and
1% at K Index 3 and over.

No swards were infested at pH 5.4 or less,
7% at pH 5.5-5.9,
4% at pH 6.0-6.4 and
4% at pH 6.5 and over.

5.0 Environmental factors which reduce or inhibit infestation

5.1 A dense well-managed sward can minimise infestation, since seedling docks are poor competitors, but if the sward is opened up docks readily germinate and establish (Whytock, Davies and Younie, 1987). According to Chancellor (1970) Curled Dock can disappear from dense grassland as the plants may die after seeding and seedlings cannot establish, despite seeds in the soil. However, prevention of flowering, by mowing or grazing may encourage perennity according to Foster (1989).

5.2 Shade, severe trampling and flooding can all inhibit the formation of flowering heads (Anon, 1970). Broad-leaved Dock will grow on most soil types but not very well on peat or where drainage is poor (Courtney, 1973).

6.0 Losses and Harmful Effects due to Docks

6.1 As with thistles and ragworts the main pressure on reserve managers to control docks comes from others not involved in botanical conservation. However, in both agriculture and on nature reserves, **grass yield** is directly proportional to the area covered by docks. Docks have been shown to reduce grass yields by up to 30% when present at densities of 10 plants m^{-2} (Anon, WRO, 1984). There is evidence that removal of Broad-leaved Dock populations giving over 20% ground cover can result in increased grass production. Dock competition with ryegrass in an intensively managed sward may not be the same as for other grasses, or even with ryegrass when no fertiliser is used. In practice excessive amounts of this weed only lead to poor quality silages (Hance and Holly, 1990).

6.2 The effect of docks on total **herbage yield** depends on:-

- the amount of ground covered by docks,
- the relative response of the docks and other sward constituents to fertiliser nitrogen, and
- the cutting or grazing regimes adopted.

6.3 Approximately 1% less perennial ryegrass dry matter is produced for each 1% of ground cover of docks (Oswald and Haggar, 1983), if cut three or four times per season, and dock infestation is high, ie above 2-5% of ground cover.

6.4 A monoculture (of 32 docks m^{-2}) Broad-leaved Dock only produced 19 to 72% of the yield of a similarly fertilised and cut perennial ryegrass sward in an experiment by Courtney (1985). The more frequently docks were cut the less annual dry matter they provided. Despite docks' association with high nitrogen regimes or high use of organic manures, docks were also shown to be less responsive to nitrogen than ryegrass (Courtney, 1985).

6.5 Herbage yield is seldom, if ever, the most important criterion on a nature reserve; but from a farmers' view-point it may be a priority, so a potential conflict with graziers or hay meadow licensees may necessitate account being taken of the presence of yield-reducing weeds. The extent to which docks reduce annual grass yield is much greater when swards are cut 3-4 times per year than is the case if they are cut more frequently (Courtney, 1985). Relatively few fields are cut more than 4 times per year; but this treatment is meant to simulate grazing. From work by Savory and Soper (1973) and Oswald and Haggar (1983) it is believed that there is generally no reduction in total herbage yield at below 5-10% ground cover of dock under simulated grazing. So it would be expected that there is no reduction in herbage yield on most nature reserves which are grazed and unfertilised and where less than 5% of ground is covered with docks. Data from Northern Ireland (Courtney and Johnston, 1978) suggests that the voluntary intake of docks is about 80% of the value for grass. In addition, digestibility is about 80% of that of grass (Courtney, 1985); but this varies over the season (Barber, 1985). Taking the average values together, it is estimated that docks are only 65% of the feeding value as grass, in a grazing situation. Hence, nature reserves are likely to produce less energy for grazing animals when docks are present.

6.6 In general, probably little harm is done by docks; but Pammel (1911) in his Manual of Poisonous Plants states that Curled Dock induces nausea, watery brown faeces, copius urination, dry spasmodic cough, and perspiration; but no record of animal death has been found. Sorrels (also *Rumex* species) are known to reduce yield and cause oxalate poisoning, particularly in sheep (Cooper and Johnson,1984).

7.0 Beneficial Effects of Docks

7.1 At certain times of the year when grass and other herbage growth may be suppressed due to drought or other factors, docks may be a useful feed and provide higher levels of certain nutrients, particularly phosphorus, potassium and magnesium. The latter may help reduce the chance of milk fever (hypomagnesaemia) in ewes and highly productive dairy cows. Many farmers recognise the benefits from grazing permanent pasture compared with leys, especially the reduced incidence of hypomagnesaemia. However, while herbs may be rich in minerals it is energy which limits production, not mineral deficiencies which can be remedied cheaply and easily from a bag. Certainly grazing animals eat docks and it is unlikely they would do so if they did not at times prefer to vary their diet, or deliberately eat docks to provide some form of supplement to their diet.

7.2 At a leafy stage docks have a high protein content but this is only moderately digestible in the rumen. Workers in Northern Ireland have noted that they are less readily eaten than grass (Courtney, 1985), although intake by dairy cows under intensive grazing was only 12% less than that of grass (Anon, P3243, 1990).

7.3 Barber (1985) quantified the nutritional value of Broad-leaved Docks at different sampling dates - see overleaf.

Table 1 Chemical analyses of Broad-leaved Docks at various stages of growth expressed as a percentage dry matter.

Date cut	Dry matter	Total Ash	Crude Protein	Crude Fibre	Ethyl Extractives ie Fat
May	16.1	10.3	25.6	-	2.9
June	19.8	7.5	16.6	15.5	2.1
July	20.0	7.4	12.0	22.6	1.6
For comparison, ryegrass:-					
May	19.6	7.8	14.8	23.6	2.3
June	20.9	7.2	12.1	26.8	2.0
July	24.9	7.3	8.7	31.2	1.6

Table 2: Digestibility, protein and energy values of Broad-leaved Dock at different stages of growth expressed on a dry matter basis

Date cut	In vitro DOMD %	Digestible Crude Protein $g\ kg^{-1}$	Metabolisable Energy $MJ\ kg^{-1}$
May	63.4	166	10.0
June	53.6	61	8.3
July	40.6	51	6.2

7.4 From the above it can be seen that the plants become much less useful to the animal in nutritional terms as the season progresses, and flowering begins.

Table 3: For comparison, ryegrass digestibility, protein and energy values at different stages of growth expressed on a dry matter basis:-

Date cut	In vitro DOMD %	Digestible Crude Protein $g\ kg^{-1}$	Metabolisable Energy $MJ\ kg^{-1}$
May	72.9	103	11.6
June	67.8	75	10.7
July	58.1	44	8.4

Table 4 Illustrates the major mineral and trace element composition of samples of Broad-leaved Docks taken in late May to early June, expressed on a dry matter basis

% Ca	% P	% Mg	% Na	Mn	mg kg^{-1} Zn	Cu	Co
0.72	0.45	0.32	0.20	34	128	9	0.15

For comparison, ryegrass:-

% Ca	% P	% Mg	% Na	Mn	mg kg^{-1} Zn	Cu	Co
0.46	0.27	0.14	0.18	200	23	8.5	1.10

7.5 Docks also have a higher level of potassium than ryegrass (Anon, P3243, 1990).

7.6 In ecological terms, docks also act as host for butterfly and moth larvae. The Small Copper butterfly (*Lycaena phlaeas*) lays its eggs singly on dock and sorrel leaves (Newman, 1977); docks only being used very occasionally (Jefferson, personal communication). The larva after hatching spends the winter in partial hibernation, lying in a groove which it has eaten in a leaf cuticle. It then pupates in late April and emerges as a butterfly in mid-May. The Large Copper (*Lycaena dispar batava*) feeds on Water Dock and this butterfly is confined to Wood Walton Fen (Newman, 1977), and the race now found is Dutch, the British race now being extinct. The Ghost Moth (*Hepialus humuli*) feeds on roots of docks as well as grasses, burdock, dead-nettle, dandelion, nettles and other species (Morris, 1985).

7.7 **Scarce and rare invertebrates are associated with all the plant species covered by this report, therefore if any doubt exists about effects on such species, please contact English Natures' invertebrate specialists in the Species Conservation Branch.** This particularly true when rarer related species may be affected by control measures or management changes. Similar consultation is recommended when management alterations are contemplated which affect the weed species covered by this report in unusual situations eg *Rumex crispus* on shingle.

8.0 Current Dock Control Techniques on National Nature Reserves (NNRs)

8.1 Many reserves do not have a current dock problem, therefore for whatever reason the current management offers control, or avoidance of infestation.

8.2 However, this is not particularly useful information where people do have dock infestations, because of either current or historical management which has resulted in dock infestation. On such sites the need is for appropriate control techniques which are suitable for the individual circumstances of these sites which have a problem.

8.3 Keith Payne (personal communication) reports that Curled Docks have been quite successfully hand-pulled at North Meadow NNR in damp but not dry soil conditions, reducing dock numbers. Curled Docks have less branched tap-roots, than Broad-leaved Docks but if pulling after dry weather was attempted the tap-roots broke off too near the surface. He says that ideally one wants to pull out the thicker 15-20 cm (6-8") at the top of tap-root. Hance and Holly (1990) suggest a more modest 10 cm (4") for Broad-leaved Docks and elsewhere they refer to 7-10 cm as the depth of the vegetatively reproductive parts but this may be an under-estimate.

8.4 The docks are pulled in May once the flower stalks have started to lengthen, so they can be pulled before flowering, and they are removed from the site. The latter will avoid seed return from any early-formed fruits.

8.5 This is on a fertile meadow next to the River Thames grazed by horses and because horse grazing, with winter flooding, helps provide too many germination sites the problem has not been eliminated. The docks tend to occur on the higher parts of the inundation area and the flooding only lasts a few days, and occurs 2 or 3 time each winter, so the docks probably are flooded for too short a period to kill the perennial tap-roots. Dredging by the river authority 20 years age has continued to provide an infested strip of docks.

8.6 At Ashford Hill the Broad-leaved Docks are present as scattered plants and are not a conservation problem, except one dense patch where the cattle are fed. However, the grazing licensee regarded the docks as a problem, so chemical control was attempted by English Nature staff. Neither weed-wiping with glyphosate nor spot-spraying with Broadshot or 2,4 D were particularly successful. The weed wiper unless dripping gave poor control, and where dripping occurred it burnt a hole in the sward, providing further dock germination sites. Using 2,4 D the the tops died but the plants regrew from the tap-root.

9.0 Cultural Control by Management

9.1 Management practices which will help to minimise the level of dock infestation are suggested by Whytock, Davies and Younie (1987) but they include some contentious suggestions. These are adequate drainage and maintaining good soil fertility. These are desirable attributes of agricultural grassland; but to suggest such attributes will minimise infestation must include the caveat - with appropriate management. Many well drained and fertile swards have uncontrolled dock populations; however, in such situations it may be easier for appropriate management to control docks than in less well drained and infertile swards.

9.2 For the farmer, but not the conservationist, the choice of high-tillering and persistent varieties may help if reseeding. Deep ploughing may offer temporary control but root fragments near the surface will regenerate. Ploughing followed by fallowing and repeated summer cultivation exhausts root nutrients and also controls seedling docks; however, unless part of a strategy on set-aside arable land this is not usually acceptable for economic reasons (Whytock, Davies and Younie, 1987). To indicate the size of the soil seed bank, Hunt and Harkness (1968) said there can be up to 5 million dock seeds per acre in the top 6 inches (15 cm), equivalent to 12.5 million seeds per hectare, compared with grass seeds sown at one million seeds per acre (2.5 million per hectare).

9.3 On agricultural holdings, a combination of cultural and chemical techniques can be used to reduce infestations of mature docks. Repeated discing or rotary cultivation breaks up the tap-roots and less vigorous growth is then more readily controlled by herbicides (Whytock, Davies and Younie, 1987).

9.4 Cultural Control by Management - Effect of Grazing

Aim to prevent winter-kill of grass by grazing to 5 cm sward height or less in the autumn, so reducing the risk of frost-damage, which would allow docks to compete more vigorously or establish. Avoid poaching, allow minimal grazing during the winter, and use a "sacrifice" area for grazing when damage is inevitable. These are recommended by Whytock, Davies and Younie (1987). Sheep are said to discourage dock infestation whilst horses with their selective grazing habits tend to encourage infestation (Foster, 1989).

9.5 Because dock infestations tend to be linked to sward damage rather than over-grazing *per se*, the comments in Part I covering thistles and target sward heights have been omitted here. However, annual stocking limits and other means of avoiding poaching or sward damage may help reduce the number of potential germination sites available to docks, and so the comments are still relevant to docks.

10.0 Cultural Control by Management - Effect of Cutting and Hand-weeding Techniques

10.1 Cutting prevents seeding, but does not kill dock plants; indeed Broad-leaved Docks can thrive and send up new shoots following defoliation (Whytock, Davies and Younie, 1987).

10.2 Silage-making tends to encourage dock infestation (Haggar, 1980) but will prevent the main flush of docks from seeding in early summer. The association with silage-cutting may be due to some plants producing seed heads late in the year, or prevention of flowering by mowing may encourage perennity according to Foster (1989). The ensilage process kills dock seeds claimed Whytock, Davies and Younie (1987). However, it would be more true to say dock seed stored in silage suffers reduced viability of mature seed and almost complete loss of viability of immature seed, particularly if 0.5% formic acid (a common silage additive) is used (Masuda *et al.*,1984). Late hay gives docks the ideal opportunity to seed; but earlier cuts particularly with the later flowering *R. obtusifolius* may reduce seeding.

10.3 The Board of Agriculture Leaflet No. 251 (Revised 1913) recommended that "in grassland, docks must be attacked by regular spudding (ie digging out from below the ground with a spud, which is either spade-like, with a narrow chisel shaped blade or a digging fork with 3 broad prongs), or by removal with a docking iron when the ground is soft. The operation should take place well before flowering, and all parts or plants should be burnt. It is the height of folly to throw docks into the hedgerow or ditch, for they are practically certain to live and produce seed in their new quarters. A pinch of sulphate of ammonia (a fertiliser) placed on the surface of the spudded docks will almost certainly destroy the root. The fleshy roots of docks are so deep seated it is almost impossible to remove them completely, the result being that the portion left grows again." It is important to note that this recommendation for hand control includes very selective application of chemical, to avoid regrowth undoing the work by spudding, or use of a docking iron.

10.4 "Docking" or pulling docks by hand was recommended for arable situations, where docks would generally have smaller tap roots, in soil more recently loosened by cultivation than most grassland. Short rotations, hoeing, use of pure seeds are also recommended.

11.0 Effect of Organic Manures

11.1 Applications of organic manures, particularly slurry, are associated with dock infestations. This is largely because dock seed can survive in organic manures and be spread with them. Trials have shown that dock seeds can survive long periods of immersion in slurry (UKMANI, 1974). After 16 weeks at 20°C, 10% seeds germinated, whilst after 24 weeks at 8-10°C, 26% of seeds germinated. Besson *et al.*, 1986 found aerated and fermented slurry reduced germination compared with stored unaerated slurry, and that this effect was more marked in pig than in cattle slurry.

11.2 The sward damage that occurs with spreading of organic manures and the smothering of grass provides suitable germination sites. Thus, the dormant seeds germinate on being given light, air and space, and are spread at a shallow depth suitable for germination. Vehicular traffic can also break root-stocks encouraging further vegetative spread.

11.3 The advice must then be to avoid application of organic manures derived from or applied to pastures already infested with docks, to avoid creation, or exacerbation of a dock problem, particularly if the management of the site or pasture is unlikely to contain the problem. Sheep grazing and early hay cutting regimes tend to be infrequently associated with high dock populations.

11.4 Where cutting or topping prevents seeding, particularly of Curled Dock, the application of uninfested livestock manures may be allowed, especially if the pastures have few existing dock plants. The avoidance of sward damage when spreading organic manures is essential, because even if the manure contains few seeds and the pasture is relatively free from infestation, seeds may still be blown in, or carried in by animals or vehicles, and on finding suitable germination sites cause a problem that could have been avoided. Thus, one is tempted to suggest the almost impractical ideal recommendation that spread of organic manures should be confined to relatively dry soil conditions in wetter months, to avoid the manure killing the sward and to allow the manure to be washed into the sward. Use of low ground pressure tyres, avoidance of wet patches or steep slopes, and not driving large concentrations of stock through treated pastures are all recommended. Steep slopes are more likely to cause run-off creating nutrient enriched areas and a potential threat of nitrogen contamination of surface waters through drainage. Limits on the timing of spreading and maximum amounts of organic manures to be spread should be specified, as occurs in Environmentally Sensitive Areas (ESAs) - such limits may need to be specified on an individual reserve basis, if this has not been done already. It is important that restrictions are practical, otherwise it would be better to stipulate that no use of organic manures is allowed.

12.0 Chemical Control of Docks using Herbicides

12.1 Unfertilised grass is likely to take longer to recover from animal poaching or human trampling and this increases the likelihood of dock establishment but also may favour other species with appropriate management.

12.2 On a NNR the usual aim of applying a herbicide is to control a single species invading a plant community. The aim in conventional agriculture is often the reverse, ie to control a weed community in a single crop. In neither is complete eradication necessary or cost-effective; but management control is required.

12.3 Herbicides may be cost-effective management tools in the hands of the farmer or site manager. Unlike hand treatments which can give selective control of individual species, no specific herbicide is yet available for only dock control, but one may be available from Shell Agrochemicals in 1993. If this becomes available it could damage rarer dock species,so if these are to be conserved care in application is needed. Currently the most selective dock-killer available is Starane 2 (fluroxypyr), but this can directly or by drift affect other non-target species not listed on the label (Boatman and Bain, 1992). See the label for species for which control is claimed; but other susceptible species include:-

Common Mallow (*Malva sylvestris*)
Common Toadflax (*Linaria vulgaris*)
Corn Buttercup (*Ranunculus arvensis*)
Field Bindweed (*Convolvulus arvensis*)
Hazel (*Corylus avellana*)
Hedge Bedstraw (*Galium mollugo*)
Night Flowering Catchfly (*Silene noctiflora*)
Perforate St John's Wort (*Hypericum perforatum*)
Rough Poppy (*Papaver hybridum*)
Round-leaved Fluellen (*Kickxia spuria*)
Shepherds Needle (*Scandix pecten-veneris*)
Travellers Joy (*Clematis vitalba*)
White Campion (*Silene alba*)

12.4 Other materials with varying effect on non-target species may be used through weed-wiper, knapsack sprayer or tractor mounted boom sprayer, depending on the individual circumstances. The most specific means of application are either by weed-wiper or a knapsack to give a spot-spray. However, if using the latter to kill large clumps of weeds, the large bare patch will need to be filled by sowing grass seed or preferably, seed collected from the site and this may still need careful management to prevent further weed ingress.

12.5 Herbicidal drift or accidental scorch is to be avoided wherever possible on farms or sites managed for conservation, particularly if it reduces sward competition with docks. The drift of herbicides has been studied (Davis *et al.*, 1992; Elliot and Wilson, 1983.) The side-effects of herbicides, which have or may be used, on conservation sites will never be given as much publicity as their effect on the main target species. Agrochemical companies and others have such data but it can be difficult to obtain. Such information or references available to the author at the time of writing is included where relevant.

12.6 There are published guidelines and legislation governing the use of herbicides on farms (eg Code of Good Agricultural Practice, Food and Environmental Protection Act 1985, Wildlife and Countryside Act, 1981) and on conservation sites (Cooke, 1986; Cooke, 1990; English Nature Pollution News No.2). The last reference includes the following guidelines:-

a) Non-chemical methods are preferred whenever possible;

b) A herbicide should not be used to deal with the symptom of a problem without the ultimate cause being tackled if this is feasible;

c) Only a few listed herbicides (Cooke, 1986; English Nature Circular - Cooke 4.12.91) may be used without prior consultation with the Science Directorate of English Nature.

12.7 The list in Cooke (1986) only included two herbicides which would have any significant effect on docks - asulam, and glyphosate.

12.8 Asulam is a translocated herbicide available for dock control. However, control is often disappointing, and takes 3-6 weeks, and is therefore recommended when active growth is occurring before flowering (Cooke, 1986). If flowering has begun viable seed may be produced before the herbicide takes effect. Rates of 1.1-1.7 kg per hectare are recommended for dock control when overall spraying. If control is incomplete, spot spraying with a solution of 2.4 to 4.8 grammes per litre of spray is recommended (Cooke, 1986). Asulam is not approved through rope-wick applicators but has been tried experimentally against bracken but not docks.

12.9 Glyphosate is not as effective on broad-leaved species as on grasses. As with all herbicides sufficient material needs to be applied for control. Specific reference is made by Cooke to use of glyphosate for dock control.

12.10 However, dock root systems constantly produce new aerial shoots so any reduction in infestation is usually temporary. Particularly where weeds are dense, or travelling speed is too high, one pass of a weed-wiper is unlikely to transfer sufficient chemical.

12.11 The height of application using a rope wick is critical. Photosynthetic assimilates, and thus phloem-mobile herbicides like glyphosate, move predominantly towards the stem apex from leaves growing on the upper part of the plant but to the roots from basal leaves. As glyphosate is mainly applied on to the upper leaves of the plant, translocation to the roots could be less than if lower leaves were treated.

12.12 A herbicide added to the list by Cooke (1987) is 'Broadshot' (dicamba, triclopyr and 2,4 D). This has good activity against docks, but given its broad spectrum (hence the name) weed-wiper application would generally be required. A 5 l/ha spray is reported as giving 97% control (Bird, 1985) and weed-wiper applications using a 1:3 dilution in 2 passes checked docks and gave up to 90% control when assessed 3 months later.

12.13 Dicamba as 'Tracker' applied through a weed-wiper would control docks and can be used without specific permission from English Natures' Science Directorate (Cooke, 1989).

12.14 2,4 D and 'Grazon 90' (clopyralid + triclopyr) is believed to have been used on various English Nature sites as a knapsack spot spray (Malcolm Whitmore, personal communication); but this should not be used without permission from the Science Directorate.

12.15 There are many other products which could be considered for dock control on agricultural holdings or conservation sites - these are given at Appendix III and V with their spectrum of activity and timing. **None should be used without permission from the Science Directorate, and some are particularly inappropriate on botanically-rich sites, especially through a tractor mounted hydraulic boom sprayer.** A farmer may use the broad-spectrum products through a boom sprayer and will principally choose a material which controls the species required in the relevant crop at the time required at the least cost with minimum management difficulty. Farmers do prefer basic, relatively inexpensive hormone type herbicides for dock and general weed control in grassland, arguing that it is difficult to justify use of more expensive materials. An exception occurs where clover is an important sward constituent. In relation to justifying cost of weed control, the benefits may last over a period of years and so make justification easier from an agronomic view-point. Another factor which needs consideration by both farmers and site managers is their responsibilities under the Control of Substances Hazardous to Health (COSHH) and the need to select the least hazardous product which is suitable.

12.16 A herbicide product label should always be read, prior to purchase, or use, and the user should comply with the statutory conditions of use. The label rates given should not be exceeded but lower rates may be appropriate. Off-label uses may be available to an individual farmer or site manager through the long term off-label arrangements which apply until 1 January 1994 (Anon, 1992, Ivens, 1992).

13.0 Factors which influence control

13.1 The timing and period of herbicide applications has been studied but opinions still vary on optimum timing for different treatments.

13.2 Obviously, to pull docks it is necessary that they have produced a flowering stem.

13.3 Courtney (1973) suggests good control of docks using herbicides can be obtained at any time between May and September, provided that the docks have a large leaf area and are not in flower. He adds that control is unlikely to be 100% and a further routine herbicide application approximately every other year will continue to be necessary to prevent recovery of the population from established plants and from seedlings. Despite further herbicide molecules being available since this statement, it is still true that no herbicide on the market consistently gives 100% control. Fluroxypyr as an overall spray is possibly the most consistent currently available dock-killer and it has given higher levels of control when applied in July or August than when applied in May (Standell, 1987; Thompson, 1987). Up to 94% control has been recorded with 400g ai ha^{-1}, when assessed one year after spraying (Thompson, 1987). The soil type, climate, phenotype and genetic variation can all influence the response to control measures (Hume and Cavers 1982b). For example, plants on sands may be small and spreading and so less suitable for rope-wick herbicide treatments than taller, more upright plants on silts and clays. Plants from dry regions have highly overlapping suppressed branches and relatively small stomata; attributes that can affect herbicide uptake, growth rate and hence control, achieved. Docks from dry, warm areas produce much larger achenes (seeds) (Hume and Cavers, 1983a) and these have difering dormancy and seedling characters. Hume and Cavers, (1983ab) found that *R. crispus* populations differ in response to photoperiod, vernalisation, and life span. Thus some populations were annuals, or short-lived perennials while in other populations all the plants needed a winter experience before flowering could occur. Such differences have obvious implications for control, and help explain why these are such common and "successful" weeds.

13.4 Courtney and Johnston (1974) studied time of herbicide application in relation to defoliation, using asulam at 1.12 kg ae ha^{-1}, mecoprop at 3.57 kg ai ha^{-1} and a dicamba + mecoprop mix, 0.56 + 1.12 kg ai ha^{-1}. All three herbicides gave similar levels of dock control. Three herbicide timings were studied - May, August and a September/ October and three intervals between spraying and subsequent cutting, in their effect on dock regrowth the following year. They found that the August spray timing was generally most effective, reducing dock dry matter production the following season to only 4.1% of the untreated control. However, the dicamba + mecoprop mix also gave this level of control from the May timing.

13.5 The spray to defoliation intervals for particular herbicides had a marked effect on regrowth. For example, mecoprop sprayed in May followed by 28 days until cutting gave relatively poor control (40%) as measured by dock dry matter as a percentage of the unsprayed control the following year. Asulam and the mecoprop + dicamba mix at at a similar timing and cutting interval gave 60% control; yet a 14 day interval improved control dramatically to 80% or over for all three products. Presumably this shorter interval resulted in the roots having less time to build up reserves, and consequently reduced vigour (and survival?) the following season.

13.6 The optimum timing and cutting interval for dock control with each product was as follows:-

asulam - optimum spray timing was August with a 7 day spray-cutting interval - which resulted in virtually no regrowth the following year. Indeed asulam consistently produced lower dock regrowth if it was followed 7 days later by a cut no matter what the spray timing.

mecoprop - optimum spray timing was August with a 14 day spray-cutting interval; which was equivalent to a September spray with a 28 day spray-cutting interval - resulting in 3% dock dry matter as percentage of untreated in the following year.

dicamba + mecoprop - optimum spray timing was August with a 7 day spray-cutting interval, which was equivalent to a September spray and 28 day spray-cutting interval - resulting in 3% dock dry matter as percentage of untreated in the following year.

13.7 These results show that herbicide effects may be enhanced by cutting at an appropriate interval after spraying, the interval depending on the time of year and the product applied. For dock control, with asulam the consistent effect of cutting 7 days later is easy to remember.

13.8 However, life is not quite so simple because with asulam the optimum defoliation interval for maximum total herbage seemed to show a non-significant trend to get shorter as the season progressed. Total herbage production was highest from a 28 day interval in May, 14 days in August and 7 days in September. The highest total yield from an asulam treatment was the August 14 day interval but this resulted in a dock regrowth of 35% in the year following treatment compared with an untreated control.

13.9 The best combinations of dock control and maximum total herbage production with herbicide and defoliation interval were mecoprop sprayed in August with a 7 day spray-cut interval and asulam sprayed in September and cut 7 days later.

13.10 The above results indicate that herbicide use may need supplementation with cutting for best effect. However, cutting in August or September after herbicide use is not likely to be popular on many nature reserves. However, if a hay cut is taken then herbicide is used after a 4 week regrowth a late second hay cut may be possible.

13.11 According to Fryer and Makepeace (1978) - spraying of MCPA or asulam should take place when the plant is growing strongly, and before flowering, or after defoliation. Mecoprop should be applied after cutting, when flowering but before seeding in July, the spray being applied 14 days after cutting. Dicamba should be applied pre-seed setting, when active growth is occurring. Benazolin + MCPA + 2,4 DB should be applied when the stem has elongated just prior to flowering, at any time in the season when the docks are actively growing. However, the results of Courtney and Johnston (1974) given earlier in this section of the report are worth studying, and seem to contradict some the above recommendations, for asulam and dicamba. Good results reported by them from August applications of asulam, mecoprop and dicamba + mecoprop and those of others using triclopyr and fluroxypyr (Hill and Hood, 1982; Standell, 1987) suggest August and other timings may be ideal.

14.0 Choice of Herbicide

14.1 Herbicides are approved for use in a particular crop or situation. They mainly vary in their spectrum, efficacy, timing, hazard to health, cost, availability and ease of application. Decisions on product choice may be influenced by other factors - past experience, available knowledge, and the alternatives available. With certain products there is a need to exclude stock from treated pastures, which can also occur when herbicides are used on pastures containing poisonous weeds like ragwort.

14.2 Conservation site managers may need to consider constraints such a need for permission to use certain products. Herbicides for dock control is given at Appendix III. Particular attention should be given to the use of clover safe herbicides if clover is to be preserved in a sward.

15.0 Herbicidal Control Strategy for Docks - See also Appendix III

15.1 Spraying can reduce infestations by altering the competitive balance in favour of the grasses which can then cover the area more densely. The main effect of dock control is increasing the grass content of a sward.

15.2 Mature docks, particularly Broad-leaved Docks are generally resistant to many herbicides.

15.3 Dock shoots are readily killed by growth regulator herbicides but due to the ability to regenerate from root-stocks and new seed germinations the long term effect is variable. Products approved for use in established grassland with activity against docks include:-

asulam (Asulox) - clover safe; but Yorkshire Fog, Smooth Meadow-grass, Cocksfoot and Bents (*Agrostis* spp) are susceptible
asulam + mecoprop + MCPA (not currently marketed)
benazolin + 2,4 DB + MCPA (Legumex Extra, Setter 33)
clopyralid + triclopyr (Grazon 90)
clopyralid + mecoprop (not currently marketed)
2,4 D (eg BASF 2,4 D Ester, Campbells Destox, Campbell Bioweed)
dicamba (Tracker) - may not be readily available
dicamba + MCPA + mecoprop (eg Campbells Grassland Herbicide, Docklene, Hysward)
dicamba + mecoprop (eg Di-Farmon, Farmon Condox, Hygrass)
dicamba + mecoprop + triclopyr (Fettel)
dicamba + triclopyr + 2,4 D (Broadshot)
fluroxypyr (Starane 2)
glyphosate (Roundup - approved in grassland for use either prior to sward destruction or as a selective application through a weed-wiper; but not approved in grassland through a knapsack sprayer - this approval relates to forestry, non-crop areas, aquatic situations and top-fruit orchards)
MCPA (eg BASF MCPA Amine 50, Phenoxylene)
MCPA + MCPB (eg MSS MCPB + MCPA, Trifolex-tra, Tropotox-Plus)
mecoprop (= CMPP) and the mecoprop-p isomer (the latter is now more commonly available and recommended to reduce the risk of contamination of water)
triclopyr (Garlon 2)

Note: Muster is a glyphosate formulation but it is only approved for sward destruction. It is not approved for use through a weed-wiper, nor for the selective control of grassland weeds by knapsack-spraying.

15.4 Old literature includes dichlorprop but it is not currently approved for use as a 'straight' in grassland, and can only be used in some mixtures on grass seed crops and then off-label. Similarly 2,4 DB is not approved for use in grass as such and would only check docks; however, it is approved for grass undersown in cereals (where clover important- plants should have at least 1 trifoliate leaf). Maleic hydrazide as a spot treatment has been found to control docks (Anon, 1970) and is available for use in amenity grass, grass near water and in mixture with dicamba and MCPA for use in amenity grass and roadside verges. However, it has a very depressive effect on grass growth.

15.5 Williams (1984) gives susceptible ratings for both dock species with

asulam + mecoprop + MCPA; and
dicamba + mecoprop + 2,4,5-T.

Williams (1984) gives moderately susceptible ratings for
2,4 DB + 2,4 D + MCPA (Curled Docks only)
2,4,5-T +2,4 D =/- dicamba (Broad-leaved and Curled docks)

Moderately resistant ratings are given for both species with
2,3,6 TBA + dicamba + MCPA

None of the immediately above quoted by Williams are currently approved as formulated products in the UK.

15.6 Curled Docks are moderately resistant to MCPB and Broad-leaved docks are resistant in established pasture but it is approved for leys and in newly sown grass/clover leys both docks are cited as moderately susceptible. Where clover important- plants should have at least one trifoliate leaf.

15.7 Research papers (Hawton and Johnson, 1983; Soper and Hutchinson, 1976; Standell, 1987) and other references (Long and Brenchley, 1946) include comments to use of the following in established grassland, but those below are not approved for use in grassland in the UK, for good reasons and must not be used even if stocks can be found:-

dinoseb amine or acetate
2,4D + dinoseb
MCPB + asulam +MCPA
metsulfuron-methyl
sodium chlorate

15.8 Other products with activity against docks can be used in newly sown grassland:-

bentazone + cyanazine + 2,4 DB (Topshot)
bentazone + MCPA + MCPB (Acumen)
2,4 DB + MCPA
bromoxynil + ioxynil + mecoprop (for ryegrass and amenity grass only and docks only checked not controlled)

15.9 In ADAS trials on Broad-leaved Docks using weed-wipers, very poor control resulted generally when using glyphosate. Unusually better control sometimes resulted from one pass and not two passes. The latter gave no control in one trial. Variation in dock numbers was due in part to new seedling production especially in dunged and trodden areas. Actual counting of docks was difficult when multi-crowns existed. ADAS found glyphosate produced foliar symptoms but did not kill the docks. Although the symptoms were more severe when two passes were made the kill was no better due to insufficient chemical transfer, possibly due to wiper height being too high or wicks too dry through glyphosates' poor flow rate. ADAS also looked at dicamba through a weed wiper and generally obtained higher rates of kill. Dicamba has better flow characteristics than glyphosate but again poorer control of docks occurred with two passes compared to after one pass.

15.10 ADAS results 1980-3, (Anon, 1981, 1982, 1983) have been summarised in the table below:- (where dock numbers on treated plots increased nil control is recorded, where not tested a dash is given)

<u>Table 5: Dock Control by Weed-Wiping</u>- individual trial results

	Percentage Dock Control							
1 pass glyphosate Hectaspan MKI	62	19.3	59.4	1	40	-	-	-
2 pass glyphosate Hectaspan MKI	8.3	35	62.2	Nil	28	-	-	-
3 pass glyphosate Hectaspan MKI	-	-	-	Nil	-	-	-	-
1 pass glyphosate Wedge Wik	-	-	-	-	58.3	-	-	-
2 pass glyphosate Wedge Wik	-	-	-	-	44	-	-	-
1 pass dicamba Hectaspan MKI	-	15.4	-	23	55.6	87.5	14	69.1
2 pass dicamba Hectaspan MKI	-	48.2	-	-	10.4	-	44	62.6
1 pass dicamba Hectaspan MKI followed by same again 2 or 3 months later	-	-	-	-	-	-	55	67.8
1 pass dicamba Wedge Wik	-	-	-	-	-	94.4	-	-
1 pass 2,4 D Hectaspan MKI	-	-	-	14	-	-	-	-
1 pass sodium chlorate Hectaspan MKI	-	-	-	Nil	-	-	-	-
2 pass sodium chlorate Hectaspan MKI	-	-	-	Nil	-	-	-	-
1 pass picloram Hectaspan MKI	-	-	-	-	30.1	-	-	-

Table 6: Averages of ADAS Dock Control Trials using Weed-Wipers

	Mean Percentage Dock Control where tested
1 pass glyphosate Hectaspan MKI	32.7
2 pass glyphosate Hectaspan MKI	26.7
3 pass glyphosate Hectaspan MKI	Nil
1 pass glyphosate Wedge Wik	58.3
2 pass glyphosate Wedge Wik	44.0
1 pass dicamba Hectaspan MKI	44.1
2 pass dicamba Hectaspan MKI	41.3
1 pass dicamba Hectaspan MKI followed by same again 2 or 3 months later	61.4
1 pass dicamba Wedge Wik	94.4
1 pass 2,4 D Hectaspan MKI	14.0
1 pass sodium chlorate Hectaspan MKI	Nil
2 pass sodium chlorate Hectaspan MKI	Nil
1 pass picloram Hectaspan MKI	30.1

15.11 One can see variation in performance between machines, herbicides, sites and years. Hectaspan before they went into liquidation produced a Mark II machine which did perform better than the Mark I on thistles, but was never tested by ADAS on docks.

15.12 Unlike with thistles two passes of a weed wiper did not generally give superior control of docks compared with one pass, except with the dicamba treatments which were more effective when separated by two or three months growth. Oswald (1978 and 1980) found satisfactory control of docks even when only one leaf was treated by hand-painting with glyphosate and an alginate to stick the product on the plant.

15.13 The Weed Research Organisation (now defunct) played an important role in developing the technique of smearing translocated herbicides (eg glyphosate) on tall growing perennial weeds, including docks (Oswald, 1978 and 1980), prior to the development of the weed-wipers which exploited weed-sward height differentials. Useful control of dock plant numbers - up to 70% (without grass damage) has been achieved using dicamba applied through a rope wick-applicator when lowered into the grass canopy to 20 cm (8") and 85% when lowered to 10 cm (4") (Oswald 1985). Further trials with this material are recommended.

15.14 In the ADAS trials, it may be due to height of application there was no improvement in kill when two passes were made with a weed-wiper compared with where only one pass was made. When using glyphosate (or other materials when tested in the early trials) weed-wiper wicks were set at just above maximum sward height. When either dicamba was applied, giving over 60% control of docks, or when picloram was used the wicks were generally set at the average height of the grass, usually about 5-7 cm. Although in one trial the sward was 25 cm high and a wick height of 15 cm was used. Spectacular results were achieved with dicamba (87-94% kill of docks) at one site with wicks at very low height and with very high chemical usage (12 l/ha). This indicates the need for maximum transference of chemical whatever the target with a weed-wiper. However, the lack of selectivity of glyphosate precludes wicks set at low heights.

15.15 Oswald (1985) published results which showed a rope-wick applicator giving almost complete control of *R. obtusifolius*, with little regrowth for at least one year after treatment. He found with a grass canopy height of 32 cm (13") a rope wick containing dicamba in a solution of 120 g l^{-1} ae at two-thirds this height - ie 20 cm (8"), and despite slower kill than lower heights gave equivalent control of docks and creeping thistle as with the wick at the bottom of the canopy. He found even better control from wick heights of 10 cm (4"), without grass damage. 10 cm is the height the author of this report recommends for English Nature sites, as was used by John Bacon when testing the Royal Agricultural College prototype in the summer of 1992 with clopyralid on thistles. Obviously there has to be sufficient transference and height adjustments may need to be made in individual circumstances.

15.16 Hard grazing before application may be needed to minimise sward damage and reduce chemical usage. Hard grazing may also help to increase the height differential between sward and weeds to improve efficacy of rope wick applicators.

15.17 A common problem with glyphosate through a weed-wiper is poor flow through being sticky and oily. The recommended dilution is one part Roundup to one part water; but one part Roundup to two parts water is recommended for hot dry conditions (F.B.Cooper, personal communication). Surfactants used with the material in spraying have not been tried to improve flow or effect.

15.18 When spraying with the clover damaging product MCPA is to be used hard grazing prior to spraying will reduce clover leaf area and so reduce uptake (Ivens, 1978).

15.19 Triclopyr (Garlon 2) has been studied by Hill and Hood (1982) as an overall spray. Initial good control declined after a year and needed a repeat application as is common with many dock herbicides.

15.20 As with thistles long-term control is easier in arable land or newly sown leys where the roots have been broken by cultivation, than in old grassland with mature docks having deep tap-roots. These reduce the effectiveness of translocated herbicides.

15.21 Again as with thistles, one spray treatment seldom eradicates docks from permanent pasture - therefore if at first you do not succeed, do not give up. It is emphasised that a change in management to improve the competition from herbage plants may be essential for lasting control (Anon, L51, 1976).

16.0 Appropriate Application Technique

16.1 For useful control of an undesirable species and the minimum environmental damage there is a need for correct choice of application method and careful application of a weed-killer.

16.2 Application techniques to be considered are

a) Boom spraying - few conservation sites allow such application, but it is the most common method of applying herbicides on farms, being the least labour intensive, quickest, and cheapest method of weed control in many agricultural situations

b) Knapsack spraying for spot-treatment - appropriate where small areas require spraying but the saving in chemical cost and minimisation of usage can be out-weighed by labour costs

c) Weed-wiping - in the past poor control has often resulted from use of weed wipers; but as this report indicates, new machinery is being developed, which combined with relatively recently developed herbicides may mean greater success and usage of this technique in future.

The reasons for past poor control include too rapid a forward speed through the sward, lack of height differential, irregular terrain, and a desire to obtain effective control in one pass with herbicides which needed two passes (Anon, 1984; Garstang, 1985). One may add at too great a height resulting in insufficient weed coverage with herbicide. People often learn by trial and error! Any new machine will have to be used appropriately.

16.3 Whatever the application technique chosen, it requires concentration, skill and expertise in use.

16.4 Operators for successful herbicide usage must ensure:-

careful application,
avoidance of misses, overlaps, drift, and
use of the correct volume at the correct pressure and dilution
when necessary making adjustments and
always checking the equipment is functioning correctly

16.5 Problems occur when there is a lack of care, and this need for care puts off many site managers or their staff from use of herbicides. It cannot be ignored if the task is delegated to a contractor. Whenever communications are involved there is a need for clearly written instructions from someone who knows what is to be done to someone who will read and follow them.

16.6 This may all seem obvious but the frequency of problems and the errors that do occur are usually due to operator or communication error. Poor control from a herbicide, assuming it was initially chosen correctly, is usually due to mis-application.

16.7 Product labels may not always be sufficiently detailed for an individual user's requirement. Nature reserve managers will frequently be disappointed in the amount of information on product labels which is relevant to their needs.

16.8 Garstang (1985) states that the techniques currently available for the control of perennial weeds do lend themselves to development of control strategies, given the likely insufficient control from single product applications.

16.9 Label recommendations are complex enough as it is, and it would seem unlikely that it will ever be possible to encapsulate such strategies for perennial weed control on product labels.

17.0 Biological Control of Docks - Invertebrate

17.1 Cavers and Harper (1964) provide a list of predators and parasites associated with Broad-leaved and Curled Docks.

17.2 The native beetle *Gastrophysa viridula* has been the subject of a number of papers (Bentley and Whittaker, 1979; Whittaker *et al.*, 1989, Smith and Whittaker, 1980 a and b; Bentley *et al.*, 1980 and Whittaker, 1982). This beetle needs another agent eg flooding (Whittaker, 1982), to complement its activity to eradicate docks. This is hardly surprising, no organism would survive if it eradicated its food source. Whittaker's papers include studies on the effects of phytophagous invertebrates on dock populations. If the reader wishes to know which phytophagous invertebrates are associated with particular plant species the Institute of Terrestrial Ecology at Monks Wood has a phytophagous insects databank.

17.3 *Aphis rumis* - a sap sucking aphid feeds on dock; but it is not known if it is a virus vector. The feeding of this species will not control docks, but they are host specific.

17.4 The larva of a fly *Pegomya nigritarsis* (Dock Miner) is found in Britain and inhabits docks, and other *Polygonum* species.

17.5 The author has attempted to extrapolate information which may be relevant to British docks from a paper on invertebrates found on docks in Japan written by Miyazaki (1978). Japanese docks act as hosts for two members of the *Coleoptera* family - these are *Galerucella vittaticollis* and *Hypera rumicis*. These Japanese species are not listed in MAFF Technical Bulletin No. 6 as of economic importance in Britain but several similar species are listed.

17.6 Hopkins studied weevil larvae of the *Apion* spp which live within dock leaf stalks ((1978 and 1980); but they are parasitised by *Hymenoptera* (Hopkins, 1984).

17.7 In short, no invertebrate has yet been found to give effective control of docks.

17.8 Biological Control of Docks - Fungal Pathogens

Sedlar *et al* (1983) lists 55 species of fungi (excluding rusts) associated with these same docks, 17 of which have potential for biological control. In addition, 3 of the 8 rusts associated with docks have potential for biological control (Sedlar *et al*, 1983). This gives a total of 20 which are said to have potential as biological control agents (Greaves, 1986)

17.9 Particular interest has been shown in the rust fungus *Uromyces rumicis* (Schubiger *et al.*, 1986), *Phoma* species, *Cercospora* species (Greaves, 1986) and in *Colletotrichum* spp.(Glasgow and Templeton, 1983).

17.10 *Uromyces rumicis* caused severe damage to Curled Docks and lesser but significant damage to Broad-leaved Docks (Schubiger *et al.*, 1986). Inman (1971) found only 43% of the rusted *R.crispus* plants which had suffered severe foliar damage after infection showed any evidence of regrowth the following season, compared with 94% of healthy (fungicide treated) plants.

17.11 In the USA 'Collego' a formulation of *Colletotrichum gleosporoides* f. sp. aeschynomene is sold to control Northern Joint Vetch (*Aeschynomene virginica*) in rice and soya bean, (Greaves, 1986) but it not known whether it would have any activity on docks nor whether it has been tested on docks.

17.12 Biological Control of Docks - Grazing by wild mammals and birds

Grazing mammals probably eat dock leaves as do domestic stock; but control using them is impractical. Similarly dock seeds are similar and related to Buckwheat, so could provide bird food but it is not known if they do so.

17.13 Biological Control of Docks - Integrated Control Measures

Schubiger *et al.* (1986) suggested grazing by the beetle *Gastrophysa viridula* could cause injury to docks enhancing the effect of *Uromyces rumicis*.

18.0 Ideas for Further Research

18.1 It is recommended that there is liaison with research workers and conservation bodies in New Zealand, Australia, Canada, Holland and the United States, who often have similar problems. It is suggested that continued monitoring of the literature on a regular basis is necessary and that this will enable experimentation on new control techniques to begin in Britain as early as possible.

18.2 A trials programme could be devised to follow up some of the following ideas:-

a) Some experimenters have found that any part of the root of *R. obtusifolius* can produce new plants whilst others have found it is only the top 10 cm (4") which has this capability. It seems the time of year when fragmentation occurs is important. Regeneration is more likely from deeper root portions when fragmentation occurs in the spring compared with other times of the year (Anon, 1970). Clarification of vegetative capacity may be useful.

Curled Docks have less branched tap-roots than Broad-leaved Docks, but during dry weather if pulling is attempted the tap-roots tend break off too near the surface. Keith Payne (personal communication) says that ideally one wants to pull out the thicker 15-20 cm (6-8") at the top of tap-root of Curled Dock. Hance and Holly (1990) suggest a more modest 10 cm (4") for Broad-leaved Docks and elsewhere they refer to 7-10 cm as the depth of the vegetatively reproductive parts but this may be optimistic. New research could indicate the appropriate figure, for each species, and if it varies according to season, or with the amount of carbohydrate and other reserves in the root.

b) The height of application using a rope wick is critical. Photosynthetic assimilates, and thus phloem-mobile herbicides like glyphosate, move predominantly towards the stem apex from leaves growing on the upper part of the plant but to the roots from basal leaves. As glyphosate is mainly applied on to the upper leaves, translocation could be less than if lower leaves were treated. Research may be worthwhile in determining the movement of glyphosate and other herbicides from the site of application to the roots or other above ground parts, in the field, at different plant growth stages under differing water regimes.

c) Investigation of the grazing habits of different ages, sexes and breeds of animal may be worthwhile, for example, anecdotal evidence suggests that goats eat thistles more readily than other stock, Beulah sheep are useful in controlling scrub, Swaledale ewes eat ragwort while Dorset Horns do not. and so on. This may be linked to examples of grazing management, such as folding at Martin Down NNR, mixed grazing as at Wylye Down NNR, flexible mixed grazing at Parsonage Down NNR and natural grazing, for example by rabbits and deer at Porton Down.

d) Herbicide effects may be enhanced by cutting at an appropriate interval after spraying, the interval depending on the time of year and the product applied (Courtney and Johnston, 1974). For many products the relevant interval at particular spray timings has not been identified, nor the effect on total herbage yield. This could be researched.

18.3 It is important that Injurious Weeds are looked at in context, as part of the ecosystem of each site. At a FWAG/NCC Seminar on 10 August 1983 to discuss topics relevant to understanding herb-rich chalk swards linked to Parsonage Down NNR, Roger Haggar (now at IGER Aberystwyth) suggested the following (Russell and Way, 1983):-

a) to measure the growth curves of the major indigenous grasses which are likely to differ substantially from the seasonal growth curve of a heavily fertilised, perennial ryegrass ley. The data would enable optimum stocking rates to be worked out for particular livestock systems at different sites;

b) to demonstrate the adverse effect of fertiliser nitrogen on species diversity and to see if this adverse effect could be lessened by increasing stocking density at key times of the year.

c) to measure the benefits to animal production of having a range of herbs to choose from compared with a monoculture of perennial ryegrass;

d) to monitor which plant species animals select at different times of the year;

e) to review the literature on the nutritive value of different species;

f) to devise a two paddock grazing system to more fully utilise banks at Parsonage Down where most of the relic chalk grassland lies;

g) to see if plant growth regulators can be used to maintain high species diversity, even in the absence of grazing. (This latter point maybe useful on railways and next to roads which constitute large areas on which nature conservation is possible.)

18.4 Alan Adamson (NCC) at the same seminar (Russell and Way, 1983) agreed with a) and e) above and added research was needed on nutritive values. Roger Haggar added research was needed to indicate which livestock consumed which plants, to indicate the species on which nutritional information is required, and this may vary between sites, ages and breeds of stock, and seasons.

Alan Adamson also commented that supplementary feeding at critical times of the year could increase animal production and stocking rates.

18.5 Peter Schofield (NCC) and Jack Rossiter (GRI) suggested that research could be undertaken on herb-rich swards - yield, composition, ground cover, animal consumption, forage quality, and animal production. At present English Nature does have a contract with the Department of the Environment and the Ministry of Agriculture, Fisheries and Food which is examining the effect of fertilisers on animal liveweight gain, herbage yields, sward digestibilities as the season progresses and botanical composition on the Somerset Levels (Jefferson, personal communication). This research might be repeated elsewhere. Research could also be undertaken on resting swards at different times, length of growing season and for individual species - period of production, pattern of production, ability to withstand drought, mineral balances, and palatability (Russell and Way, 1983).

18.6 Norman Moore (FWAG) suggested research on the interaction of rabbit and sheep and/or cattle grazing, on flora and fauna (Russell and Way, 1983).

18.7 Tom Bryson and Bryn Green of Wye College suggested that the effect of agistment (winter out-grazing by sheep) and burning in the absence of regular grazing should be investigated. This would cover the effects on the sward, and invertebrates. Research could be undertaken into different burning strategies and timings (Russell and Way, 1983).

18.8 Johnny Johnson (Rothamsted) questioned the effect of low levels of nitrogen, phosphate and potash, given that dung contains these nutrients, and wondered how variation in nutrient content in small areas varied, over (say) a 1 metre square grid, and could this be linked to variation in flora (Russell and Way, 1983).

18.9 Peter Schofield (NCC) asked "Does the typical pattern of grass growth match the grass and herb growth curve" at a particular site? "If not, should animal husbandry be altered to match ewe and lamb needs with sward growth? Should NCC produce grass and herb growth curves" for different species? There is a need to know how each herb species reacts to the minerals in fertiliser application, its role as a provider of trace elements particularly selenium and copper (to grazing animals), its ability to withstand competition and its productivity curve (Russell and Way, 1983).

It is suggested that NNRs and SSSIs may offer facilities for research.

18.10 Some of the above suggestions are contentious; however, they do indicate gaps in our knowledge and would help quantify effects of certain management practices, and may point the way forward to strategies for the future. Such research would be useful in managing Environmentally Sensitive Areas (ESAs) and Set-Aside land in a manner sympathetic to the environment, so link funding with various organisations including MAFF could be considered.

NB Because of the biennial nature of Curled Dock, whatever control techniques are investigated, (hand-pulling, herbicidal or biological or use of grazing animals), it is important that the degree of control which results from treatment is monitored for <u>at least</u> the two following seasons after treatment. Due to the perennial nature of Broad-leaved Dock it is important that the degree of control is monitored over <u>at least</u> three seasons.

19.0 Recommendations

19.1 These fall into two categories, those to be applied to all sites and those which may be relevant in a particular situation, or need modification to individual circumstances:-

19.2 **Avoid poaching or damage to the sward**, particularly in wet conditions when such damage is more likely to occur, from the following:-

- vehicles
- ditching/ hedging/ river bank maintenance
- frequent animal movement
- animals congregating regularly in one area for feeding (unless a deliberate 'sacrifice area' is a practical necessity)

Sheep grazing are less likely to cause poaching than cattle and tend to be infrequently associated with high dock populations.

19.3 **Avoid application of organic manures derived from or applied to pastures already infested with docks**, to avoid creation, or exacerbation of a dock problem, particularly if the management of the site or pasture is unlikely to contain the problem. Where cutting or topping prevents seeding, particularly of Curled Dock, the application of uninfested livestock manures may be allowed, especially if the pastures have few existing dock plants. The avoidance of sward damage when spreading organic manures is essential. Even if the manure contains few seeds and the pasture is relatively free from infestation, seeds may still be blown in, or carried in by animals or vehicles, and on finding suitable germination sites due to manure spreading a problem can result that could have been avoided. Thus, one is tempted to suggest the almost impractical ideal recommendation that spread of organic manures should be confined to relatively dry soil conditions in wetter months, to avoid the manure killing the sward and to allow the manure to be washed into the sward. Use of low ground pressure tyres, avoidance of wet patches or steep slopes, and not driving large concentrations of stock through manured pastures are all recommended. Steep slopes are more likely to cause run-off creating nutrient enriched areas and a potential threat of nitrogen contamination of surface waters through drainage. Limits on the timing of spreading and maximum amounts of organic manures to be spread should be specified, as occurs in Environmentally Sensitive Areas (ESA's) - such limits may need to be specified on an individual reserve basis, if this has not been done already. It is important that restrictions are practical, otherwise it would be better to stipulate that no use of organic manures is allowed.

19.4 **Prevent weed seeding and vegetative regeneration** by appropriate techniques. These include the following (which may not be relevant in every situation):-

a) hand-control techniques, such as cutting with a machete, or scythe; or spudding with a spade, or pulling - preferably plants should be removed and burnt

b) weed-wiping when maximum weed growth is occurring - this will tend to be when the rosette is sending up a flowering shoot.

Minimise the damage to the grass and other flora. If possible, use the most selective herbicide available (in the case of docks, this is fluroxypyr) although other herbicides can be considered (e.g. dicamba) particularly where a mixture of Injurious Weeds exists and use the prototype weed-wiper devised by the Royal Agricultural College at a wick-height of 10 cm, this is likely to result in the best control of the target species. A second-best alternative is to use a relatively non-selective herbicide wait until a sufficient height differential exists between the sward and the target weeds, and setting the wick height above the sward canopy. The latter technique is only really suitable on level ground.

Whatever type of herbicide is used aim to maximise chemical transfer, by driving at the correct speed, ensuring adequate flow rate, the optimum height and making two passes instead of one, not missing any infested areas, and so on.

c) top or cut infested areas with a mower, just before flowering when the plant has expended its maximum energy reserves, but the flower buds have not opened. By concentrating on the worst infestations which have little botanical diversity, it is possible to minimise damage to the sward and other flora.

d) on hay meadows, take a hay cut just before the target weeds flowers open, rather than after flowering, if possible. The seed bank will maintain most species for a varying period according to their seed dormancy and longevity; but beware of losing late flowering annuals.

Early hay cutting regimes tend to be infrequently associated with high dock populations. However, early cutting may not always be desirable from a nature conservation point of view. This may be due to the botanical need to allow annuals like Yellow Rattle (*Rhinanthus minor*) to flower and set seed, or to allow ground-nesting birds to rear their young, particularly breeding waders in wet grassland.

19.5 **Apply herbicide through a weed-wiper in August or later in the autumn**, as low as the terrain and chemical chosen allows without causing sward damage to maximise herbicide transfer to the targets.

19.6 **Use grazing livestock to perform controlled grazing** to create a denser, thicker sward where possible. Avoid under or over-grazing, or erosion on slopes. Ensure stock levels are regularly adjusted according to the amount of grazing available and the ground conditions. Provide adequate fencing, water, or supplementary feeding or move stock off vulnerable areas. If it is deliberate policy to practice intensive grazing at critical times of the year, be prepared to adopt other dock control techniques.

19.7 **Avoid burning or any other operation which results in bare ground.** If bare ground is unavoidable, have cleaned seed (free from 'weeds') ready to sow over such areas, these seeds should have been taken at different harvest dates from the reserve previously, and be prepared to control weeds during the establishment phase. Natural regeneration without over-sowing should rarely be used.

19.8 **Try to alternate cutting or grazing regimes** to intensify utilisation to try to produce a thicker sward, or use grazing with different types of livestock either by mixed grazing or use various livestock alternately. Beware of changing sward composition and losing desirable species.

19.9 **As a last resort, spot or boom spray when and where necessary, if it is practical.** Avoid herbicide drift, ensure timing of operations is ideal for the particular weed target and the chemical chosen to be used. Chose a material consistent with the site objectives from Appendices III and IV. When spraying ensure that sufficient leaf area is exposed and that docks are growing actively.

20.0 Action Calendar for Botanically-rich Grassland

This calendar sets out an ideal strategy for control of ragwort, and other weeds that exploit bare ground due to poaching or over-grazing. It is not practical to follow it in all circumstances, and it will not acceptable on all sites every year, each site needs to be managed according to its individual objectives and resources. However, the following general principles can be followed in most circumstances:-

- avoid fertiliser use,
- avoid application of stored organic manures where possible,
- avoid cutting of botanically-rich grassland before mid-July

- avoid or minimise poaching or damage to the sward, particularly in wet conditions when such damage is more likely to occur, from the following:-

  - vehicles
  - ditching/ hedging/ river bank maintenance
  - frequent animal movement
  - animals congregating regularly in one area (unless a deliberate 'sacrifice area' is a practical necessity)
  - if supplementary feeding is allowed on a particular site, the feed should either be concentrates free of viable seeds or forage be free of thistles, docks and ragworts and restricted to areas of low conservation value

The following management guidelines, will reduce the risk of weed infestation and help to prevent spread of weeds when inadvertent invasion occurs:-

January Where possible, remove any sheep which are grazing on fields which are later to be grazed, give priority to fields needed soon after lambing, (or exceptionally, where a very early silage cut is to be taken - to reduce the risk of poaching or leptospirosis) and maximise grass growth before turnout. Consider away-wintering, housing or use of a sacrifice area; if sheep out-wintering is unavoidable do not graze below 3 cm.

Do not allow cattle grazing in winter, on botanically-rich sites.

February If sheep are grazing on fields which are to be cut for hay, (or silage) remove them. Check/repair fencing and water supply. Do not allow sheep grazing on swards below 3 cm height.

March Turn out ewes with lambs on to areas which have not been grazed recently. Before cattle turnout, start measuring sward height on or soon after March 10; once a week if cold, twice a week if warm.

Aim to turnout when ground is dry and for set-stocked areas sward height is 1 cm above the height given in Table 3 (Part 1: Section 11.8 on page 19) and height is increasing. For rotationally grazed areas sward height at turnout can be up to 5 cm above the targets given in Table 3. If grass exceeds 5 cm above the target height, use an electric fence to strip graze. Subsequently target heights up to 2 cm above can be allowed before under-grazing occurs; if sward height falls close to, or below, the values given in Table 3, over-grazing is occurring. Increase or reduce stock numbers to maintain target sward height. Alternatively use an electric fence to adjust grazing area; check fences regularly, and close off parts of fields to prevent excessive damage or over-grazing. If necessary supplementary feed with concentrates, particularly if animals have recently given birth, and grass is limited ie close to the target given in Table 3 (Part 1: Section 11.8 on page 19).

If applying organic manures to cutting fields apply no later than mid-March; spread thinly to reduce contamination of fodder and minimise sward damage; if not applied now, store until after cutting. If muck-spreading or chain harrowing is allowed it should be restricted to areas of low conservation value.

April Only continue to feed sheep supplements if sward height is less than 4 cm and not increasing. Do not be afraid to graze at 7 ewes or more to the acre, to avoid grass exceeding 5 cm height, provided that grass was not over-grazed earlier, and poaching or over-grazing (ie grass height below 4 cm) can be avoided.

May Your most important month. Stocking density should be at its peak in late May. Do not allow grass height to be more than 2 cm above target, as given in Table 3 (Part 1: Section 11.8 on page 19); if necessary, stock heavily, strip graze and fence off an area for fodder conservation. Once thistles are slightly above the rest of the sward consider use of herbicide preferably applied by a weed-wiper at 10 cm above ground.

June If the sward becomes stemmy, and if this is undesirable, an area may be closed up for hay, possibly using an electric fence, or one might try to increase stock numbers. However, gradually allow sward height to increase, particularly on drought-prone sites.

Once docks are slightly above the rest of the sward consider weed-wiping. Use a weed-wiper when maximum weed growth is occurring - this will tend to be when the rosette is sending up a flowering shoot. Use the most selective herbicide available, if possible, Shell Agrochemicals hope to have approval for such a dock-killing chemical in 1993, including approval for application through a weed-wiper. Otherwise for dock control, other herbicides could be considered (e.g. dicamba) particularly where a mixture of Injurious Weeds exists, preferably applied by a weed-wiper at 10 cm above ground to minimise the damage to the grass and other flora. See Section 21.2 b) above.

July	Ensure that swards are not over-grazed, see table 3 (Part 1: Section 11.8 on page 19), add 1-2 cm to target heights if on droughty sites, and try to maintain sward density. If areas become thin, reduce grazing pressure to allow self-seeding, to thicken sward later. Cut docks just before flowering, as low as possible, and remove cut parts to minimise risk of seeding. Prevent weed seeding and vegetative regeneration by appropriate techniques - see Section 21.2. above.
August	Graze hay/big bale silage aftermaths once regrowth reaches about 2 cm above target sward heights given in Table 3 (Part 1: Section 11.8 on page 19); but if grazing area includes previously uncut areas you may graze earlier than this. If dense weed patches are controlled, consider sowing seed from other parts of the site (which is 'weed'-free) on bare or thin patches. Cut docks again if necessary as low as possible. If earlier control to prevent seeding was missed: apply a herbicide through a weed-wiper in August or later in the autumn before the first frosts, as low as the terrain and chemical chosen allows without causing sward damage to maximise herbicide transfer to the targets. This may still reduce perennial plant populations, seed viability and late seeding with all dock species and given that the primary objective of control of Broad-leaved Dock is to kill the tap root a translocated material such as glyphosate should be used. The earlier this herbicide is applied the better, to maximise effect.
September	If earlier control to prevent seeding was missed: apply a herbicide through a weed-wiper before the first frosts, as low as the terrain and chemical chosen allows without causing sward damage to maximise herbicide transfer to the targets. This may still reduce seed viability and late seeding with all thistle species and given that the primary objective of control of Broad-leaved Dock is to kill the tap root a translocated material such as glyphosate should be used. The earlier this herbicide is applied the better, to maximise effect.
October	House cattle, including calves before a reduction in their performance and serious poaching occurs. Wean spring born suckler calves prior to housing. Only allow stock to stay out if dry conditions allow minimal poaching. Avoid poaching or damage to the sward, particularly in wet conditions when such damage is more likely to occur.
November	Consider allowing sheep to graze down to 4-5 cm, after cattle housing, to remove surplus grass and minimise frost-kill. Such grazing may be an extra source of income, as well as increasing sward density; but avoid over-grazing or poaching, to minimise weed invasion sites. Continue measuring sward once a fortnight through the winter.
December	Do not allow sheep to graze below 3 cm, and do not allow poaching of the sward.

21.0 Conclusions

21.1 Understanding the biology of weed species is helpful in devising control strategies and it helps to indicate suitable timings, reasons why a particular technique succeeds or fails, and promising avenues for research into control techniques.

21.2 Control is possible if sufficient effort can be justified and sustained. However, as is often the case, prevention is better than cure, and avoidance of poaching, bare ground, under-grazing or over-grazing should be the aims of all site managers.

21.3 There is no "instant cure", often many years effort is required to clear an infestation; but if control is gradually achieved it may help produce a more "natural," stable equilibrium of the desired species in a sward.

21.4 A combination of timely husbandry operations, maybe with herbicide use, based on an understanding of the weed's growth characteristics should prevent it becoming a menace, or enable site managers to be confident of winning the war against undesirable species with the minimum cost.

22.0 **References** - <u>Part II Docks</u>

Anon (1970) Control of Docks in Grassland, ADAS Notebook Item 367, 5 pp

Anon (1976) Advisory Leaflet 46, Weed Control - Docks, ADAS/MAFF, Pinner, Middlesex, 6 pp.

Anon (1981) AG06575 Broad-leaf dock - chemical control. Comparision of rope wick and spraying technique, ADAS Research and Development Reports, Reference Book 227 (81), Grassland and Forage Crops 1980, ADAS, pp 189-190.

Anon (1982) AG06561 Grassland - control of docks by selective application of herbicides. ADAS Research and Development Reports, Reference Book 227 (82), Grassland and Forage Crops 1981, ADAS, pp 174-175.

Anon (1982) AG 06502 Broad-leaved weed control,in established swards, ADAS Research and Development Reports, Reference Book 227 (82), Grassland and Forage Crops 1981, ADAS, pp 178-179.

Anon (1983) AG 06561 Control of docks by selective application of herbicides. Research and Development Reports. Grassland Fodder Conservation and Forage Crops 1982, ADAS Agricultural Service, MAFF, pp 171-173.

Anon (1983) AG 06502 Broad-leaved weed control in established swards, Research and Development Reports. Grassland Fodder Conservation and Forage Crops 1982, ADAS Agricultural Service, MAFF, pp 174-176.

Anon (1983) AG 06711 Control of docks by selective application of herbicides. Research and Development Reports. Grassland Fodder Conservation and Forage Crops 1982, ADAS Agricultural Service, MAFF, pp 177-179

Anon (1984) Improved control of important broad-leaved weeds in permanent swards. Weed Research Organisation Tenth Report 1982-1983, pp 85-86.

Anon (1987) Docks, ADAS Pamphlet 76. HMSO MAFF Alnwick, 3 pp.

Anon (1990) Pamphlet 3243 Nutritive value of broad-leaved weeds and forage herbs in grassland, ADAS London.

Anon (1992) Weeds Act 1959, Control of injurious weeds, MAFF/WOAD, 12 pp.

Bacon, J., personal communication.

Barber, W.P.L (1985) The nutritive value of common weeds. <u>British Grassland Society Occasional Symposium</u> No. 18. Edited by Brockman, J.S. British Crop Protection Council Monograph No. 29, pp 104-111.

Bellamy, G. personal communication.

Bentley, S. and Whittaker, J.B. (1979) Effects of grazing by a chrysomelid beetle *Gastrophysa viridula* on competition between *Rumex obtusifolius* and *Rumex crispus*. <u>Journal of Ecology</u> 67, pp 79-90.

Besson, J.M, Schmitt, R, Lehmann, V and Soder, M. (1986) Differences in germination behaviour of weed seeds following treatment with slurry which has been stored, aerated or fermented for methane production. Mitteilungen für die Schweizerische Landwirtschaft 35, pp73-80, Weed Abstracts (1987) 36, 2774.

Bird, D P (1985) Optimising the control of perennial broad-leaved and woody weeds in established grassland with Broadshot using conventional and novel applicators, British Grassland Occasional Symposium No. 18, Edited by Brockman, J.S., British Crop Protection Council Monograph No. 29, pp 273-4. UK.

Board of Agriculture (1913) Leaflet 251 Common Weeds I, Docks and Sorrels (*Rumex* sp.), pp 3-5.

Boatman, N.D. and Bain, A.B. (1992) Evaluation of quinmerac and fluroxypyr against hedgerow and uncommon arable weeds. Tests of Agrochemicals and Cultivars 13, Annals of Applied Biology 120 (Supplement), pp 42-43.

Cavers (1974) Germination polymorphism in *Rumex crispus*. The effects of different storage conditions on germination responses of seeds collected from individual plants. Canadian Journal of Botany, 52, pp 575-583.

Cavers, P.B. and Harper, J.L. (1964) Biological Flora of the British Isles *Rumex obtusifolius L.* and *Rumex crispus L.* Journal of Ecology, 52, pp 737-766.

Cavers, P.B., and Harper, J.L. (1966) Germination polymorphism in *Rumex crispus* and *Rumex obtusifolius*, Journal of Ecology, 54, pp 367-382.

Chancellor, R.J. (1970) Biological background to the control of three perennial broad-leaved weeds. Proceedings 10th British Weed Control Conference, 3, pp 1114-1120.

Clapham, A.R., Tutin, T.G. Warburg, E.F. (1962) Flora of the British Isles Cambridge University Press, Cambridge, pp 556.

Cooke, A.S. (1986) The use of herbicides on nature reserves. Focus on Nature Conservation 14, Nature Conservancy Council, 80 pp.

Cooke, A.S. (1987) Regional Circular, English Nature, Peterborough, dated 15.5.87.

Cooke A.S. (1989) Regional Circular, English Nature, Peterborough, dated 23.2.89.

Cooke, A.S. (1991) The Use of Herbicide on NNRs, English Nature Circular 4.12.91

Cooke, A.S. (1992) English Nature Pollution News No. 2, English Nature, Peterborough, pp 4.

Cooper, F.B. personal communication)

Courtney, A.D. (1973) Noxious Weeds in Grassland - docks, thistles and ragwort, Agriculture in Northern Ireland 48, pp 22-25.

Courtney, A. (1983) Grassland weed problems and their control, 20th Review of Herbicide Usage 1983, pp 30-32.

Courtney, A.D. (1985) Impact and control of docks in grassland, British Grassland Society Occasional Symposium No. 18, Edited by Brockman, J.S., British Crop Protection Council Monograph No. 29, pp 120-127.

Courtney, A.D. and Johnson, R.T. (1974) Time of herbicide application for the control of docks (*Rumex obtusifolius*) in a grassland conservation system. Proceedings 12th British Weed Control Conference 1974, pp 751-760.

Courtney, A.D. and Johnson, R. (1978) A consideration of the contribution to production of *Rumex obtusifolius* in a grazing regime. Proceedings of the 1978 Crop Protection Conference - Weeds, pp 325-331.

Davies B.N.K. (Editor) *et al* (1992) Environmental Impact of Pesticide Drift, Institute of Terrestrial Ecology (National Environment Research Council) and others, Appendix 2, pp 1-19.

Dixon, T., personal communication.

Elliot, J.G. and Wilson, B.J. (1983) The influence of weather on the efficiency and safety of pesticide application. The drift of herbicides. Occasional Publication No. 3, British Crop Protection Council, 135 pp.

Forbes, J.C., Kilgour, D.W., Carnegie, H.M. (1980) Some causes of poor control of *Senecio jacobaea* and by herbicides. Proceedings 1980 British Crop Protection Conference - Weeds, pp 461-468.

Foster, L (1989) The biology and non-chemical control of dock species *Rumex obtusifolius* and *R.crispus*, Biological Agriculture and Horticulture, 1989, 6 (1), pp 11-25.

Fryer, J.D. and Makepeace, R.J. (1982 Edition) Weed Control Handbook, Volume II, - Recommendations. Issued by British Crop Protection Council, Published by Blackwell Scientific Publications, Oxford, pp 233-390

Garstang, J.R. (1985) An advisory view, British Grassland Society Occasional Symposium No. 18, Edited by Brockman, J.S., British Crop Protection Monograph No. 29, pp 234-242.

Gill, N.T. and Vear, K.C. (1958) Agricultural Botany. Gerald Duckworth and Co. Ltd, London, 636 pp.

Glasgow, R.T. and Templeton, G.E. (1983) Bioherbicidal potential of an endemic *Colletotrichium* for curly dock control. Proceedings of the Southern Weed Science Society 36th Annual Meeting 355. Arkansas University, Fayetteville. From: Weed Research Abstracts (1985) **34** 2205.

Greaves, M.P. (1985) Developments on biological control in Weeds, pests and diseases of grassland and herbage legumes, British Grassland Society Occasional Symposium No. 18,(ed. Brockman, J.S.), British Crop Protection Society Monograph No. 29, pp 150-160.

Green, J.O. (1982) A sample survey of grassland in England and Wales 1970-1972. The Grassland Research Institute, Hurley, 39 pp

Grigson, G. (1955) The Englishman's Flora, J.M. Dent and Sons Ltd, London, pp 235-236.

Haggar, R.J. (1980) Survey of the incidence of docks (*Rumex* spp.) in grassland in ten districts in the UK in 1972. ADAS Quarterly Review 39, pp 256-270.

Hance, R.J. and Holly,K. (Eds) (1990) Weed Control Handbook Volume I: Principles, Eighth Edition. Issued by British Crop Protection Council and published for them by Blackwell Scientific Publications, Oxford, pp 21-42

Hanf, M. (1983) The arable weeds of Europe with their seedlings and seeds. BASF United Kingdom Limited, Hadleigh, Suffolk, UK, 494 pp.

Hawton, D., and Johnston, I.D.G., (1983) Chemical control of weeds in temperate winter dairy pastures on the Atherton Tableland, Tropical Grasslands, 17, (3), pp 128-131, Australia.

Hinchelwood, D., personal communication.

Hill, D.M. and Hood, R.J. (1982) Triclopyr for controlling broad-leaved weeds in grassland. Proceedings British Crop Protection Conference - Weeds, 1, 369-374 pp.

Hopkins, A. (1982) An investigation of relationships between the composition of swards and their environment and management. M. Phil. Thesis, University of Reading.

Hopkins, M.J.G. (1978) Interactions between *Apion* spp. and *Rumex* spp. Thesis, Lancaster University, UK. 93 pp from Weed Abstracts (1982) 31, 2221.

Hopkins, M.J.G. (1980) Interactions between *Apion* spp. and *Polygonaceae* 2 *Apion voilaceum* and *Rumex obtusifolus*. Ecological Entomology 5, pp 241-247.

Hopkins, M.J.C. (1984) The parasite complex associated with stem boring Apion feeding on Rumex spp. Entomologists Monthly Magazine 120.

Hopkins, A., Matkin, Elizabeth A., Ellis, Julia, A. Peel, S. (1985) S.W. England Grassland Survey 1983, 1. Age, structure and sward composition of permanent and arable grassland and their relation to manageability, fertilizer and other management features. Grass and Forage Science, 40, pp 349-359.

Hopkins, A. and Green, J.O. (1979) The effect of soil fertility and drainage on sward changes, in Changes in Sward Composition and Productivity, Charles, A.H. and Haggar, R.J. (eds), Proceedings Occasional Symposium No 10. British Grassland Society, Hurley, pp 115-129.

Hopkins, A. and Peel, S. (1985) Incidence of Weeds in Permanent Grassland. British Grassland Society Occasional Symposium No. 18. Edited by Brockman, J.S. British Crop Protection Council Monograph No. 29, pp 93-103.

Hume L. and Cavers P.B. (1982a) Geographic variation in a widespread perennial weed, *Rumex crispus*. The relative amounts of genetic and environmentally induced variation amongst populations. Canadian Journal of Botany, 60, pp 1928-1937.

Hume L. and Cavers P.B. (1982b) Adaptation in widespread populations of*Rumex crispus* as determined by composite diagrams. Canadian Journal of Botany, 60, pp 2637-2651.

Hume L. and Cavers P.B. (1983a) Resource allocation and reproductive and life-history strategies in widespread populations of *Rumex crispus*. Canadian Journal of Botany, 61, pp 1276-1282.

Hume L. and Cavers P.B. (1983b) Differences in the flowering requirements of widespread populations of *Rumex crispus*. Canadian Journal of Botany, 61, pp 2760-2761.

Hunt, I.V. and Harkness, R.D. (1968) Docks in grassland, Scottish Agriculture 47, pp 160-162.

Inman, R.E. (1971) A preliminary evaluation of *Rumex* rust as a biological control agent for curly dock, Phytopathology 61, pp 102-107.

Ivens, G.W. (Ed) (1992) The UK Pesticide Guide, CAB International and British Crop Protection Council.

Jeangros, B. and Nösberger, J. (1992) Comparison of the growth response of *Rumex obtusifolius* L. and *Lolium perenne* L. to photon flux density, Weed Research 32, pp 311-316.

Kasai, T., Okuda, M., Sano, H., Machizuki, H., Sato, H. and Sakamura, S. (1988) Biological activity of the consituents in roots of ezo-no-gistigishi (*Rumex obtusifolius*), Agricultural and Biological Chemistry 46, pp 2809-2813.

Long, H.C. and Brenchley, Winifred, E. (1948) Suppression of weeds by fertilisers and chemicals. Crosby Lockwood and Son Ltd, London, 87 pp.

Massey, M. personal communication.

Masuda, Y., Nishimura, T., Kobayashi, T., Yamano, D., Nakano, Y. and Goto I. (1984). Germination ability of *Rumex obtusifolius L.* in silages. Science Bulletin of the Faculty of Agriculture, Kyushu University, 38, pp 181-185. From Weed Abstracts, (1984), 33, 2953.

Miyazaki, M. (1979) An annotated list of insects feeding on *Rumex obtusifolius L.* (Polygonaceae) in Japan (Biological control of grassland weeds). Kenkyu hokoku Sochi Shikenjo, March 1979 (14), Nishinasuno, Tochigi, pp 124-139. Japan.

Morris, P. (1985) (Editor) Natural history of the British Isles, Marks and Spencer Plc., London, 288 pp.

Newman, L. Hugh (1977) Looking at butterflies, Collins, London, 144 pp.

Oswald, A.K. (1978) The control of *Rumex obtusifolius* in grassland by selective application of herbicides, Proceedings 1978 British Crop Protection Conference - Weeds, pp 475-481.

Oswald, A.K. (1980) Progress in the development of the selective application of herbicides to control *Rumex obtusifolius* in grassland, Proceedings 1980 British Crop Protection Conference - Weeds, pp 209-215.

Oswald, A.K. (1985) The height directed application of dicamba for controlling *Rumex obtusifolius* and *Cirsium arvense* in grassland, 1985 British Crop Protection Council Monograph No.28, Symposium on Application and Biology, Edited by Southcombe, E.S.E., British Crop Protection Council, Croydon, UK, pp 55-61.

Oswald, A.K. and Haggar, R.J. (1983) The effects of *Rumex obtusifolus* on the seasonal yield of two mainly perennial ryegrass swards. Grass and Forage Science, 38, pp 187-191.

Pammel, L.H. (1911) Manual of Poisonous Plants, Cedar Rapids, Iowa, USA, 977 pp.

Payne, K., personal communication.

Peel, S. and Hopkins, A. (1980) The incidence of weeds in grassland, Proceedings 1980 British Crop Protection Conference - Weeds, 3, 1980, pp 877-890.

Perrott, T. (1987). Weed control in grassland. Grass Farmer No. 26, pp 12-13.

Roberts, E.H. and Totterall, S. (1981) Seed dormancy in *Rumex* species in response to environmental factors: review article. Plant Cell and Environment, 4, p 97-106.

Savory, B.M. and Soper, D. (1973) Response of a pasture to the removal of docks (*Rumex* spp), Weed Research, 13, pp 224-230.

Schubiger, F.X., Défago, G., Kern, H. and Sedlar, L. (1986) Damage to *Rumex crispus L.* and *Rumex obtusifolius L.* caused by the rust fungus *Uromyces rumicis* (Schum) Wint. Weed Research 26 (5), p 347-350.

Sedlar, L., Vonmoos, R., Défago, G., Kern, H. (1983) Fungi occurring on selected weeds a compilation from literature data, Institut für Phytomedizin, Eidgenössische Technische Hochschule, ETH-Zentrum, Zürich, Switzerland, 99pp.

Seymour, P.R., (1989) Invertebrates of economic importance in Britain - common and scientific names, MAFF Technical Bulletin No. 6, Her Majestys' Stationery Office, London, 147 pp.

Smith, A., personal communication.

Smith, R.W. and Whittaker, J.B. (1980b) Factors affecting *Gastrophysa viridula* populations (*Coleoptera: Chrysomelidae*) in different habitats. Journal of Animal Ecology, 49, pp 537-548.

Soper, D., and Hutchinson, A.S., (1976) Mixtures of asulam/ phenoxyalkanoic herbicides for general weed control in permanent pasture, Proceedings 1976 British Crop Protection Conference - Weeds, 2, pp 583-589.

Standell, C.J. (1987) Control of Dock and Creeping Thistle in ryegrass and red fescue swards. Proceedings 1987 British Crop Protection Conference Vol 3, pp 743-750.

Swift, G., Holmes, J.C., Cleland, A.T., Fortune, D., Wood, J. (1983) The grassland of east Scotland - A Survey 1976-78, East of Scotland College of Agriculture Bulletin No. 29.

Thompson, A.R., (1987) Fluroxypyr: broad-leaved weed control in grassland, Proceedings 1987 British Crop Protection Conference - Weeds, 2, pp 735-750.

Toynton, P., personal communcation.

Ukmani (1974) Biology and control of *Rumex* species in grassland. Annual Report on Research and Technical Work of the Ministry of Agriculture for Northern Ireland, 95 pp.

Whitmore, M.,personal communication.

Whittaker, J.B. (1982) Effect of grazing by a chyrsomelid beetle *Gastrophysa viridula* on growth and survival of *Rumex crispus* on a shingle bank. Journal of Ecology, 80, pp 291-296.

Whittaker, J.B. Ellistone, J. and Patrick, C.K. (1979) Dynamics of chrysomelid beetle *Gastrophysa viridula* in a hazardous natural habitat. Journal of Animal Ecology 48, pp 973-986.

Whytock, G.P., Davies, D.H.K., and Younie, D., (1987) Control of docks, Technical Note T33, Scottish Agricultural College, Cleeve Gardens, Perth, 3 pp.

Williams, R.D. (Editor) (1984) Crop protection handbook - Grass and clover swards. British Crop Protection Council, Croydon, England, 104 pp.

PART III - COMMON AND MARSH RAGWORT AUTECOLOGY AND CONTROL

1.0 Introduction

1.1 The importance of ragworts to farmers and nature reserve staff is not due to their high incidence, but the fact that they are poisonous to livestock, and can particularly cause problems when dry, and therefore palatable, in hay.

1.2 Ragworts are only thought to occur on 1-2% of British grassland overall (Green, 1982; Peel and Hopkins, 1980; Hopkins and Peel, 1985). Ragworts may be more common on roadside verges, particularly Hoary Ragwort (Watt, 1987), and certainly various ragworts occur in high concentrations locally, including various Nature Reserves and SSSIs. Everyone of the English Nature managers surveyed for this report reported reserves with widespread ragwort problems (T. Dixon, M. Massey, P. Toynton, A. Smith, G. Bellamy, K. Payne, D. Hinchelwood, and J. Bacon, personal communications). Of 29 sites discussed over half (15 sites) had widespread ragwort problems and a further 10% (3 sites) had localised infestations. Only one of the sites (Lower Derwent Valley NNR, N.Yorks) was recognised as having problems with Marsh Ragwort; all the rest suffered from Common Ragwort infestations. In addition, Ian Nicol, Site Manager at Hambledon Hill reports widespread ragwort problems on this reserve (personal communication).

1.3 The cost of ragwort control can be considerable; Ian Nicol reports that **1 man day per acre** was required over 155 acres at Hambledon Hill in 1992.

1.4 Other ragworts are also present on various Nature Reserves and SSSIs; but have not been individually studied for this report. Watt (1987) reports a Nature Conservancy Council survey of 52 British grassland sites which contained Hoary Ragwort, which was particularly prevalent in those cut for hay.

1.5 This weed genus (*Senecio* species) causes concern because ragworts contain various cumulative alkaloid poisons to grazing animals, which affect the liver and when eaten in quantity can cause death. Death can occur sometime after feeding so the cause is not always obvious, and consequently the numbers of animals which suffer from ragwort poisoning are probably underestimated.

1.6 In general, with the possible exception of young stock and sheep, grazing animals will avoid eating growing plants, particularly when they are mature. In chopped silage, however, cattle cannot easily isolate the weed and therefore it is eaten. Hence, its presence in pastures reduces the value of the herbage for grazing, and necessitates control before hay or silage can be safely taken from infested fields. This all costs money and reduces profitability, so on a livestock holding ragworts can be the most important weeds occurring in grassland from an economic view.

1.7 Ragwort poisoning of farm livestock, even today, probably causes higher economic losses in Britain than all other plants combined (Cooper and Johnson, 1984). Ragwort truly deserves the title "weed" in agricultural terms, and is listed as an Injurious Weed under the Weeds Act, 1959.

1.8 Ecologically, over 200 insect species are said to feed on Common Ragwort even benefiting from plant poisons in reducing their attractiveness to predators. Thus, control on a conservation site is to achieve a balance that is in keeping with the site aims, to avoid the weed interfering with management, being a threat to neighbouring land or grazing stock, and yet preserve the site diversity.

1.9 Common Ragwort is predominantly a weed associated with light soils and infertile pastures, particularly near the coast.

1.10 In addition to Common Ragwort (*Senecio jacobaea*) and Marsh Ragwort (*Senecio aquaticus*), at least 20 other *Senecio* species and hybrids have been found in Britain:-

Alpine Ragwort (*S. fuchsii*)
Broad-leaved Ragwort (*S. fluviatilis*)
Fen Ragwort (*S. paludosus*)
Field Fleawort (*S. integrifolius* ssp *integrifolius* and ssp. *maritimus*) - rare
German Ivy (*S. mikanoides*)
Groundsel (*S. vulgaris* ssp *vulgaris* and ssp *denticulatus*)
Heath Groundsel (*S. sylvaticus*)
Hoary Ragwort (*S. erucifolius*)
Marsh Fleawort (*S. palustris* or *congestus*) - extinct in UK?
Oxford Ragwort (*S. squalidus*)
S. smithii
Senecio cambrensis - intermediate between *S. vulgaris* and *S. squalidus*
Senecio doria - rare
Senecio X *albescens*
= hybrid *S.bicolor* ssp. *cineria* X *S. erucifolius*
Senecio inadequidens
Senecio X *londinesis* = *S. squalidus* X *S. viscosus* - hybrid
Senecio X *Ostenfeldii* = *S. aquaticus* X *S. jacobaea* - hybrid
Senecio vernalis
Senecio X *viscidulus* = *S. sylvaticus* X *S. viscosus* - hybrid
Silver Ragwort (*S. cineraria* or *bicolor* ssp. *cineria*)
Sticky Groundsel (*S. viscosus*)

1.11 More information appears to be available on Common Ragwort than any other weed species. Grigson (1955) lists no less than 58 local British names for *Senecio jacobaea*, compared to 16 for *Rumex obtusifolius*. Brenchley (1920) gave 56 popular and local names for *S. jacobaea*.

2.0 **Common Ragwort Biology and Ecology**

2.1 Common names: Ragwort, Common Ragwort, Tansy Ragwort, Benweed, Ragweed, etc.

2.2 Latin names: *Senecio jacobaea* L.; the following are synonyms - *S. trapezuntinius* Boiss.; *S. leucophyllus* DC.; and *S. auricola* Bourg.

One variety var. *floxulosus* DC. (synonym var. *nudans*?) has no ray florets, thus all its seeds (strictly termed 'cypselas') are hairy.

2.3 Common Ragwort is the most widespread species of the ragworts, normally it is a biennial; but it can become perennial, particularly when grazing or cutting prevents flowering, or it is disturbed. Damage to the crowns can make the plant behave as a perennial through the regeneration of new rosettes, even after flowering the carbohydrate reserves may be large enough to allow some vegetative reproduction from unspecialised organs (Otzen, 1977). Common Ragwort (*Senecio jacobaea*) is non-stoloniferous, but the branching tap-root allows possible regeneration. Surprisingly for a biennial, Forbes (1977b) found that 53% of plants regenerated rosettes from the crown after flowering.

2.4 Vegetative regeneration has implications for control strategies. If control measures rely on prevention of seeding or minimising seedling establishment but take no account of vegetative regeneration they are unlikely to be successful (Forbes, 1985).

2.5 Life Cycle of Common Ragwort

Generally ragwort germinates and establishes itself one year, overwinters as a rosette and flowers from late June or July of the following year before dying. Flowering can occur between June and October. Usually self-pollinated, rarely insect-pollinated yet visited by bees and flies. Many rosettes die without flowering, and there are large annual fluctuations in population.

2.6 Population Dynamics of Common Ragwort

Common Ragwort is characterised by violent fluctuations in population density from year to year (Goodman and Gillham, 1954; Forbes, 1974b). The size of the ragwort population is greatly affected by the weather, especially rainfall (Cox and McEnvoy, 1983). Drier conditions can favour *S. jacobaea* and wetter conditions can favour *S. aquaticus*, relative to other species but both thrive in wetter springs and summers.

2.7 A study of *S. jacobaea* population dynamics by Forbes (1977b) revealed that about three-quarters of plants which reached the rosette stage died without going on to flower, but the greatest losses by far occurred earlier, only 1% of viable seeds gave rise to established seedlings. Forbes (1985) indicates only 1% of seeds need to be viable to maintain population density; because he states that a 90% reduction in viable seed production stills allows the return of ten times more seeds than are required to maintain population density.

2.8 It was pointed out by Harper and White (1974) that where seed establishment is risky, the greater reserves of a biennial, compared with an annual, should allow it to produce more seed overall. In such sites where germination sites and resources are available only intermittently, annuals have to undergo the high risk of seedling establishment each year and perennials only have an advantage if the site remains favourable for several years. Biennials like ragwort (as with Spear Thistle and Curled Dock) store just enough energy to survive to the second year, and having had twice as long as annuals for assimilation, then put all their reserves in to seed production (Hart, 1977). However, ragwort often fails to behave as a true biennial. For example, Forbes (1977a) studied a ragwort population in Aberdeenshire, and found of the plants that flowered in the first two years, or survived in to a third year, 8% were annuals, 39% were biennials and 53% perennials. This classification assumes seedlings were correctly identified as such and not shoots regenerating from root fragments.

2.9 Flowering of Ragworts

Plants of ragwort must attain a threshold size to be able to flower and this may take more than 3 years (van der Meijden and van der Waals Kooi, 1979). This study also demonstrated that herbivore damage, for example from Cinnabar Moth larvae (*Tyria jacobaea* L.), may delay flowering so that ragwort can behave as a perennial. They also found that after the flowers on a plant had turned brown vegetative reproduction was no longer possible. However, Forbes (1977a) found 14 out of 32 plants which flowered one year were still alive the next.

2.10 Watt (1977) tries to reconcile these differing results by suggesting that the apparently single plants that flowered on Forbes' site were, in reality, more than one plant. She suggests this might have occurred if two or more seedlings had established very close together, or if the original plant had been damaged by grazing, so that subsequently separate plants were formed, and she cites (Harper and Wood, 1957) for the latter suggestion. A personal view is that ragwort populations vary genetically between sites and this with site and climatic factors, particularly soil moisture availability, determine survivability, making it reasonable to observe differing longevity between plants, irrespective of other explanations.

2.11 Seed Production of Common Ragwort

Flowering plants produce large numbers of seeds (= cypselas) which are variously dispersed by the wind, especially in dry conditions. The main means of spread is by seeds. Seeds derived from ray florets are glaborous and hence fall directly from their parent, those derived from disc florets are hairy, with a pappus twice as long as the seed, the latter is 2mm long, and these seeds are more readily dispersed by wind. The ray seeds emanate from female florets at the edge of the capitulum and the disc seeds from the hermaphroditic florets at the centre. This formation and the earlier ripening of the anthers ensures that a single insect vector will cross-pollinate a large number of flowers.

2.12 There are generally 13 ray seeds per capitulum, but the number of disc seeds is very variable, depending on the plant vigour (Harper and Wood, 1957). Others claim that the average total number of seeds per capitulum remains fairly constant at about 70 in Britain but the number of capitula per plant varies with plant vigour and environmental conditions (McClements, 1992). McEnvoy (1984b) found 58 disc seeds per capitulum, on plants he examined, with an average weight of 0.199 mg, compared to ray seed which averaged 0.286 mg. Similarly Cameron (1935) found an average of 57 disc seeds per capitulum at one site. Disc seeds are released shortly after maturity but the ray seeds may be held on to the capitulum until the parent dies. McEnvoy (1984b) points out that disc seeds with their pappus are particularly well adapted to wind dispersal and the colonisation of new, open sites. He suggests ray seeds are fitted for establishing in the gap left by their parent rosette. This means that clearance operations may provide an opportunity for these seeds to germinate and establish. Keith Payne (personal communication, quoting Harper and Wood, 1957) states the number of seeds produced varies from 5,000 to 120,000 per plant. Courtney (1973) gives seed production as up to 150,000 per plant.

2.13 Seed is mainly produced during August and September is mostly shed around the parent plant with a very limited dispersal, according to many sources. Poole and Cairns (1940) showed 60% of seed was shed round the base of its parent and very little travelled beyond 5m. That which travelled over 36 metres from its parent was on average 35% lighter than that deposited near the parent and was 5% less likely to germinate. McEnvoy and Cox (1987) found that only 17% fell from the parent plant; of these - 89% travelled less than 5 m, and none travelled more than 14 m. The remaining 83% were attached to the parent plant or dispersed less than 1 m. Workers at the North of Scotland Agricultural College (Anon, 1975) found that 1217 seeds per metre^2 were viable within a ragwort infested patch. This compared with 40 viable seeds per metre^2 (3.3% of the former) at a distance of 40 metres from an infested patch of ragwort. Occasionally dispersal occurs over much greater distances. Even in Britain small whirlwinds occur in hot, dry conditions and under these conditions dispersal can be widespread, and over a long distance, but such dispersal is rare. Seed may also be spread by water after a flood (Anon, 1967).

2.14 In general, this information means that when ragwort is not present in a pasture, any infested neighbouring fields pose little threat, and if a plant does shed seed its offspring will look to establishing in similar conditions to their parent. Hence, prevention of seeding and avoidance of suitable establishment conditions are the key strategies to adopt where low ragwort numbers are present. Ragworts should not be ignored until they become a more obvious threat. When infestations have reached a high level the large number of seeds waiting nearby to exploit any clearance operations means such operations can prove futile, if the surrounding vegetation offers little competition or is over-grazed or poached. Similarly, if a late hay cut is taken, the removal of adults which are flowering and seeding with other vegetation allows in light to a relatively thin sward, increasing the chances of new seedlings germinating and establishing later.

2.15 McEnvoy (1984a) mapped the occurrence of naturally dispersed ragwort seedlings in the vicinity of dead flower stalks. He found that seedling densities were higher in the openings left by dead rosettes than in the areas of taller vegetation surrounding the gaps. This shows that the gap (mean diameter 13 cm) left by a ragwort after it dies is important in enabling new seedlings to replace their parent (Watt, 1987).

2.16 Seeds can germinate anytime of year but predominantly germinate in two main flushes either in August to October or during April-May. The main emergence period is the spring (Watt, 1987 reporting a personal communication from H.A Roberts, NVRS).

2.17 Ragwort seeds germinate readily in light (Wesson and Wareing, 1969a), but secondary dormancy is induced by burial (Wesson and Wareing, 1969b). Coverage with a 4mm layer of sand increased germination probably due to increased humidity (van der Meijden and van der Waals Kooi, 1979). They agreed with Thompson and Makepeace (1983) who found that 99% of ragwort seeds buried between 0-2 cm died within 4-6 years but it took 10-16 years for seeds buried below 4 cm to decline to this level. Hence, seeds can lie dormant for 10-16 years if buried below 4 cm (1.6"); but few seeds germinate after one year under cultivated conditions (Watt, 1987 reporting a personal communication from H.A Roberts, NVRS).

2.18 McClements (1992), as part of his PhD thesis, looked at the relative occurrence of 20 species which made up 98.4% of the seedlings which germinated from the soil seed bank of 175 fields in County Fermanagh, Northern Ireland. The largest proportion of germinating seedlings (77.7%) were grasses. *S. aquaticus* was the fifth most abundant species despite only 1.7% of the germinating seedlings being of this species. Common Ragwort ranked 19th (0.042%). (For information, docks were the ninth most common species (0.47%), and *Cirsium* species ranked 17th, but these species commonly regenerate vegetatively from roots.) McClements does not state the germinating conditions which he used to estimate the relative occurrence of seeds in the soil seed bank and which may not have suited particular species. However, given that ragwort was common in this area, it can be seen that if conditions favour ragwort even a relatively low proportion of the total seed bank may still represent a large seed burden for a particular species and produce a troublesome infestation.

2.19 McClements does not quote the average incidence of adult plants of these species, but his survey showed three times as many fields contained Marsh Ragwort compared with Common Ragwort. He also states that seed production of Marsh ragwort is not as prolific as *S. jacobaea*. The localised nature of ragwort problems seems to be due to favourable inherent environmental conditions combined with management practices which determine continued persistence. While the majority of ragwort infestations are small, the soil seed bank reserves provide potential for the problem to increase.

2.20 <u>Germination and Establishment of Common Ragwort</u>

Ragwort seeds generally have no innate dormancy providing that conditions for germination are favourable at the time of seed dispersal. However, not all seeds germinate after dispersal. Germination can occur in late autumn, the following spring and even one year later. Differences are also apparent between individual seeds in their germination requirements. Frost and drought after initial imbibition may induce dormancy (van der Meijden and van der Waals Kooi, 1979).

2.21 Most ragwort germination studies have failed to make any distinction between germination and establishment phases. The microclimatic requirements for one may not be suitable for the other. High humidity encourages establishment (Sheldon, 1974) so a wet spring is not only more likely to give poaching conditions but also higher humidity and better establishment. He found flushes of *S. jacobaea* germination occurred between January and March. However, Graham and Hutchings (1988) noted germination occurred mainly during the spring and summer on chalk grassland.

2.22 The chances of germination and establishment of ragworts are greater where vegetation has been cleared (van der Meijden and van der Waals Kooi, 1979). The size of bare patch, amount of nitrogen available and poor sward competition all influence germination and establishment (Watt, 1984). This indicates that although the weed is commonly found in infertile situations it shows a pronounced response to nutrient availability. Watt (1987) also showed large gaps (greater than 15 cm) caused a larger diurnal fluctuation in temperature than small gaps and consequently higher germination, which was greatest with a diurnal fluctuation of 12.2°C.

2.23 Germination and establishment from seed are encouraged in a sward where gaps exist due to poaching and over-grazing as with docks and thistles. Sheldon (1974) found germination was 5% when seeds were sown with no compaction compared to 37% in artificially compacted soil. Where such delayed germination occurs it is not as critical as poor establishment of germinated seed. Sheldon found that soil compaction reduced establishment from 68% to 3% when no compaction was compared to where a pressure of 0.8 kg per metre^2; this is a lot less than the 3.5 kg m^{-2} exerted by a cows' hoof. This adverse effect of compaction is thought to be due to the mechanical obstruction of radicle penetration. This might explain why National Farm Survey data (Hopkins and Peel, 1985) linked ragwort to sandier and lighter textured soils. Soil crusting may reduce establishment when the soil clay content is high. However, raindrops may improve establishment conditions as well as damaging slow growing seedlings (Sheldon, 1974).

2.24 In glasshouse tests, freshly collected seeds of ragwort showed 83% germination. When sown outside in bare patches of artificial ryegrass swards 68% established, and in grazed fields 19.5% established (Watt, 1987). Cameron (1935) found under optimum laboratory conditions germination on filter paper takes up to eight days at 15°C.

2.25 Ray seeds are slower to germinate than disc seeds (Watt, 1987). Ray seeds are heavier than disk achenes and have a lower germination percentage (Baker-Kratz and Maguire, 1984). McEnvoy (1984) showed that this reduced germination was due to the physical inhibition of the ray achenes thicker pericarp. However, the thicker pericarp of ray seeds may give them greater protection from feeding animals (McEvoy, 1984b).

2.26 In a vigorous undamaged sward, germination and successful establishment are unlikely to occur. Keith Payne (personal communication; quoting Cameron, 1935) cites an experiment where seeds were sown into different sward conditions. In long grass or short, dense turf no seedlings were found after sowing. In over-grazed pasture 2.36% of seeds produced seedlings; on hard exposed soil 24% of seeds produced seedlings and on open soil, 63.5% of seeds established.

2.27 If root fragmentation occurs in October rather than the spring there is more likelihood of regeneration from root fragments. If the plant is a rosette at the time, not having yet flowered, Henson (1969) showed new shoots came from 60% of such root cuttings compared to 20% from plants which had flowered. No new shoots resulted from cuttings planted in April.

2.28 <u>Occurrence of Common Ragwort</u>

Common ragwort is associated with free-draining calcareous soils (van der Meijden, 1974), and drought-prone sites, indeed drought tolerance may enable it to establish when drought reduces the vigour or even kills surrounding vegetation. On Port Meadow NNR, Oxford, it is found on areas which tend not to flood in winter (Watt, 1987). Although the species can produce arenchyma (ie air-filled root tissue) if flooded, it cannot survive long periods under water (Smirnoff and Crawford, 1983). When roots are short of oxygen as they are under poor drainage conditions, ragwort shoots show poor growth compared to *S. aquaticus* (Lambers, Noord and Posthumus, 1979).

2.29 Common Ragwort is a weed of dunes, waste places, waysides, neglected, under- or over-grazed pastures on all but the poorest soils. Established swards are liable to infestation following damage which allows the seed to germinate in bare soil. Surveys (Watt, 1987) show it is especially characteristic of badly managed neutral or calcareous (but can frequent acidic) grasslands where poaching breaks the sward, or drought kills turf patches or where there is heavy rabbit infestation. It is characteristic of a stage in sand-dune development from personal observation. Leys are most vulnerable before they form a close turf or the sward becomes thin due to the disappearance of short-lived species or low fertility.

2.30 Common ragwort is abundant throughout the British Isles, reaching 670 m (2200 ft) in Scotland. It occurs in Europe, Scandinavia, N Africa, W Asia and the Caucasus. It has been introduced in to N America, Australia and New Zealand.

2.31 <u>Common Ragwort Height:</u> normally 30-100 cm ; but can reach 150 cm.

2.32 *Senecio* X Ostenfeldii is a hybrid of *S. aquaticus* X *S. jacobaea*, and this is particularly found in Orkney (Kent, 1964).

3.0 **Marsh Ragwort Biology and Ecology**

3.1 Common names: Marsh Ragwort

3.2 Latin name: *Senecio aquaticus* L.

3.3 Life cycle of Marsh Ragwort

Marsh Ragwort differs from Common Ragwort in having elliptical or oval undivided basal leaves, the stem leaves have large oval end lobes, and the smaller inflorescences are on shorter stems and more loosely spreading than *S. jacobaea*. Flowering is generally during July-August, so the flowering period is shorter than for *S. jacobaea*. The seeds are 2.5-3 mm long and are all hairless, but have a pappus twice as long as the seed.

3.4 Much of what has been said above for Common Ragwort is also true for Marsh Ragwort. It is more strictly a biennial than *S. jacobaea*; but, like Common Ragwort, it can become perennial particularly if grazing or cutting prevents flowering. In *S. aquaticus* the reserves of carbohydrate decline dramatically after flowering (Otzen, 1977). It is apparently as dangerous as *S. jacobaea* (Evans and Evans, 1949), and two alkaloids have been identified in Marsh Ragwort (McClements, 1992).

3.5 Life Cycle of Marsh Ragwort

Marsh Ragwort seedlings germinate and establish during one year, overwinter as rosettes and flower from late June or July until the August of the following year, this is a shorter flowering period than *S. jacobaea*. The seed produced during August and September is mostly shed around the parent plant with a very limited dispersal. The seeds germinate predominantly in two main flushes either in August to October or during April-May. Germination and establishment from seed are encouraged in a sward where gaps exist due to poaching and over-grazing as with docks and thistles. In a vigorous sward, germination and successful establishment are unlikely to occur.

3.6 Marsh Ragwort (*Senecio aquaticus*) is non-stoloniferous, but it does have a branching tap-root from which regeneration is possible. The main means of spread is by seeds.

3.7 Occurrence of Marsh Ragwort

It occurs in wet meadows, ditches, muds, and marshes, and is most prevalent in higher rainfall or upland areas, particularly in the west and north of Britain, up to an altitude of 460 m (1500 ft). It occurs across western and central Europe northwards from northern Italy, up to Scandinavia.

3.8 Marsh Ragwort is commonly believed to be more prevalent on heavier soils; however Forbes (1976) found an association with lighter soils in Orkney.

3.9 Marsh Ragwort Tolerance of Poor Drainage

When grown in low oxygen media, as if under poor drainage conditions, Marsh Ragwort roots have a higher rate of respiration than *S. jacobaea* (Lambers, 1976), they have a higher internal oxygen concentration (Lambers, Steingrover and Smakman, 1978) and they show better shoot growth (Lambers, Noord and Posthumus, 1979).

3.10 Marsh Ragwort Height: 25-100 cm.

4.0 <u>Incidence of Common and Marsh Ragworts</u>

4.1 Localised infestations rather than general infestation seem to occur. Davies (1953) reported 20% of the grassland around Fishguard infested and in north-west Anglesey 4% of grassland was "fairly severely" infested. He also found that where pastures were grazed by sheep or mown for hay ragwort was not as prevalent.

4.2 More recently, in England and Wales as a whole, only 1-2% of grass swards were seriously infested (Peel and Hopkins, 1980; Hopkins and Peel, 1985). Ragwort is more common in Scotland (Forbes 1984; North of Scotland College, 1984) and the Orkney Islands (Forbes, 1974a) and in parts of Northern Ireland (McClements, 1992).

4.3 Forbes (1974a) surveyed Orkney grassland and found over half the fields (54%) examined containing at least some Marsh Ragwort and 26% of fields had more than 1 plant per 100 metre². Orkney is unusual in that *S. aquaticus* is more common than *S. jacobaea*; Forbes (1974a) only found 6% of fields contained the latter, and in half of them (3%) both species occurred together. In this study Forbes was able to correlate ragwort incidence to soil surface wetness, age of sward and low sheep stocking rate. In a later study Forbes (1976) was able to add light soil texture (surprisingly), and sward openness to this list.

4.4 Severe *S. jacobaea* infestations are also found in Canada, Oregon, western Washington State, Australia, New Zealand and the Netherlands.

5.0 **Effect of Environmental Factors**

5.1 Inherent environmental factors have a large influence on the occurrence of ragworts; obviously, unless the environmental conditions are suitable, the plants do not occur, and some conditions are more favourable than others, determining the potential infestation. The expression of this potential is determined by management factors and current or previous incidence, so environmental factors are of secondary importance. The extent to which environmental conditions favour occurrence are outlined below.

6.0 **Environmental Factors - which predispose an area to infestation**

6.1 Generally ragworts are more common on poorer grassland (Courtney, 1973). High ragwort populations appear to be localised (McClements, 1992). This suggests that infestation is linked to past history, including seed bank reserves, and environmental factors. Surveys examining ragwort incidence in detail have consequently concentrated on local regions (Davies, 1953; Forbes, 1974a; McClements, 1992). These surveys have tried to correlate incidence with management and edaphic factors.

6.2 McClements (1992) cites some of the factors which influence Common and Marsh Ragwort incidence; and quotes his results from a survey of 400 fields in County Fermanagh:

a) <u>stocking density</u> - from his work, these correlations were non-significant; but incidence tended to increase at lower sheep densities and increased with higher cattle densities

6.2 cont b) grass conservation management, silage or hay - cutting for silage significantly reduced ragwort incidence; but hay cutting had no effect. There was a significant decline in ragwort incidence as number of cuts increased from none to three. Both *S. jacobaea* and *S. aquaticus* showed a similar response to cutting frequency.

c) sward grazing management - ragworts were less common at lower sheep densities and more common with higher cattle stocking rates, (others have noticed an association with horse grazing).

d) sward age - ragworts may be more common on older swards, McClements (1992) found that 51% of permanent pastures (swards over 10 years old) were infested with either or both species, compared with 37% of swards reseeded in the last 5 years, and 26% reseeded 5 to 10 years previously.

When only infested fields were analysed: 76% of the infested fields were permanent pastures.

There was a tendency for *S. jacobaea* to show an even greater incidence in permanent pasture (82.2%) compared with *S. aquaticus* (72.6%). These latter figures do not average 76% due to single species occurring at some sites and a mixture at others.

e) sward density - McClements (1992) scored fields on percentage bare ground; he found that the more bare ground existed, the greater the chance of ragwort being present, and higher ragwort infestation levels were associated with poor sward density.

f) soil type (which determines available water capacity). Although there was no significant correlation between soil type and ragwort incidence, there was a significant relationship between predominant species and soil type. No *S.aquaticus* was found on sandy soils, and yet over 56% of *S. aquaticus* was found on clay soils. As pH increased *S. aquaticus* number decreased significantly.

g) drainage status - significant links with ragwort incidence were found:-

i) Of swards infested with *S.jacobaea*:

42.2% were free draining,
35.6% had restricted drainage and
22.2% were liable to waterlogging.

ii) Of swards infested with *S. aquaticus*:

19.7% were free draining,
58.6% had restricted drainage and
21.7% were liable to waterlogging.

These results would suggest that *S. jacobaea* is associated with free-draining soils whereas *S. aquaticus* is associated with restricted drainage.

6.2 cont However, the above figures hide the overall statistics for both ragwort species:

34% of free-draining fields contained ragwort,
48% of fields with restricted drainage had ragwort and
56% of fields liable to waterlogging had ragwort present.

Larger ragwort population densities were more common on fields liable to waterlogging, which one might largely associate with poaching risk. However, McClements separated risk of waterlogging from poaching risk. He found that 55.6% of the largest infestations (>3.75 plants m^{-2}) were recorded on fields liable to waterlogging. When only poaching risk was evaluated, 78% of the largest ragwort infestations were sometimes or frequently poached. The lower incidence in waterlogging compared to poaching situations is an indication that neither Common nor Marsh Ragwort like very wet conditions but we know from other sources that Common Ragwort is particularly limited by waterlogging.

h) <u>fertiliser applications</u> - as soil phosphate status increased overall ragwort numbers declined, particularly for *S. aquaticus*.

i) <u>herbicide applications</u>

6.3 Forbes (1974 and 1976) studied up to 22 such environmental factors as might influence ragwort incidence, in a survey of Orkney undertaken in 1973. Forbes linked Marsh Ragwort incidence to:

a) <u>soil surface wetness</u> - there was a positive and significant correlation between ragwort density and soil surface wetness in both Forbes' 1974 and 1976 papers. (Prevalence has been associated with hollows where water tends to lie after flooding at the Lower Derwent Valley NNR (Jefferson, personal communication.)

b) <u>age of sward</u> - in both Forbes' papers a significant effect was found that as sward age increased so did ragwort density, which led Forbes (1974) to suggest that more frequent ploughing (on agricultural land) would reduce the scale of the problem; but he added that it is doubtful whether the costs involved would be economically justifiable.

c) <u>sheep stocking rate</u> - in both Forbes' surveys, as sheep stocking rate increased ragwort numbers decreased; but no link was found with cattle numbers

d) <u>light soil texture</u> - in Forbes' 1976 paper a link with sandy soils was shown, which had been unexpected by Forbes. He indicates that when factors were considered singly this correlation was obscured by the high correlation between surface wetness and clayey texture. McClements (1992) work cited above, did not find any *S. aquaticus* on sandy soils; but Forbes in 1974 did state, with reference to the 1973 survey, that the absence of correlation between ragwort and soil texture shows that *S. aquaticus* is by no means confined to heavy soils.

e) <u>sward openness</u> - in Forbes' 1976 paper, very open swards showed a higher *S. aquaticus* score than closed swards

6.4 Forbes' 1973 Orkney survey also showed that *S. aquaticus* seems to prefer more sheltered situations, is perhaps more abundant near the shore than further inland, and may be encouraged by high potash fertiliser application. There is an obvious association of Marsh Ragwort with old or permanent pastures, especially where no cutting for hay or silage has taken place for many years (Forbes, 1976).

6.5 Forbes (1976) also carried out an experiment which showed that 180 kg N ha^{-1} and high stocking rate (1500 kg liveweight of cattle ha^{-1}) markedly reduced the infestation of *S. aquaticus*. However, another experiment (see Table 1 below) showed that the ragwort may only be suppressed, where there was a considerable population of rosette plants, even in the most intensively managed areas, practically no flowering heads were seen, which may give the impression of a reduction in infestation. (Anon, 1975)

Table 1: Effect of intensity of management on ragwort density.

Treatment	Rosettes April 1974	Flowering Aug. 1974	Rosettes April 1975	Flowering Aug. 1975
1 beast/ac, 50 units/ac set-stocked	102.6	22.5	200	277.2
2 beasts/ac, 150 units/ac paddock-grazed	102.2	5.3	50	13.7
3 beasts/ac, 250 units/ac paddock-grazed	69.3	0.2	14	0.3

(Anon, 1975)

6.6 Environmental Factors - effect on *Senecio jacobaea*

Common ragwort is associated with free-draining calcareous soils (van der Meijden, 1974), and drought-prone sites, indeed drought tolerance may enable it to establish when drought reduces the vigour or even kills surrounding vegetation.

6.7 Common Ragwort is a weed of dunes, waste places, waysides, neglected, under- or over-grazed pastures on all but the poorest soils. Established swards are liable to infestation following damage which allows the seed to germinate in bare soil. Surveys (Watt, 1987) show it is especially characteristic of badly managed neutral or calcareous grasslands where poaching breaks the sward, or drought kills turf patches or where there is heavy rabbit infestation. It is characteristic of a stage in sand-dune development from personal observation.

6.8 Leys are most vulnerable before they form a close turf or the sward becomes thin due to the disappearance of short-lived species or low fertility.

6.9 *S. jacobaea* can be prevalent in swards receiving low inputs of fertiliser nitrogen, but including swards where legumes are important (Forbes, 1982). In the National Farm Survey, ragwort infestations were concentrated on a few farms, surprisingly these were mainly dairy farms, on sandy or light textured soils (Hopkins and Peel, 1985). There was a survey in 1986 of 10,000 ha of upland grassland in seven districts of England and Wales, which had been previously surveyed in 1970-72. This showed that ragwort was mainly confined to swards receiving little or no fertiliser nitrogen, and which were under-utilised or grazed only by cattle (Hopkins *et al.*, 1988).

6.10 To explain why an unusually high incidence of *S. jacobaea* occurred in young grass in Moray and Nairn, in Scotland, Forbes (1984) suggested that the low rainfall and freely draining soils of that area undoubtedly favour a drought-tolerant species like *S. jacobaea*.

6.11 Rabbits tend to be more common on sandier and lighter soils, with their scraping of the soil surface it is to expected that they act to provide invasion sites for ragwort, and by their close cropping of surrounding herbage create the suitable conditions for spread; however, they can graze young ragwort, so may also reduce the effect of the damage they have previously caused. Dry conditions on light soils which have rabbit infestation almost certainly favour the Common Ragwort. The better drought resistance of ragwort giving this plant a greater ability to survive such grazing than other herbage species.

6.12 Ragwort is a problem in New Zealand dairy pastures which rely on clover for nitrogen but are intensively stocked and receive phosphate and potash (Thompson and Makepeace, 1983).

6.13 <u>Environmental Factors - effect on *Senecio aquaticus*</u>

Marsh Ragwort occurs in wet meadows, ditches, muds, and marshes, and is most prevalent in higher rainfall or upland areas. Forbes (1974a) was able to correlate ragwort incidence to soil surface wetness, age of sward and low sheep stocking rate. It is commonly believed to be more prevalent on heavier soils; however Forbes (1976) was surprisingly able to add light soil texture, and sward openness to the factors associated with high Marsh Ragwort incidence.

6.14 When grown in low oxygen media as if under poor drainage conditions, marsh ragwort roots have a higher rate of respiration than *S. jacobaea* (Lambers, 1976), they have a higher internal oxygen concentration (Lambers, Steingrover and Smakman, 1978) and they show better shoot growth (Lambers, Noord and Posthumus, 1979).

6.15 McClements (1992) results are quoted in detail above, linking ragwort to grazed fields, over 10 years old, with poor drainage, poaching, and bare ground on clay soils.

7.0 Environmental Factors - which reduce or inhibit infestation

7.1 Violent fluctuations in population density are a well known feature of the ecology of *S. jacobaea* even in the absence of human interference (Goodman and Gillham, 1954; Harper and Wood, 1957) and in one study almost 50% of mature vegetative plants died in one year without coming to flower (Forbes,1977). Obviously control measures including reseeding, sheep grazing or use of herbicides can accentuate or mask such environmental effects, which have not been explained.

7.2 On Port Meadow NNR, Oxford, Common Ragwort is found on areas which tend not to flood in winter (Watt, 1987). Although the species can produce arenchyma (ie air-filled root tissue) if flooded, it cannot survive long periods (over 32 weeks) under water (Smirnoff and Crawford, 1983). When roots are short of oxygen as they are under poor drainage conditions, ragwort shoots show poor growth compared to *S. aquaticus* (Lambers, Noord and Posthumus, 1979).

8.0 **Losses and Harmful Effects due to Ragworts-** dangers of poisoning

8.1 Cattle and horses are particularly susceptible to poisoning by eating ragwort fresh or after cutting. Sheep and goats are more resistant but not immune. Young stock of all classes are more susceptible than mature animals.

8.2 Sheep readily eat the rosettes and crowns of ragwort in winter and spring, provided the weed is not too abundant they will rarely come to harm. Cattle are normally repelled by the bitter taste, but can develop a depraved appetite for the plant which prompts them to select for it (Anon, SAC, 1976). Under certain circumstances cattle may eat ragwort in pasture, for example when grass is scarce due to drought, cold or over-stocking (Donald and Shanks, 1956; Forbes, 1985). Cutting and wilting will make ragworts more palatable to stock (Anon, 1982). Poisoning most usually occurs after eating infested hay, silage or dried grass (Donald and Shanks, 1956; Petrie and Logan, 1980-1). Stock do not reject it in this form; but the poisons are unaffected by the conservation process. In silage these alkaloids can contaminate a whole silo. Herbicides also make ragwort more palatable to stock through increasing concentration of sugars and water soluble carbohydrate (Irvine *et al.*, 1977).

8.3 Clinical signs of poisoning

The main references for this section is Cooper and Johnson (1984) and Watt (1987).

8.4 When animals have eaten Common Ragwort, signs of poisoning may appear quickly, death occurring within 6-10 days of the first signs, or animals may remain in a gradually declining state for weeks or even months, for this reason the cause is often overlooked. This variation in effect can be due to age of the animal, health, the actual concentration of alkaloids in the particular plants it has eaten, which can range according to plant age and genetic make-up and other factors. Dried ragwort concentrations of pyrrolizidine alkaloids range in total amount from 0.11%-0.18% of the dry matter (Aplin, Benn and Rothschild, 1968; Buckmaster, Cheeke, and Shull, 1976; Dickinson et al., 1976; King 1980) and these are of different toxicities and their relative proportions vary with environmental conditions and stage of growth. The flowers contain even higher total concentrations of alkaloids from 0.15-0.30% of the dry matter (Deinzer *et al.*, 1977). So far 9 alkaloids have been studied closely (Johnson, 1978; Segall and Krick, 1979). It has been suggested that the alkaloids themselves are not toxic to the liver, but they may be metabolised in the liver to bound pyrrole derivatives that are toxic (Mattocks, 1968).

8.5 The early signs of chronic poisoning may be only seen after consumption of the plant has ceased. The signs are loss of condition, loss of appetite, abdominal pain, usually constipation, but occasionally diarrhoea (sometimes with blood), or jaundice. The pulse is weak and rapid but the temperature remains normal (Long, 1924). The loss of appetite means that animals become less productive - reducing growth rates or milk production.

8.6 Ragwort can rapidly reduce the milk butterfat production of cows by 30% (Miller, 1936), whether this is a direct consequence of the alkaloids or an indirect effect due to reducing intake of forage is not known.

8.7 There is evidence that stock reared on ragwort infested farms are less likely to suffer from poisoning at pasture than introduced beasts (Anon, L280, 1982). However, this may be linked to less discrimination, when stock are introduced from a ragwort-free area (Courtney and Johnston, Ag in NI, undated).

8.8 Deer appear to be resistant to ragwort poisoning (Dean and Winward, 1974), and experiments on rabbits showed low intestinal absorption of alkaloids, (Pierson, Cheeke and Dickinson, 1977) and/or efficient urinary excretion (Swick *et al.*, 1982b). Pigs and chickens have been shown to be susceptible to poisoning in experiments (Anon, P280, 1982).

8.9 In the final stages of poisoning, nervous signs may develop particularly in horses, donkeys and cattle which include restlessness, aimless, uncoordinated movement, apparent blindness and partial paralysis. Cattle may develop mania and become fierce and unapproachable. There appears to be a point at which catastrophic breakdown of the digestive and nervous system occurs. The animal only dies when the liver hepatocytes cease to function and are not regenerated or when they are already impaired and stressed e.g. by a rapid change in diet or bad weather (Johnson, 1978). This implies that liver cells can regenerate and hence, with time, the liver can recover, if the poisoning ceases. It is said that when an animal is recovering from ragwort poisoning it should be kept on a low protein diet so that nervous disorders are not exacerbated (McGinness, 1980).

8.10 However, others state that the effect of the poisons are cumulative so that a small intake of ragwort over a long period is as damaging as a large intake on a single occasion (Anon, 1986). Irreversible damage to the liver occurs for which there is no cure (Anon, 1986).

8.11 If there is no cure, can poisoning be prevented? Vitamin B12 and cobalt have been suggested by Watt (1987) as possible treatments which may prevent poisoning from pyrrolizidine alkaloids. However, in general mineral and vitamin supplements do not protect calves against ragwort poisoning (Johnson,1982) even if they are successful in adult cattle (Duby, 1979).

8.12 Warren (1970) summarised the many papers of Schoental which demonstrated that young, male animals on a low protein diet are most susceptible to ragwort poisoning. Thus, low protein may make an animal more susceptible but once poisoning occurs high protein may exacerbate the condition (McGinness, 1980).

8.13 In Nova Scotia ragwort poisoning was found to be linked to forage with low levels of copper, phosphate and cobalt, even when grass was plentiful. Thus it was suggested that ragwort may be selected to provide a supplementary source of minerals and provision of mineral supplements should prevent stock losses from ragwort toxicity (Palfrey, MacLean and Langille, 1967). Adult cattle may benefit from vitamin and mineral supplementation - Duby (1979) showed this allowed cattle to cope with a low but usually toxic level of ragwort in the diet. However, Johnson (1982) believed that rather than a mineral imbalance reducing resistance to toxicosis, when such an imbalance occurred, appetite changes stimulated an increased intake of ragwort.

8.14 Toxic and Lethal doses

Figures vary widely for toxic and lethal doses (Anon, SAC, 1976; Gill and Vear 1958; Goeger *et al.*, 1982; Johnson, 1978; Mortimer and White, 1975; White, 1983).

8.15 In experimental feeding, cattle tolerated up to 1.5% of their body weight of the dried plant in a 15 day period, (this would be equivalent to a maximum of about 6kg of dried ragwort for a 400 kg beast) but certainly died if given 2% of their weight (equivalent to about 8 kg in total) ie 1.25 g of dried S. jacobaea per kilogramme of body weight per day fed for 20 days (Johnson, 1978). However, it is not known how old these animals or plants were nor the plant dry matter percentages so these figures as quoted by Cooper and Johnson (1984) are relatively meaningless. Another source states that a fatal dose for cattle is probably around 3 kg (Anon, SAC, 1976). According to Gill and Vear (1958) 2-10 pounds (1-5 kg) of fresh material is probably a serious or fatal dose, but again neither plant age nor alkaloid concentration is mentioned.

8.16 Sheep, fed experimentally, with 0.3% dried *Senecio jacobaea* of their body weight (ie 3 g per kg of body weight) daily for 16 days did not develop clinical signs, but liver function was impaired and there was 70% mortality during the next six months (Mortimer and White, 1975). MAFF in an early ragwort leaflet comments that "the somewhat general view that sheep can eat ragwort with impunity has been shown by trials at the Ministry's Laboratory to be incorrect" (Long, 1924). However, in a later ADAS/MAFF leaflet (Anon, 1982) the use of sheep as a means of maintaining a low level or prevent establishment of ragwort is advocated. The same leaflet also states that sheep should not be used to control heavy infestations; the health of lambs especially is at risk when large quantities are eaten. Similar advice is given in North America (Sharrow and Mosher, 1982) and in Australia (Amor *et al.*, 1983).

8.17 Cheeke (1984) found that adult sheep and goats required a total of two to three times their body weight of Common Ragwort to be lethal. However, only a small number of animals were used in this study. Goeger *et al.*, 1982 showed feeding Common Ragwort to goats that 1.25 to 4 times the animals' body weight needed to be eaten before death.

8.18 In sheep, but not in cattle or horses, ragwort consumption causes copper accumulation by the liver (Mason, 1980; Swick, Cheeke and Buhler, 1982). Such poisoning is more severe if the animals after eating ragwort as part of their conserved forage in yards are then transferred to clover-rich swards (a species high in copper) or dosed with copper compounds against worms. Sheep are quite prone to copper toxicity yet exhibit greater resistance than cattle to ragwort poisoning. This resistance to ragwort is probably due to differences in liver alkaloid metabolism (Watt, 1987). This hypothesis is supported by the discovery of Swick *et al.*, (1983b) that sheep have a high activity of liver microsomal epoxide hydrolase and so a low capacity to metabolise pyrrolizidine alkaloids in to the toxic pyrroles.

8.19 However, there is no specific treatment for ragwort poisoning, but supportive treatment for the digestive disturbances, and removal of affected animals from infested pasture may enable recovery. It is recommended that dietary protein is limited because the nervous symptoms often develop after intake of high protein feed.

8.20 A simple method of testing the serum of cattle can assess liver function, and be used on a monthly basis for 6 months after a case of ragwort poisoning has been confirmed (Lloyd, 1957). Watt (1987) suggests that this should detect sub-clinical cases so that they can be slaughtered for human consumption before the appearance of clinical symptoms. The most characteristic symptom on post-mortem in cattle is cirrhosis, or hardening, of the liver (Anon, SAC, 1976).

8.21 In the USA toxic alkaloids from Senecio jacobaea have been found in honey, but despite being a potential hazard, there is no evidence that such honey contains sufficient alkaloids to be toxic to Man. Besides the honey is deep yellow in colour, and has a strong, unpleasant taste and smell.

9.0 Beneficial Effects of Ragworts

9.1 Ragwort is very rich in sodium, chlorine and copper (Fairburn and Thomas, 1959). However, little work on the nutritive value of ragwort exists due to its toxicity which makes such research considered academic because the plants are such a health risk. Such research is not just of academic interest because animals, particularly sheep, do eat ragwort and to understand what it contains at different stages of growth, and the amount normally consumed, as opposed to what represents a toxic amount, may be of practical interest. Therefore it is recommended that study of the nutritive value of ragwort may prove worthwhile.

9.2 Some authors say as many as 200 insects visit ragwort (Smith, 1980; Watt, in press), including bees and hover flies (Clapham, Tutin and Warburg, 1962). A study in Sussex (Wiggins, 1977) showed of all the native flowering plants it received the greatest number of visits by butterflies.

9.3 One of the insects which depend upon ragwort is the native Cinnabar Moth (*Tyria jacobaea*) which feeds on ragwort leaves and flowers in June and July. However, it is the ragwort population which control the Cinnabar Moth population and not *vice-versa* (Dempster and Lakhani, 1979).

9.4 Cinnabar moth caterpillars are eaten by moles and birds as well as being parasitised by at least nine Ichneumons and two Braconids (Dempster, 1971).

9.5 Ragwort Flea Beetle (*Longitarsus jacobaea*) also occurs in Britain, and elsewhere in the world (Newton, 1933).

9.6 There is a Ragwort Seed Fly (*Pegohylemyia seneciella* Mead; otherwise called *Hylemya seneciella and Delia seneciella*).

9.7 All of these individually named ragwort-dependent invertebrate species have been shipped from Britain to other parts of the world where ragwort exists, as possible biological control agents; but generally they have not succeeded in giving control of ragwort. However, limited and local successes have occurred in North America when an additional factor has helped the predator. These species are covered in more detail in the later section on biological control.

10.0 **Current Ragwort Control Techniques on National Nature Reserves (NNRs) - see Appendix I.**

10.1 Ragwort can be a serious problem in species-rich grassland and the Nature Conservancy Council has been forced to have ragwort hand-pulled repeatedly on at least 13 NNRs in the last 24 years (Watt, 1987 reporting a personal communication from D.A. Wells).

10.2 On any site under the management of English Nature, Scottish Natural Heritage and the Countryside Council for Wales, consent is required from the Site Manager before any potentially damaging operations are carried out, and all weed control is potentially damaging to a site, no matter how selective; because attempts at control are intended to alter the botanical balance of the sward, control may itself exacerbate infestations, or cause accidental reduction of ecological diversity.

10.3 Furthermore, when herbicide use is proposed permission may also need to be obtained from the Science Directorate of English Nature before herbicide application. If agrochemicals are used, there is a risk from herbicide-treated plants or herbicidal drift affecting neighbouring plants. However, when site management perpetuates a weed problem, and other techniques cannot contain the Injurious Weeds then careful herbicide use may be the best option. It would be sensible to define boundaries for any control techniques, monitoring the species present in an area both before and after treatment, limiting any control techniques until the effects on a small but representative area have been assessed.

10.4 On flat areas without significant biological interest such as buffer land around a nature reserve occupiers might use a broad-spectrum herbicide on such agricultural land. Such a herbicide must be a product approved for use in grassland and the statutory conditions of use must be met.

10.5 On NNRs and SSSIs, apart from the wish to avoid using herbicides, and the inconvenience of stock removal after treating ragwort, there is the further restriction that permission needs to be obtained from the Science Directorate of English Nature. Other conservation areas may not need such permission but it would be wise to consult and obtain comments from the Science Directorate of English Nature, and other bodies, if appropriate.

10.6 Explanations for avoidance of herbicide use include lack of sufficiently selective herbicides or use of vehicular mounted application equipment is impractical. However, hand-held weed-wipers could overcome these problems but there then comes the problem of finding suitably qualified staff (who hold the relevant NPTC Certificate of Competence, when the land is not their own) and the laborious nature of the task. Even if hand weed-wiping is more effective than hand-pulling, it is more costly and less convenient. There is also the inconvenience caused by the need to remove stock until treated plants have disintegrated and disappeared to minimise the risk of poisoning. This is because treated plants will be more palatable to stock than untreated plants. If one tried to reduce this risk by hand-pulling ragwort plants, after treatment, this operation could reduce likely herbicide translocation. This would make it more likely that vegetative regeneration could occur, negating all the cost and effort.

10.7 Current Ragwort Control Techniques on NNRs of *S. jacobaea*

Common Ragwort has been a fluctuating problem on the Port Meadow SSSI, in Oxford. The problem has increased in recent years with increased winter grazing and a greater proportion of horses being grazed by the Commoners (Watt, in press).

10.8 Keith Payne (personal communication) reports that Port Meadow has uncontrolled common grazing. It is under-grazed in summer by horses and cattle and over-grazed by horses in the winter, the latter resulting in poor spring growth. This has resulted in a range of weed problems including dense areas of Creeping Thistle, Spear Thistle and Nodding/Musk Thistle (*Carduus nutans*), in addition to ragwort, the latter is confined to areas which tend not to flood in winter. Ragwort is seen as a "recent" problem because until the 1930's the meadow used to flood regularly, keeping ragwort and the thistles mentioned above in check.

10.9 The Pewsey Down chalk grassland NNR in Wiltshire, is managed in two ways. On the part owned by English Nature, sheep graze in the summer with cattle, and Common Ragwort has been greatly reduced (Watt, in press). However, on the part of the site where Nature Reserve Agreements exist, only cattle graze in the summer and there is a severe ragwort problem. Keith Payne suggested in a personal communication to Watt, that once a site has been grazed in spring and summer for 4 to 5 years by sheep the resultant low levels of ragwort may be maintained by sheep grazing every 2 or 3 years in summer. The author believes that this will depend on the site and other management factors, and will rarely be sufficient, on sites prone to infestation.

10.10 Keith Payne (personal communication) reported experiments at Pewsey Down to investigate whether sheep grazing between early May and early August, at low stocking rates combined with cattle grazing, might control ragwort without harming desirable flower species. After a successful small scale trial on about 14 acres of downland, where roughly 7 acres of adjacent grass ley occurred, the experiment was repeated on another area, without use of adjacent leys. In areas where the sheep congregated, (eg on improved grazing, near to water troughs), it was found that the sheep controlled the ragwort and preferentially grazed the other flower species. This had quite a disastrous effect on some floristically-rich areas. Flowers which were affected included Early Gentian (*Gentianella angelica*), Yellow Rattle (*Rhinanthus minor*), Spiny Restharrow (*Ononis spinosa*). Similarly, but less affected, Sainfoin (*Onobrychis viciifolius*) numbers were reduced by sheep grazing. Flowering orchids (*Orchidaceae*) numbers were greatly reduced where sheep grazed. Keith Payne concluded that mixed grazing may be appropriate on some sites and not on others; as an example of this he cites, another area of the Pewsey Down Reserve which has had mixed grazing, mainly with sheep, for about 10 years, which is ragwort-free.

10.11 Keith Payne (personal communication) believes hand-pulling to be a cosmetic exercise and largely a waste of time except in the interests of good neighbourly relations. This view is echoed by others eg Maurice Massey, and Graham Bellamy (personal communications) who tend to rely on sheep grazing.

10.12 Some English Nature managers (eg Tony Smith, personal communication) make the point that the amount of ragwort on many reserves is not a problem from a conservation view-point, it does not significantly affect density of other flora nor cause a problem as a seed source. However, local farmers want to see ragwort controlled, so site managers have been trying hand-pulling, amongst other techniques, including use of herbicides, with variable, and often disappointing results. Such techniques are necessary when grazing has given insufficient control, in fact it may have exacerbated the problem, especially in drought years where over-grazing has occurred.

10.13 Tony Smith (personal communication) states that in the valley bottom at Woodnook Valley in Lincolnshire, a site grazed by cattle, Common Ragwort has only needed pulling since 1987, and it has only really been widespread since 1989. This is due to drought conditions, with the same amount of grazing animals as previously, but the shorter, open turf has been more easily broken open by hoof damage, allowing ragwort colonisation. Tony likens hand-pulling to "painting the Forth Bridge". He ruefully comments that in 1992 (not a dry summer and autumn) there was more ragwort than previously despite 3-5 years of pulling and removal by English Nature staff and British Trust of Conservation Volunteers to clear flowering ragwort. He is 95% confident that seed set and shed has not been allowed.

10.14 These are only some of the comments made during the survey; but they indicate that sheep have proven useful on some sites, but can cause a reduction of certain desirable flora, and flooding whilst useful in limiting spread is hardly a practical means of control. Cattle and horse grazing do nothing to solve ragwort problems and may exacerbate them. Hand-pulling and hay-cutting do not provide a solution to widespread infestations. Thus, we consider herbicides.

10.15 From the survey undertaken for this report, it seems that herbicides have generally been avoided, this is mainly due to the risk of poisoning stock from herbicide-treated ragwort plants.

10.16 The survey undertaken for this report found that herbicide use been attempted for Common Ragwort control on only two of the seventeen sites where Common Ragwort is present in significant numbers. These were both using a hand-held weed-wiper containing glyphosate (='Roundup'). This treatment was apparently successful at Martindown and Silverines Meadow, on the single occasion it has been used at each site.

10.17 At Martindown NNR the treatment was applied at or after flowering but before senescence, and apparently reduced the subsequent problem.

10.18 At Silverines Meadow SSSI, a site owned by a private farmer occupier, the farmer obtained consent to use a hand-held weed-wiper and apply glyphosate. (It would be difficult to tractor weed-wipe the 2 acre area where the ragwort is prevalent.) This treatment was applied in early to mid-August, at or after flowering had started, application was deliberately delayed beyond the rosette stage of the ragwort to protect non-target species from the unselective glyphosate.

10.19 With a biennial death often follows flowering so the treatments may have been largely unnecessary; but the study of this weeds' autecology did show perennial plants do occur, and rosettes which have not flowered occur alongside those that have flowered, if treated, both types of plant will die. The comment that the problem was subsequently reduced may have been due to natural fluctuation in ragwort numbers; but glyphosate can affect the viability of the seed of treated plants so further research into this technique is recommended by the author.

10.20 <u>Current Ragwort Control Techniques on NNRs of *S. aquaticus*</u>

The Lower Derwent Valley NNR in North Yorkshire and North Humberside is a wetland reserve of 1020 acres (413 Ha) within a larger suite of SSSIs covering a total of 2500 acres (1000 Ha). On the hay meadows at Derwent Ings SSSI can be flooded for 4 to 5 months of the year and *S. aquaticus* is increasing; this was reported in the mid-1980's by Tim Dixon, the Site Manager, in a personal communication to Watt (in press). This SSSI is cut at the beginning of July and has traditionally been grazed by sheep from August 12th to the end of October. Watt (in press) states that "the problem is greatest where there is no sheep grazing or they have been replaced by cattle who do not eat the plant and also cause poaching. In contrast the sheep eat out the rosettes and their grazing leads to formation of dense swards." Presumably the sheep only eat rosettes of new seedlings and not mature plants.

10.21 As part of the survey undertaken for this report, Tim Dixon reported (personal communication) that Marsh Ragwort is his biggest weed problem, it occurs in every meadow he manages and the problem varies from year to year. Hand-pulling is mainly carried out by licencees, contractors and British Trust for Nature Conservation Volunteers. Marsh Ragwort pulling cost English Nature £9000 at this one site alone in 1992.

10.22 The Lower Derwent Valley site is poorly drained Boulder clay covered with alluvium and next to a river. In winter the reserve may contain 20,000 wildfowl which on wet ground can cause considerable poaching, creating gaps in the grassland which ragwort can colonise.

10.23 Tim Dixon says that he can generally predict where Marsh Ragwort will occur; because the weed occurs on wetter areas of the meadows which periodically flood but cannot cope with swampy conditions. Tim Dixon (personal communication) undertakes a survey each spring of the distribution of Marsh Ragwort to target his control measures. The spring survey is supplemented by information from the farmers who take out licences to cut the hay meadows. There is little ragwort in those fields which are only grazed, whatever the management, mainly because these are too wet for Marsh Ragwort; but obviously where sheep grazing occurs sheep would aid control. Despite the name Marsh Ragwort, it appears it cannot survive on a grazing marsh!

10.24 Overall the control measures have resulted in a slight decrease in Marsh Ragwort at the Lower Derwent Valley between 1987 and 1992. This is in spite of a reduction in overall sheep numbers/stocking rate since 1987 because sheep enterprises have generally been less profitable. The sheep are usually owned by grazing licencees.

10.25 In the Lower Derwent Valley control is usually attempted in the hay meadows by grazing "quite hard" with 4 to 5 draft Swaledale ewes per acre for 1 or 2 years from May to the end of October to reduce the population and then hand-pulling in the following seasons. This enables a speedy reversion to the traditional management of cutting for hay, rather than because any lack of confidence that sheep would not keep the ragwort under control indefinitely. **(Caution: if spring grazing replaces hay and traditional aftermath grazing, even for a short time, annual flora may be lost, eg Yellow Rattle *Rhinanthus minor*, particularly if there is no persistent seedbank.)**

10.26 Where heavy infestations occur ragwort plants are cut removed and burnt.

10.27 Other means of control involve restrictions on operations, which are common to most nature reserves and SSSIs, these include:

- no supplementary feeding in fields

- no use of fertilisers, or slurry; however lime and farm yard manure may be used, even if such lime and manure applications are uncommon.

- stock are removed by order of the Site Manager on flooding.

10.28 At the Lower Derwent Valley NNR, MCPA was applied by a knapsack sprayer as an experiment in 1988. Marsh Ragwort was the only biennial in the treated 2 metre^2 square quadrats, so when the rest of the sward had died down, in October/ November, the basal rosettes of Marsh Ragwort were treated with 1.4 kg ha^{-1} of MCPA. Success was variable, with no apparent control in some quadrats, possibly due to the weather at such a late timing and MCPA not being the most-effective ragwort herbicide available.

10.29 Spray treatment has not been repeated because such work has not been included in the work plan of the staff and because the current staff do not hold a NPTC Certificate of Competence for use of a Knapsack Sprayer.

11.0 Cultural Control by Management - Effect of Grazing

11.1 Cattle and horses are more selective in their grazing than sheep. Coup (1959) advocated the grazing by a 'flying flock' ie old draft ewes, at a high stocking rate to eat out the ragwort and to remove them before terminal liver damage has been caused. This is the technique used at Lower Derwent Valley NNR using draft Swaledale ewes with no lambs at foot.

11.2 Anecdotal evidence suggests sheep will eat young ragwort and avoid mature plants. Some breeds may avoid the plant altogether - Dorset Horns grazing Hambledon Hill from mid-May to mid-June 1992 did not touch it (Ian Nicol, personal communication).

11.3 Questions are raised by these differential grazing habits; these questions include do sheep ingest minimal alkaloids when eating young ragwort in spring, or do they artificially raise their copper intakes, in which case are copper levels in other herbage plants lower in the spring compared to other times of year?

11.4 It has been noted in the past that copper levels are often low in peaty and chalky soils, which may or may not result in copper deficiency in the grazing animal. Copper deficiency severe enough to restrict grass growth has not been reported in the UK, but it has been diagnosed on blanket peat in Ireland (Grennan, 1966).

11.5 Cocksfoot generally has a higher level of copper than other grasses (Spedding and Diekmahns, 1972). Contradictory changes in copper levels have been reported through the season - Fleming (1963) reporting a decline over the period from 4 April to 28 June, while Hemingway (1962) noted an increase over the whole growing season. Conflicting results have also been reported on the effect of fertiliser nitrogen on herbage copper contents (Whitehead, 1966a, and b). Further research would appear to be required.

11.6 Research is required regarding the alkaloid contents of ragworts at different stages of growth, intakes of alkaloids and other nutrients, particularly copper, by ewes, tolerance of different breeds of mature sheep to ragwort.

11.7 Until further research is completed while Coup's recommendation would appear to work in practice; but it is a risky recommendation, and is best to always minimise such risks and sheep grazing should not be adopted in certain higher risk situations.

11.8 Cooper and Johnson (1984), as veterinarians, state the practise of sheep grazing to reduce a ragwort infestation is not recommended. This advice minimises the risk of poisoning from a veterinary view-point and should be borne in mind when trying to adopt a pragmatic strategy for each site, balancing the site aims and the health of livestock and the needs of those who may purchase such stock. A chosen strategy may need to be defended later so site managers should explore ways of minimising risk as suggested below.

11.9 Where ragwort is not common and animals can graze selectively, ie without over-grazing, then sheep may incidentally help to keep infestations under control. Wherever ragwort problems arise on NNRs or SSSIs it would seem managers currently rely on sheep grazing to control infestations, preferably using controlled grazing, as hard as possible in the spring, for 14 days at a time.

11.10 Some of the ways to minimise the risks of ragwort poisoning include:-

1 do not allow young animals access to ragwort infested swards - graze with the least susceptible class of stock available, possibly goats or draft ewes, when ragwort plants are young and relatively infrequent. If high ragwort densities occur - consider alternative means of control

2 avoid grazing ragwort infested pastures with heavily worm-burdened animals, particularly when recently dosed with copper compounds or scheduled to be dosed with such compounds in future

3 avoid moving hungry animals on to ragwort infested pastures

4 avoid timing hard grazing of an area when the ragwort plants are mature - if in a drought this is likely to occur, provide uninfested supplementary energy feeds or access to uninfested areas adjacent to the infested area

5 do not graze soon after any cutting, topping or herbicide use before the ragwort plants have disintegrated and disappeared

6 never feed ragwort infested hay or silage

7 when turning out housed animals or animals fed with supplementary feeds on to ragwort infested pastures ensure they have a high protein diet, which ceases gradually before turnout, and make any dietary changes gradual to minimise the risk of rumen upset

8 never feed high protein or high copper feeds after ingestion of ragwort

9 never allow stock suffering from vitamin or mineral deficiencies or imbalances to eat ragwort,

10 when stock risk eating ragwort consider the need to provide additional vitamin and mineral supplementation, particularly vitamin B12, found in bran and other foods, and ensure any food supplements contain no copper

11 never allow animals which are scouring or show any other signs of digestive upset or illness on to ragwort infested pastures, remove them immediately they show any such signs

12 never allow ragwort to be eaten for more than 14 days at a time

13 avoid poaching of any sward, and particularly where it may allow the establishment of new ragwort seedlings these may just just replace the current ragwort plants after grazing

14 adopt ragwort control measures, especially in fields for cutting.

11.11 If the grazing of ragwort infested pastures is allowed there may be a moral obligation to any potential purchaser of such animals, who should be told of the likely liver damage. The resultant low price that is likely to ensue, as well as care for animal welfare should persuade English Nature staff that this practice is not to be recommended on pastures known to contain high infestations of ragwort. The likely outcry from the public that would arise if a conservation body like English Nature deliberately allowed stock to be exposed to a high risk of such poisoning, should persuade staff that other means of control of severe ragwort infestations should be used.

11.12 No studies have been reported of the competitive ability of ragwort against a grass sward but it is clear from casual observation that it is not a vigorous competitor in intensively managed grassland. In Orkney, Forbes (1976) achieved complete elimination of *S. aquaticus* from pasture within two seasons by increasing cattle stocking rate and nitrogen fertiliser application without recourse to herbicides.

12.0 **Effect of Cutting and hand control techniques**

12.1 Apart from sheep grazing, hand-pulling is currently the most popular technique of direct ragwort control on nature reserves, from the survey of English Nature managers undertaken for this report. Hand-pulling is selective, but laborious, often ineffective and costly, particularly when large areas of infestation occur. Cutting poses risks of poisoning stock whether by topping, hay-cutting or mowing for silage. In short, it is rare for either hand-pulling or cutting to give satisfactory control of ragworts, and the reasons for this are outlined below.

12.2 Cutting

This common practice may do more harm than good. Cutting of the stems at the early flowering stage reduces seed production but does not destroy the plant and indeed it encourages its development by stimulating the growth of side shoots. Cut plants often produce a second crop of short flowering heads which are impossible to cut efficiently. They grow more vigorously than uncut plants the following year.

12.3 Cut plants left lying in the field may still set seed and are a serious poisoning risk. They should therefore be removed and burned.

12.4 ADAS/MAFF and the Scottish Colleges state that

"cutting is NOT RECOMMENDED **except where the field is to be ploughed the following spring**" (Anon, 1976; 1979; 1982).

Ploughing is clearly inappropriate on nature reserves, or other conservation sites, ancient monuments, etc.

12.5 Pulling

Obviously, to pull ragworts it is necessary that they have produced a flowering stem.

12.6 Directly quoting from the Scottish Colleges leaflet on the control of ragwort:-

"Even when plants are pulled apparently cleanly from the ground, root fragments remain in the soil. These can produce new plants which establish readily or allow seeds to germinate in the space left by the parent plant."

12.7 Hand-pulling **and removal** of the plant is practised to some extent on farmland and commonly on nature reserves. For heavy infestations or large areas hand-pulling is not only ineffectual, but laborious and probably impractical. Hand-pulling is NOT RECOMMENDED **except for very small or light infestations of ragwort which would be uneconomic to deal with in any other way.** It is sometimes worthwhile to clean up a field before silage or hay cutting when there are a few ragwort plants present. On agricultural land these may be survivors after a herbicide treatment (Anon 1976; 1979). If hand-pulling is practised, damp soil would appear to favour more complete removal of the roots than dry soil conditions.

12.8 There are anecdotal stories of ragwort affecting the health of people who spend long periods hand-pulling ragwort (Tim Dixon and McArthy, personal communications); however, no reports have been published in the scientific literature - possibly because hand-pulling is less common today than in the past, reducing the risk of susceptible individuals undertaking work which will harm them, and a scientific experiment to induce such symptoms would be impractical. However, wearing suitable gloves and clothing is recommended when extensive hand-pulling of ragwort is practised.

13.0 Effect of Organic Manures

13.1 It is appreciated that apart from direct deposition of dung by grazing animals the spreading of manures from housed stock is rarely allowed on conservation sites. However, slurry or farm yard manure is an almost inevitable waste/ by-product on livestock farms; which consequently means spread of such manures. To predict the likely effects of organic manures on ragwort incidence is not easy, given a lack of experimental data on the subject.

13.2 However, the nutrients contained in organic manures have been studied occasionally. Generally ragwort is found in poorer grassland (Courtney, 1973), which has little fertiliser nitrogen applied (Forbes, 1982; Hopkins and Peel, 1985); hence, if organic manures were applied they might be expected to improve the competitiveness of grass species particularly at the expense of ragwort and, it may be said, many other herb species. From the reports of Thompson and Makepeace (1983) clover nitrogen, phosphate and potash applications do not appear to put ragwort at such a competitive disadvantage as fertiliser nitrogen.

13.3 Watt (1984) showed how high levels of nitrogen and phosphate could help improve ragwort establishment especially when a herbicide (propyzamide) was used to suppress grass growth or a large gap in the sward existed.

13.4 Watt (1985) found both *S. jacobaea* and Hoary Ragwort (*S. erucifolius*) established better on old cowpats (27.5% of seeds established) compared with molehills which were hazardous sites (where 10% established).

13.5 It is said that ragwort is a poor competitor, therefore anything which improves the competitiveness of surrounding herbage, relative to ragwort, is likely to reduce infestation. Depending on the herbage and the situation, the nutrients contained in organic manures could put ragwort at a competitive disadvantage, and so reduce incidence. By the same token if the surrounding herbage has been damaged, the nutrients in organic manures are just as capable of increasing ragwort incidence, particularly if the surrounding herbage is selectively grazed by cattle. Similarly if mowing occurs, say for hay, after ragwort seeding this may suppress grass growth, particularly where grass regrowth is inhibited by a very short sward being left or where drought conditions follow mowing or hard grazing.

14.0 Chemical Control of Ragworts using Herbicides

14.1 Ragwort can be controlled using herbicides and sufficient is known about optimum timing to largely render ragwort a problem of communication in agricultural land. Maurice Massey (personal communication) expressed the sentiments of many other English Nature managers when he said that "the problem of Injurious Weeds, as defined by the 1959 Weeds Act, to other land users is over-stated, given such weeds have no chance of establishment in intensive farmland and the 1959 Weeds Act forces chemicals to be used to attack ragwort and other 'weed' species in areas where they should not be eradicated." However, on agricultural land, lower inputs and more environmentally-friendly farming methods are being encouraged and adopted, particularly in Environmentally Sensitive Areas and on set-aside land. On many farms where grassland occurs longer term leys and permanent pastures are replacing short-term leys, so ragwort still poses an economic threat in many situations where it occurs.

14.2 Ragwort will continue to be an undesirable plant in many situations, and need controlling for the foreseeable future. Agrochemicals may rarely be able to be applied with sufficient selectivity to warrant their application to nature reserves; however, effective chemicals do exist and these are now reviewed with the factors which dictate their usage and effect.

14.3 Factors which influence herbicidal control

In the course of farm advisory work it is clear that the major deterrent to the use of herbicides for ragwort control is the inevitable damage to clover, which is a particularly valuable sward component where ragwort tends to be a problem - ie low-input management systems on soils prone to drought or low fertility Forbes, 1984). One might also add the expense of control may not be easily met by farmers using low input systems; but the potential loss of livestock through ragwort poisoning is still likely to make long-term control economically justifiable.

14.4 The timing or herbicide applications is important. Delaying ragwort spraying until June or July after flower-bud formation gives good control of non-flowering seedlings but indifferent control of second-year and older plants. Hence, **for grazed swards the optimum time for spraying is earlier, in late April or May, when older plants are still at the rosette stage and is now recommended** (Anon, 1982). Do not spray hay and silage fields in the spring unless a period of at least 4-6 weeks can be allowed for the stems to wither away before cutting.

14.5 **Particularly for fields intended for hay or silage, the best time to spray is the autumn, from mid-September to November, of the year preceding cutting**; this allows the weed to die, and so reduces the risk of fodder contamination. Autumn spraying might interfere less with stock management than earlier in the year but livestock still need to be moved from pastures to be treated both to avoid grazing reducing ragwort leaf area and to avoid poisoning after spraying. Close grazing of ragwort may make this weed more difficult to kill chemically.

14.6 Trials in Scotland, Orkney and in the English Midlands have shown similar results, to those given in Table 2.

Table 2: Ragwort control from herbicides applied at different times of the year (given as % control one year after treatment):

	Time of herbicide application 26 March % Control	17 June % Control	8 November % Control
Asulam	87	94	46
2,4 D	86	99	83

(ADAS, 1982)

14.7 The effectiveness of the autumn spraying was probably reduced by rain which followed spraying.

14.8 **Table 3:** Ragwort % control one year (and two years) after treatment:

	Time of herbicide application May/ June % Control		October/ November % Control	
	Rosettes	Flowering Plants	Rosettes	Flowering Plants
2,4 D	94 (84)	98 (98)	0 (19)	86 (8)
MCPA	88 (44)	68 (77)	18 (13)	81 (24)
Clopyralid	92 (75)	78 (99)	51 (13)	85 (30)
Triclopyr	92 (31)	93 (84)	0 (11)	52 (21)
Clopyralid+ Triclopyr	83 (100)	93 (99)	26 (0)	88 (16)

(Richards *et al.*, 1983)

14.9 Once any control measures have been used to reduce initial populations, repeated treatments, combined with improved grassland management, will be needed to prevent re-infestation.

14.10 According to Fryer and Makepeace (1978) - spraying of MCPA or 2,4 D will normally kill ragwort plants at all stages of growth before the flower buds are well-formed; 2,4 D ester has usually given the most-effective control in agricultural grassland, and it is more rain-fast than other materials. However, this is becoming less easy to obtain than the amine formulation of 2,4 D. Results may be variable because if the flowering buds are sprayed too late they may still produce flowers and viable seed in the season of spraying or new seedlings or regrowth from roots may occur after spraying. The success of spray treatment depends largely on whether the field becomes re-colonised after spraying. A single treatment may not be successful and repeat applications may be necessary.

15.0 **Choice of Herbicide**

15.1 Herbicides are approved for use in a particular crop or situation. They mainly vary in their spectrum, efficacy, timing, hazard to health, cost, availability and ease of application. Decisions on product choice may be influenced by other factors - past experience, available knowledge, and the alternatives available. With all products used for ragwort control there is a need to exclude stock from treated pastures.

15.2 Conservation site managers may need to consider constraints such a need for permission to use certain products. A selection chart for ragwort control is given at Appendix III. **Not all the pesticides listed are suitable for use in nature reserves - do not apply any pesticide without first consulting the Science Directorate of English Nature.** Particular attention should be given to the use of clover-safe herbicides if legumes are to be preserved in a sward. Mecoprop, clopyralid, 2,4 D, MCPA and other hormone herbicides will all damage or kill clover and other broad-leaved species.

Note: no label claims of ragwort control exist for mecoprop (=CMPP) and the mecoprop-p isomer.

15.3 <u>Herbicidal control strategy for ragworts - see Appendix III</u>

Spraying can reduce infestations by altering the competitive balance in favour of the grasses which can then cover the area more densely.

15.4 Ragwort seedlings are readily killed by growth regulator herbicides but because treated mature plants can regenerate from root-stocks and other ragworts can establish from new seed germinations the long-term effect of such herbicides variable.

15.5 **NB It is important to note that existence of herbicidal activity against ragworts does not mean that control can be expected from all of the following; some herbicides, like asulam, at certain rates, merely suppress ragworts.**

15.6 Products approved for use in established grassland with <u>claimed activity</u> (according to product labels) against ragworts include:-

asulam (Asulox) - clover safe; but Yorkshire Fog, Smooth Meadow-grass, Cocksfoot and Bents (*Agrostis* spp) are susceptible
asulam + mecoprop + MCPA (not currently marketed)
clopyralid + triclopyr (Grazon 90)
clopyralid + mecoprop (not currently marketed)
2,4 D (eg BASF 2,4 D Ester, Campbells Destox, Campbells Bioweed)
dicamba (Tracker)
dicamba + MCPA + mecoprop (eg Campbells Grassland Herbicide, Docklene, Hysward) - ragwort is **moderately resistant**
dicamba + mecoprop (eg Di-Farmon, Farmon Condox, Hygrass) - ragwort is **moderately resistant**
dicamba + mecoprop + triclopyr (Fettel)
dicamba + triclopyr + 2,4 D (Broadshot)
glyphosate (Roundup - approved in grassland for use either prior to sward destruction or as a selective application through a weed-wiper; but not approved in grassland through a knapsack sprayer - that approval relates to forestry, non-crop areas, aquatic situations and top-fruit orchards)

15.6 cont **Note**: Muster is a glyphosate formulation but it is only approved for sward destruction. It is not approved for use through a weed-wiper, nor for the selective control of grassland weeds by knapsack-spraying.
MCPA (eg BASF MCPA Amine 50, Phenoxylene)

15.7 Old literature includes spot treatment with dry sodium chlorate (a dessert spoonful to each plant). Care must be taken as there is a risk of this chemical bursting into flames. It is totally unsuitable for use on nature reserves due to its lack of selectivity, persistence and fire hazard. Similarly old references to dichlorprop should be ignored.

15.8 Ragworts are <u>incorrectly</u> listed as resistant to:

benazolin + 2,4 DB + MCPA,
MCPB
MCPA + MCPB
2,4 DB
triclopyr

15.9 The reason for ragworts being <u>incorrectly</u> listed as resistant to the above is that insufficient evidence of control was submitted to the approval authorities or less than 85% was obtained in trials. The approval authorities look for high levels of efficacy (85% or over), but 84.9% kill is still very effective.

15.10 If, or when, these and other herbicides which claim no control of ragwort are used, possibly to control other weeds, they can cause foliage effects, as well as making ragwort more palatable to stock, so either do not treat ragwort with these herbicides, or exclude stock from treated areas just as if a more effective product had been used. As an example of the modesty of such ratings: when applied in November in one trial (Forbes, 1982):

7 l ha^{-1} of benazolin + 2,4 DB + MCPA gave 72% ragwort control, when measured in the following July,

2.3 MCPB @ 2.3 kg ae ha^{-1} gave 82% ragwort control and

MCPB + MCPA as Tropotox Plus gave 77% control of ragwort .

15.11 In the same trial 2,4 D ester gave 100% control, MCPA gave 99% control and asulam gave 92% control @ 1.1 kg ai ha^{-1}, and 96% control @ 2.3 kg ai ha^{-1}.

15.12 In the trial (see Table 3 cited in Section 14.8) by Richards *et al.* (1983) triclopyr gave 92% control of rosettes up to one year after spraying in May/June and 31% control two years after spraying; with respectively 93% and 84% control of flowering plants from a similar spray timing. However, results were very disappointing from a October/ November treatment.

15.13 Where incomplete kill results from a herbicide the stock exclusion period may even be longer than the usually quoted 3-4 weeks, which in itself may be optimistic. The risk of livestock poisoning is such that it is essential to examine treated plants to ensure minimal risk to stock, rather than rely on a fixed period to elapse before turnout without checking the pasture.

15.14 Williams (1984) gives no herbicide completely susceptible ratings for ragwort species. He omits any claims for asulam, clopyralid, dicamba, mecoprop, triclopyr + clopyralid, and triclopyr + dicamba + mecoprop. Williams (1984) gives moderately susceptible ratings for

* asulam + mecoprop + MCPA
  2,4 D
* dicamba + mecoprop + 2,4,5-T.
  MCPA
* 2,4,5-T + 2,4 D +/- dicamba

15.15 Moderately resistant ratings are given by Williams (1984) for ragwort control with:

dicamba + mecoprop

15.16 None of the starred herbicides given immediately above and quoted by Williams are currently approved as formulated products in the UK. This shows the range of products available for ragwort control is quite limited but not as limited as Williams implies. Since 1984 other products have been approved.

15.17 ADAS (Cooper, 1992) indicates Common Ragwort is susceptible to:

2,4 D + dicamba + mecoprop - however this is only approved in rough grazing, amenity grass and non-crop areas

15.18 Cooper comments that despite no label claims for Grazon 90 (clopyralid + triclopyr) a high proportion of ragwort plants will be killed.

15.19 Cooper (1992) indicates Common Ragwort is moderately susceptible to:

a tank-mix of clopyralid + MCPA - no formulated product is currently available
2,4 D
the 5 l ha^{-1} rate of 2,4 D + dicamba + triclopyr (= 'Broadshot')
MCPA

15.20 Cooper (1992) indicates Common Ragwort is moderately resistant to:

dicamba + mecoprop
dicamba + MCPA + mecoprop

15.21 Research papers (Thompson, 1974, and 1977, Taylor 1973, Thompson and Saunders, 1980, and 1982) and other references (Brenchley and Long, 1946) include comments to use of the following in established grassland, but those below are not approved for use in grassland in the UK, for good reasons and must not be used even if stocks can be found:-

chlorthiamid
dichlobenil
dinoseb amine or acetate
2,4 D + picloram
2,4 D + dicamba
picloram granules
sodium chlorate

15.22 Other products with activity against ragworts can be used in newly sown grassland; but there is no available chemical which claims to be suitable for killing all ragwort in newly-sown clover-containing leys. However, if necessary, in addition to many of the products listed above in section 15.6, the following will have some useful effect:-

a) In newly sown clover-containing grassland:

bentazone + MCPA + MCPB (Acumen)
benazolin + 2,4 DB + MCPA (Legumex Extra, Setter 33)
MCPB

b) In newly-sown grassland which does not contain legumes:

bentazone + cyanazine + 2,4 DB (Topshot)
benazolin + bromoxynil + ioxynil (Asset)
bromoxynil + ioxynil + mecoprop (for ryegrass and amenity grass only - ragworts only checked not controlled)

2,4 DB + MCPA
MCPB + MCPA

15.23 Fortunately ragwort is rarely a serious problem in first-year grass. This is mainly because ragwort cannot tolerate soil disturbance, good ploughing kills all established plants. The weed rarely appears in arable rotations, which include short-term leys but occasionally causes problems in arable silage, following incomplete ploughing or maybe regeneration from seed. However, in nature reserves ploughing is environmentally undesirable, and as in many agricultural situations, ploughing may be, physically or economically, impracticable. However, whatever the method of grass re-establishment it may not be long before ragwort reappears when management is inappropriate.

15.24 Treatment using weed-wipers is not recommended for ragwort control in grassland whether used for livestock grazing or conservation for hay or silage, unless the risk of poisoning is minimised by stock removal or unless sufficient allowed interval is given between treatment and cutting. Because of the risk of poisoning stock, following herbicide application to ragwort, and the problem of missing rosettes, which could cause user disatisfaction later, ADAS trials have not looked at ragwort control using weed-wipers. However, a number of materials with approval for use through a weed wiper would give some control of ragwort. These herbicides include:

a) clopyralid (however, the off-label approval number 0662/92 relates only to use to control thistles; therefore usage to control ragwort in the absence of thistles with clopyralid through a weed wiper is illegal)

b) dicamba - this may not be readily available as a 'straight'

c) dicamba + triclopyr + 2,4 D (= 'Broadshot') - Shell have expressed reservations and would prefer that this is not used on ragwort-infested fields to avoid possible user disatisfaction when rosettes are missed, and the risk of stock poisoning from treated plants.

d) glyphosate

15.25 Better control is likely to result from two passes, but obviously would give little or no control of new seedlings which have not yet sent up a flowering stem, due to insufficient weed height

15.26 One might also expect variation in performance between machines, herbicides, sites and years. A wick height of 10 cm is the height the author recommends for English Nature sites, as was used by John Bacon when testing the Royal Agricultural College prototype in the summer of 1992 with clopyralid on thistles. Obviously there has to be sufficient transference and height adjustments may need to be made in individual circumstances.

15.27 Hard grazing before weed-wiping or herbicide application by other techniques may be needed, but not so hard as to include significant ragwort grazing. Before using a weed-wiper, grazing may help to minimise sward damage and reduce chemical usage. Hard grazing may also help to increase the height differential between sward and weeds to improve efficacy of rope wick applicators.

15.28 A common problem with glyphosate through a weed-wiper is poor flow through being sticky and oily. The recommended dilution in a weed wiper is one part glyphosate to one part water; but one part glyphosate to two parts water is recommended for hot dry conditions (F.B. Cooper, personal communication). Surfactants used with the material in spraying have not been tried to improve flow or effect. Research on this may be worthwhile.

15.29 When spraying with the clover damaging product MCPA is to be used hard grazing prior to spraying will reduce clover leaf area and so reduce uptake (Ivens, 1978).

15.30 As with thistles long-term control is easier in arable land or newly sown leys where the roots have been broken by cultivation, than in old grassland.

15.31 Again as with thistles and docks, one spray treatment seldom eradicates ragwort from permanent pasture - therefore if at first you do not succeed, do not give up. It is emphasised with all Injurious Weeds that a change in management to improve the competition from herbage plants may be essential for lasting control (Anon, L51, 1976).

16.0 Appropriate Application Technique

16.1 For useful control of an undesirable species and the minimum environmental damage there is a need for correct choice of application method and careful application of a weed-killer.

16.2 Application techniques to be considered are:-

a) Boom spraying - few conservation sites allow such application, but it is the most common method of applying herbicides on farms, being the least labour intensive, quickest, and cheapest method of weed control in many agricultural situations

b) Knapsack spraying for spot-treatment - appropriate where small areas require spraying but the saving in chemical cost and minimisation of usage can be out-weighed by labour costs

c) Weed-wiping - in the past poor control has often resulted from use of weed-wipers; but as this report indicates, new machinery is being developed, which combined with relatively recently developed herbicides may mean greater success and usage of this technique in future.

The reasons for past poor control with weed-wipers include too rapid a forward speed through the sward, lack of height differential, irregular terrain, and a desire to obtain effective control in one pass with herbicides which needed two passes (Anon, 1984; Garstang, 1985). One may add at too great a height resulting in insufficient weed coverage with herbicide. Any new weed-wiping machine will have to be used appropriately.

16.3 Whatever the application technique chosen, it requires concentration, skill and expertise in use.

16.4 Operators for successful herbicide usage must ensure:-

careful application,
avoidance of misses, overlaps, drift, and
use of the correct volume at the correct pressure and dilution
when necessary making adjustments and
always checking the equipment is functioning correctly

16.5 Problems occur when there is a lack of care, and this need for care puts off many site managers or their staff from use of herbicides. It cannot be ignored even if the task is delegated to a contractor. Whenever communications are involved there is a need for clearly written instructions from someone who knows what is to be done to someone who will read and follow them.

16.6 This may all seem obvious but the frequency of problems and the errors that do occur are usually due to operator or communication error. Poor control from a herbicide, assuming it was initially chosen correctly, is usually due to mis-application.

16.7 Product labels may not always be sufficiently detailed for an individual user's requirement. Nature reserve managers will frequently be disappointed in the amount of information on product labels which is relevant to their needs. Staff in the Science Directorate of English Nature may be able to advise potential users of herbicides when the need arises.

16.8 Garstang (1985) states that the techniques currently available for the control of perennial weeds do lend themselves to development of control strategies, given the likely insufficient control from single product applications.

16.9 Label recommendations are complex enough as it is, and it would seem unlikely that it will ever be possible to encapsulate such strategies for perennial weed control on product labels.

17.0 **Biological Control of Ragwort**

<u>Biological Control of Ragwort - Invertebrate</u>

It is doubtful whether insects could ever usefully contribute to ragwort control; because ragwort and the insects that feed on it and their own predators and fungal pathogens live in a dynamic equilibrium (van der Meijden 1979; Lakhani and Dempster, 1981).

17.1 One of the insects which depend upon ragwort is the native Cinnabar Moth (*Tyria jacobaea*) a member of the *Lepidoptera: Arctiidae*, which feeds on ragwort leaves and flowers in June and July. Cinnabar Moth caterpillars are eaten by moles and birds as well as being parasitised by at least nine Ichneumons and two Braconids (Dempster, 1971).

17.2 It is the ragwort population which controls the Cinnabar Moth population and not *vice-versa* (Dempster and Lakhani, 1979). Another difficulty is the resilience of the weed itself. Even severely defoliated *S. jacobaea* plants are capable of substantial compensatory seed production (Islam and Crawley, 1983). This is considerably greater in wet years or wet sites compared with dry ones, with a corresponding reduction in efficacy of biological control (Cox and McEnvoy, 1983). Cinnabar Moth caterpillars by defoliating the plant may delay flowering so that the ragwort can behave as a perennial.

17.3 In Canada the time available between defoliation by Cinnabar moth and the onset of frost is critical (Harris *et al.*, 1978a), the later the frost the greater the time for recovery. In Britain, there is such a long interval between feeding in June and July by Cinnabar Moth and the onset of frosts or likely flooding, the moth has little effect.

17.4 There are two Ragwort Seed Flies (*Pegohylemyia seneciella* Mead; otherwise called *Hylemya seneciella and Delia seneciella*), and Pegohylemyia jacobaea, which are members of the *Diptera: Anthomyiidae*. The larvae of these flies attack the flower heads.

17.5 Ragwort Flea Beetle (*Longitarsus jacobaeae*) which is a member of the *Coleoptera: Chrysomelidae*, also occurs in Britain, and elsewhere in the world (Newton, 1933). Ragwort Flea Beetle larvae feed by tunnelling into the root crown. They have been used successfully for biological control of ragwort (Hawkes, 1981; Hawkes and Johnson, 1978). James, McEvoy and Cox (1992) found in a field experiment 95% control of vegetative ragwort densities and 39% reduction of flower production by flea beetles alone. When combined with simulated Cinnabar Moth damage capitulum production was reduced by 98% and no viable seeds were produced. These findings support the strategy of introducing complementary enemies which attack different stages and at different times. However, Carabid, Staphylinid, Arachnid and Acarine species represent potential predators (Ireson and Terauds, 1982). Fecundity is influenced by temperature, photoperiod and humidity (Frick, 1971; Frick and Johnson, 1972), so that local field conditions may result in low field populations compared to that expected from laboratory studies, when females can lay about 400 eggs (Ireson and Terauds, 1982). In England adults emerge in late July.

17.6 All of these individually named ragwort-dependent invertebrate species have been shipped from Britain to other parts of the world where ragwort exists, as possible biological control agents. Over one quarter of a million Cinnabar Moth pupae were sent from England to New Zealand between 1926 and 1931 (Samways, 1981; Syrett, Schele, and Philip, 1984). This was followed in 1928 to 1939 by shipments of Ragwort Seed Flies (Syrett, Schele, and Philip, 1984); over half a million of *Pegohylemyia seneciella* larvae were sent out in 1937 alone (Samways, 1981).

17.7 Other consignments of invertebrates for attempted biological control of ragwort were sent from Britain to Australia, Canada, Tasmania, and the United States. In New Zealand the Cinnabar Moth almost died out due to parasitoids turning from the native Magpie Moth to the introduced *Tyria jacobaea*. One of the Ragwort Seed Fly species (*Pegohylemyia seneciella*) appears to have died out; because all recent recoveries have been *Pegohylemyia jacobaea* (Holloway, 1983). In Australia neither the moth nor flies established, despite several attempts, due to predation, parasitisation and disease.

17.8 Some biological control of ragwort has occurred in parts of North America; but even here, these invertebrates have rarely succeeded in giving control. Limited and local successes have occurred in North America when an additional factor has helped the predator. In Nova Scotia the weed dies from the combined effects of the Cinnabar Moth and cold weather. The moth attacks the weed two months before the onset of frosty weather, which does not allow the plant to build up sufficient root reserves which would otherwise enable it to survive the winter (Harris *et al.*, 1978b).

17.9 In California the Cinnabar Moth has given excellent control close to the initial introduction site. However, the moth is reluctant to spread and so control remains local. The action of Cinnabar Moth is now being complemented by Ragwort Seed Fly (*Pegohylemyia seneciella* Mead; and Ragwort Flea Beetle (*Longitarsus jacobaea*).

17.10 As implied above, certain conditions must prevail for effective biological control. Dempster (1975) and Harris (1981) have studied the biology of Cinnabar Moth. The soil must be well-drained to avoid the high mortality of moth pupae which occurs in waterlogged soil; hence it is less likely to be found on *S. aquaticus* than *S. jacobaea*. The climate must restrict ragwort regeneration after defoliation, as in Nova Scotia, and over-grazing must be controlled so that grasses and other herbage can smother young and regenerating ragwort.

17.11 <u>Biological Control of Ragwort - Fungal Pathogens</u>

Greaves (1985) said that much work was being done in Europe on behalf of the USDA. However, the literature search carried out for this report did not find any further references to this work. Sedlar *et al.* (1983) list 19 potential biological control fungi of *Senecio* species. Field data from recent work may provide more information; but at present no control is available by inundative inoculation using fungal pathogens of ragworts.

17.12 Biological Control of Ragwort - Grazing by wild mammals and birds

Rabbits, like Common Ragwort, tend to be more common on sandier and lighter soils, with their scraping of the soil surface it is to expected that they act to provide invasion sites for ragwort, and by their close cropping of surrounding herbage create the suitable conditions for spread; however, they can graze young ragwort, so may also reduce the effect of the damage they have previously caused. Rabbits show low intestinal absorption of alkaloids, (Pierson, Cheeke and Dickinson, 1977) and/or efficient urinary excretion (Swick *et al.*, 1982b).

17.13 Dry conditions on light soils almost certainly also favour the Common Ragwort. The better drought resistance of ragwort gives this plant a greater ability to survive rabbit grazing than other herbage species, so as a practical means of ragwort control rabbits offer little hope. However, on certain sites it is appreciated that rabbits can be useful and may even be fenced in to provide short turf, droppings and particular ecological niches.

17.14 Deer appear to be resistant to ragwort poisoning (Dean and Winward, 1974), but as they can rarely be confined to ragwort infested areas due to the high fences required, and their wild nature, it is unlikely to be cost-effective to use deer for ragwort control.

17.15 There are no references to other native wild mammals or birds eating ragwort; but wild goats may graze ragwort.

17.16 Biological Control of Ragwort - Integrated Control Measures

Harris (1981) suggests that in general weeds are most often killed by an accumulation of stresses, such as climatic factors and plant competition. He suggests that biological control agents should be considered additional stress factors. Where ragwort regrows after defoliation by Cinnabar Moth addition of a second species, the Ragwort Flea Beetle, may be effective in giving control (Hawkes and Johnson, 1978). Defoliation by the Cinnabar Moth caterpillars is complemented by the activity of the Ragwort Flea Beetle larvae which tunnel into the root crown. To date no other examples of successful integrated control of ragwort using applied treatments have been published. However, experimentation on various options could be tried.

18.0 Ideas for Further Research

18.1 It is recommended that there is liaison with research workers and conservation bodies in New Zealand, Australia, Canada, Tasmania and the United States, who have ragwort problems. It is suggested that continued monitoring of the literature on a regular basis is necessary and that this will enable experimentation on new control techniques to begin in Britain as early as possible.

18.2 As stated in Section 11.5, conflicting results have been reported on the effect of fertiliser nitrogen on herbage copper contents (Whitehead, 1966a, b). Further research would appear to be required.

18.3 As noted in Section 9.1, ragwort is very rich in sodium, chlorine and copper (Fairburn and Thomas, 1959). However, little work on the nutritive value of ragwort exists due to its toxicity which makes such research considered academic because the plants are such a health risk. Such research is not just of academic interest because animals, particularly sheep, do eat ragwort. For us to understand what ragworts contain at different stages of growth, and the amount normally consumed, as opposed to what represents a toxic amount, may be of practical interest. Therefore it is suggested that study of the nutritive value of ragwort may prove worthwhile.

18.4 Research is required regarding the alkaloid contents of ragworts at different stages of growth, intakes of alkaloids and other nutrients, particularly copper, by ewes, tolerance of different **breeds of mature** sheep to ragwort. Given how often such animals are used to keep ragwort populations under control, this research is vital.

NB Because of the biennial nature of ragwort, whatever control techniques are investigated, (hand-pulling, herbicidal or biological or use of grazing animals), it is important that <u>the degree of control which results in the two following seasons after treatment is monitored.</u>

18.5 Investigation of the grazing habits of different ages, sexes and breeds of animal may be worthwhile, for example, evidence exists that goats eat ragwort with more immunity than other stock, Swaledale ewes eat ragwort while Dorset Horns do not. and so on. This may be linked to examples of grazing management, such as folding at Martin Down NNR, mixed grazing as at Wylye Down NNR, flexible mixed grazing at Parsonage Down NNR and natural grazing, for example by rabbits and deer at Porton Down.

18.6 To-date no research has been reported in Britain using weed-wipers to control ragworts. Such use is advocated in New Zealand in sales literature for weed-wipers there. Given the benefits of selective application by weed-wipers in nature reserves it is essential that the effect of weed-wipers on ragwort is studied, particularly where accidental treatment may occur when treating other weeds, like thistles. Obviously, treatment using weed-wipers is not recommended in grassland used for livestock grazing or conservation for hay or silage, unless the risk of poisoning is minimised by stock removal or unless sufficient allowed interval is given between treatment and cutting.

18.7 Quantification of the time for herbicide-treated plants to disintegrate and disappear would help indicate the safe interval between treatment and cutting or grazing.

18.8 Glyphosate can affect the viability of the seed of treated plants so further research into its application to flowering and post-flowering ragworts through a weed-wiper is recommended. The height of application using a rope wick is critical on effect of herbicides. Research may be worthwhile in determining the movement of glyphosate and other herbicides from the site of application to the roots or other above ground parts, in the field, at different plant growth stages under differing water regimes.

Use of glyphosate in the autumn is worth further study, even if it proves ineffective, it will allow managers to quantify the likely effects.

As indicated in Section 15.28, a common problem with glyphosate through a weed-wiper is poor flow through being sticky and oily. Surfactants used with the material in spraying have not been tried to improve flow or effect. Research on this may be worthwhile.

18.9 Sedlar *et al.* (1983) list fungal pathogens with potential as biological control agents of ragworts. These vary in their host specificity, so this should be researched with an assessment of the pathogenicity of various potential fungal pathogens with their effects at various times of the year. Biological control agents should be screened to ensure that desirable species are not attacked. So far no potential methods of biological control have been successful enough for this to be a problem in the field, but any research should consider the potential risk to desirable species of plants, fauna and other species.

18.10 Integrated control of ragwort using applied treatments using various options could be tried. These include examination of optimum timing of management operations and integration with low doses of herbicides, defoliation by Cinnabar Moth, attack by Ragwort Seed Flies and Ragwort Flea Beetle. However, where desirable *Senecio* species may be affected, such treatments could prove unfortunate.

18.11 New research could indicate the appropriate length and portions of ragwort roots capable of regenerating, the conditions under which regeneration will and will not occur, and examination to see whether it varies according to season, or with the amount of carbohydrate and other reserves in the root.

18.12 It is important that Injurious Weeds are looked at in context, as part of the ecosystem of each site. See Section 18.3 and the following sections of Part II of this report concerning docks for ideas which are just as relevant to thistles and ragwort. These ideas were first expressed at a FWAG/NCC Seminar in August 1983 to discuss topics relevant to understanding herb-rich chalk swards. It is suggested that all NNRs and SSSIs could offer facilities for research into the effect of Injurious Weeds as part of their particular site ecosystems, having said this, concentration on a few sites would be more practical.

18.13 Some of the above ideas may not provide practical control methods; however, they do indicate gaps in our knowledge and would help quantify effects of certain management practices, and may point the way forward to strategies for the future. Such research would be useful in managing Environmentally Sensitive Areas (ESAs) and Set-Aside land in a manner sympathetic to the environment, so link funding with various organisations including MAFF could be considered.

19.0 Recommendations

19.1 These fall into two categories, those to be applied to all sites and those which may be relevant in a particular situation, or need modification to individual circumstances:-

19.2 **Avoid poaching or damage to the sward**, particularly in wet conditions when such damage is more likely to occur, from the following:-

- vehicles
- ditching/ hedging/ river bank maintenance
- frequent animal movement
- animals congregating regularly in one area for feeding (unless a deliberate 'sacrifice area' is a practical necessity)

Sheep grazing is less likely to cause poaching than cattle and tend to be infrequently associated with high ragwort populations.

19.3 One is driven to suggesting that **spreading of organic manures should be confined to relatively dry or frosty soil conditions in wetter months**, which is an almost impractical ideal recommendation. This would avoid the manure killing the sward and to allow the manure to be washed into the sward. Use of low ground pressure tyres, avoidance of wet patches or steep slopes, and not driving large concentrations of stock through manured pastures are all recommended. Steep slopes are more likely to cause run-off creating nutrient enriched areas and a potential threat of nitrogen contamination of surface waters through drainage. In nature reserves, limits on the period of muck spreading and the maximum amounts of organic manures to be spread should be specified, as occurs in Environmentally Sensitive Areas (ESAs) - such limits may need to be specified on an individual reserve basis, where this has not been done already. It is important that restrictions are practical, otherwise it would be better to stipulate that no use of organic manures is allowed.

19.4 **Prevent weed seeding and rootstock regeneration by appropriate techniques.** Whatever technique is used, minimise the damage to the grass and other flora. Techniques include the following (which may not be relevant in every situation):-

a) <u>sheep grazing</u>, in accordance with the guidelines given in Section 11.10 on how to minimise risk of poisoning

b) <u>hand-control techniques</u>, such as hand-pulling, removal and burning off-site

19.4 cont c) weed-wiping or spot-spraying with a knapsack, when maximum weed growth is occurring - this will tend to be when the rosette is sending up a flowering shoot, in May or June.

19.5 If possible, use the most selective herbicide available (in the case of ragworts, this is clopyralid, even though the weed does not appear on the product label) although other herbicides can be considered (e.g. dicamba) particularly where a mixture of Injurious Weeds exists and use the prototype weed-wiper devised by the Royal Agricultural College at a wick-height of 10 cm, this is likely to result in the best control of the target species.

A second-best alternative is to use a relatively non-selective herbicide like glyphosate and to wait until a sufficient height differential exists between the sward and the target weeds, and set the wick height above the sward canopy. The latter technique is only really suitable on level ground, when other desired species have died down and will probably prove unsatisfactory. However, research into the use of unselective herbicides in the autumn would enable more accurate prediction of the results.

Whatever type of herbicide is used aim to maximise chemical transfer, by driving at the correct speed, ensuring adequate flow rate, the optimum height and making two passes instead of one, not missing any infested areas, and so on.

19.6 **Apply herbicide through a weed-wiper in August or later in the autumn**, as low as the terrain and chemical chosen allows without causing sward damage to maximise herbicide transfer to the targets.

19.7 **Use grazing stock to perform controlled grazing** to create a denser, thicker sward where possible before ragwort infestation. If infestation is slight, mature ewes could allowed to graze quite intensively until mid-May. Avoid under or over-grazing, or erosion on slopes. Ensure stock levels are regularly adjusted according to the amount of grazing available and the ground conditions. Provide adequate fencing, water, or supplementary feeding or move stock off vulnerable areas. If it is deliberate policy to practice intensive grazing at critical times of the year, be prepared to adopt other ragwort control techniques.

19.8 **Avoid burning or any other operation which results in bare ground** anywhere. If it is unavoidable, have cleaned seed (free from 'weeds') ready to sow over such areas, these seeds should have been taken at different harvest dates from the reserve previously, and be prepared to control weeds during the establishment phase. Natural regeneration without over-sowing should rarely be used.

19.9 **Try to alternate cutting or grazing regimes** to intensify utilisation to try to produce a thicker sward, or use grazing with different types of livestock either by mixed grazing or use various livestock alternately. Beware of changing sward composition and losing desirable species.

19.10 **As a last resort, spot or boom spraying can be considered** when and where necessary, and if it is practical. Avoid herbicide drift, ensure timing of operations is ideal for the particular weed target and the chemical chosen to be used. Choose a material consistent with the site objectives from Appendices III and IV. When spraying ensure that sufficient leaf area is exposed and that ragworts are growing actively in mid-May to mid June.

20.0 Action Calendar for Botanically-rich Grassland

This calendar sets out an ideal strategy for control of ragwort, and other weeds that exploit bare ground due to poaching or over-grazing. It is not practical to follow it in all circumstances, and it will not acceptable on all sites every year, each site needs to be managed according to its individual objectives and resources. However, the following general principles can be followed in most circumstances:-

- avoid fertiliser use,
- avoid application of stored organic manures where possible,
- avoid cutting of botanically-rich grassland before mid-July
- <u>avoid or minimise poaching or damage to the sward</u>, particularly in wet conditions when such damage is more likely to occur, from the following:-
  - vehicles
  - ditching/ hedging/ river bank maintenance
  - frequent animal movement
  - animals congregating regularly in one area (unless a deliberate 'sacrifice area' is a practical necessity)
  - if supplementry feeding is allowed on a particular site, it should either be concentrates free of viable seeds or forage which is free of thistles, docks and ragworts and restricted to areas of low conservation value

The following management guidelines, will reduce the risk of weed infestation and help to prevent spread of weeds when inadvertent invasion occurs:-

January Where possible, remove any sheep which are grazing on fields which are later to be grazed, give priority to fields needed soon after lambing, (or exceptionally, where a very early silage cut is to be taken - to reduce the risk of poaching or leptospirosis) and maximise grass growth before turnout. Consider away-wintering, housing or use of a sacrifice area; if sheep out-wintering is unavoidable do not graze below 3 cm.

Do not allow cattle grazing in winter, on botanically-rich sites.

February If sheep are grazing on fields which are to be cut for hay, (or silage) remove them. Check/repair fencing and water supply. Do not allow sheep grazing on swards below 3 cm height.

March	Turn out ewes with lambs on to areas which have not been grazed recently.

Before cattle turnout, start measuring sward height on or soon after March 10; once a week if cold, twice a week if warm.

Aim to turnout when ground is dry and for set-stocked areas sward height is 1 cm above the height given in Table 3 (Part 1: Section 11.8 on page 19) and height is increasing. For rotationally grazed areas sward height at turnout can be up to 5 cm above the targets given in Table 3. If grass exceeds 5 cm above the target height, use an electric fence to strip graze. Subsequently target heights up to 2 cm above can be allowed before under-grazing occurs; if sward height falls close to, or below, the values given in Table 3 (Part 1: Section 11.8 on page 19), over-grazing is occurring. Increase or reduce stock numbers to maintain target sward height. Alternatively use an electric fence to adjust grazing area; check fences regularly, and close off parts of fields to prevent excessive damage or over-grazing. If necessary supplementary feed with concentrates, particularly if animals have recently given birth, and grass is limited ie close to the target given in Table 3 (Part 1: Section 11.8 on page 19).

If applying organic manures to cutting fields apply no later than mid-March and in dry weather or on frosty ground; spread thinly to reduce contamination of fodder and minimise sward damage; if not applied now, store until after cutting. If muck-spreading or chain harrowing is allowed it should be restricted to areas of low conservation value, and as infrequently as possible. Beware of run-off or nutrient movement on sloping or uneven ground.

April	Only continue to feed sheep energy blocks/supplements if sward height is less than 4 cm and not increasing. Do not be afraid to graze at 7 ewes or more to the acre, to avoid grass exceeding 5 cm height, provided that grass was not over-grazed earlier, and poaching or over-grazing (ie grass height below 4 cm) can be avoided.

May	Your most important month. Stocking density should be at its peak in late May. Do not allow grass height to be more than 2 cm above target, as given in Table 3 (Part 1: Section 11.8 on page 19); if necessary, stock heavily, strip graze and fence off an area for fodder conservation. Once thistles are slightly above the rest of the sward consider use of herbicide preferably applied by a weed-wiper at 10 cm above ground.

June	If the sward becomes stemmy, and if this is undesirable, an area may be closed up for hay, possibly using an electric fence, or try to increase stock numbers. However, gradually allow sward height to increase, particularly on drought-prone sites.

July Ensure that swards are not over-grazed, see Table 3 (Part 1: Section 11.8 on page 19), add 1-2 cm to target heights if on droughty sites, and try to maintain sward density. If areas become thin, reduce grazing pressure to allow self-seeding, to thicken sward later.

Once ragworts are above the rest of the sward consider pulling, this is essential on fields intended for cutting, when the resulting fodder will be fed to stock. Ragwort identification for pulling is easiest when the rosette is sending up a flowering shoot. Remove pulled plants to minimise risk of poisoning stock and to avoid seed return. Prevent weed seeding and vegetative regeneration by appropriate techniques - see Section 19.4.

Weed-wiping ragwort is not recommended unless the fields are not to be grazed for at least 4 weeks and after any treated plants will have decomposed completely.

August Graze hay/big bale silage aftermaths once regrowth reaches about 2 cm above target sward heights given in Table 3 (Part 1: Section 11.8 on page 19); but if grazing area includes previously uncut areas you may graze earlier than this.

If bare areas are obvious consider sowing seed from other parts of the site (which is 'weed'-free) on bare or thin patches.

Pull ragworts again if necessary.

September If earlier control to prevent seeding was missed: consider applying a herbicide through a weed-wiper in September or later in the autumn before the first frosts, as low as the terrain and chemical chosen allows without causing sward damage to maximise herbicide transfer to the targets. This may still reduce weed populations, (and may have an incidental reduction in seed viability and late seeding). In an effort to kill the tap root a translocated material such as glyphosate should be used. The earlier this herbicide is applied the better, to maximise effect.

October House cattle, including calves before a reduction in their performance and serious poaching occurs. Wean spring born suckler calves prior to housing. Only allow stock to stay out if dry conditions allow minimal poaching.

November Consider allowing sheep to graze down to 4-5 cm, after cattle housing, to remove surplus grass and minimise frost-kill. Such grazing may be an extra source of income, as well as increasing sward density; but avoid over-grazing or poaching, to minimise weed invasion sites. Continue measuring sward once a fortnight through the winter.

December Do not allow sheep to graze below 3 cm, and do not allow poaching of the sward.

21.0 Conclusions

21.1 Understanding the biology of weed species is helpful in devising control strategies and it helps to indicate suitable timings, reasons why a particular technique succeeds or fails, and promising avenues for research into control techniques. As with the recommendation in Section 18.4 referring to period over which control should be monitored, failure to understand the autecology of this weed may detract from the quality of the research undertaken to progress our knowledge further, or result in failure to control a ragwort problem on an infested site. Therefore, it is highly desirable that anyone who wishes to contribute towards solution of ragwort infestations, whether by scientific research or control in one area of a nature reserve, takes the trouble to read the whole of Part III of this report.

21.2 Ragwort control is possible, if sufficient effort can be justified and sustained. However, as is often the case, prevention is better than cure, and avoidance of poaching, bare ground, under-grazing or over-grazing should be the aims of all site managers. Poor management will usually reduce the incidence of desirable species as well providing suitable conditions for undesirable species, such as ragwort.

21.3 There is no "instant cure", often many years effort is required to clear an infestation; but if control is gradually achieved it may help produce a more "natural," stable equilibrium of the desired species in a sward.

21.4 A combination of timely husbandry operations, maybe with herbicide use, based on an understanding of the weed's growth characteristics should prevent it becoming a menace, or enable site managers to be confident of winning the war against undesirable species with the minimum cost.

23.0 **References** - Part III Ragworts

Amor, R.L., Lane, D.W., and Jackson, K.W. (1983) Observations on the influence of grazing by sheep or cattle on the density and colour of ragwort. Australian Weeds, 2 (3), pp 94-95.

Anon (1967) Ragwort (*Senecio jacobaea*) declared a noxious weed, Tasmanian Journal of Agriculture, 38, pp 157-159.

Anon, 1975, Investigation of grassland weeds: ecology and control of ragwort, Research investigations and field trials 1974-75, pp 138-140.

Anon (1976) Weed Control: Ragwort AW 51, ADAS/Ministry of Agriculture, Fisheries and Food, HMSO, London, UK.

Anon (1976) Ragwort, ADAS Leaflet 51

Anon (1976) Ragwort, College Leaflet No 26, North of Scotland College of Agriculture, 6 pp.

Anon (1979) Scottish Agricultural Colleagues, 'The Control of Ragwort', Publication 38, 7 pp.

Anon (1982) Ragwort, Leaflet 280, ADAS/MAFF, Alnwick, 6 pp.

Anon (1982) GA 08077 Ragwort control in permanent pasture - timing of herbicide, ADAS Research and Debvelopment Reports, Grassland, Fodder Conservation and Forage crops 1982, Reference Book 227 (82), ADAS.

Anon (1982) GA 08077 Ragwort control in permanent pasture - timing of herbicide, ADAS Research and Debvelopment Reports, Grassland, Fodder Conservation and Forage crops 1982, Reference Book 227 (82), ADAS.

Anon (1984) Broad-leaved weed control in established swards. Research and development reports, Grassland, Fodder Conservation and Forage Crops, ADAS/MAFF, 1983, pp 174-176.

Anon (1986) Ragwort, ADAS Pamphlet 280,

Aplin, R T, Benn, M.H, J Rothschild, M (1968) Poisonous alkaloids in the body tissues of cinnabar moth. Nature, 219, pp 747-748, UK.

Bacon, J., personal communication.

Baker-Kratz and Maguire (1984) cited by McClements, I., (1992) Marsh ragwort (*Senecio aquaticus*), PhD Thesis, Queens' University, Belfast.

Bellamy, G. personal communication.

Buckmaster, G.W., Cheeke, P.R. and Shull, L.R. (1976) Pyrrolizidine alkaloid poisoning in rats:- protective effects of dietary cysteine. Journal of Animal Science, 43, pp 464-473.

Cameron, E., (1935) A study of the natural control of ragwort (*Senecio jacobaea*). Journal of Ecology, 23, pp 265-322.

Cheeke, P.R. (1984) cited by McClements, I., (1992) Marsh ragwort (*Senecio aquaticus*), PhD Thesis, Queens' University, Belfast.

Clapham, A.R., Tutin, T.G. and Warburg, E.F. (1962) Flora of the British Isles, Cambridge University Press, Cambridge, pp 867-869.

Cooper, F.B. (1992) Chemical weed control in grassland, herbage legumes and grass seed crops 1992/93, ADAS Internal Publication, 38 pp.

Cooper, F.B. personal communication.

Cooper, M.R., Johnson, A.W. (1984) Poisonous plants in Britain and their effects on animals and Man. MAFF Ref Book No. 161, London, UK, Her Majestys' Stationery Office , pp 83-87.

Coup, M.R. (1959) Common plants poisonous to stock. New Zealand Journal of Agriculture, **98**, pp 61-69.

Courtney, A (1975) Ragwort control in grassland - an alternative strategy. Agriculture in Northern Ireland, **50**, (6), pp 177-180

Courtney, A.D. and Johnston, R.T. (1974) Time of herbicide application for the control of docks (*Rumex obtusifolius*) in a grassland conservation system. Proceedings 12th British Weed Control Conference (1974), pp 751-760.

Cox, C.S. and McEnvoy, P.B. (1983) Effect of summer moisture stress on the capacity on tansy ragwort (*Senecio jacobaea*) to compensate for the defoliation by cinnabar moth (*Tyria jacobaeae*). Journal of Applied Ecology **20**, pp 225-234.

Davies, A.J. (1953) The Ragwort problem in Wales. Proceedings of the 1st British Weed Control Conference, pp 204-210.

Dean, R.E. and Winward, A.H. (1974) An investigation into the possibility of tansy ragwort poisoning of black-tailed deer. Journal of Wildlife Diseases, **10**, pp 166-169.

Deinzer, M.L., Thompson, P.A., Burgett, B.M., Isaacson, D.L. (1977) Pyrrolizidine alkaloids: their occurrence in honey from tansy ragwort (*Senecio jacobaea* L.). Science, **195**, pp 497-499.

Dempster, J.P. (1971) The population ecology of the cinnabar moth *Tyria jacobaeae L. (Lepidoptera: Archidae)*. Oecologia, **7**, pp 26-67.

Dempster, J.P. (1975) Animal Population Ecology. Academic Press, London.

Dempster, J.P. and Lakhani, K.H. (1979) A population model for cinnabar moth and its food plant, ragwort. Journal of Animal Ecology, **48**, pp 143-163.

Dickinson, J.D., Cooke, M.P., King, R.R., Mohamed, P.A. (1976) Milk transfer of pyrrolizidine alkaloids in cattle. Journal of the American Veterinary Association **169**, pp 1192-1196.

Dixon, T., personal communication.

Donald, L.G. and Stranks, P.C. (1956) Ragwort poisoning from silage. British Veterinary Journal 112, pp 307-311.

Duby, G.D. (1979) Tansy Ragwort, Modern Veterinary Practice 56, pp 183-188.

Evans, W.C. and Evans, E.J.R. (1949) Poisoning of farm animals by the marsh ragwort (*Senecio aquaticus*), Nature 164, London, pp 30-31.

Forbes, J.C. (1974) Spraying and cutting experiments on ragwort (*Senecio jacobaea L.* and *S.aquaticus Hill*). Proceedings 12th British Crop Protection Conference - Weeds 2, pp 743-750.

Forbes, J.C. (1974a) A survey of ragwort in Orkney, in Weed Control in the Northern Environment: British Crop Protection Council Monograph No. 10, pp 115-120.

Forbes, J.C. (1974b) Spraying and cutting experiments on ragwort. Proceedings of the 12th British Weed Control Conference, pp 743-750.

Forbes, J.C. (1976) Influence of management and environmental factors on distribution of the marsh ragwort (*Senecio aquaticus Huds*) in agricultural grassland in Orkney. Journal of Applied Ecology 13 (3), pp 985-990.

Forbes, J.C. (1977a) Chemical Control of Marsh Ragwort (*Senecio aquaticus*) in established grassland. Weed Research 17, pp 247-250.

Forbes, J.C. (1977b) Population flux and mortality in ragwort (*Senecio jacobaea* L.) infestation. Weed Research 17, pp 387-391.

Forbes, J.C. (1982) Evaluating herbicides for selective control of *Senecio jacobaea* in grass/clover swards. Proceedings of the 1982 British Crop Protection Conference - Weeds, pp 375-379.

Forbes, J.C. (1984) Changes in the incidence of ragwort (*Senecio jacobaea*) infestation of grassland over a 4 year period in N.E. Scotland. Weed Research 24, pp 431-438.

Forbes, J.C. (1985) The impact and control of Ragwort in grassland. British Grassland Society Occasional Symposium No. 18, Weeds, pests and diseases of grassland and herbage legumes, pp 147-154.

Frick, K.E. (1971) *Longitarsus jacobaeae* (Coleoptera *Chrysmelidae*, a flea beetle for the biological control of tansy ragwort II. Life-history of a Swiss biotype. Annals of the Entomological Society of America, 64, pp 834-840.

Frick, K.E., Johnson, G.R. (1973) *Longitarsus jacobaea* (Coleoptera: *Chrysomelidae*), a flea beetle for the biological control of tansy ragwort: 4. Life history and adult aestivation of an Italian biotype. Annals of the Entomological Society of America, 66, pp 358-367.

Fryer, J.D. and Makepeace, R.J. (1978) Weed Control Handbook, Volume II: Recommendations, British Crop Protection Council, Published by Blackwell Scientific Publications, Oxford, pp 233-390.

Garstang, J.R. (1985) An advisory view, British Grassland Society Occasional Symposium No. 18. Edited by Brockman, J.S. British Crop Protection Council Monograph No. 29, pp 234-242.

Gill, N.T. and Vear, K.C. (1982) Agricultural Botany, Volumes I and II.

Goeger, D.E., Cheeke, P.R., Schmitz, J.A., and Buhler D.R., (1982) Toxicity of tansy ragwort to goats, American Journal of Veterinary Research, 43, pp 252-254.

Goodman, G.T. and Gillham, M.E. (1954) Ecology of the Pembrokeshire islands II. Stokholm environment and vegetation. Journal of Ecology 42, pp 296-327.

Graham and Hutchings (1988) cited by McClements, I., (1992) Marsh ragwort (*Senecio aquaticus*), PhD Thesis, Queens' University, Belfast.

Greaves, M.P. (1985) Developments in biological control, in Weeds, pests and diseases in grasslands and herbage legumes, edited by Brockman, J.S., British Crop Protection Council Monograph No. 29, pp 155-160.

Grennan, E.J., (1966) Copper deficiency in pasture on blanket peat, Irish Journal of Agricultural Research, 5, pp 147-153.

Grigson, G. (1955) The Englishman's Flora, J.M. Dent and Sons Ltd, London, pp 363.

Harper, J.L. and White, J. (1974) The demography of plants. Annual Report of Ecology and Systematics 5, pp 419-468.

Harper, J.L. and Wood, W.A. (1957) Biological flora of the British Isles. *Senecio jacobaea L.*, Journal of Ecology, 45, pp 617-637.

Harris, P., Thompson, L.S., Wilkinson, A.T.S., and Neary, M.E. (1978a). Reproductive biology of tansy ragwort, climate and biological control by the cinnabar moth in Canada, Proceedings 4th International Symposium on Biological Control of Weeds, Gainesville, 1976, pp 163-173.

Harris, P., Wilkinson, A.T.S., Thompson, L.S., and Neary, M.E., (1978b) Interaction between Cinnabar moth *Tyria jacobaeae* L. Lep. *Arctiidae* and ragwort *Senecio jacobaea* L. (*Compositae*) in Canada, Proceedings of the 4th International Symposium on the Biologcal Control of Weeds, Gainesville, 1976, pp 174-180.

Harris, P., Wilkinson A.T.S., and Myers, J.H., (1981) *Senecio jacobaea* l. tansy ragwort (*Compositae*), in Biological control programmes against insects and weeds in Canada 1969-1980, (Eds. Kelleher, J.S., and Hulme, M.A.), Commonwealth Agricultural Bureau, Farnham Royal, UK.

Hart, R., (1977) Why are biennials so few? American Naturalist 111, pp 174-180.

Hawkes, R.B. (1981) Biological control of tansy ragwort in the state of Oregon, USA. Proceedings 5th International Symposium on Biological Control of Weeds, pp 623-626.

Hawkes, R.B. and Johnson, G.R. (1978) *Longitarsus jacobaeae* aids moth in the biological control of tansy ragwort. Proceedings 4th International Symposium on the Biological Control of Weeds, Gainesville, 1976, 4, pp 193-196.

Hemmingway, R.G., (1962) Copper, molybdenum, manganese and iron contents of herbage as influenced by fertiliser treatments over a 3 year period, Journal of British Grassland Society, 17, pp 182-187.

Henson, I.E. (1969) Studies on the regeneration of perennial weeds in the glasshouse 1. Temperature species. Technical Report of the Agricultural Research Council Weed Research Oganization No. 12, 23 pp.

Hinchelwood, D., personal communication.

Holloway, B.A., (1983)Species of ragwort seedflies imported into New Zealand (*Diptera: Anthomyiidae*), New Zealand Journal of Agricultural Research, 26, pp 245-249.

Hopkins, A., Wainwright, Joanna, Murray, P.J., Bowling, P.J. and Webb, Morag (1988) 1986 Survey of upland grassland in England and Wales: changes in age, structure and botanical composition since 1970-72 in relation to grassland management and physical features. Grass and Forage Science, 43, pp 185-198.

Hopkins and Peel (1985). Incidence of Weeds in Permanent Grassland, British Grassland Society Occasional Symposium No. 18. Edited by Brockman, J.S., British Crop Protection Council Monograph No. 29, pp 93-103.

Ireson, J.E. and Terauds, A. (1982) Preliminary observation on the ragwort flea beetle (*Longitarsus jacobaeae*) introduced into Tasmania to control ragwort (*Senecio jacobaea*) (Pasture Weed), Australian Weeds, Vol. 1 (4), June 1982, Victoria, pp 3-6, Australia.

Irvine, A.M., Forbes, J.C., Draper, S.R. (1977) Effect of 2,4-D on the water-soluble carbohydrate content of ragwort (*Senecio jacobaea*) leaves. Weed Research, 117, pp 169-172.

Islam, Z. and Crawley, M.J. (1983) Compensation and regrowth in ragwort (*Senecio jacobaea*) attacked by cinnabar moth (*Tyria jacobaeae*). Journal of Ecology 71, pp 829-843.

Ivens, G.W. (1978) Californian Thistle - New Zealand Journal of Agriculture, 137, pp 13-14.

James, R.R., McEvoy P.B. and Cox C.S. (1992) Combining the cinnabar moth (*Tyria jacobaeae*) and the ragwort flea beetle (*Longitarsus jacobaeae*) for the control of ragwort (*Senecio jacobaea*): an experimental analysis, Journal of Applied Ecology, 29, pp 589-596.

Johnson, A.E. (1978) Tolerance of cattle to tansy ragwort. American Journal of Veterinary Research, 39, pp 1542-1544.

Johnson, A.E. (1982) Failure of mineral-vitamin supplements to prevent tansy ragwort (*Senecio jacobaea*) toxicosis in cattle. American Journal of Veterinary Research, 43, p 718-723.

Kent, D.H. (1964) Plant Notes. *Senecio* Proceedings of the Botanical Society of the British Isles, 5, pp 232.

King, R.R. (1980) Transfer of pyrrolizidine alkaloids from *Seenecia jacobaea* into the milk of cattle and goats and the effects on calves and kids consuming this milk. PhD Thesis, Washington State University, USA.

Lakhani, R.H. and Dempster, J.P. (1981) Cinnabar moth and its food plant, ragwort: further analysis of a simple interaction model. Journal of Animal Ecology, 50, pp 231-249.

Lambers, H. (1976) Respiration and NADH - oxidation of the roots of flood-tolerant and flood-intolerant Senecio species as affected by anaerobiosis. Physiologia Plantarum, 37, pp 117-122.

Lambers, H. and Noord, R and Posthumus, F. (1979) Respiration of Senecio shoots: inhibition during photosynthesis, resistance to cyanid and relation to growth and maintenance. Physiologia Plantarum, 45, pp 351-356.

Lambers, H., Steingrover, E., Smakman, E. (1978) The significance of oxygen transport and of metabolic adaption in flood-tolerance of Senecio species. Physiologia Plantarum, 43, pp 277-281.

Lloyd, J.R. (1957) The use of liver function test in the prognosis of ragwort poisoning in cattle. Veterinary Record, 69, pp 623-625.

Long, H.C. (1924) Plants poisonous to livestock, Second Edition Revised, Cambridge University Press, Cambridge, pp 44-46.

Long, H.C., and Brenchley, Winnifred, E. (1948) Suppression of weeds by fertilisers and chemicals, Crosby Lockwood and Son Ltd, London, pp 87.

Massey, M. personal communication.

McClements, I., (1992) Marsh ragwort (*Senecio aquaticus*), PhD Thesis, Queens' University, Belfast.

McEnvoy, P.B. (1984a) Dormancy and dispersal in dimorphic achenes of tansy ragwort, *Senecio jacobaea* L. (*Compositae*), Oecologica, 61, pp 160-168.

McEnvoy, P.B. (1984b) Seedling dispersion and the persistence of ragwort *Senecio jacobaea* (*compositae* in a grassland dominated by perennial species. Oikos, 42, pp 138-143.

McEnvoy, P.B. and Cox, C.S. (1987) cited by McClements, I., (1992) Marsh ragwort (*Senecio aquaticus*), PhD Thesis, Queens' University, Belfast.

McGuinness, J.P. (1980) *Senecio jacobaea* as a cause for hepatic encephalopathy. California Veterinarian 34, pp20-22.

Mason, R.W. (1980) Ragwort poisoning. Journal of Agriculture, Tasmania 51, pp 51-52.

Mattocks, A.R. (1968) Toxicity of pyrrolizidine alkaloids, Nature, London, 217, pp 723-728.

Miller, D. (1936) Biological control of noxious weeds. New Zealand Journal of Science and Technology 18, 581-584.

Mortimer, P.H. and White, E.P. (1975) Toxicity of some composite (*Senecio*) weeds. Proceedings of the 29th New Zealand Weed and Pest Control Conference, pp 88-91.

Nicol, Ian, personal communication.

Newton, H.C.F. (1933) On the biology of some species of Longitarsus (Col., Chrysom.) living on ragwort. Bulletin of Entomological Research, 24, 511-520.

North of Scotland College (1984) Weed control in grassland. Research Investigations and Field Trials 1982-83, pp 88-90.

Otzen, D. (1977) Life forms of three *Senecio* species in relation to accumulation and utilisation of non-structural carbohydrates, Acta Botanica Neerlandica, 26, pp 401-409.

Palfrey, G.D., MacLean, K.S. and Langille, W.M. (1967) Correlation between incidence of ragwort (*Senecio jacobaea*) poisoning and lack of mineral in cattle. Weed Research, 7, pp 171-175.

Payne, K., personal communication.

Peel, S. and Hopkins, A. (1980). The incidence of weeds in grassland. British Crop Protection Conference - Weeds 1980, pp 877-890.

Petrie and Logan (1980-1) cited by McClements, I., (1992) Marsh Ragwort (*Senecio aquaticus*) biology and control, PhD Thesis, Queens' University, Belfast.

Pierson, M.L., Cheeke, P.R. and Dickinson, E.D. (1977) Resistance of the rabbit to dietry pyrrolizidine (Senecio) alkaloid, Research Communications in Chemiocal Pathology and Pharmacology 1977, 16, pp 561-564.

Poole, A.L. and Cairns, D. (1940) Botanical aspects of ragwort (*Senecio jacobaea*) control. Bulletin of New Zealand Department of Scientific and Industrial Research, 82, pp 1-61.

Richards, M.C., Swift, G., Cleland, A.T., and Davies, D.H.K. (1983) Evaluation of 3,6-dichloropicolinic acid, triclopyr, 2,4-D ester and MCPA, alone and in mixtures, for *Senecio Jacobaea* control in grassland. Annals of Applied Biology 102 Supplement (Tests of Agrochemicals and Cultivars 4,) pp 104-105.

Samways, M.I. (1981) Biological Control of Pests and Weeds. The Institute of Biology No. 132, Edward Arnold, 57 pp.

Sedlar, L., Vanmoos, R., Defago, G., Kern, H. (1983) Fungi occurring on selected weeds. A compilation from literature data. Zürich. Institut für Phytomedizin, ETH-Zentrum, 99 pp, Switzerland.

Segal, H.G. and Krick, T.P. (1979) Pyrrolizidine alkaloids organohalogen derivative isolated from *Senecio jacobaea* (tansy ragwort) Toxicology Letters **44**, pp 193-198.

Sharrow, S.H. and Mosher, W.D. (1982) Sheep as a biological control agent for tansy ragwort. Journal of Range Management, 35, pp 480-482.

Sheldon, J.C., (1974) The behaviour of seeds in soil, 3. The influence of seed morphology and the behaviour of seedlings on the establishment of plants from surface-lying seeds, Journal of Ecology, 62, pp 47-66.

Smirnoff, N., and Crawford, R.M.M., (1983) Variation in the structure and response to flooding of root arenchyma in some wetland plants, Annals of Botany, 51, pp237-249.

Smith, A., personal communication.

Smith, C.J., (1980) Ecology of the English Chalk, Academic Press, London, 573 pp.

Spedding, G.R.W. and Diekmahns, E.C. (1972) Grasses and legumes in British Agriculture. Commonwealth Agricultural Bureaux. Bulletin 49, 511 pp.

Swick, R.A., Cheeke, P.R. and Buhler D.R., (1982a) Subcellular distribution of hepatic copper and serum ceruloplasmin in rats intoxicated by oral pyrrolizidine (*Senecio*) alkaloids, Journal of Animal Science, 55, pp 1425-1430.

Swick, R.A., Cheeke, P.R., Patton, N.M., and Buhler, D.R., (1982b) Absorption and excretion of pyrrolizidine (*Senecio*) alkaloids and their effects on mineral metabolism in rabbits, Journal of Animal Science, 55, pp 1417-1424.

Swick, R.A., Miranda, C.L., Cheeke, P.R., and Buhler, D.R. (1983b) Effect of phenobarbital on toxicity of pyrrolizidine (*Senecio*) alkaloids in sheep, Journal of Animal Science, 56, pp 887-894.

Syrett, P., Schele, S.M., and Philip, B.A., (1984) Renewed activities in biological control of ragwort, Proceedings of 37th New Zealand Weed and Pest Control Conference 1984, pp 37-41.

Taylor, R.L. (1973) Control of Ragwort, Proceedings of the 26th New Zealand Weed and Pest Control Conference, Auckland, 1972 pp 50-52.

Toynton, P., personal communcation.

Thompson, A. (1977) Herbicides for the spot treatment of ragwort in pasture, Proceedings of the 30th New Zealand Weed and Pest Control Conference 1977, pp 34-37.

Thompson, A. (1983) Pasture weed control by rope-wick applicator, Proceedings 36th New Zealand Weed and Pest Control Conference 1983, pp 96-98, Thompson, A. and Makepeace, W. (1983) Longevity of buried ragwort (*Senecio jacobaea*) seed. New Zealand Journal of Experimental Agriculture, 11, p 89-90.

Thompson, A., and Saunders, A.E., (1984) A combination of 2,4 D and MCPA, alone and in combination for the control of ragwort, Proceedings 37th New Zealand Weed and Pest Control Conference, pp 33-36.

Thompson, A. and Saunders, A.E., (1986) The efect of fertiliser on ragwort in pasture, Proceedings of New Zealand Weed and Pest Control Conference, July 1986, pp 175-178.

Toynton, P., personal communication

Van Der Meijden, E. (1974) The distribution of *Senecio jacobaea* L. and *Tyria jacobaeae* L. in relation to soil properties Acta Botanica Neerlandica, 23, pp 681-690.

Van Der Meijden, E. (1979) Herbivore exploitation of a fugitive plant species: local survival and extinction of the cinnabar moth and ragwort in a heterogenous environment. Oecologia, 42, pp 307-323.

Van Der Meijden, E. and Van Der Waals Kooi, R.E., (1979) The population of *Senecio jacobaea* L. in a sand dune system, 1. Reproductive strategy and the biennial habit, Journal of Ecology, 67, pp 131-153.

Warren, F.L. (1970) *Senecio* alkaloids, in The Alkaloids, Chemistry and Physiology, Volume XII, (Editor R.H.F. Manke), New York, USA, Academic Press, pp 245-331.

Watt, T.A. (1984) The effect of proyzamide and fertilizer on the establishment of ragwort in grassland. Aspects of Applied Biology, 5. Weed Control and Vegetation Management in forest and amenity areas, pp 109-116.

Watt, T.A. (1987) Establishment of *Senecio jacobaea* L. from seed in grassland and in boxed swards, Weed Research, 27, (4), pp 267-274.

Watt, T.A. (1987) Establishment and growth of *Senecio jacobaea* L. and *Senecio erucifolius* L. in grassland, Weed Research, 27 (4), pp 259-266.

Watt, T.A. (1987) The biology and toxicity of ragwort (*Senecio jacobaea* L.) and its herbicidal and biological control, Herbage Abstracts, 57, pp 1-16.

Watt, T.A. In press. Ragwort - Friend and Foe, The Biologist, February 1993.

Wesson, G. and Wareing, P.F. (1969a) The role of light in the germination of naturally occurring populations of buried weed seeds, Journal of Experimental Botany, 20, pp 402-413.

Wesson, G. and Wareing, P.F. (1969b) The induction of light sensitivity in weed seeds by burial, Journal of Experimental Botany, 20, pp 414-425.

White, R.D., (1983) Mutagenic and toxicological implications of pyrrolizidine (*Senecio*) alkaloids, Dissertation Abstracts International, B, 43, 2077.

Whitehead D.C., (1966a) Nutrient minerals in grassland herbage, Review Series. 1/1966 Commonwealth Bureau Pasture Field Crops, Farnham Royal: Commonwealth Agricultural Bureau, pp 86.

Whitehead, D.C., (1966b) Data on the mineral composition of grassland herbage, Grassland Research Institute, Hurley and the Welsh Plant Breeding Station, Aberystwyth, Technical Report No. 4, Grassland Research Institute, pp 55.

Whitmore, M.,personal communication.

Wiggins, E.D., (1977) (Editor) Report of an article in Hastings and East Sussex Naturalist 1977, 12, pp 37-42. Botanical Society of the British Isles News, 17, pp 12.

Williams, R.D., (Editor) (1984) Crop protection handbook - Grass and clover swards, British Crop Protection council, 104 pp.

APPENDICES

I Survey of English Nature Managers
Table 1 Summary
Tables 2 -13 Comments made by individual managers

II Suitability of herbicides for newly sown and established grass

III Chemical control of thistles, docks and ragworts in agricultural grassland

IV Susceptibility of weeds to herbicides in established grassland

V Examples of proprietary products of active ingredients mentioned in this report

VI Put your foot in it - do the welly boot test

VII The cow equivalent unit

VIII Plan of action for the control of ragwort in grassland

IX Off-label approval for Clopyralid No 0662/92

X Guidance note to those intending to use a pesticide off-label

XI Soil indices

KEY TO SURVEY OF MANAGERS -APPENDIX 1

For the sites discussed here, a numeric key has been produced for this report, these numbers are not allocated by English Nature and to avoid confusion, it is recommended that they are not regarded as references for citation elsewhere:-

The following was discussed with: Tim Dixon (given as 'TD'), Site Manager
1 = Lower Derwent Valley

The following were discussed with: Maurice Massey (MM), Senior Site Manager for English Natures' East Region
2 = Upwood Meadows
3 = Ramsey
4 = Wood Walton Fen

The following was discussed with: Paul Toynton (PT), Site Manager
5 = Martindown

The following were discussed with: Tony Smith (AS), English Natures' Assistant Conservation Officer for Lincolnshire
6 = Silverines Meadow
7 = Woodnook Valley
8 = Cliff House
9 = Hollywell Banks

The following were discussed with: Graham Bellamy (GB), Site Manager
10 = Knocking Hoe
11 = Barton Hills
12 = Buckingham Thick Copse (Rides within a wood)

The following were discussed with: Keith Payne (KP), currently English Natures' Conservation Officer for Oxfordshire - but previously involved with
13 = Pewsey Down
14 = Fyfield Down - geomorphic site, not a botanical site
15 = North Meadow
16 = Ashford Hill
17 = Port Meadow

The following were discussed with: David Hinchelwood (DH), Senior Site Manager, English Natures' South Region
18 = Parsonage Down
19 = North Norfolk Coast
20 = Chimney Meadows

The following were discussed with: John Bacon (JB), Senior Site Manager, English Natures' West Midlands Region
21 = Unidentified at John Bacons' request
22 = Bredon Hill (also discussed with Malcolm Whitmore)
23 = Unidentified at John Bacons' request
24 = Wyre Forest
25 = Derbyshire Dales
26 = Mottey Meadows
27 = Unidentified at John Bacons' request
28 = Unidentified at John Bacons' request
29 = Various Cotswold SSSIs

APPENDIX 1 - TABLE 1

SUMMARY OF FINDINGS OF A SURVEY OF ENGLISH NATURE MANAGERS 1992

See key to match sites to numbers given in table below

Letters indicate other thistle species are also present at these sites, and should not be ignored, some are dominant, others are rare at such sites

a = Woolly (Headed) Thistle - rare this far north

b = Stemless (rare) and Nodding/ Musk Thistles present

c = Stemless Thistle present (rare)

d = Woolly Thistle and Nodding/ Musk Thistle present

e = Woolly, Carline and Stemless Thistles present

f = Woolly (Headed) Thistle present

(-) = localised weed problems exist with this site

Manager consulted	TD	MM	PT	AS	GB	KP	DH	JB
Problem Weed	Occurs at Site Number (see key):-							
Creeping Thistle <u>(C. arvense)</u>	1	2,3	5	8a,9	11,12	13b,14f (15),17d	18,19	21,22,23,24,25c 26,27,28,(29)
Spear Thistle <u>(C. vulgare)</u>	-	2	-	(8a,9)	10,11e	13b,14f 17d	18	(21),22,(25c) 26,27,28,29
Broad-leaved Dock <u>(R. obtusifolius)</u>	(1)	-	-	-	-	(15),16	-	(21),23,24,25c 26,27
Curled Dock <u>(R. crispus)</u>	-	-	-	-	-	15,(16)	-	(21),23,24,25c 26,27
Common Ragwort <u>(S. jacobaea)</u>	-	4	5	6,7c	10,(11e)	13b 17d	19	21,22,24,25c (26),27,(28),29
Marsh Ragwort <u>(S. aquaticus)</u>	1	-	-	-	-	-	-	-

APPENDIX 1 - TABLE 2

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted T.Dixon

Problem Weeds occurring at the Lower Derwent Valley NNR

Creeping Thistle (<u>C. arvense</u>)	Topping, using All-Terrain Vehicle (ATV) + Flail mower is used to control <u>C. arvense</u>. Contractors using knapsack sprayers - MCPA, Broadshot, and Fettel are used when necessary. Contractors have used a boom-sprayer on ditch spoil - applying 2,4 D ester, or glyphosate?
Broad-leaved Dock (<u>R. obtusifolius</u>)	Not discussed. (Only a localised problem at this site).
Marsh Ragwort (<u>S. aquaticus</u>)	Sheep grazing occurs. Cutting for hay/big bale silage occurs in some meadows after:- Hand-pulling in these cutting fields. Aim to minimise poaching by removing sheep when wet or at end October. No feeding in fields is allowed. (Flooding occurs, creating conditions suitable for spread and re-invasion).

APPENDIX 1 - TABLE 3

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted M.Massey

Problem Weeds occurring at the Upwood Meadows NNR, and Ramsey Site

Creeping Thistle (*C. arvense*)	Grassland Management - the main aim is to create desired turf structure by appropriate stocking with livestock. Mowing before flowering and mowing re-growths, is practised at Upwood Meadows. Remove stock during a drought or when wet. No herbicides are used. No action required or taken when insufficient populations of creeping thistle to cause concern to English Nature staff, and where no neighbours are affected.
Spear Thistle (*C. vulgare*)	Grassland Management - the main aim is to create desired turf structure by appropriate stocking with livestock. Mowing before flowering and mowing re-growths, practised at Upwood Meadows but ridge and furrow cause problems. Spudding with a spade 1" below ground surface. Remove stock in drought or when wet. No herbicides are used. Where insufficient populations exist to cause concern, and no neighbours, then no action required.
Docks (*R. obtusifolius*) (*R. crispus*)	Not discussed (No problems mentioned).

The main problem weed occurring at Wood Walton Fen:-

Common Ragwort (*S. jacobaea*)	The principal means of control is by sheep grazing. Cutting for hay is practised after:- Hand-pulling in hay fields, but dump pulled plants in scrub, no use of black plastic sacks, burial or burning. No hand-pulling on grazing fields. Minimise poaching by removing sheep when wet or during a drought. No feeding in fields is allowed. No herbicides are used.
Grassland Management:	Emphasis on appropriate stocking rates to achieve desired sward heights. Use of target grazing heights in certain areas depend on conservation aims: tussocky grass 4-5" long is required for invertebrates; where a more diverse flora is required a shorter sward is produced.

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted	P.Toynton

Problem Weeds occurring at Martindown NNR

Creeping Thistle <u>(C. arvense)</u>	No herbicides are used at present. In the past, an ITE weed-wiping experiment using glyphosate, occurred in 1986. This was successful in reducing thistle numbers in the following seasons when applied after flowering but before senescence.
Spear Thistle & Docks	Not discussed (No problems mentioned).
Common Ragwort <u>(S. jacobaea)</u>	Sheep grazing in November (40 ewes per hectare) and in April (10-15 ewes per hectare), in addition to hard grazing through the summer - rotational grazing for 2-3 weeks on each paddock, on area managed by English Nature staff. Where graziers manage sheep - stocking is less controlled and laxly grazed (1.5 - 3 ewes per hectare at most), resulting in more ragwort problems. Where electric fencing is used, there appears to be the least ragwort. Where herb-rich denser swards exist there is less ragwort. No cutting for hay or silage, no use of fertilisers, lime, or farmyard manures. No hand-pulling is practised. No feeding in fields is allowed. No herbicides used, except once, in 1986, tried weed-wiping with glyphosate which was successful in reducing ragwort numbers in the following seasons, when applied after flowering but before senescence. No winter grazing occurs from 15 November to 1 March - sheep go on to turnips. (Rabbit grazing occurs).

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted T.Smith

Problem Weeds occurring at Cliff House (CH) and Holywell Banks (HB)

Creeping Thistle (*C. arvense*)	On improved and semi-improved areas only, topping has been practised since 1990; takes place before flowering. Sheep grazing occurs. (No hay cuts are taken). No herbicides are used now - but before 1990 a hand-held sprayer was used at Cliff House, to apply MCPA.
Spear Thistle (*C. vulgare*) **Occurs in patches**	On improved and semi-improved areas only, topping has been practised since 1990; takes place before flowering. Sheep grazing occurs. (No hay cuts are taken). No herbicides are used now - but before 1990 a hand-held sprayer was used on 2 occasions.
Docks (*R. obtusifolius*) (*R. crispus*)	Not discussed. (No problems mentioned).

Main Problem Weed occurring at Silverines Meadow and Woodnook Valley

Common Ragwort (*S. jacobaea*)	Hand-pulling and removal is the main means of control before seed set/ shed; been practised for 5 years. Use BTCV teams and Trainline work-experience people. Hand-pulling is done in early-mid August, followed by a clear-up operation during the period from end of August to mid-September. Only cattle grazing at Silverenes Meadow; with 8 'Continental beef cross' cattle at Woodnook Valley graze from May to Sept. No hay cutting is practised at either site. No herbicides are used - but at Silverines Meadow farmer did once obtain consent to use a hand-held weed-wiper to apply glyphosate. This was successful. The aim is to avoid over-grazing; however, in recent dry summers despite no extra stock grazing the reserves the prolonged droughts increased grazing pressure. This produced a short turf, more easily broken open by hoof damage has allowed colonisation by ragwort. This is exacerbated by the fact that it is a problem to get weedy areas grazed at all. At Woodnook Valley there are ragwort seed sources around the reserve. Generally there is no ragwort problem if the farmer does not want control.

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted G.Bellamy

Problem Weeds occurring at Barton Hills and Rides in Buckingham Thick Copse

Creeping Thistle <u>(C. arvense)</u>	At Barton, on a grazing licence, sheep graze from April to Christmas/New Year lightly stocked with 1 ewe per acre, with lambs at <u>(C. arvense)</u> foot during the summer. More densely stocked until 1990 at 2 ewes per acre, as a means of improving the sward. At Barton, it is an area that the sheep over-graze that has become infested. This is a night-time "camp", on a hill-top. The Creeping Thistle has seeded in gaps in the turf. Thistles are a problem where scrub clearance has occurred or on fire-sites ie where there is no competing vegetation. (No hay cuts are taken; but at Buckingham Thick Copse the rides are cut and raked off in June-July and again in Sept-Oct) No herbicides are used.

Problem Weeds occurring at Knocking Hoe and Barton Hills

Spear Thistle <u>(C. vulgare)</u>	Cutting takes place from Mid-July to early August before flowering. Aim to stop seeding. At Barton, on a grazing licence, sheep graze from April to Christmas/New Year lightly stocked with 1 ewe per acre, with lambs at foot during the summer. More densely stocked until 1990 at 2 ewes per acre, as a means of improving the sward. At Barton it is an area that the sheep over-graze that has become infested. This is a night-time "camp", on a hill-top, when their dung decomposes the gap is invaded by Spear Thistles. At Knocking Hoe sheep and rabbits compete for grass. The sheep numbers vary; but average only 1 ewe per 2 acres due to the rabbit grazing pressure, which results in parts of the site offering no sheep grazing. In the past, over-grazing has occurred in the summer. Now grazing parts of the site selectively in the autumn. Public access has limited rabbit control to shooting and ferreting. (No hay cuts taken now; but at Knocking Hoe in the past hay was taken). No herbicides have been used recently; but in the past parts of both sites were improved. No fertilisers, lime or organic manures have been applied. The presence of Woolly Thistle, Carline Thistle and Stemless Thistle limit control methods.
Docks <u>(R. obtusifolius)</u> <u>(R. crispus)</u>	Not discussed. (No problems mentioned).

Problem Weeds occurring at Knocking Hoe (at Barton sheep control ragwort)

Common Ragwort <u>(S. jacobaea)</u>	Hand-pulling and burning of removed plants is the main means of control before seed set/ shed. Use English Nature volunteers. Hand-pulling is done in early-mid August. No hay cutting is practised at either site. No herbicides are used. Ragwort control is practised in the interest of good neighbour relations. Aim to avoid over-grazing; but to keep a close sward.

APPENDIX 1 - TABLE 7

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted K.Payne

Problem Weeds occurring at Pewsey Down (see also David Hinchelwood's comments overleaf on Pewsey Down).

Creeping Thistle (*C. arvense*) Spear Thistle (*C. vulgare*)	At Pewsey, cattle graze whole reserve and sheep also graze half of it. No hay cuts taken; but the thistles are cut and left in situ at the beginning of July and once in August. This timing is a compromise due to the presence of nodding thistle in addition to creeping and spear thistles. However, it has proved successful. No herbicides are used.

Problem Weeds occurring at Fyfield Down - a site which can be over-grazed

Creeping Thistle (*C. arvense*)	Weed-wiping has been tried with Broadshot (dicamba, triclopyr and 2,4 D) but due to late application was not very successful. No hay cuts taken; but the thistles are cut and left in situ at the beginning of July and once in August. This timing is a compromise due to the presence of nodding thistle in addition to creeping and spear thistles. However, it has proved successful. No herbicides are used.
Spear Thistle (*C. vulgare*)	Cutting takes place from Mid-July to early August before flowering. Aim to stop seeding.

Problem Weeds occurring at North Meadow and Ashford Hill - on these hay meadows the aftermaths are grazed at North Meadow by cattle and horses and at Ashford Hill by cattle only.

Docks (*R. obtusifolius*) (*R. crispus*)	At Ashford Hill, these are not a conservation problem in themselves; but the licencee regarded them as a problem. Weed-wiping with glyphosate was tried one year and spot-spraying with Broadshot (dicamba, triclopyr and 2,4 D) or 2,4 D alone was tried in another year. Neither were particularly successful. The weed-wiper transferred insufficient glyphosate to give control unless the wicks were dripping, in which case the herbicide burnt a hole in the sward even where no docks were present. 2,4 D where sprayed killed off the tops but the docks regrew from their tap-roots. At North Meadow, docks are pulled from damp soil in May once started to "shoot" before flowering, and then dumped off-site.

Problem Weeds occurring at Pewsey Down - in addition to creeping thistle mentioned above

Common Ragwort (*S. jacobaea*)	Hand-pulling is regarded as purely cosmetic and a waste of time except to keep neighbours happy. No hay cutting occurs. Traditionally this site was cattle grazed; now the worst half is mixed grazed with sheep, which has controlled the ragwort. No herbicides are used due to the risk of cattle eating herbicide-treated ragwort plants. Ragwort control is practised in the interest of good neighbour relations. Aim to avoid over-grazing; but to keep a close sward.

APPENDIX 1 - TABLE 8

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted K.Payne

Problem Weeds occurring at Port Meadow - uncontrolled common grazing, under-grazed by horses and cattle in summer, and over-grazed and poached by horse in winter. Cattle are taken off in the autumn. In the past, flooding kept the thistles under control, until a weir was built in the 1930's; and sheep controlled the ragwort up to the 1920's.

Creeping Thistle (*C. arvense*)	Cutting occurs from time to time, (suggesting it is not part of a planned strategy?) Knapsack spraying with glyphosate has been tried.
Common Ragwort (*S. jacobaea*)	No hay cutting occurs.

APPENDIX 1 - TABLE 9

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted D.Hinchelwood

Problem Weed occurring at Pewsey Down

Creeping Thistle (<u>C. arvense</u>)

At Pewsey, cattle graze whole reserve and sheep also graze half of it.

No satisfactory answer has yet been found. Creeping thistle occurs on areas of grassland which are wet and flooded during the winter, which with poaching kills the vegetation, leaving bare mud, creating invasion sites for thistles.

Contractors were used in 1992 at a cost of £800 plus English Nature staff for thistle control.

No hay cuts taken; but the thistles are cut at the beginning of July and once in August.

No herbicides are used. Stemless thistle is present on certain areas of the reserve (Milk Hill and Wansdyke) which are to be conserved.

Problem Weeds occurring at Parsonage Down - this is a working chalk grassland farm, with 300 acres of unimproved chalk downland, in addition to improved pastures, which are sown with standard agricultural grasses as permanent pasture or long-term leys. The stocking rate has been the same for the last 40-50 years, it is not obviously under or over-grazed, no bare areas exist. The site manager has a very high standard of grassland management. Rotational grazing around 10-12 compartments is practised, and when ready fields are cut for hay, never silage, on the improved areas. On the old downland, specified numbers of breeding cows and followers, graze with variable numbers of ewes and lambs.

Creeping Thistle (<u>C.arvense</u>)

A mixture of sheep and cattle graze this farm, and there is generally no problem if sufficient labour and machinery is available. Creeping thistle occurs on the back-up (unimproved?) land. The problem is increasing and exacerbated by "dry years". Chalk sites commonly have shallow soils, and where drought (or over-grazing) increases the proportion of bare ground there is an increased thistle (and ragwort) problem in the following year.

Topping is carried out to control creeping thistles, starting in late June and each infested area is usually cut twice in a season.

(Rabbits are a problem, and a lot is spent on their control)

Spear Thistle (<u>C. vulgare</u>)

This weed extends to parts of the old downland, but is mainly a problem of the improved downland.

Spudding is the main means of control of spear thistles and there is generally no problem if sufficient labour is available at a time when it is easily identified just before flowering.

In 1992, it was mistakenly topped, in the absence of the manager.

Problem Weeds at Chimney Meadows - hay meadows associated with a beef unit, with the animals in-wintered on straw bedding.

Creeping Thistle (<u>C.arvense</u>)

Farm-yard manure and fertiliser is applied to the improved pastures.

Hay is taken from about 1½ fields of the 6 or 7 that make up the reserve, the same field is never cut for two successive years.

Bad patches of thistles are sprayed with a knapsack sprayer, containing Roundup (glyphosate)?

Comment: Section 15 Management Agreements for SSSIs might be amended to indicate the latitude that might be allowed in individual circumstances.

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted J.Bacon

John Bacon covered the problem weeds occurring at Bredon Hill, Wyre Forest, the Derbyshire Dales, various Cotswold SSSIs, Mottey Meadows, and various sites unidentified by request (Sites 21, 23, 27 and 28 given below and on the summary table earlier.) Stock are taken off when wet at 1 weeks notice, and if over-grazing is seen stock are taken off to prevent poaching on all sites. The ability to adjust stocking rates occurs on all sites, managers aiming to produce the optimum sward heights "by eye". Many of these sites have been agriculturally "improved" in the past, including ploughing, which may have contributed to their current weed problems. Where no improvements have occurred (as in the Wyre Forest and Cotswolds, feeding of hay and straw in the fields has spread weeds.

Creeping Thistle <u>(C.arvense)</u>	This is by far the commonest weed, trials are currently in progress, to investigate means of control, including a prototype weed-wiper to apply clopyralid. This is because in areas the problem is beyond cutting, which is the most successful technique generally available. However, weed wiping with the prototype appeared slow (2 hours 40 minutes per hectare to cover 51 ha, at one site); modifications should improve on this for the future. Contact John Bacon for further details, if required.

Main Weed Problems at Site 21 - a wildfowl reserve, where the aim is for the birds to have suitable conditions in late autumn and early winter. The site is managed by agricultural tenants, who apply 2 or 3 fertiliser dressings per year on the basis of soil analysis for phosphate and potash, each dressing gives 20 units per acre (25 kg/ha) of nitrogen.

Creeping Thistle <u>(C. arvense)</u>	Affects an estimated 20 out of a total of about 200 acres, which is only grazed by cattle between May and September or October, varying between fields, and Canada and Greylag Geese - there is no sheep grazing nor hay cuts taken. At present, no control on grazing levels is practised: but this is desired for the future. Machine cutting occurs just before seed set, topping is never carried out to manage sward height.
Ragwort <u>(S. jacobaea)</u>	Hand-pulling is practised, at flowering, in mid to late July (Rabbits are common - causing over-grazing)

Main Weed Problems at Bredon Hill - some comments supplied by Malcolm Whitmore (personal communication)

Creeping Thistle <u>(C.arvense)</u>	Affects an estimated 50-60 acres out of the total reserve area, which is only grazed by cattle and sheep, the site is managed to produce areas of short and areas of long grass; but thistle problems are thought to occur due to scrub clearance and cattle poaching in winter. Cutting occurs just before flowering, in June and July where possible. Spot spraying has been done in June, with hand-lances off a tractor/quad mounted sprayer, to apply Grazon 90. The prototype weed-wiper was used here, pre-flowering, and despite a high clover content of the sward, the height differential with the thistles was such that the clopyralid had no effect on the clover.
Spear Thistle <u>(C. vulgare)</u>	Control methods not discussed.
Ragwort <u>(S. jacobaea)</u>	Sheep grazing is the main means of control. (Rabbits cause over-grazing).

APPENDIX 1 - TABLE 11

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted J.Bacon

Main Weed Problems at Site 23 - a boggy SSSI covered by a Section 15 Management Agreement, an organic approach is adopted to avoid use of herbicides.

Creeping Thistle (<u>C.arvense</u>)	Rotational dairy cattle grazing is followed by topping, in the past silage was taken. Now no fertiliser is applied. Flail cutting occurs just before seed set, in June and July where possible. Spraying of buffer land around the site has been done.
Docks (<u>R.obtusifolius</u> and <u>R.crispus</u>)	Control methods not discussed.

Main Weed Problems in Wyre Forest- in meadows, some sheep and odd cattle graze in autumn and early winter, fallow deer graze all year round. A late hay cut is taken from some meadows. Hay and straw fed on meadows in the past.

Creeping Thistle (<u>C.arvense</u>)	Affects 1-2 acres out of a total of about 30 acres of grassland. It is mainly an oak wood, with about 20 flower-rich meadows within it. Thistles are associated with where hay was fed to stock in the past, before English Nature took control. Knapsack spraying and weed-wiping with clopyralid have been tried. Hand cutting and using a small mower in June has also been used, where possible, but ant-hills limit flail mowing.
Docks (<u>R.obtusifolius</u> and <u>R.crispus</u>)	Control methods not discussed.
Ragwort (<u>S.jacobaea</u>)	Hand-pulling is the main means of control.

Main Weed Problems on the Derbyshire Dales and the Cotswold SSSIs - no livestock are owned by English Nature on these sites, licencees work with English Nature staff to control the grazing which occurs from May to early winter. Hay and straw fed in the fields in the past.

Creeping Thistle (<u>C.arvense</u>)	Affects scattered patches in individual meadows. Thistles are associated with where hay was fed to stock in the past. Different farmers try various means of control, where sheep and/or cattle graze, no hay is taken. Where scrub clearance has occurred thistles follow - especially if the scrub formed a canopy or semi-canopy. (Rabbits are common).
Docks (<u>R.obtusifolius</u> and <u>R.crispus</u>)	Control methods not discussed.
Ragwort (<u>S.jacobaea</u>)	Sheep grazing is the main means of control. Stocking may reach 1-3 per hectare in May. (Rabbits are common).

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted J.Bacon

Main Weed Problems at Mottey Meadows - wet meadows, where flooding occurs for 1 or 2 weeks most winters, making weed infestation more likely. The sward height are managed to RSPB criteria, for breeding waders, like curlew, snipe and lapwing; but the site is also rich in flora and invertebrates. Summer grazing occurs from May/ June to September, with hay meadows, cut once, generally after mid-July and let for aftermath grazing for cattle and sheep in September - October.

Creeping Thistle (C. arvense)	Affects ditch spoil around the perimeter of the site. Hay making largely keeps the problem out of the field centres. On the ditch spoil a knapsack sprayer and weed-wiper keeps the thistles under control when necessary.
Docks (R.obtusifolius and R.crispus)	Control methods not discussed; but farm-yard manure has been applied every 5 to 10 years, this is likely to favour docks.

Problems at Site 27 - a new site for English Nature - managed for birds, invertebrates and flora; cattle graze during May and from August to October. Geese also graze the meadows and a few fields are taken for hay. Rabbits and Canada Geese graze the meadows.

Control methods not discussed.

Main Weed Problems at Site 28 - parkland, on heavy clay, managed for lichens and invertebrates as well as the flora, covered by a Section 16 Nature Reserve Agreement. Mainly sheep grazing (600 ewes + lambs) with 140 deer (+ young-stock) plus a few cattle, it is intended to increase these; geese also graze the meadows - a few fields are taken for hay. Winter grazing has caused weed problems, now from December to March, sheep numbers are limited to 150 maximum, with the rest of the ewes and cattle being housed overwinter. A further aim is to avoid use of pesticides and fertilisers, in the past spring fertilisers, mainly nitrogen, were applied; now compensation is paid to avoid their use. Rabbits are common. Some of the land was reseeded and limed between 1963-1968.

Creeping Thistle (C.arvense)	Up to 5 years ago, before English Nature were involved, the previous management used Broadshot (dicamba, triclopyr and 2,4 D) or MCPA. Flail cutting twice a year or as necessary seemed to aggravate the problem. However, the prototype weed wiper was used on half the site to good effect in 1992, and cutting controlled the rest of the creeping thistles.
Spear Thistle (C. vulgare), Docks (R.obtusifolius), (R.crispus), Ragwort (S.jacobaea)	Control methods not discussed.

WEED CONTROL METHODS USED BY ENGLISH NATURE MANAGERS 1992

Manager consulted J.Bacon

Comment: Creeping thistle mainly represent a visual problem, which is emotive, giving conservationists a bad name. People hate to see "a mess". Generally 10% of current thistle numbers are desired. Permanent grasslands rarely have severe weed problems. However, over-grazing in winter, feeding hay and straw in fields and where stock are confined to small areas for periods to induce problems.

John Bacon is investigating repeatedly trying to pull thistles vertically and using a machine if possible, without them breaking off at ground level, so it should only be done when the soil is damp; the aim being to pull 2-3" of root each time. The thistles are then removed. However, this technique is likely to be slow and of marginal success, especially given the opportunities for re-seeding in the bare ground created by this technique.

The prototype weed wiper, with wicks only 7.5 cm off the ground, appears to be a much more successful technique at present. Details from John Bacon, due to possible patent application requiring confidentiality.

APPENDIX II : Suitability of Herbicides for Newly Sown and Established Grass:

	Newly Sown Crops		Established Crops		
	Grass	Grass/ clover	Grass Seed	Grass	Grass+ Clover
<u>Post-emergence</u>					
asulam(9)	No	No	No	/	/
benzolin / 2,4-DB/MCPA(3)	/	/(1)	No	/	/(12)
bromoxynil / ethofumesate / ioxynil (4)	/	No	/	/	No
clopyralid	No	No	No	/	No
clopyralid / mecoprop	/	No	No	/	/(11)
clopyralid / triclopyr	No	No	No	/(15)	/(11)
2,4-D amine	/	No	/	/	/(11)
2,4-D/dicamba/ mecoprop	No	No	No	/	No
2,4-D/dicamba/ triclopyr (15)	No	No	No	/	/(17)
2,4-DB (1)	/	/	No	No	/(7)
2,4-D amine	/(13)	No	/	/	/(11)
dicamba / mecroprop / triclopyr (16)	/(13)	No	/	/	/(11)
dicamba / mecoprop(10)	No	No	No	/	No
dicamba / MCPA / mecoprop	No	No	No	/(10)	/(11)
fluroxypyr	/	No	No	/	No
MCPA (3)	/	/(6)	/	/	/(11)
MCPB (2)(5)	-	/	/	/	/(12)
MCPB / MCPA (3)	/	/(8)	No	/(8)	/(8)
mecoprop (14)	/	No	/	/	/(11)
triclopyr	No	No	No	/	No

(1) Apply only at the 1 to 3 trifoliate leaf stage of red clover. Apply to white clover at any stage from 1 trifoliate leaf.
(2) Apply when clover has at least 1 trifoliate leaf and grass is tillering.
(3) Apply when grass has at least 2-3 leaves.
(4) Apply only to grass species specified on the label - ie ryegrasses, tall fescue, meadow fescue, certain varieties of cocksfoot and timothy.
(5) Check label for suitable clover varieties.
(6) Product recommendations vary. Some labels do not recommend use on undersown cereals unless there is dense weed growth sheltering clovers. White clovers sometimes excluded. Clovers should have at least one trifoliate leaf, on some labels red clover should have at least 2 trifoliate leaves.
(7) When grasses have at least 3 fully expanded leaves.
(8) Product labels vary. Clovers should have at least 1 true or 1 trifoliate leaf. Maximum size of red clover varies with product either 3 true leaves or not after the flower stalk starts to form.
(9) Grasses may be checked or damaged according to rate and species.
(10) Established grass or grass/clover but clover will be killed or severely checked. use where clover is not an important constituent of sward.
(11) Clovers present will be severely checked or killed.
(12) Do not apply to established red clover.
(13) Some products only - in specified and limited circumstances.
(14) Some products only - spray from when the grass has 3 leaves and is beginning to tiller
(15) For use where nettles, docks and thistles are a problem.
(16) Use where nettles and docks are a problem.
(17) Spot treatment only.

APPENDIX III

CHEMICAL CONTROL OF THISTLES, DOCKS AND RAGWORT IN AGRICULTURAL GRASSLAND - with susceptibilities of other commonly found species

Key to following tables

NB Not all the pesticides listed here are suitable for use in nature reserves - they have approval for use in agricultural grassland. Often their weed spectrum is too broad for use in sensitive situations, including where drift may be important. Please consult Dr Arnie Cooke of English Natures' Science Directorate before using any pesticides listed here and not covered by previous communications from him.

SD = seedlings MP = mature plant

Product Guide = Manufacturers literature ; **however not all species which are susceptible are claimed - given amount of experimental work and cost involved.**

Microherb = A Herbicide Selection Computer Programme;

WCH = Weed Control Handbook Volume II Recommendations
Edited by Fryer, J.D & Makepeace, R.J.; Eighth Edition, 1978

* = See comments on right hand side of table

*[1] = WCH more conservative = MS;

*[2] = Product labels and WCH state R; but some trials suggest MS-MR - BEWARE!

*[3] = Only Spear Thistle mentioned on the label

APPENDIX III

CONTROL OF BROAD LEAVED WEEDS IN AGRICULTURAL GRASSLAND - Products not containing Mecoprop (but may not be clover safe)

NB Not all the pesticides listed here are suitable for use in nature reserves - they have approval for use in agricultural grassland. Often their weed spectrum is too broad for use in sensitive situations, including where drift may be important. Please consult Dr Arnie Cooke of English Natures' Science Directorate before using any pesticides listed here and not covered by previous communications from him.

	Common Chickweed	Charlock	Mayweeds	Docks R.crispus	Rumex obtusifolius	Knotgrass	Ragworts	Thistles	Creeping Buttercup	Perennial Nettle	Source
11. asulam	-	-	-	S(MP)	S (MP)	-	-	-	-	-	Microherb
12. benazolin/ioxynil/bromxynil	S	S	S	S(SD)	S (SD)	S	-	-	-	-	Product guide
13. clopyralid	-	-	S	-	-	MS	-	S	-	-	Microherb
14. clopyralid/triclopyr	-	-	S	S	S	-	S	S	MS	S	Product manual and experience
15. 2,4 D	R	S	S*	S(SD) MS(MP)	S (SD) MR(MP)	S	S*[1]	S (SD) MS(MP)	S	MS	*Scentless only WCH
16. dicamba/triclopyr/2,4 D	-	-	-	S(MP)	S (MP)	-	MS	S	S	S	Product guide
17. 2,4-DP (= Dichlorprop salt)	S	S	R	-	S	MR	-	S (SD)	-	-	Product manual
18. fluroxypyr	S	R	MS	S(SD) S(MP)	S (SD) S (MP)	S	-	R	R	S	Microherb
19. fluroxypyr + MCPA	S	S	MS	S(SD)	S (SD) R (MP)	S	S	S(SD)	S	S**	Composite of product guides ** according to rate
20. glyphosate(selective app)	-	-	-	S(MP)	S (MP)	-	S	S	-	S	If satisfactory height differential
21. glyphosate (overall)	S	S	S	S	S	S	S	S	S	S	Microherb
22. MCPA	R	S	-	S(SD) MS(MP)	S (SD) R (MP)	R	S*[1]	S (SD)	S	MS	Microherb WCH
23. MCPA / MCPB	-	S (SD) MS(MP)	-	S (SD) MS(MP)	- -	-	R*[2]	S (SD)*[3] MR(MP)*[3]	S	-	Product manual
24. MCPB	R	S (SD) MS(MP)	R	S (SD) MS(MP)	S (SD) R (MP)	-	R*[2]	S (SD)*[3] MS(MP)*[3]	S	-	Product manual WCH
25. triclopyr	-	-	-	S(MP)	S (MP)	-	R*[2](MP)	-	S	S	Microherb

APPENDIX III   CONTROL OF BROAD LEAVED WEEDS - AGRICULTURAL GRASSLAND   Products containing Mecoprop (not clover safe)

NB Not all the pesticides listed here are suitable for use in nature reserves - they have approval for use in agricultural grassland. Often their weed spectrum is too broad for use in sensitive situations, including where drift may be important. Please consult Dr Arnie Cooke of English Natures' Science Directorate before using any pesticides listed here and not covered by previous communications from him.

	Common Chickweed	Charlock	Mayweeds	Docks R. crispus	Docks R. obtusifolius	Knotgrass	Ragworts	Thistles	Creeping Buttercup	Perennial Nettle	Source
1. bromoxynil/ioxynil/mecoprop	S	S	S	MR	MR	S	-	-	-	-	Product guide
2. Low dose dicamba/MCPA/mecoprop	S	S	R	S(SD)	S(SD)	S	R	S(SD)	R-S	MS	Product guide
3. High dose dicamba/MCPA/mecoprop	S	-	-	MS(MP) S(MP)	MS(MP) S (MP)		R	MS(MP) MS(MP)	S	S-MS	Product guide
4. Low dose dicamba/mecoprop	S	S	S*	S(SD) MS(MP)	S (SD)	S	MS	S (SD)	S	MS	*Scentless only Product guide
5. High dose dicamba/mecoprop	S	S	S	MS/S(MP)	MS/S	S	-	MS/S	MS/S	MS	Product guide & Microherb
6. dicamba/mecoprop/triclopyr	-	-	-	S(MP)	-	-	-	MS	S	S	Product guide
7. mecoprop (p-isomer)	S	S	MS*	S (SD) MS(MP)	S (SD) MS(MP)	MR	-	S (SD) MS(MP)	S (SD) MS(MP)	- -	* Scentless only Product guide
8. mecoprop (racemic mix)	S	S	MS*	S (SD) MR(MP)	S (SD) MR(MP)	MR	-	S (SD) MS (MP)	S	S (SD) MS(MP)	* Scentless only WCH
9. mecoprop/2,4-D	S	S	MS*	S (SD) MS(MP)	S (SD) MP(MP)	MS	S	S (SD)	S	-	Scentless only product guide an Microherb
10. mecoprop/dicamba/2,4-D (Rough grazings)	-	-	-	S	S	-	S	S	-	S	Microherb

APPENDIX IV

Susceptibility of weeds to herbicides in established grassland *(Check crop tolerance to herbicide in Table 1 and on product label)

	Bracken	Buttercup-bulbous	Buttercup-creeping	Buttercup meadow	Cat's ear	Chickweed-common	Daisy	Dandelion	Dock Broad-leaved(est)	Dock Curled (est)	Hawkbit,autumn	Horsetails	Knapweed-common	Meadowsweet	Nettle-common	Plantain	Ragwort-common	Rush-compact*	Rush-hard*	Rush-heath*	Rush - soft*	Selfheal	Sorrel,common	Sorrel,sheeps	Sowthistle-perennial	Thistle creeping(est	Thistle dwarf(est)	Thistle spear	Wild onion	Yarrow	Yellow rattle*
Asulam	S	-	-	-	-	-	-	-	S(4)	S(4)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
benazolin + 2, 4-DB + MCPA	-	R	S	-	-	S	R	MR	MS	MS	-	MS(1)	-	-	MS(1)	S	R	-	-	-	R	-	-	-	MS(1)	MS	-	MS	-	-	-
clopyralid + fluroxypyr	R	-	-	-	-	S	-	S	S	S	-	-	-	-	S	-	-	-	-	-	-	-	-	-	S	S	-	S	-	MS	-
clopyralid + MCPA (tank mix)	R	MR	MS	MS	MS	MS	MS	S	MS	MS	MS	-	MS	-	-	S	MS	-	-	-	MS	MR	MS	MS	S	S	MS	S	-	MS	-
clopyralid + triclopyr	-	MR(6)	MR(6)	MR(6)	-	-	S	S	S(4)	S(4)	-	-	MR(6)	-	S	S	**	-	-	-	-	-	-	-	MS(1)	MS(1)	S	S	-	S	-
2, 4-D	R	MR	S	MS	MS	MR	MS	MS	MR	MS	S	MR	MS	MR	MS	S	MS	MS	-	-	MS	-	MS	MS	-	MS	-	MS	-	MR(6)	-
2, 4-D + dicamba mecoprop	-	-	-	-	-	-	-	-	S	S	-	-	-	-	S	-	S	-	-	-	-	-	-	-	-	S	S	S	-	-	-
2, 4-D + dicamba + triclopyr	R	MR	S(7)	-	-	-	MS	MS	S(7)	S(7)	S	R	-	-	S	S	MS(7)	-	-	-	S(7)	-	S	S	-	S	-	S	-	MS	-
dicamba + MCPA + mecoprop	-	MS	S	-	-	S	MS	MS	MS(2)	MS(2)	-	MS	-	-	MS(2)	S	MR	-	-	-	MS	-	-	-	MS(3)	MS(2)	-	S	R	-	-
dicamba + mecoprop***	-	MR	MS	-	-	-	S	MS	S(2)	S(2)	-	MS	-	-	MS	S	MR	-	-	-	MS	-	S	-	MS	MS	-	MS	-	-	-
dicamba + mecoprop + triclopyr	-	-	S	-	-	-	-	MS	S	S	-	-	-	MS	S	-	-	-	-	-	-	-	-	-	-	MS	-	MS	-	-	-
ethofumesate	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
fluroxypyr	-	-	-	-	-	S	-	S	S	S	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MCPA	R	MR	MS	MS	MS	MR	MS	MR	MR	MS	MS	MR	MS	MR	MR	S	MS	MS	MR	R	MS	MS	MR	MS	MS	MS	MR	S	MR	MR	MR
MCPB	R	MR	S	MS	-	R	MR	R	R	MR	MS	MR	-	R	MR	S	R	-	R	R	MR	-	-	-	MS	MS	-	MS	-	R	-
MCPA + MCPB	-	MR	S	-	-	-	-	R	MR	MS	-	MR	-	-	MR	S	R	-	-	-	MR	-	-	-	MR	MS	-	S	-	-	-
mecoprop	R	MR	S	MS	MS	S	S	MR	MS	MS	MS	R	-	-	MS	S	-	-	-	-	MR	-	R	R	MR	MS	-	MS	MR	MR	S*
triclopyr	-	-	S(5)	-	-	-	-	S(5)	S(4)	S(4)	-	MS(9)		-	S	-	R	-	-	-	-	-	-	-	-	-	R	R	R	-	-

APPENDIX IV

Symbols

S = Consistently good control - both shoots and roots.
MS = Aerial growth usually killed and a useful measure of long term control obtained under suitable conditions.
MR = Variable effect on aerial growth, appreciable long-term control unlikely.
R = No useful effect.

(1) Top growth killed only.
(2) Foliage killed and serious depletion of root stocks.
(3) Kills shoots and some roots.
(4) Repeat applications may be necessary in severe infestations and with long established plants.
(5) Use rate for dock control.
(6) Useful suppression claimed.
(7) Use high rate.
(8) Seedlings up to 2 leaves.
(9) Recommendation being reconfirmed by trials during 1991/92.
* Ex weed control handbook.
** Although no label claim is made for ragwort control, extra care should be taken with livestock following the use of Grazon 90 since a high proportion of ragwort plants will be killed.
*** Refers to products containing a high dose of dicamba.

APPENDIX V TABLE Examples of Approved Proprietary Products of active ingredients mentioned in this report

Active ingredient	Trade Name	Marketing Company
asulam	Asulox	Rhone Poulenc
benazolin / bromoxynil / ioxynil	Asset	Schering
benazolin / 2, 4-DB / MCPA	Legumex Extra	Schering
	Setter 33	Dow Elanco
bentazone / cyanazine / 2, 4-DB	Topshot	Shell
bentazone / MCPA / MCPB	Acumen	BASF
bromoxynil / dichlorprop / ioxynil / MCPA	Actril	Rhone Poulenc
	Atlas Minerva	Atlas
bromoxynil /ethofumesate /ioxynil	Nortron Leyclene	Schering
bromoxynil / ioxynil	Deloxil	Hoechst
	Oxytril CM	Rhone Poulenc
bromoxynil / ioxynil / mecoprop	Swipe 560 EC	Ciba-Geigy
carbetamide	Carbetamex	Rhone Poulenc
clopyralid / triclopyr	Grazon 90	Dow Elanco
2, 4-D amine	Agricorn D	Farmers Crop Chemicals
	Atlas 2,4-D	Atlas
	Campbell's Dioweed 50	MTM
	Farmon 2,4-D	Farm Protection
	MSS 2,4-D Amine	Mirfield
	Syford	Synchemicals
2,4-D esters (becoming more difficult to obtain)	BASF 2,4-D Ester 480	BASF
	Destox (no longer manufactured)	MTM
	MSS 2,4-D Ester	Mirfield
	For-Ester	Synchemicals
2,4-D/ dicamba / mecoprop	Wood and Brush Killer (New Formula)	Synchemicals
2,4-D/ dicamba / triclopyr	Broadshot	Shell

APPENDIX V TABLE Examples of Approved Proprietary Products of active (CONTINUED) ingredients mentioned in this report

Active ingredient	Trade Name	Marketing Company
2,4-D / mecoprop	Sydex	Synchemicals
2,4-DB	Campbell's 2,4-DB Straight	MTM
2,4-DB / linuron / MCPA	Alistel	Farm Protection
	Clovacorn Extra	Farmers Crop Chemicals
2,4-DB / MCPA	Agrichem DB Plus	
	Campbell's Redlegor	MTM
	MSS 2,4-DB Plus	Mirfield
dicamba (Telephone PBI on 0992-23957 if difficult to obtain)	Tracker	PBI
dicamba / dichlorprop / MCPA (no longer available)	Chafer Mephetol Extra	Chafer
dicamba / MCPA / mecoprop	Banlene	Schering
	Campbell's Grassland Herbicide	MTM
	Docklene	Schering
	Headland Relay	WBC Technology
	Herrisol	Bayer
	Hyprone	Agrichem
	Hysword	Agrichem
	MSS Mircam Plus	Mirfield
	Pasturol	Farmers Crop Chemicals
dicamba / mecoprop	Di-Farmon	Farm Protection
	Endox	Farm Crop Chemicals
	Farmon Condox	Farm Protection
	Hygrass	Agrichem
dicamba / mecoprop / triclopyr	Fettel	Farm Protection
2,4-DP (dichlorprop)	Campbell's Redipon	MTM
	MSS 2,4-DP	Mirfield

APPENDIX V TABLE (CONTINUED) Examples of Approved Proprietary Products of active ingredients mentioned in this report

Active ingredient	Trade Name	Marketing Company
fluroxypyr	Starane 2	Dow Elanco
glyphosate	Muster	ICI
	Gallup Glyphosate	Barclay
	Roundup	Monsanto and Schering
	Roundup Four 80	Monsanto
	Sting CT	Monsanto
linuron	Afalon	Hoechst
	Du Pont Linuron 50	Du Pont
	Du Pont Linuron 44	Du Pont
	Rotalin	Farm Protection
MCPA	Agricorn MCPA 25	Agrichem
	Agricorn 500	Farmers Crop Chemicals
	Agritox 50	Rhone Poulenc
	Atlas MCPA	Atlas
	BASF MCPA Amine 50	BASF
	Campbell's MCPA 50	MTM
	Campbell's MCPA 25	MTM
	Farmon MCPA 50	Farm Protection
	Phenoxylene 50	Schering
MCPA / MCPB	Campbell's Bellmac Plus	MTM
	MSS MCPB + MCPA	Mirfield
	Trifolex-Tra	Shell
	Tropotox Plus	Rhone Poulenc
MCPB	Campbell's Bellmac Straight	MTM
mecoprop	Campbell's CMPP	MTM
	Clenecorn	Farmers Crop Chemicals
	Clifton CMPP Amine 60	Clifton
	Hymac	Agrichem
	Iso-Cornox 57	Schering

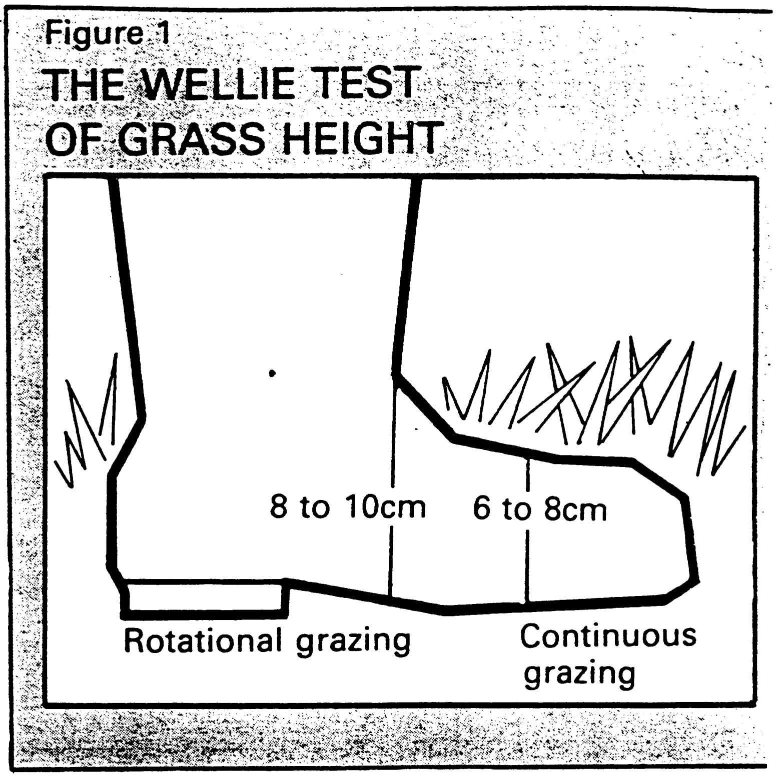
APPENDIX V TABLE (CONTINUED) **Examples of Approved Proprietary Products of active ingredients mentioned in this report**

Active ingredient	Trade Name	Marketing Company
mecoprop-p	Astix	Rhone Poulenc
	Dulplosan New System CMPP	BASF
	Optica	MSS
paraquat	Gramoxone 100	ICI and Schering
	Scythe	Cyanamid
propyzamide	Kerb 50W	PBI and Rohm and Hass
	Kerb Flow	Rohm and Haas
	Kerb Flowable	PBI
triclopyr	Garlon 2	ICI

GRASSLAND

'ut your oot in it — o the wellie oot test

ƎFORMANCE as the grazing season progresses often decline; milk yields are not as high as ected, beef and lamb daily gains are reduced. y? In the eighth article in his series on money n grass, DR MIKE WILKINSON describes how avoid a disappointing second half and outlines e goals for midsummer grazing management.



Under rotational grazing the target post-grazing grass heigt should be 8-10cms in grazed areas. With continuous grazing th height should be 6-8cms or level with the toe of the wellington.

URING the grazing season cows have to harvest their own feed. As the season resses, acceptable grass nes increasingly difficult to as areas of rejected herbage ulate. The rejected herbage s from previous fouling and ing. In addition, the rate of growth is slower than in ;, and in periods of hot, dry ner, growth can virtually completely because of lack ter.

ows rarely graze for more an 9 hours a day," says Dr David Leaver, of the West of Scotland College of Agriculture's Crichton Royal Farm, Dumfries. "The consequence of this is that grass intake declines during the season. As grass availability is reduced, the cows cannot fully compensate by increasing their grazing time."

Typical results from the Crichton Royal trials are in Table 1 (page 102). The average intakes will vary according to grass availability and individual intake will vary according to cow milk yield, but the general trend for intake to decline towards the end of the season has been observed at other research centres. It reflects the inability of the cow to increase the time spent grazing each day to compensate for the reduced supply of acceptable grass.

This decline in intake is not confined to dairy cows; calves, beef cattle and sheep are also likely to undergo periods in mid and late season when the availability of "good" grass is low.

To prevent intake declining, we can ensure an adequate supply of "good" grass by changing fields regularly and having dense swards of the correct height on offer to the animals at all times. Or we can offer a supplementary feed.

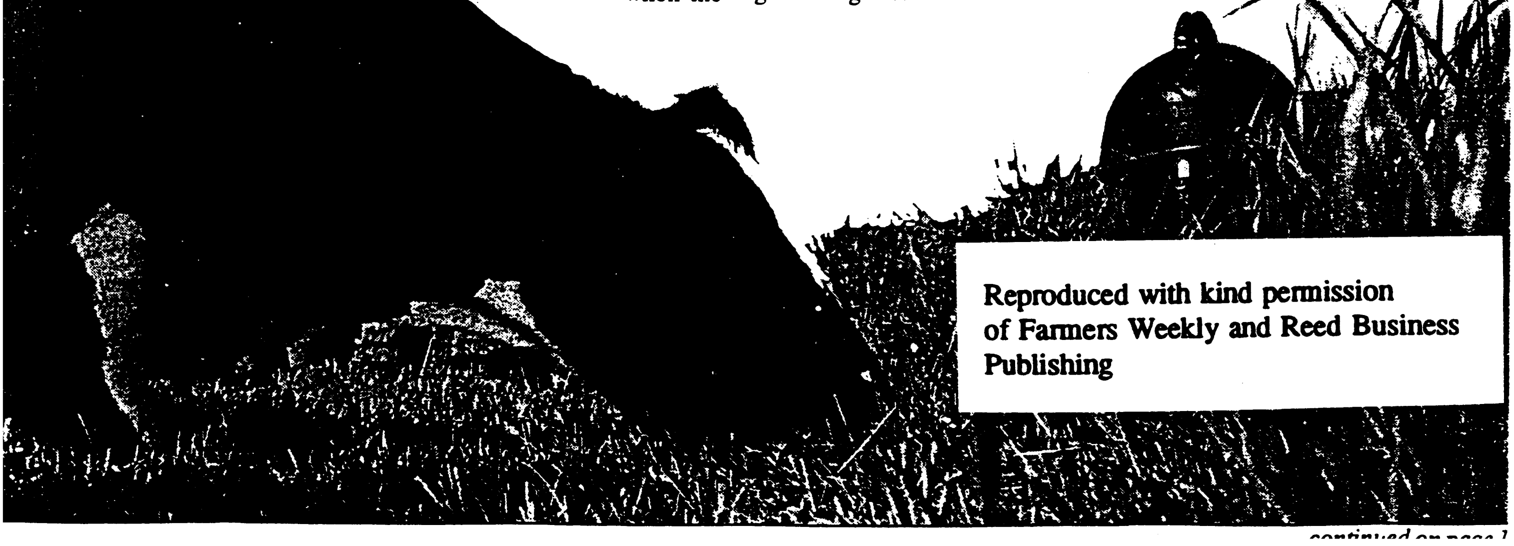
Dr Stewart Jamieson, a Dumfriesshire dairy farmer, is well aware of the importance of having the correct amount of grass on offer at all times.

"My cows are set-stocked," he says. "I aim to ensure that grass height remains at the top of my wellington uppers. If it grows above that height, I'm wasting grass."

The "Wellie Test" is illustrated in Figure 1. The recommended heights of grass refer to grazed, not rejected areas. With rotational grazing the target height refers to grass post-grazing. In the case of continuous grazing the daily grass height should be maintained at wellington-upper height (6 8cm) at all times. If grass heig falls below these targets, intake likely to be depressed and produ tion will decline. If grass height above the targets in Figure grass wastage will be increased.

Assessing grass allowance is d ficult. Not all wellies, or blades grass, are the same height. Als if grass growth is slow, there m not be additional grazing availat in another field.

Recent trials have shown t value of a buffer feed when gra is in short supply. Its value lies being a tactical feed whic although it may be on offer eve day, is only likely to be eat when the cow finds her supply "good" grass for grazing is lo Another important feature of t buffer feed is that it must not eaten in preference to gras otherwise it will simply substitute



continued on page 1

The cow equivalent unit

The PPG adopted a new scale of 'livestock units' for the calculation of stocking rates. The term 'cow equivalent' has been used rather than 'livestock unit' to make it clear that the contribution of all classes of stock were calculated in terms of a standard dairy cow. The scale was based on the relative intakes of bulk feed of different classes of stock. A review of available intake data by Baker (1964) showed that intake is linearly related to liveweight, the calculated regression line being: $y = 0.0234x + 0.32$ (y = kg dry matter intake, x = kg liveweight).

The data used included lactating cows and growing cattle ie animals at average levels of production rather than at maintenance only. Sheep were not included in the regression but the limited data available fitted the equation quite well. Experiments carried out more recently at GRI and elsewhere confirm this (eg Gibb and Treacher 1978, Hadjipieris and Holmes 1966, Langlands 1977, Young and Corbett 1972). These intakes were somewhat higher than would be expected from the ME requirements of sheep as stated in MAFF Technical Bulletin 33, due mainly to a higher allowance being made for outdoor activity.

As is usual in scales of livestock units, a typical dairy cow is taken as 1.00. In the National Farm Study the average weight of Friesian dairy cows was approximately 550 kg. Using the above equation, the intake of this cow was calculated to be 13.19 kg/day. All other livestock were related to this intake to give the following equation for the calculation of a cow equivalent:

$$\text{Cow equivalent} = \frac{0.0234 \,.\, \text{liveweight} + 0.32}{13.19}$$

The livestock unit scale used by the Meat and Livestock Commission is based on the same regression equation, but the standard cow is taken as 500 kg.

Adjustment for beef cows and ewes

The values calculated from this equation were acceptable for mature livestock and non-suckling growing livestock, but not for suckling calves and lambs. A substantial proportion of the intake of suckling animals is in the form of milk, the production of which had already been allowed for in the intake of cows and/or ewes. Thus to use these values for both the suckling animal and the dam would be an overestimate of their combined non-milk intake.

It was, therefore, necessary to reduce the combined value of a beef cow and calf, or a ewe and lamb, to a level which more accurately reflects their combined intake. It was not possible to distinguish between suckling and weaned calves, so the adjustment had to be made in respect of the cow. Similarly, it was more convenient to adjust the value of the ewe.

The adjustment was based on the proportion of the annual ME requirement of the beef cow or ewe which was used for milk production, assuming average levels of milk yield, which was approximately 25% in both cases. The cow equivalent values were, therefore, reduced by 25% for beef suckler cows and ewes as follows:

$$\text{Cow equivalent (beef cows and ewes)} = \frac{(0.0234 \,.\, \text{liveweight} + 0.32)\,0.75}{13.19}$$

NB. The intake of dairy cows assumed an average milk yield and there was no adjustment for actual milk yields. This is the procedure adopted by other recording organisations, eg ADAS Dairy Management Scheme, MMB Low-Cost Production Scheme, ICI Dairymaid Scheme, BOCM Silcock Dairy Recording Scheme. Dairy calves rarely suckle for more than a day or two and no adjustment has been made for this intake.

The cow equivalent values for all stock on each farm were calculated using their actual (or estimated) weights, but examples of values for a range of liveweights are shown below:–

Liveweight (kg)	CE value for stock other than beef cows and ewes		CE value for beef cows and ewes	
10	0.04	Growing sheep, gimmers (10–40)		
20	0.06			
30	0.08			
40	0.10		0.08	Light ewes
60	0.13	Growing cattle, heifers (60–480)	0.10	Medium ewes
80	0.17		0.13	Heavy ewes
100	0.20			
150	0.29			
200	0.38			
250	0.47			
300	0.56			
350	0.64			
400	0.73	Channel Is. cows	0.56	Light beef cows
450	0.82		0.61	
480	0.88		0.66	Av. beef cows
500	0.91	Friesian dairy cows (500–600)	0.68	Heavy beef cows
550	1.00		0.75	
600	1.09			
650	1.18			

References

BAKER R D (1964). Grassland Recording III. A reappraisal of the use of livestock and SE standards in assessing the utilized production from grassland. *Journal of the British Grassland Society*. **19**, 149–155.

GIBB M J and TREACHER T T (1978). The effect of herbage allowance on herbage intake and performance of ewes and their twin lambs grazing perennial ryegrass. *J. Agric. Sci. Camb* **90**, 139–147.

HADJIPIERIS G and HOLMES W (1966). Studies on feed intake and feed utilization by sheep. I. Voluntary feed intake of dry, pregnant and lactating ewes. *J. Agric. Sci.* **66**, 217–223.

LANGLANDS J P (1977). The intake and production of lactating Merino ewes and their lambs grazed at different stocking rates. *Aust. J. Agric. Res.* **28**, 133–142.

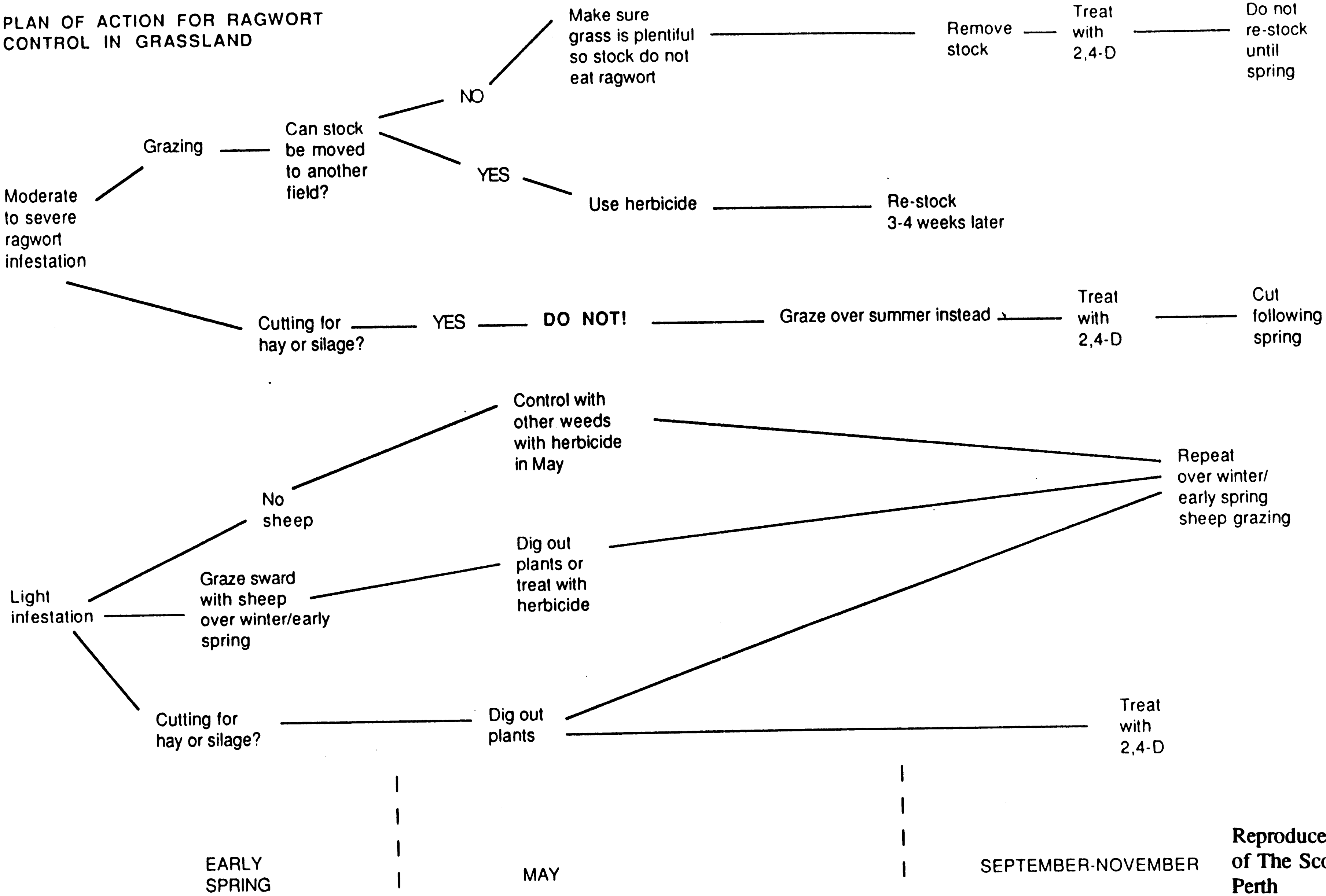
MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (1975). Technical Bulletin 33. Energy allowances and feeding systems for ruminants. London: HMSO.

YOUNG B A and CORBETT J L (1972). Maintenance energy requirement of grazing sheep in relation to herbage availability. *Aust. J. Agric. Res.* **23**, 57–76.

Reproduced from: FORBES, T.J. DIBB, C, GREEN, J.O., HOPKINS, A. & PEEL, S. (1980). Permanent grassland factors affecting the productivity of permanent grassland: a national farm study. Permanent pasture Group, Grassland Research Institute Hurley.

APPENDIX VIII

PLAN OF ACTION FOR RAGWORT CONTROL IN GRASSLAND



Reproduced with kind permission of The Scottish Agricultural College, Perth

Reference: Davies, D.H.K. and Frame, J. (1987)
Ragwort poisoning in livestock and prevention by control, T 96. Scottish Agricultural College, Perth, 5pp.

NOTICE OF APPROVAL NO. 0662/92

CONTROL OF PESTICIDES REGULATIONS 1986
(S.I. 1986 NO. 1510):
APPROVAL FOR OFF-LABEL USE OF AN APPROVED PESTICIDE PRODUCT

This approval provides for the use of the product named below in respect of crops and situations, other than those included on the product label. Such "off-label use", as it is known, is at all times done at the user's choosing, and the commercial risk is entirely his or hers.

The conditions below are statutory. They must be complied with when the off-label use occurs. Failure to abide by the conditions of approval may constitute a breach of that approval, and a contravention of the Control of Pesticides Regulations 1986. The conditions shown below supersede any on the label which would otherwise apply.

Level and scope: In exercise of the powers conferred by regulation 5 of the Control of Pesticides Regulations 1986 (SI 1986/1510) and of all other powers enabling them in that behalf, the Minister of Agriculture, Fisheries and Food and the Secretary of State, hereby jointly give full approval for the use of

Product name: 'Dow Shield' containing

Active ingredient: 200 g/l clopyralid

Marketed by: DowElanco Ltd under MAFF NO. 05578 subject to the conditions relating to off-label use set out below:

Date of issue: 5 June 1992

Date of expiry: unlimited (subject to the continuing approval of MAFF 05578)

Field of use: ONLY AS AN AGRICULTURAL/HORTICULTURAL HERBICIDE

Crop/situation	Maximum individual dose (litre product /hectare)	Maximum number of treatments: (per year)	Latest time of application: (before harvest)
Established grassland as a spot treatment	see other specific restrictions	one	7 days
Grass seed crop	1.0	two	7 days

Operator protection:

(1) Engineering control of operator exposure must be used where reasonably practicable in addition to the following personal protective equipment:

(a) Operators must wear suitable protective gloves and face protection (faceshield) when handling the concentrate.

(b) Operators must wear suitable protective gloves and face protection (faceshield) when using hand held weed wipers and adjusting and cleaning equipment after use.

(2) However, engineering controls may replace personal protective equipment if a COSHH assessment shows they provide an equal or higher standard of protection.

Other specific restrictions:

(1) This product must only be applied if the terms of this approval, the product label and/or leaflet and any additional guidance on off-label approvals have first been read and understood.

(2) Livestock must be kept out of treated areas for at least seven days following treatment and until poisonous weeds such as ragwort have died and become unpalatable.

(3) When the product is applied through a weed wiper it must be diluted with at least an equal volume of water.

Signed ....
(Authorised signatory)

Date ....

Application Reference Number: COP 92/00128

THIS NOTICE OF APPROVAL IS NUMBER 0462 of 1992

This approval relates to the use of 'Dow Shield' when applied

(1) Through a weed wiper for the control of *Cirsium* spp on established grassland at a dilution of 1:1 or 1:2 (product:water).

(2) Via conventional hydraulic ground based equipment to grass seed crops.

Do not apply to crops undersown with clover or other legumes. When applying to grass seed crops the straw at harvest should be baled and carted away or burnt. Where the straw is chopped or incorporated do not plant winter beans in the same year as treatment with 'Dow Shield'. This straw should not be used as straw in compost, poultry litter, manure or spent mushroom compost.

APPENDIX X

"OFF-LABEL" USE OF PESTICIDES - GUIDANCE NOTE TO THOSE INTENDING TO USE A PESTICIDE "OFF-LABEL"

This note has been prepared jointly by the Health and Safety Executive and the Ministry of Agriculture, Fisheries and Food. It reminds those intending to use an approved pesticide product "off-label" (that is, in a way in which no label recommendation exists) of the detailed arrangements now in place, of obligations upon users, and in particular the need to safeguard themselves, others, and the environment. It is therefore important that the note is read carefully, and in conjunction with other official advice and guidance on the off-label arrangements.

Why do there have to be approvals for off-label use?

1. Since 1 January 1988, the regulations controlling pesticides have meant that an approved product may only be used according to the precise terms of its approval relating to use. For example, if a product states on the label that it may be used on wheat, then that is the <u>only</u> crop on which that product can normally be used.

2. There are, of course, many products approved for use on cereals, because this is a large and important crop, and it is therefore economic for agrochemical manufactures to do the extensive trials work needed for their products to be approved for the use in this way. The same is true for many of the "major" crops grown in this country. However, it is not the case for those crops, particularly horticultural ones, where acreages are low. Minor crops do not feature on many product labels and therefore without special measures, growers would, because of the new regulations, have an unduly restricted range of products to use. This is why we now have a system of approvals for off-label use.

So how is an "off-label" approval given?

3. There are two ways. Some off-label approvals are given under what are known as the "interim arrangements" which will apply until the end of 1988. In simple terms, what these offer is a straightforward extension of use from one crop to another. To give examples, a pesticide product which states on the label that it may be used on barley may also, under the interim arrangements, now be used on oats, rye and certain other cereals; one labelled for use on apples may also be used on pears; and so on.

e) any limitation on area or quantity allowed to be treated;

f) operator protection or requirements for operator training;

g) environmental protection.

In addition you may also need to assess the individual circumstances of use.

9. The interim "Off-label" usage will fall into two main categories. (i) There will be those cases where the crop, the rate and method of application and the conditions under which the product is to be applied are very similar to those for which the product was originally approved, eg products approved for apples to be applied to pears, at the same application rate. (ii) There will also be cases where the crop and application conditions are widely different from those on which the original approval was based. This may include for example, the use of a field crop pesticide normally applied by tractor mounted sprayer, for which the intended off-label use is application to flowers using a knapsack sprayer.

10. In cases where the crop and application procedure are very similar to those of the main approval, the user will still need to compare circumstances of use to assess the possible risks and to consider whether the manufacturers' existing recommendations relating to dilution rates, application equipment, timing of application and operator protection etc remain appropriate. The user will need to observe any requirements for the personal protection of the operator which are a condition of the approval and also any obligations under the Poisonous Substances in Agriculture Regulations 1984, which may be applicable.

11. In other cases where the crop, the system of cultivation, the method of application, the stage of growth or the conditions under which the pesticide is to be applied are totally different, the manufacturers' recommendations are unlikely to be appropriate. It then falls to the user to make a thorough assessment of the operation to identify what precautionary measures are necessary, The purpose of the assessment is to enable a valid decision to be made about measures necessary to control any hazardous effects of pesticide use. It also enables the user to demonstrate both to himself and other persons that all factors pertinent to the work have been considered and that an informed and valid judgement which will allow application to take place safely has been reached. A record should be kept of any action taken. A minimum assessment should include :-

APPENDIX XI CLASSIFICATION OF SOIL ANALYSIS RESULTS FOR SAMPLES ANALYSED BY STANDARD ADAS PROCEDURES

(See MAFF Reference Book 427, *The analysis of agricultural materials*)

Index	Phosphorus (mg/litre)	Potassium (mg/litre)	Magnesium (mg/litre)
0	0–9	0–60	0–25
1	10–15	61–120	26–50
2	16–25	121–240	51–100
3	26–45	241–400	101–175
4	46–70	401–600	176–250
5	71–100	601–900	251–350
6	101–140	901–1500	351–600
7	141–200	1501–2400	601–1000
8	201–280	2401–3600	1001–1500
9	over 280	over 3600	over 1500