8 Other management practices

8.1 General introduction

This chapter provides advice on a range of miscellaneous management practices which are likely to affect lowland semi-natural grassland. Some of the practices covered, such as the application of inorganic fertilisers for example, are associated more with intensively managed swards and if applied to semi-natural grassland would lead to detrimental changes in species composition. Some of the other topics covered such as the management of ditches and water levels often have a more positive nature conservation benefit.

Where possible, the agricultural objectives for particular management practices are outlined to assist conservation advisors in discussions with farmers and landowners who may own and manage semi-natural grassland.

8.2 Artificial fertilisers

8.2.1 Background and definitions

Inorganic or artificial fertilisers are widely used in grassland production in UK agriculture. Very few soils are able to supply sufficient quantities of all the nutrients necessary for the high yields and quality of grass crop required for capital intensive farming. The three most important nutrients required from inorganic fertilisers for grassland production are nitrogen (N), phosphorus (P) and potassium (K).

These are available singly ('straights') or as a combination of N, P and K in compound fertilisers. By law, bags of inorganic fertilisers must state the content of nutrients expressed in terms of the percentage composition of N, P_20_5 and K_20.

8.2.2 Nitrogen fertilisers

A variety of chemical compounds are supplied commercially as sources of nitrogen and these include ammonium nitrate ($NH_4\,N0_3$) (for example the commercial products Nitram and Extran) which have an N content of 34.5%, ammonium sulphate $(NH_4)_2\,S0_4$ with a N content of 21%, Urea ($CO(NH_2)_2$) with an N content of 46% and calcium ammonium nitrate ($NH_4\,N0_3 + CaC0_3$) with a N content ranging between 21 and 26% (trade product eg Nitrochalk). Ammonium nitrate and urea are soluble in water and are often used as major sources of N in liquid fertilisers.

8.2.3 Phosphate and potassium (potash) fertilisers

Phosphate and potassium are applied as compound fertilisers usually with one of the N sources detailed above (N, P, K fertiliser). The most common phosphate sources are triple superphosphate ($Ca(H_2P0_4)_2$ with a P_20_5 content between 45% and 47% and ground mineral phosphate ($Ca\ P0_4$) with a P_20_5 content of *c*30%.

The most common potash sources are potassium chloride (Muriate of potash) (KCl) with a K_20 content of 60% and potassium sulphate (Sulphate of potash) ($K_2 S0_4$) with a K_20 content of 50%.

Examples of commonly used compound fertilisers in agricultural grassland production include ICI 'First Cut' (15:10:20 composition) and 'Second Cut' (25:5:5) and Norsk Hydro '29:5:5', '20:10:10' and '25:5:5'. The numbers refer to percentage content of N, P_20_5 and K_20 respectively in the compound fertiliser. For example a 50kg bag of 20:10:10 compound fertiliser contains the equivalent of 10kg of N, 5kg of P_20_5 and 5kg of K_20. Over a year, improved grass swards require these nutrients in the proportion $4N:1P_20_5:1K_20$. Prior to metrication, a unit of fertiliser was defined as 1% of 1 cwt (ie 112 lb). A nitrogen fertiliser with 15% N in each cwt is said to contain 15 units of N. Following metrication the equivalent would be 1% of 50kg. A 50kg bag of 20:10:10 would contain 20 units of N equivalent to 10kg of N.

Most fertilisers are sold in solid form principally as powders, crystals, granules (prills) and are spread evenly over the surface of a grass field when the nutrients are most required. Solid fertiliser is usually broadcast by tractor mounted spreaders consisting of a hopper discharging fertiliser into a spreading mechanism. The most popular have a spinning disc or oscillating spout which distributes fertiliser in swathes of variable width.

8.2.4 The use of fertilisers on semi-natural grassland

Research has shown that applications of artificial fertiliser, either as 'straight' N or compound NPK fertiliser, to semi-natural grassland rapidly reduce the species-richness and diversity of the sward with a loss of nature conservation value (see for example Smith 1980, Tallowin 1996, Williams 1978, Mountford *et al* 1993, Williams 1978, Willems *et al* 1993, Kirkham *et al* 1996).

Mountford *et al* 1993 demonstrated that there was a noticeable effect on the species composition of unimproved neutral grassland on the Somerset Levels even at very low application rates of fertiliser N (*c*25kg/ha/year). On the most intensively managed grasslands application rates can exceed 300kg/ha/year.

Fertiliser application stimulates the growth of competitive grasses at the expense of other plants, notably broadleaved herbs, resulting in species extinctions and consequent reduction in species richness. There is little research which documents the impact of phosphate and potash applied in the absence of nitrogen as this situation rarely arises in a farming context. However, Silvertown *et al* (1994) demonstrated that various fertiliser treatments, including P and K applied singly, reduced numbers of green winged orchid *Orchis morio* compared with an unfertilised control in an experiment at Bratoft Meadows, Lincolnshire. Kirkham, *et al* (1996) demonstrated that phosphate was the most influential of the three principal elements (NPK) in causing botanical change in a small plot experiment on unimproved neutral grassland on the Somerset Levels. In their experiment, no treatment received P in the absence of potash (K). However, when P and K were applied with 0 or 25kg/ha/year N legumes (*Trifolium* spp.) increased in abundance. Given the latter species ability to fix nitrogen, their increase could potentially lead to a further depression in species-richness. Given the scarcity of semi-natural grasslands and the potential for damage it is recommended that P or K should not be applied to semi-natural grassland.

Overall, the use of artificial fertilisers on any type of unimproved semi-natural grassland is generally unacceptable.

In some circumstances, for example, where grassland is already semi-improved, the continued use of existing low levels of artificial fertiliser (eg less than 25kg/ha N, <12.5kg/ha P and K) may be acceptable. This will clearly depend on the particular nature conservation objectives in specified situations.

8.3 Animal slurry/farmyard manure

8.3.1 Introduction - animal slurry

Slurry is a semi-fluid mixture of faeces and urine deposited in buildings where livestock (principally cattle, pigs and poultry) are kept indoors and where little or no bedding is provided. It is normally stored in lagoons or tanks where it is diluted with water, mixed and then is either piped to the fields or is pumped direct into a tanker for transport to the field for spreading.

Animal slurry has value as a source of essential plant nutrients (N, P and K) but its composition can be very variable. Composition is influenced by the type and age of the producing animals, livestock diet, dilution and the length of time of storage.

Slurry is a waste by-product which must be disposed of. It is normally applied to permanent grassland as a fertiliser in November/December before spring grazing or in autumn, winter and spring on grassland which is to be cut for hay or silage the following May or June.

8.3.2 The use of animal slurry on semi-natural grassland

Slurry provides an immediately available and organic source of N, P and K. It should not be used on semi-natural grassland as evidence suggests that it will cause a decline in the species-richness of the sward for the same reasons as for artificial fertiliser (see Section 8.2, sub-section 8.2.4). It may also physically smother or ‘scorch’ the sward producing bare ground and the elimination of species and may lead to infestation by grassland weed species.

8.3.3 Introduction - farmyard manure

Farmyard manure consists of animal excreta incorporated with bedding material, usually straw. Farmyard manure is normally stored to rot down prior to spreading. The nutrient content and its availability is variable and will depend on manure type, livestock diets, storage conditions, age and application time and method. Farmyard manure can provide an important source of N, P and K for grass production systems, as well as increasing the humus content of the soil and its nutrient holding ability.

8.3.4 The use of farmyard manure on semi-natural grassland

The use of light well-distributed dressings of **well-rotted farmyard manure** (ie preferably where this has been stored for a minimum of twelve months) on semi-natural grasslands is acceptable where both the following circumstances are satisfied:

- On neutral grasslands which are mown for hay, ie NVC communities MG3, MG5, MG11 and MG13
- On grasslands where there is a history of farmyard manure use and no evidence of damage to the nature conservation value

Based on current knowledge, it is recommended that application rates should not exceed 20 tonnes/ha every three to five years applied in a single dressing on lowland meadows. Higher rates and frequencies should be avoided as these may result in a decrease in species-richness and diversity (Simpson & Jefferson 1996). In upland meadows (normally MG3 but occasionally MG5) the use of an **annual or biennial** light, well-distributed dressing of well-rotted farmyard manure (ie preferably where this has been stored for a minimum of 12 months) from cattle on semi-natural grasslands is acceptable provided it can be demonstrated that this has been a traditional practice and has maintained the nature conservation value. This should normally be applied prior to shutting up for hay. Annual rates of application should be guided by past practice but should not exceed 12t/ha.

Farmyard manure **should not routinely** be applied to MG4 flood meadows unless there is evidence that crop yields are falling in response to reduced nutrient importation from flooding. If hay yield falls below *c*2.5t/ha/year, application of well-rotted fym at rates of 20t/ha every 3-5 years is acceptable to ensure continued agricultural management. This practice should be kept under review in tandem with monitoring of the botanical composition, crop yield and flooding frequency.

NB: These guidelines on farmyard manure use will be kept under review as and when further knowledge is acquired.

The use of poultry litters/manures should be avoided as these are high in available nutrients, particularly N and K.

From an agricultural perspective, there is debate as to the most appropriate time for farmyard manure applications in terms of maximising plant uptake. This may actually vary according to factors such as soil type and climate. In practice, most applications occur in spring. On sites supporting breeding waders and wildfowl timing of application should avoid the period 15 March to 15 July (or 1 August where corncrakes are present).

The key difference between farmyard manure and slurry/artificial fertilisers is in the length of time over which nutrients are released. The rapid release of nutrients from artificial fertilisers and slurry gives competitive grasses an advantage over herb species at the time of application (Spring). This ultimately results in a decrease in species-richness in semi-natural grasslands as a result of competitive exclusion. This situation does not arise with light dressings of farmyard manure as the nutrients are released more gradually over a prolonged time period. For a useful review of the use of farmyard manure on grassland see Simpson & Jefferson 1996.

8.3.5 Introduction - sewage sludge

Sewage sludge from sewage treatment works is often made available to farmers cheaply as a source of nutrients. Several types of sewage sludge are available: i) raw which is rarely used due to the presence of pathogenic organisms; ii) digested sludge, which is made by fermenting the raw material aerobically and contains 96-97 per cent water so can be spread directly onto the land and iii) dried sewage sludge which has been dehydrated to form a solid.

Sewage sludges differ from most other manures in that they contain virtually no potassium (potash) and consequently they are not such a useful source of nutrients as animal manures. Sewage sludge can contain high levels of potentially toxic elements (for example zinc) which can lead to reduced grass yields, may be toxic to or induce element deficiencies in animals, or affect human-beings eating meat from livestock. The use of sewage sludge on grassland and other crops is governed by the Sludge (use in agriculture) Regulations (1989) and a code of practice has been produced to assist users (DoE 1996). The regulations were reviewed in 1993 (MAFF/DoE 1993).

As a result of concerns by retailers about microbial pathogens, agreement has been reached with the water companies that further treatment of sludge is necessary prior to its use on agricultural land. Legislation to implement this is expected during 1999 and this will place further legal controls over the standard treatment of sludge appropriate for different agricultural uses.

8.3.6 The use of sewage sludge on semi-natural grassland

Advice is the same as for animal slurry, ie sewage sludge should not be used on unimproved semi-natural grassland.

8.4 Lime

8.4.1 Introduction - lime

Lime is a term applied to various materials containing calcium (often in the form of calcium carbonate ($CaCo_3$)) usually derived from natural deposits of chalk and limestone.

Lime is often applied to grassland by farmers to offset losses of calcium by leaching and cropping of herbage. On some soils this can lead to increasing soil acidity which can limit grass growth by influencing the availability of nutrients and causing toxicities of iron, aluminium and manganese. The optimum pH for improved grassland on mineral soils is around pH 6.0. It is this level that farmers will aim to maintain by the addition of lime, especially to grassland soils which do not have a naturally high calcium content. A variety of materials are used to provide lime; including ground chalk and limestones, calcareous shell sands and calcified seaweed (see Section 8.4, sub-sections 8.4.3-8.4.6). Normally, lime is applied to grassland in spring.

8.4.2 The use of lime on semi-natural grassland

Liming as far as can be determined, has traditionally been applied by farmers to a range of semi-natural grassland communities in various parts of Britain. However, it is unclear to the extent to which liming treatment has created or maintained, in part, the species composition of different types of lowland grassland. There may also be scope for using lime to restore previous grassland types that may have changed as a result of acidification. There is clearly a need for further research on the relationship between lime use and grassland community composition.

The following guidance is based on current knowledge and has been revised following the production of Tallowin (1998). However, the advice will continue to be kept under review. It is firstly important to determine the nature conservation objectives for a particular site before considering liming policy and this will often be aided by historical information on floristic composition and management practices.

“ Liming is not normally an acceptable practice on semi-natural acidic grasslands (NVC communities U1-U4). Its use will modify the species composition of the sward by favouring species characteristic of neutral or calcareous soils at the expense of plant species which avoid soils with high pH.

“ Tallowin (1998) has tentatively suggested that lime addition could be used to cause subtle shifts between acid grassland sub-communities e.g. from the typical form of U4 grassland towards the U4c sub-community or from acid grassland to neutral grassland (U4a to MG5c). However, there is little evidence for this and it is suggested that lime should not be applied to acid grassland unless there is compelling evidence that there has been a recent shift between communities or sub-communities. Clearly, this is an area where experimental study is required.

“ Lime should not normally be applied to the fen meadow or rush pastures (M22, M23, M24, M25 & M26). Tallowin 1998 has suggested that periodic low applications of lime could allow calcicolous elements to be encouraged in some of these communities (e.g. to assist the maintenance of M24b and prevent reversion to M24c) . However, there is little evidence for this and it is suggested that lime should not be applied these grassland types unless there is compelling evidence that there has been recent shifts between communities or sub-communities. Clearly, this is an area where experimental study is required.

“ The occasional application of lime is acceptable on other semi-natural neutral grasslands and on calcareous grasslands, provided it has been a long-established practice and is not applied to ‘chalk heath’ vegetation or where there is an intimate mosaic of calcareous and acid grassland. It is recommended that lime application be permitted every five to ten years. There is evidence that occasional liming was a traditional practice on many hay meadow systems and Rodwell (1992), for example, suggests that liming and light dressings of farmyard manure may have been instrumental in maintaining the richness and diversity of the northern hay meadow community (MG3 *Briza* sub-community). If there is evidence that occasional liming has been a long established practice or, in the case of neutral grasslands, that the soil pH has fallen below 5.0, it would be appropriate to actively encourage its continuation.

“ Where there is compelling evidence that there has been a recent shift between grassland types as a result of acidification, it may be appropriate to apply lime to restore the previous community where this is the objective. Possible examples include ii) shifts between MG5 sub-communities ii) between U4a and MG5c and iii) MG3 and U4/U5. It should be stressed that evidence for these shifts are circumstantial and published evidence is largely lacking.

“ Never apply more than three tonnes/hectare of calcium oxide (Ca0) equivalent at one dressing.

(Neutralising value (NV) is the standard basis for comparing liming materials. NV is determined by laboratory analysis and is expressed as a percentage of the effect that would be obtained if Ca0 had been used (ie Ca0 NV=100). For example 100kg of ground limestone with a NV of 55 is required for the same NV as 55kg of Ca0.)

“ Lime should not be stored in piles on the grassland as it will damage the sward by scorching.

“ Lime should not be applied between 15 March to 15 July on grasslands supporting ground nesting birds.

8.4.3 Introduction - liming materials: seaweed source

Calcified seaweed is sold either as a graded material or as a dried and milled powder. It is an effective liming agent with a neutralizing value (NV) of 40-50. Analysis of the material from producers shows that it contains about 46% CaO, 4.8% MgO plus small amounts of minerals such as sulphur (0.26%), sodium (0.65%), potassium (0.04%) and phosphorous (0.04%), Calcified seaweed also contains a range of trace elements (Tallowin 1998).

8.4.4 The use of organic sources of lime on semi-natural grassland

The phosphorus and potassium inputs of c. 0.25 kg/ha respectively at the recommended application rates of 625-630 kg/ha are very low and probably too small to have a significant impact on the species-richness of semi-natural grasslands. However, this contention needs to be substantiated by experimentation (Tallowin 1998). As a precautionary measure, it is therefore probably best to use alternative liming materials. In addition, it is more costly than other sources of lime. If it is used, it should be noted that the source of calcified seaweed is Maerl[1] which has a restricted distribution in Britain and is considered to be marine conservation importance. This product should only be used from sources where it has been harvested in a sustainable manner.

8.4.5 Introduction - liming materials: other sources

A number of industrial by-products are sometimes used as liming materials. Examples include sugar beet factory sludge, water works waste and blast furnace slag (basic slag).

[1] Maerl consists of one or more of the following species: *Phymatolithon calcareum, Lithothamnian corallioides* and *L. glaciale*.

8.4.6 The use of other sources of lime on semi-natural grasslands

The calcium carbonate content of industrial by-products is very variable and some also contain N, P and K, for example basic slag contains varying amounts of P. In addition some materials have a caustic quality. None of these products should be applied to semi-natural grasslands.

8.5 Miscellaneous applications

8.5.1 General introduction

A variety of other materials are sometimes used on grasslands either as fertilisers, or as sources of lime or to supply trace element. These include organic based fertilisers derived from plant or animal materials and other miscellaneous substances, some of which are industrial by-products, for example paper pulp sludge.

8.5.2 Introduction - organic fertilisers

Organic nitrogen fertilisers include hoof and horn meals, dried blood, liquid seaweed and wool shoddy. Organic sources of phosphate (P_20_5) include bone meals, fish meals and fish guano.

The behaviour of organic based fertilisers is not always predictable although it is claimed that the majority have slow release properties. Unless they are by-products they are generally more costly than other types of fertilisers.

A range of organic fertiliser products are available commercially including compound fertilisers supplying N, P and K.

8.5.3 The use of organic fertilisers on semi-natural grassland

“ As with inorganic fertilisers, organic-based fertiliser compounds should not be used on semi-natural grasslands.

“ While it is possible that some organic fertilisers have slow release properties similar to farmyard manure, a precautionary approach should be normally adopted and their use avoided even on hay meadow systems. In any case, materials high in phosphorus (eg products containing bone meal) should not be used on semi-natural grasslands.

8.5.4 The use of trace element additives

There are products available which supply trace elements for livestock (Copper, Selenium, Iodine, Cobalt, Zinc and Sodium) by spreading to grassland in areas where there is a soil deficiency. These normally consist of salt granules coated with the trace elements which are spread using a conventional fertiliser spreader.

These are normally spread up to ten days before livestock are intended to graze or six weeks before silage/hay is due to be cut. The nutrients are taken up by the herbage gradually through the growing season which in turn supplies the essential elements to the animals. They are normally spread at rates of 50 kg per hectare.

The main concern relates to the sodium chloride content and whether this might change soil pH (i.e. acidification). Whilst this does seem unlikely to be a concern given the low application rates involved, it is suggested that a precautionary stance is adopted and that alternative methods of supplying the trace elements to livestock are used such as dietary supplements or oral administration.

8.6 Application of pesticides including the use of veterinary products

8.6.1 Definitions

In this section the definition of pest and pesticide follows that used in the Food and Environment Protection Act 1985 Section 16(15). Pest means a) any organism harmful to plants or to wood or other plant products; b) any undesired plant; and c) any harmful creature. Pesticide means any substance, preparation or organism prepared or used for destroying any pest.

8.6.2 General introduction - herbicides

This sub-section deals with the general non-selective use of herbicides by tractor mounted booms of varying widths (range 6-24m) which have nozzles located along their length at *c*0.5 m intervals.

Further information on the selective use of herbicides for controlling grassland weed species can be found in Chapter 5 (Grazing) and the treatment of cut scrub (Chapter 12).

8.6.3 The use of herbicides on semi-natural grassland

No blanket spraying of herbicide should take place on semi-natural grassland. Targeted techniques such as knapsack spraying or weed wiping may sometimes be acceptable for the control of undesirable species in grassland (see Chapter 7), if no other method is available.

8.6.4 General introduction - pesticides

Pesticides are defined here as manufactured chemicals applied against pest and disease organisms other than vascular plants (ie weeds). This definition includes insecticides, molluscides, and fungicides.

The use of pesticides on permanent grassland in the UK is not common.

There are, however, a variety of organisms which can be pests of grassland including fungi (rusts, mildews etc), invertebrates (aphids, frit fly, leatherjackets, slugs, snails and wireworms) and mammals (mole). Table 6.1 lists the main pesticides used in permanent grassland in the UK.

8.6.5 The use of pesticides on semi-natural grassland

The majority of the compounds listed in Table 6.1 may affect non-target invertebrate organisms. Some of these species may either contribute to the conservation value of semi-natural grassland or may have an important role in the functioning of the grassland ecosystem.

For these reasons, no fungicides, insecticides or molluscicides should normally be applied to semi-natural grassland. If in doubt seek further advice.

Moles are often considered as pests of grassland by landowners due to the creation of mole hills which:

a. may result in soil contamination of the grass crop, especially silage;

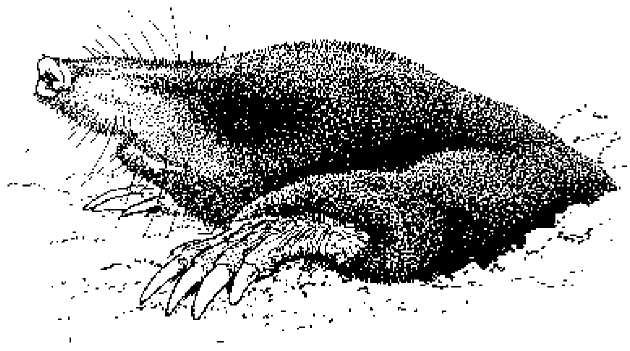
b. can reduce grassland productivity locally;

c. can cause problems for the machinery used for hay and silage making;

d. may provide sites for weed establishment

Moles are a native component of grassland ecosystems and requests to control them should only be sanctioned when there is a proven severe problem.

Strychnine (see Table 8.1) is widely used to control moles and is undoubtedly very effective. This is undertaken by treating worms with strychnine powder which are then inserted into mole tunnels as bait. However, there are concerns over strychnine including its toxicity to humans and aluminium phosphide may be used as an alternative (see below).



[© T. McOwat]

Table 8.1 Pesticides* used on permanent grassland in the UK

Target organism(s)	Compound	Examples of commercial product(s)/brand (1996)	Comments
Fungi including rusts, mildews etc	Propiconazole	Mantis 250 EC Radar Tilt 250EC	Harmful to fish and livestock
	Triadimefon	Bayleton Standan Triadimefon	Harmful to fish
Aphids	Pirimicarb	Aphox Phantom Pirimor	Harmful to livestock
Cutworms Leatherjackets Wireworms	Gamma-HCH	Ashlade Gamma HCH Atlas Steward Gamma-Col Fumite Lindane Unicrop Leatherjacket Pellets	Organochlorine Harmful to livestock Harmful to fish
Frit fly Leatherjackets	Triazophos	Hostathion	Organophosphorus Harmful to livestock and other animals including fish
Frit fly Leatherjackets	Chlorpyrifos	Barclay Clinch Dursban 4 Spannit Talon	Organophosphorus Harmful to fish and livestock
Slugs Snails	Metaldehyde	A wide range of brands available	Harmful to livestock and other animals including fish
Slugs Snails	Methiocarb	Decoy Draza Exit	Harmful to game, wild birds and animals, fish and aquatic life
Moles	Strychnine hydrochloride	Not available as a branded product	A commodity chemical rather than a pesticide. Very toxic to mammals and birds
Moles	Aluminium Phosphide (generates hydrogen phosphide gas (phosphine)	Luxan Talunex	Very toxic to mammals, birds, fish and other aquatic life

Definitions

Cutworms: soil dwelling larvae (caterpillars) of Noctuid moths. Larvae can cause damage to grass crops.
Leatherjackets: soil dwelling larvae of some species of craneflies (Diptera: Tipulidae). Root feeders.
Wireworms: soil dwelling larvae of some species of click beetles (Coleoptera: Elateridae).
Frit fly: larvae of *Oscinella frit* (Diptera: Chlorophidae) which bore into stems and flowers of pasture grasses (and cereal crops).

Source: WHITEHEAD, R ed. 1998. *The UK Pesticide guide*. CAB/BCPC.
* Pesticide product approval status may change. Always consult the most recent guidance.

If strychnine is used for mole control, treated worms should be placed in tunnels at depth in order to minimise risks to non-target organisms. This risk is considered minimal as following ingestion, the mole does not usually surface to die which would otherwise carry a risk to carrion feeders of secondary poisoning (Neville 1985).

A recently available alternative to strychnine is to use aluminium phosphide tablets to kill moles. A mole tunnel between molehills should be located using a metal probe and a small hole is then pierced. Pellets or tablets may then be inserted into the tunnel using an appropriate applicator and the hole should be sealed with a plug of turf. This should be repeated at sufficient points to ensure the complete tunnel system is gassed. The aluminium phosphide pellets react with moisture and air to produce the gas (phosphine) which kills the moles. The disadvantage of this method is that it only works well in damp soil conditions.

Both strychnine and aluminium phosphide are highly toxic and are subject to the Poisons Rules 1982 and Poisons Act 1972 and should only be used by trained operators familiar with the necessary precautionary measures (see also sub-section 8.14.3). Research is continuing into alternative toxins and formulated bait bases.

Trapping can be just as effective as poisoning and gassing for small scale infestations, but it is not practicable for large scale agricultural infestations (Neville 1985). Mole traps are available from hardware shops and have the advantage of being relatively humane. Atkinson & Macdonald (1994) report on the potential use of repellants as an alternative to lethal control. They conclude that a bone-oil formulation (Renardine) repels moles for at least 28 days and may offer a realistic, effective alternative for small-scale infestations in non-agricultural situations. Development of less labour-intensive application methods may result in its use in agricultural situations. For further information on the mole as an agricultural pest and control methods see Atkinson, Macdonald & Johnson (1994).

8.6.6 Introduction - Anthelmintics

Anthelmintics are chemicals used principally to control parasitic worms in livestock particularly cattle, sheep and horses. There are three main chemical groupings available in the UK for internal parasite control; the Benzimidazoles and Probenzimidazoles (White drenches), the Imidazothiazoles and Tetrahydropyrimidines and the Avermectins (McCracken 1995). Organophosphates and pyrethroids are also used to control ectoparasites such as biting flies, mites and lice, although the Avermectins and related compounds also have some activity against ectoparasites.

Parasites cannot normally be completely eradicated and the usual aim for farmers is to maintain parasite populations below the threshold at which they cause concern. Alternation between the different chemical groupings is usually desirable to avoid the build up of resistance to one type.

8.6.7 Avermectins and related compounds

The Avermectins is the name given to a group of compounds used as veterinary medicines to control internal and external parasites of livestock. Ivermectin is the original active form marketed since the early 1980s (eg Ivomec for cattle and sheep and Eqvalan for horses all marketed by MSD Agvet), and this was closely followed by abamectin. More recently, doramectin (eg Dectomax for cattle marketed by Pfizer) and moxidectin (eg Cydectin for cattle marketed by Cyanamid (UK)), two similar chemicals, have been developed. Products are available for application in a number of ways : by injection, oral drench or pour-on and some as a slow-release bolus. The drugs are absorbed systemically after administration and are excreted mainly in the faeces. The broad spectrum of activity of Avermectins against parasites combined with their convenience of application has led to their widespread use by farmers and veterinarians.

Avermectins are excreted in the dung and remain active against many invertebrates that colonise dung. There are thus a number of nature conservation concerns:

“ Rare and scarce invertebrates might be affected.

“ The reduction in the number and variety of dung insects may reduce the food supply for insectivorous birds (including rare species such as chough) and bats such as the greater horseshoe bat.

“ Evidence suggests Ivermectin is potentially toxic to aquatic crustacea and its use on sites supporting species of conservation concern (eg tadpole shrimp *Triops cancriformis*, fairy shrimp *Chirocephalus diaphanus*) could be potentially damaging particularly where cattle are defecating into water bodies.

The length of time the dung remains toxic following treatment depends on the application method and ranges from 1-2 weeks for the oral drench to six months for the Ivermectin bolus.

8.6.8 Use of avermectins

(See also Chapter 5, sub-section 5.9.5)

On sites or in areas where there is a risk to species of conservation concern such as rare invertebrates associated with dung or species feeding on dung invertebrates then it is important to firstly assess the likely impact of avermectin use; for instance will the occurrence of dung residues coincide with the presence of the wildlife interest at a critical period? If it does then avermectins should not be used. The same applies to the related doramectin, at least until we have a fuller understanding of its impact. In many cases, avoiding use of the bolus treatment and instead using short-term avermectin treatment coupled with delaying the release of treated animals onto pasture may obviate the need for a total restriction of use in some circumstances. It should be noted that many of the insects associated with dung are restricted in their distribution or occur only in dung dropped in a particular habitat type. Dung on dry acid or calcareous grassland supports a disproportionate number of scarce species and thus use of avermectins should be carefully evaluated in these situations.

Moxidectin is reported as having a lower risk to dung fauna and can be added to the list of alternatives for use in sensitive situations although it might still pose a risk to aquatic invertebrates. There is some evidence that Organophosphates and Pyrethroids used for treating ectoparasites can have adverse effects on dung fauna (see McCracken 1995) but further work is required before a proper assessment of their use in potentially sensitive situations can be made.

Where avermectins are not being used, the other alternatives should be used (see Table 8.2) taking care to alternate use to prevent a build up of resistance. There is, to date, no evidence that these alternatives have effects on dung fauna as marked as the avermectins.

Practical advice on the storage and use of veterinary medicines is provided in Health & Safety Executive (1992).

Table 8.2 Alternative chemicals for internal/external parasite control of livestock*

Chemical group	Active compound	Livestock type	Application methods	Target organisms
Benzimidazoles (including Probenzimidoles)	Ricobendazole	C, S	oral drench	1, 2, 3, 4
	Oxfendazole	C, S, H	oral drench, bolus	1, 2, 3
	Fenbendazole	C, S, H	oral drench, bolus, in-feed	1, 2, 3
	Albendazole	C, S	oral drench, bolus	1, 2, 3, 4
	Mebendazole	H	oral drench	1, 2, 3
	Triclabendazole	S	oral drench	4
	Netobimin	C, S	oral drench	1, 2, 3, 4
	Febantel	C, S, H	oral drench, in-feed	1, 2, 3
	Thiophanate	C, S	in-feed, lick	1, 2
	Thiabendazole	C, S	oral drench	1, 2
Imidazothiazoles	Levamisole	C, S	oral, oral drench, pour-on, injection	1, 2
Tetrahydropyrimidines	Morantel tartrate	C, S	bolus, oral drench	1
	Morantel citrate	S	oral	1
	Pyrantel embonate	H	oral	1
Milbemycins	Moxidectin	C	injection	1, 2, 5
Salicylanilides & substituted phenois	Closantel	S	oral drench	4
	Nitroxynil	S, C	injection	4
	Oxyclozanide	C, S	oral drench	4
	Clorsulon	C	oral drench	4
Pyrethroids	Alphacypermethrin	C	pour-on	5
	Cypermethrin	C, S, H	pour-on, spray, ear tag, dip	5
	Deltamethrin	C, S	pour-on	5
	Flumethrin	S	dip	5
	Permethrin	C, H	dip, ear tag, pour-on	5
	Fenvalerate	C	spray	5
Organophosphates	Haloxon	H	oral	1, 4
	Diazinon	S	dip	5
	Propetamphos	S	dip	5
	Prolate	C	pour-on	5
Other	Cyromazine	S	pour-on	5
	Amitraz	C, S	dip- spray	5
	Copper (Naphthenate)	S	spray	5

Key: 1 = Gut roundworms 2 = Lungworms 3 = Tapeworms 4 = Liver fluke 5 = Ectoparasites (eg mites, flies, lice etc).C = cattle S = sheep H = horses

* Always check current recommendations. For more specific advice consult a vet.

8.6.9 Organic systems

Organic livestock systems face the problem of controlling intestinal parasites without recourse to the routine use of proprietary drugs. The aim to encourage natural immunity to disease and worm infection and prevention of infestation by good management practices. The latter is usually achieved by rotating grassland between different livestock types. For example, a three year rotation with beef cattle, followed by sheep followed by hay. It is important that once a field has, for example, been grazed by sheep, it should not be grazed by them again for a whole year in order to allow the parasitic eggs and free-living larvae to die.

8.6.10 Pesticide drift

Pesticide drift may be an issue where semi-natural grassland adjoins arable crops. This is particularly the case where aerial spraying is practised. However, there are only a small number of aerial spraying contractors involved and only a few hundred spray events per annum and only a small proportion will be close enough to grassland of nature conservation value. Nonetheless a single spray event may have potential to cause significant adverse effects through drift or overspraying.

Aerial spray contractors are legally obliged under the Control of Pesticides Regulations to consult the conservation agencies at least 72 hours in advance if they intend to spray within 1500 m of an SSSI.

If the site to be sprayed is not within 250m of a grassland site, then there is unlikely to be concern. If it is within 250m of a grassland then the response will depend on the type of pesticide to be sprayed and the key nature conservation features of the grassland. Insecticides are the key concern for grasslands, and if grassland invertebrates are likely to be exposed to drift then a buffer zone of up to 250m should be requested. Pirimicarb (see Table 8.1) is an exception; providing aquatic organisms are not exposed, the risk is low. A similar buffer could be considered for aerial spraying of fungicides or herbicides (invariably asulam) in the unlikely event that fungi or rare ferns are key features of semi-natural grasslands. Where low drift nozzles are used for aerial applications of asulam, it will often be possible to consider significantly reducing the buffer required. Revised guidance on buffers for the protection of rare ferns from aerial spraying to control bracken will be issued during 1999.

8.7 Rolling

8.7.1 Introduction

Smooth rollers towed by tractor are sometimes used in spring for levelling grassland, pressing-in stones, encouraging the tillering of grasses and flattening mole hills to prepare for hay or silage harvesting later in the season. Rollers consist of two or three smooth surfaced heavy rotating cylinders. By adding ballast to the hollow cylindrical rollers, weights from 0.5-1.3 tonne/m width can be applied.

8.7.2 The use of rolling on semi-natural grassland

Rolling is generally an acceptable practice in spring but timing is an important consideration. Rolling is more likely to be practised on grasslands on level terrain cut for hay (eg neutral grasslands). The following restrictions are advisable:

“ Where grassland is important for breeding birds rolling should not take place between 15 March or before 15 July (1 August if corncrakes present) in the lowlands.

“ Where grassland supports early flowering species which may be vulnerable to damage by rolling, such as fritillary *Fritillaria meleagris* and green-winged orchid *Orchis morio*, rolling should take place *c*6-8 weeks before flowering (ie not after *c*15 March).

“ Sites which have ant hills should not be rolled.

“ Compaction and rutting by wheels may be a major problem on damp sites. In these situations rolling should not be permitted. Alternatively all terrain vehicles (ATVs) could be used to tow equipment to avoid damage.

8.8 Chain harrowing

8.8.1 Introduction

A chain harrow consists of a large number of small tines or spikes carried on a flexible (chain) frame. They are used on grassland to break up ‘matted’ swards, to spread dung after grazing and spread molehills. They are normally tractor trailed.

8.8.2 The use of chain harrowing on semi-natural grassland

Advice is generally the same as for rolling. Harrowing may, however, be a more acceptable alternative to rolling on wet ground. It may be advisable to monitor sites to check that harrowing, where permitted, is not leading to an increase in undesirable species such as thistles, docks and ragworts which could exploit gaps in the sward created by harrowing. However, the creation of some small gaps in the sward can have beneficial effects in creating opportunities for the germination and establishment of more desirable plant species.

8.9 Sub-soiling

8.9.1 Introduction

Sub-soiling is a technique which mechanically bursts the soil creating fissures and cracks at depths of 450mm or more below the soil surface. It is achieved by towing a sub-soiling blade and chisel or `shoe' behind a crawler tractor.

The purpose of sub-soiling is to improve the drainage of soil, especially over an existing underdrainage system, or to loosen compacted soil to improve soil structure and conditions for plant growth.

8.9.2 The use of sub-soiling on semi-natural grassland

As far as semi-natural grasslands are concerned, there is no information available on the impact of sub-soiling on the plant and animal communities. However, given that one aim of sub-soiling is to improve drainage which in turn could adversely affect the nature conservation value of damper grasslands, it is advisable to adopt a precautionary approach and avoid the use of this practice.

8.10 Soil disturbance

Physical disturbance by sporadic cultivation was an important aspect of traditional management of some semi-natural grassland habitats particularly on thin/skeletal free-draining nutrient-poor calcareous or acid soils. The communities which may be maintained by periodic disturbance and which in part owe their existence to it include CG7 *Festuca ovina - Hiracium pilosella-Thymus praecox/pulegiodes* calcareous grassland, U1 *Festuca ovina-Agrostis capillaris-Rumex acetosella* parched acid grassland, inland communities characterised by *Carex arenaria* on sandy soils (eg SD10b *Carex arenaria* dune, SD11b *C. arenaria - Cornicularia aculeata* dune) and machair “grassland” (SD8 *Festuca rubra-Galium verum* dune grassland) occurring on lime-rich shell-sand on the low relief plains around the coastline of NW Scotland.

The former communities are particularly a feature of the Norfolk and Suffolk Breckland where it is known that areas of sandy soil were periodically cultivated and then returned to use for grazing (Dolman & Sutherland 1992, 1994). Machair grassland, which contributes to the machair landscape particularly in the Western Isles, has often been influenced by rotational arable cultivation. Such cultivation was of low intensity, ie it was shallow and would not have involved the addition of large amounts of nutrients compared to modern arable cropping.

Periodic soil disturbance is particularly important for maintaining populations of ephemeral plant species which cannot thrive in more closed grassland swards. Grassland types such as those considered here which have a high percentage of bare ground can be of high value for invertebrates (Edwards 1996, Kirby 1992). It is conceivable that rabbit activity could replicate the effects of cultivation in some circumstances.

The use of soil disturbance: Achieving objectives

Clearly, where there has been a long history of such management and this has been instrumental in maintaining communities of nature conservation value then it is appropriate for this to continue. This should mimic the low intensity traditional system.

In circumstances where this episodic cultivation is no longer practised it may be appropriate to mimic it by occasional rotovation. In addition, mechanical disturbance or scarification could also be used in the maintenance of secondary early successional communities of nature conservation value for example in disused calcareous quarries (these communities can equate to CG7) (Jefferson & Usher 1987). In either case the following points need to be considered:

“ Ensure disturbance is an appropriate management technique for the community with reference to historical information and ecological knowledge of community dynamics.

“ Is soil disturbance the most suitable and practical option - are there other ways of achieving nature conservation objectives, eg encouraging rabbit activity, heavy livestock grazing etc.

If these criteria are met then:

“ ensure the method of soil disturbance is shallow and is not accompanied by nutrient additions;

“ ensure undisturbed areas remain in each phase to ensure source pools of species for re-colonisation;

“ aim to rotate disturbed areas to provide a diverse and heterogenous mosaic of plant sub-communities and habitat microstructure;

“ ensure appropriate monitoring is instigated to check whether nature conservation objectives are being met.

8.11 Drain maintenance - open watercourses

8.11.1 General introduction

Drainage ditches or channels are a particular feature of lowland wet grassland in the UK and their management and maintenance is vital from both agricultural and nature conservation perspectives. Drainage ditches are important both for the range of flora and fauna they support and for the maintenance of the conservation value of the surrounding grassland which may in part depend on the maintenance of a high water table at certain times of the year.

8.11.2 Drain maintenance on semi-natural grasslands

The following general points provide guidelines in relation to ditch management:

“ Regular management of ditches by the removal of aquatic vegetation and accumulated silt by hand or machinery is acceptable and may be necessary for the maintenance of their nature conservation value.

“ Rotational dredging or partial dredging of the channel limits the impact on aquatic and emergent flora and fauna. Ideally, a ditch should be managed from one side only at a time.

“ Deepening of existing ditches is not normally acceptable.

“ Spoil from dredging or sludging should not normally be deposited on semi-natural grassland or wetland communities as it will change the species composition of the sward. Where spoil has been deposited along the edge of a ditch for many years it is acceptable to continue this practice as the nature conservation value of such areas is likely to be minimal.

“ The removal of ditch side spoil banks may lead to changes in the hydrology of adjacent wet grassland, resulting in detrimental impacts on plants and animals. It should be avoided.

“ Where the ditch invertebrate fauna is of particular importance for nature conservation and the adjacent grassland is of little value, it may be better to spread the spoil thinly on the grassland. This will ensure access to the ditch by livestock whose trampling activities can be important for maintaining an interesting community of invertebrates.

“ Ditch management should not normally be undertaken between March and July or late autumn or winter to avoid disturbance of breeding birds and wintering birds respectively. The late summer or early autumn is ideal for ditch management.

“ Use of herbicides in ditches should generally be avoided. However, selective treatment of ‘nuisance’ plants with a suitable approved herbicide may be acceptable in some circumstances. The consent of the Environment Agency is required before aquatic herbicide is applied. Herbicides approved for use against aquatic weeds or weeds growing along the banks of watercourses, are listed in Whitehead (1998). MAFF (1995) and NRA (1995) set down guidelines for the use of herbicides in or near watercourses.

“ Occasional re-profiling of ditches is acceptable if it is designed to maximise the nature conservation value (eg a gently shelving profile).

The above guidance should be acceptable where there are water vole *Arvicola terrestris* populations. This species requires situations with continuous swathes of riparian vegetation up to 2m away from the water and a stepped or steep vegetated bank for profile. Dredging should ideally be undertaken in short sections from one bank and riparian vegetation cover should be retained as practicable. For further information see Strachan (1999).

MAFF/Welsh Office 1996 is a practical guide to help flood defence authorities follow good environmental practice. It includes a section on the environmental implications of watercourse maintenance and information on relevant legislation.

8.12 Drain maintenance - sub-surface

8.12.1 Introduction - sub-surface drainage

Some semi-natural grasslands, for example some upland haymeadows (MG3 and fen meadow communities) and lowland flood meadows (MG4) are underlain by a system of sub-surface drainage. This often consists of clay tile drains discharging into an open watercourse and the system may be of some antiquity.

8.12.2 Maintenance of sub-surface drainage on semi-natural grasslands

Maintenance of such systems is likely to be necessary to prevent changes in the species composition of the grassland. For example, in some flood meadow communities deterioration of the drainage system can lead to a change from grassland to swamp communities, dominated by species such as reed sweet-grass *Glyceria maxima* which may be of less nature conservation value. Any maintenance work to sub-surface drainage underlying semi-natural grassland must be planned and executed with considerable care to minimise damage to the sward.

8.13 Water level management

8.13.1 Introduction

The water table regime is an important environmental factor determining the species composition of semi-natural grassland communities. The communities for which hydrology is an important factor are the semi-natural wet neutral grassland communities MG4, MG8, MG11 and MG13 and the fen meadow/rush pasture communities M22, M23, M24, M25, M26 and M27.

An understanding of the hydrology of wet grassland sites and the relationship between vegetation type and hydrological regime may be particularly important where: i) changes to the hydrological regime to fulfill specific nature conservation objectives are being considered, ii) the impact of a development which may affect the local hydrology is being assessed, iii) the restoration of grazing/cutting and ditch management to sites which have been left wholly or partly unmanaged.

This is important as even small hydrological changes can result in relatively rapid changes in the floristic composition. In the Somerset Levels, raised water levels to benefit breeding birds has resulted in floristic changes to species-rich flood pasture (MG8 related vegetation) moving it towards swamp and inundation communities. There is also evidence from studies at North Meadow, Cricklade (an MG4 flood meadow) that a prolonged high spring water table will favour wetland species associated with MG13 to the detriment of MG4 species (Gowing & Youngs 1997). The critical factor in driving vegetation change from flood meadow/flood pasture towards inundation and swamp communities appears to be the extent of soil aeration stress (duration of waterlogged soils in spring).

8.13.2 Recommendations

This section **does not cover the restoration of wet grassland** communities from arable or semi-improved/improved grassland. This is dealt with in detail in Treweek *et al* (1997).

Where ecological monitoring data suggests the key nature conservation feature(s) are being maintained on wet grassland under the current hydrological regime then it is unlikely that any remedial action is necessary although an understanding of the regime may be desirable. Sufficient information may sometimes be acquired from a variety of sources including landowners, the Environment Agency, Internal Drainage Boards or exceptionally historical data.

Where monitoring data indicate changes taking place or physical changes are observed (eg changes in flooding frequency, water table heights, ditch levels etc) then modifications to the hydrological regime may be necessary or detailed hydrological information may be required in the circumstances outlined above.

Modifications to the hydrological regime may be undertaken by changes to ditch management regimes, the installation of various water control structures such as bunds, dams, sluices and pumps (see Treweek *et al* 1997 and Chapter 13.1). All watercourse obstructions or works near watercourses will require Environment Agency consent.

8.14 Management of semi-improved swards to recover biodiversity

8.14.1 Introduction

Agricultural intensification and in particular, the use of inorganic fertilisers and slurry often combined with improved drainage has converted formerly species-rich semi-natural grasslands into species-poor semi-improved grasslands such as the MG6 & MG7 communities described in the National Vegetation Classification (Rodwell 1992). Increasingly, with current biodiversity initiatives there is interest in increasing the nature conservation value of such swards which often involves increasing their plant species- richness guided by the original composition of the previous unimproved semi-natural grassland type where this is known.

This section deals with situations where grasslands still retain some botanical interest and the aim is to improve the nature conservation value. The creation of grasslands of wildlife interest on areas with no existing botanical interest (e.g. ex-arable land) is dealt with in Chapter 11 and the restoration of unmanaged grasslands is dealt with in Chapter 10.

8.14.2 Management guidelines

It is essential to be clear on the objectives before embarking on the restoration management. It is particularly important to be clear as to the type and botanical composition of the grassland to be restored, the methods by which this will be achieved and over what timescale.

Restoration or recovery of semi-improved swards normally involves reducing the residual effects of the previous fertlilisation and drainage. Following on from this recovery of botanical diversity can be achieved either by natural colonisation or artificial introduction of seed or plant transplants or a combination of both.

“ *Cease all inputs of inorganic/organic fertilisers*.

It is essential to discontinue inputs of all inorganic or organic fertilisers. Ultimately, once the objectives have been achieved, continuation of traditional manuring practice could continue as in the case of meadows (see sub-sections 8.3.3 & 8.3.4.).

“ *On former wet grasslands, restore the original groundwater levels*

This can slow down the rate of nutrient mineralisation and plant production and provide the right conditions for wet grassland species.

“ *Re-instate low-intensity traditional grassland management.*

This will normally involve grazing, hay-cutting or a combination of both depending on the type of grassland being restored. This will assist in the depletion of nutrients and provide the right conditions for establishment and spread of characteristic species.

It should be stressed that nutrient depletion is a very slow process after cessation of fertiliser use and the residual effects of nutrient additions, especially Phosphorus have been projected to last for many years.

Where it is unlikely to prejudice biodiversity objectives, more frequent cutting and removal of the herbage may hasten nutrient depletion. This may be most appropriate at the outset of the restoration phase and its appropriateness will, in part, depend on the extent of the remaining botanical interest. Winter/spring grazing may at least initially provide better colonisation opportunities for plant species than grazing at other periods.

On wet grasslands this may also involve re-instatement of low-intensity ditch management and water management practices (eg water meadows).

“ *Consider botanical restoration options*

Recovery of botanical richness may be slow in semi-improved swards due to the residual effects of fertiliser which will favour competitive species and, in many situations, the lack of a natural source of plant colonists.

In addition, fertiliser application is known to deplete the soil microbial community, in particular mycorrhizal fungi (Bardgett *et al* 1995, Sparling & Tinker 1978). These fungi have been shown to promote seedling establishment and plant species diversity (Grime *et al* 1987). It has thus been suggested that the recovery of plant species diversity in improved/semi-improved grasslands may be linked to the development of Vesicular Arbuscular Mycorrhizal (VAM) fungi in soils. The lack of VAM may thus inhibit establishment or spread of certain plant species typical of semi-natural swards. Further studies are required to substantiate these claims (Bardgett *et al* 1997).

Van der Heijden *et al* 1998 conclude that below ground diversity of arbuscular mycorrhizal fungi (AMF) is a major factor contributing to the maintenance of plant divesity and ecosystem functioning. They conclude that there is a need to protect AMF species richness and consider these fungi in future management practices to maintain diverse ecosystems. As far as semi-natural grasslands are concerned, the sort of practices which are likely to be detrimental to the below ground AMF community such as ploughing and application of artificial fertilisers (Helgason *et al* 1998) will also have a negative impact on vascular plant richness (see sections 8.2 & 8.6).

The use of soil inocula taken from existing semi-natural grasslands to enhance the soil fungi of semi-improved grasslands may offer some potential if this is shown to be a barrier to the enhancement of botanical diversity.

Natural re-colonisation can be used but this is probably most appropriate in situations where there is a nearby source of the characteristic species or species are still present in the existing field in cases where previous management has not resulted in complete extinction. The seed bank can not be relied on as a source of species characteristic of semi-natural grasslands as these are rarely present after a period of agricultural improvement. In some situations boundary features such as ditches, hedgebanks and field margins may act as refuges for species characteristic of semi-natural grasslands and may be valuable source pools for re-colonisation.

Botanical richness can also be accelerated by the introduction of seed of appropriate species either by surface broadcasting or slot seeding or the introduction of container-grown transplants (see Chapter 11 for further details).

Davies *et al* (1997) suggest that the introduction of *Rhinanthus minor* may have a role in the restoration of species-rich grasslands (see also Chapter 11). This is due to its impact in reducing the productivity of grassland swards and its effect of preferential suppression of grasses and its effect in facilitation of the increase in broad-leaved herbs. These effects are normally considered to be desirable objectives in grassland restoration schemes. *Rhinanthus minor* can be established from seed in semi-improved swards and will persist provided hay cutting does not take place prior to seed set.

This technique may prove to be appropriate where the objective is to restore various semi-natural meadow communities such as the NVC communities MG3, MG4, MG5 and MG8. However, some practical field trials would be helpful in evaluating the potential of this method.

8.15 Rabbit management

8.15.1 Introduction

There may be situations where there is a need to implement rabbit control measures within or adjacent to areas of semi-natural grassland. This may arise where rabbits are causing damage to crops, pasture, animal or human foodstuffs etc. Under Section 1 of the Pests Act 1954, the occupier of any land has a continuing obligation to kill or take rabbits on his/her land or prevent damage being caused by them. Where an occupier is failing to meet his obligations under the 1954 Act, Agriculture Ministers have powers, under Section 98 of the Agriculture Act 1947 to require occupiers of land to take action against rabbits.

In addition, high rabbit population densities may lead to the degradation of the conservation value of semi-natural grasslands. However, in some cases, rabbit grazing can be beneficial for nature conservation (see Chapters 5 and 13).

8.15.2 Non-lethal control methods: barriers

Rabbits may be fenced in or out depending on the prevailing circumstances. Wire netting should comply with British Standard 1722. The specification should be a minimum width of 900mm (3') of 18 gauge, 31mm (1¼0) hexagonal mesh. The netting should be erected so that 750mm (2N60) is erected vertically and the bottom 150mm (60) is lapped on the surface of the ground towards the rabbit harbourage. Two straining wires, preferably of 2.65mm (0.010) high tensile spring steel, should be fixed (one at the top of the fence and one at the bottom) to the sides of posts and stakes which face the harbourage. Straining wires should be joined together using connectors and netting attached to the wires with fencing rings.

Turfs of grass should be placed on the lapped netting at 1m (3N30) intervals; after about a year, vegetation should grow through the mesh to hold the netting firmly in place. Stakes can be placed up to 15m (50N) apart, provided that high tensile spring steel straining wires are used, although ground undulations may dictate closer spacing. If mild steel straining wires are used, stakes can be placed no more than 4m (13N) apart. Stakes should be 1.7m (5N60) long and 50-75mm (20-30) in diameter. Irrespective of the type of straining wire used, straining posts need be placed only at the ends of the fence and at bends. Straining posts should be 2.1m (7N) long and 100-120mm (40-50) in diameter. A netting plough is available; this is a tractor-mounted machine that in one pass cuts out a trench, lays in rabbit netting and covers back, allowing long lengths to be buried quickly. Electric net fencing can also be effective particularly where there is a temporary need to exclude rabbits.

8.15.3 Direct control methods

There are a number of direct control methods which vary in their efficacy. Gassing, shooting and trapping are probably the most humane methods although measurement of humaneness is somewhat subjective. Conservation agencies who now own and manage sites where rabbit control is required may find local landowners a useful source of advice when seeking persons who are able to undertake such control.

“ **Gassing**

Gassing, which is permitted by the Prevention of Damage by Rabbits Act 1939 and the Agriculture Act 1947, is considered to be the most effective form of control where access to rabbit burrows can be obtained. It involves the use of one of the fumigant products approved under the Control of Pesticides Regulations 1986 and subject to the Poisons Act 1972 and the Poisons Rules 1982 which control the sale and use of such pesticides.

Approved products are based either on sodium cyanide or aluminium phosphide. They are applied to the rabbit burrows and rely on moisture to release a toxic gas. These compounds can be extremely toxic to humans and animals and should only be used by operators who have been suitably trained and instructed in their use. The provisions of the Control of Substances Hazardous to Health Regulations 1988 (COSHH) under the Health and Safety at Work Act 1974 need to be considered.

It is illegal to gas active badger setts or fox earths. The potentially damaging effects of gas on hibernating reptiles and amphibians, eg natterjack toads and smooth snakes or other animals which occupy rabbit burrows, need to be taken into account.

The optimum time to commence any form of direct control is November and a major effort should be made between this time and March when the population is at its lowest and prior to the main period of the breeding season (Rees *et al* 1985). Other control methods detailed below are considered to be much less effective and are labour intensive but could be considered for small infestations, where gassing is inappropriate or as follow up treatments to gassing.

“ **Shooting**

Shooting with a shotgun or .22 rifle is a widely used method of dealing with surface-living rabbits but is often ineffective unless a considerable amount of time is expended. Night shooting with lights produces the largest reductions but under the Ground Game Act 1880, it is restricted to authorised persons, ie owners, occupiers and tenants of land who possess the shooting rights. The main body of criminal law regulating the use of firearms and ammunition is contained in the Firearms Act 1968 and the Firearms (Amendment) Act 1988. Generally a firearms certificate is required for possession and use of a rifle but there are exceptions (see Parkes 1991 for further information). For shotguns, although control and use is less strict than for other firearms, a shotgun certificate is required (see Parkes 1991 and Parkes & Thornley 1994). Applications for both types of certificate should be made to the appropriate Chief Constable. A game licence (see Section 4 1860 Game Licences Act) may also be required to shoot rabbits if the person effecting control is not an owner, occupier or tenant of the land or has not gained their express permission. If in doubt seek further advice (Parkes 1991; Parkes & Thornley 1994). Game licences are available from the post office and from some district councils.

“ **Snares**

Snares should be set on rabbit runs away from cover, preferably on windy, moonless nights lacking frost. The Wildlife and Countryside Act 1981 prohibits the use of self-locking snares and requires that any other type of snare set in position is inspected at least once every day. Care is needed in siting snares as the law requires that all reasonable precautions be taken to avoid catching protected animal species, including badgers, listed on Schedules 5 and 6 of the 1981 Act. Snares should not be set where livestock are present or if there is a risk to domestic pets.

“ **Spring trapping**

Section 8 of the 1954 Pests Act and Section 50 of the 1948 Agriculture (Scotland) Act only allow the use of spring traps that have been approved by the relevant Agriculture Department. These are designed to catch and kill rabbits humanely. The Spring Trap Approval Order 1995 specifies that the following traps may be used against rabbits: Imbra Trap Mark I and II; BMI Magnum 116; Victor Conibear 120-2; Fenn Rabbit Trap Mark I, Fenn Vermin Trap Mark VI (Dual Purpose); Springer No. 6 Multi-purpose and the Juby. All traps must be set in a natural or artificial tunnel which is, in either case, suitable for the purpose. It is illegal under the Pests Act to set spring traps for rabbits other than in burrows. The traps must be placed within the overhang of the hole to reduce the risk of catching other species. The Protection of Animals Acts 1911 and 1912 and Section 1 of the Protection of Animals (Scotland) Act 1912 requires that all traps be visited at least once every day between sunrise and sunset.

When setting any type of trap or snare (see above), reasonable precautions must be taken to avoid catching protected animal species listed on Schedules 5 and 6 of the 1981 Wildlife and Countryside Act, including badgers.

“ **Drop traps**

Rabbit netting is an effective means of excluding rabbits from cropped or grassland areas but where numbers are high rabbits will eventually burrow under or climb over the net. In this situation, installing box drop traps along the fence line which separates a warren from a grazing area can be effective in reducing rabbit populations. The traps consist of a tunnel, trap-door and cellar and the rabbits fall through the trapdoor into the cellar to await humane destruction by the operator. The trap should be inspected daily on humaneness grounds and should not be sited in areas subject to flooding or where there is a high water table.

“ **Baited cage traps**

Where it is not possible to gain access to burrows harbouring rabbits, wire mesh cages baited with sliced carrots may be of use. These traps should be inspected twice a day, early in the morning and late afternoon and any captured rabbit should be humanely despatched. Due to the manpower requirements to use these traps, easy access to the site is important. Problems may also be experienced due to interference by predators such as badgers and foxes.

“ **Ferreting**

Ferreting involves the introduction of ferrets into the burrow system as a means of bolting the rabbits either into nets for humane despatch or to be shot as they merge. This method is unlikely to achieve effective control and is time-consuming to undertake.

“ **Long netting**

The following account is taken from Thompson (1994). Where rabbits are abundant, large numbers may be taken in long nets. These nets are usually 45 to 135m (150N-445N) long, 1m (3N30) wide with 5cm (20) mesh. Nets are run out at night downwind from feeding rabbits about 13m (42N) from the nearest cover. There is a line along the top of each net which is supported by 1 m sticks at 4m (13N) intervals, the slack of the net being allowed to lie loosely on the ground. Once the net is erected, the rabbits are driven into the net at speed by dogs and beaters. For further details of this technique see Wyman (1989).

8.15.4 Summary

Any strategy designed to control rabbit numbers in a given situation must minimise the impact on the nature conservation resource. No one technique is likely to be applicable to all situations. Control should always be effected in a manner which is as humane as possible.

References and further reading

ATKINSON, R.P.D. & MACDONALD, D.W. 1994. Can repellants function as a non-lethal means of controlling moles *Talpa europaea*? *Journal of Applied Ecology,* **31:** 731-736.

ATKINSON, R.P.D., MACDONALD, D.W. & JOHNSON, P.J. 1994. The status of the European Mole *Talpa europaea* L. as an agricultural pest and its management. *Mammal Review,* **24:** 73-90.

BAKKER, J.P. 1987. Restoration of species-rich grassland after a period of fertilizer application. *In*: J. van ANDEL, J.P. BAKKER & R.W. SNAYDON eds. *Disturbance in grasslands: Causes, effects and processes*. Dordrecht: Dr. W. Junk Publishers. pp 185-200.

BARDGETT, R.D., SMITH, R.S., HOBBS, P.J. & DONNISON, L. 1995. Relationships between soil microbial poulations and above ground flora in floristically diverse grassland under management change. *In*: J.C. MOORE, R.K. NILES, D.W. FRECKMAN & C. JACOBS-CARRE eds. *Integration of above- and below-ground communities: the importance of soil biota and processess to above-ground ecosystem maintenance and development*. Fort Collins: Colorado State University & Soil Society of America. pp28.

BARDGETT, R.D. 1996. Potential effects on the soil mycoflora of changes in the UK agricultural policy for upland grasslands. *In*: J.C. FRANKLAND, N. MAGAN & G.M. GADD, eds. *Fungi and Environmental Change*. Symposium of the British Mycological Society. Cambridge: Cambridge University Press. pp. 163-183.

BARDGETT, R.D., COOK,R., YEATES, G.W., DONNISON, L., HOBBS, P. & McALISTER, E. 1997. Grassland management to Promote Soil Biodiversity. *In*: R.D. SHELDRICK ed. *Grassland management in Environmentally Sensitive Areas*. British Grassland Society Occasional Symposium No. 32. Reading: British Grassland Society.pp 132-137.

COLESHAW, T. 1995. Rising to the water levels challenge. *Enact,* **3(1):** 7-9.

DALAL-CLAYTON, D.B. 1981. *Black's agricultural dictionary*. London: Adam & Charles Black.

DAVIES, D.M., GRAVES, J.D., ELIAS, C.O. & WILLIAMS, P.J. 1997. The impact of *Rhinanthus* spp. on sward productivity and composition: implications for the restoration of species-rich grasslands. *Biological Conservation,* **82**: 87-93.

DEPARTMENT OF THE ENVIRONMENT. 1996. Code of practice for agricultural use of sewage sludge. London: HMSO.

DOLMAN, P.M. & SUTHERLAND, W.J. 1992. The ecological changes of Breckland grass heaths and the consequences of management. *Journal of Applied Ecology*, **29**: 402-413.

DOLMAN, P.M. & SUTHERLAND, W.J. 1994. Use of soil disturbance in the management of Breckland Grass Heaths for nature conservation. *Journal of Environmental Management*, **41:** 123-140.

EDWARDS, M. 1996. Management of bare ground on dry grasslands and heathlands, Peterborough: EN (A5 leaflet).

ENGLISH NATURE. 1996. *Species conservation handbook.* Peterborough: English Nature.

GOWING, D.J.G. & YOUNGS, E.G. 1997. The effect of the hydrology of a Thames flood meadow on its vegetation pattern. *In*: A. LARGE, ed. *Floodplain rivers: hydrological processes and ecological significance*. British Hydrological Society Occasional Paper No. 8. Newcastle: University of Newcastle. pp 69-80.

GRIME, J.P. MACKEY, J.M.L., HILLIER, S.H. & READ, D.J. 1987 . Floristic diversity in a model system using experimental microcosms. *Nature*, **333**: 204-205.

HALLEY, R.J. & SOFFE, R.J. eds. 1995. *Primrose McConnell's The agricultural notebook* 19th edition, London: Butterworths.

HEALTH & SAFETY EXECUTIVE. 1992. *Veterinary medicines: Safe use by farmers and other animal handlers*. Health and Safety series booklet HS (G) 86. London: HMSO.

HELGASON, T., DANIELL, T.J., HUSBAND, R., FITTER, A.H. & YOUNG, J.P.Y. 1998. Ploughing up the wood-wide web? *Nature*, **394:** 431.

JEFFERSON, R. G. & USHER, M. B. 1987. The seed bank in soils of disused Chalk quarries in the Yorkshire Wolds, England: implications for conservation management. *Biological Conservation*, **42:** 287-302.

KIRBY, P. 1992. *Habitat Management for Invertebrates: a practical handbook.* Sandy: Royal Society for the Protection of Birds.

KIRKHAM, F.W., MOUNTFORD, J.O. & WILKINS, R.J. 1996. The effects of nitrogen, potassium and phosphorus addition on the vegetation of a Somerset peat moor under cutting management. *Journal of Applied Ecology*, **33:** 1013-1029.

McCRACKEN, D.I. 1995. Short note on potential environmental problems of cattle and sheep anthelmintics. *Extensive Farming Systems Unit Briefing Paper*, No. 7. Paisley: Joint Nature Conservation Committee.

McCRACKEN, D.I. & BIGNAL, E. 1991. Chemical alternative to treatment of cattle with Ivermectin. JNCC leaflet, Peterborough: Joint Nature Conservation Committee.

McCRACKEN, D.I. & FOSTER, G.N. 1992. The effect of Ivermectin on the invertebrate fauna associated with cow dung. *JNCC Report No. 112*., Peterborough: Joint Nature Conservation Committee.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD. 1995. *Guidelines for the use of herbicides on weeds in or near watercourses and lakes*. 2nd edition Booklet 2078, London: HMSO.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD/DEPARTMENT OF THE ENVIRONMENT. 1993. *Review of the rules for sewage sludge application to agricultural land. Food, safety and relevant animal health aspects of potentially toxic elements.* London: MAFF.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD/WELSH OFFICE. 1996. *Code of practice on environmental procedures for flood defence operating authorities*. London: MAFF.

MOUNTFORD, J.O., LAKHANI, K.H. & KIRKHAM, F.W. 1993. Experimental assessment of the effects of nitrogen addition under hay cutting and aftermath grazing on the vegetation of meadows on a Somerset peat moor. *Journal of Applied Ecology*, **30:** 321-332.

MOUNTFORD, J.O., LAKHANI, K.H. & HOLLAND, R.J. 1996. Reversion of grassland vegetation following the cessation of fertiliser application. *Journal of Vegetation Science*, **7**: 219-228.

NATIONAL OFFICE OF ANIMAL HEALTH. 1996. *Compendium of data sheets for veterinary products 1997-98*. Enfield: National Office of Animal Health.

NATIONAL RIVERS AUTHORITY. 1995. The use of herbicides in or near water. Peterborough: National Rivers Authority.

NEVILLE, P. 1985. Humane control of moles. *In*: D.P. BRITT, ed. *Humane control of land mammals and birds*. Potters Bar: The Universities Federation of Animal Welfare. pp 113-117.

NEWBOLD, C., HONNOR, J. & BUCKLEY, K. 1989. *Nature conservation and the management of drainage channels.* Peterborough: Nature Conservancy Council.

NEWTON, J. 1993. Organic grassland. Canterbury: Chalcombe Publications.

OOMES, M.J.M., OLFF, H. & ALTENA, H.J. 1996. Effects of vegetation management and raising the water table on nutrient dynamics and vegetation change in a wet grassland. *Journal of Applied Ecology*, **33**: 576-588.

PARKES, C. 1991. *Law of the Countryside*. 4th edition. Bakewell: Association of Countryside Rangers.

PARKES, C. & THORNLEY, J. 1994. *Fair game: the law of country sports and the protection of wildlife*. 3rd edition. London: Pelham Books.

REES, W.A., ROSS, J., COWAN, D.P., TITTENSOR, A.M. & TROUT, R.C. 1985. Humane control of rabbits. *In*: D.P. BRITT, ed. *Humane control of land mammals and birds*. Potters Bar: The Universities Federation of Animal Welfare. pp 96-102.

RODWELL, J. S. ed. 1992. *British Plant Communities 3: Grassland and Montane communities.* Cambridge: Cambridge University Press.

RODWELL, J.S. in press. *British Plant Communities 5: Maritime communities and the vegetation of open habitats.* Cambridge: Cambridge University Press.

SILVERTOWN, J., WELLS, D.A., GILLMAN, M., DODD, M.E., ROBERTSON, H.J. & LAKHANI, K. H. 1994. Short-term effects and long-term after effects of fertiliser application on the flowering population of green winged orchid, *Orchis morio*. *Biological Conservation*, 69: 191-197.

SIMPSON, N.A. & JEFFERSON, R.G. 1996. Use of farmyard manure on semi-natural (meadow) grassland. Peterborough: *English Nature Research Reports*, No. 150.

SKIDMORE, P. 1991. *Insects of the British cow-dung community*. Occasional Publication No. 21. Shrewsbury: Field Studies Council.

SMITH, C.J. 1980. *Ecology of the English Chalk*. London: Academic Press.

SPARLING, G.P. & TINKER, P.B. 1978. Mycorrhizal infection in Pennine grassland. I. Levels of infection in the field. *Journal of Applied Ecology,* **15**: 943-950.

STRACHAN, R. 1999. *The Water Vole conservation handbook*. Oxford: Wildlife Conservation Research Unit.

STRONG, L. 1992. Ivermectins a review of their impact on insects of cattle dung. *Bulletin of Entomological Research,* **82:** 265-274.

TALLOWIN, J.R.B. 1996. Effects of inorganic fertilisers on flower-rich hay meadows: a review using a case study on the Somerset Levels, UK. *Grassland and Forage Abstracts,* **66:** 147-152.

TALLOWIN, J.R.B. 1998. Use and effects of lime applications on semi-natural grasslands in Britain. *Countryside Council for Wales Science Report No. 261*. Bangor: CCW.

THOMPSON, H.V. 1994. The rabbit in Britain. *In*: H.V. THOMPSON & C.M. KING, eds. *The European rabbit. The history and biology of a successful coloniser*. Oxford: Oxford University Press. pp 64-107.

TREWEEK, J., JOSÉ, P. & BENSTEAD, P. 1997. *The wet grassland guide: Managing floodplain and coastal wet grasslands for wildlife.* Sandy: Royal Society for the Protection of Birds.

VAN DER HEIJDEN, M.G.A., KLIRONOMOS, J.N., URSIC, M., MOUTOGLIS, P., STREITWOLF-ENGEL, R., BOLLER, T., WIEMKEN, A. & SANDERS, I.R. 1998. Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. *Nature*, **396:** 69-72.

WATT, T.A, TREWEEK, J.R. & WOOLMER, F.S. 1996. An experimental study of the impact of seasonal sheep grazing on formerly fertilized grassland. *Journal of Vegetation Science*, **7**: 535-542.

WHITEHEAD, R. ed. 1998. *The UK pesticide guide*. Commonwealth Agricultural Bureaux International/ British Crop Protection Council.

WILLEMS, J.H., PEET, R.K. & BIK, L. 1993. Changes in chalk-grassland structure and species-richness resulting from selective nutrient additions. *Journal of Vegetation Science,* **4:** 203-212.

WILLIAMS, E.D. 1978. *Botanical composition of the park grass plots at Rothamsted 1856-1976*. Harpenden: Rothamsted Experimental Station.

WYMAN, H. 1989. *The art of longnetting*. Brookland, Kent: Dickson Price Publishers Ltd.