

Supplementary winter feeding of wild red deer *Cervus elaphus* in Europe and North America: justifications, feeding practice and effectiveness

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ABSTRACT

1. Supplementary winter feeding of game animals, and particularly deer, is a common practice throughout northern (continental) Europe and parts of North America. Feeding is normally associated with maintaining high densities of animals for hunting, in terms of: (i) maintaining or increasing body weights and condition overwinter; (ii) improving reproductive performance and fertility; (iii) increasing overwinter survival; and (iv) reducing levels of damage caused to agriculture and forestry or the natural heritage. We consider the balance of evidence on the effectiveness of winter feeding of red deer *Cervus elaphus* in achieving these objectives. Where that evidence is equivocal, we attempt to reconcile apparent contradictions to evaluate the circumstances under which winter feeding may or may not be effective.

2. In general, feeding of red deer on open range appears to have relatively little effect on body weights or fecundity. Effects on increasing antler size and quality are variable and seem to depend on the degree to which animals may be mineral limited on native range. Effects on survival are similarly ambiguous. It is apparent, however, that to be effective in reducing mortality, any supplementation is required early in the season and not simply when heavy mortalities are already being experienced. If provision of supplementary foods is delayed until animals are perceived already to be in poor condition, such feeding may have little effect.

3. One of the primary goals of winter feeding in both Europe and the USA has become the prevention of environmental damage, particularly damage to commercial and native forests, while maintaining deer populations at densities suitable for hunting. Again, empirical evidence for effectiveness in this regard is inconclusive, with some studies showing a decrease in damage caused, some showing no effect and others showing a significant increase in local impact.

4. There are equally a number of problems associated with the provision of supplementary feeds overwinter. Those animals which come to the feeding stations may develop a reliance on the food supplement provided, reducing intake of natural forages to near zero; where feed provided is less than 100% of daily requirement, such animals may regularly lose, rather than gain condition. Feed provision is also extremely uneven at such feeding stations; dominant stags displace younger stags and hinds from the feed provided until they have themselves finished feeding. Concentrations of high densities of animals around small feed-areas may also increase the risk of infection and lead to development of high parasite burdens.

5. In an attempt to assess the current status and distribution of supplementary winter feeding in Scotland, a questionnaire was circulated to a number of individual across the country. Results of this survey are summarized and conclusions presented on the likely effectiveness of current feeding practices in achieving their aims.

Keywords: deer damage, game management, red deer, supplementary feeding, wapiti

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INTRODUCTION

Supplementary winter feeding of game animals, and particularly deer, is a relatively widespread practice throughout northern (continental) Europe and parts of North America. In order to give context to a more specific evaluation of the extent of winter feeding in Scotland, we first review the available literature to analyse the extent of supplemental feeding carried out in other countries, the reasons this supplementation is provided, the costs involved and the perceived effectiveness of the practice. We specifically consider the effects of such supplementation, in terms of: (i) maintaining or increasing body weights and condition overwinter; (ii) improving reproductive performance and fertility; (iii) increasing overwinter survival (decreasing overwinter mortality); and (iv) reducing levels of damage caused to agriculture and forestry. We then explore the potential problems experienced in relation to supplementary feeding and assess the balance of advantage and disadvantage.

Within this contextual framework, we then present results obtained from a recent survey of different landholdings across mainland Scotland, undertaken on behalf of the Deer Commission for Scotland (DCS), to assess the extent of winter feeding of red deer *Cervus elaphus*, the reasons given for undertaking feeding programmes and perceptions of effectiveness in achieving these aims.

THE EXTENT OF WINTER SUPPLEMENTATION IN CONTINENTAL EUROPE AND NORTH AMERICA

Both red and roe deer *Capreolus capreolus* are regularly provided with supplementary feed overwinter in many countries of continental Europe. This is particularly apparent in countries which have a long tradition of sport hunting (Germany, Austria, Hungary, Norway, Sweden, Denmark), but red deer, at least, are regularly or occasionally offered winter feed in nearly all countries within Europe (Gill, 1986, 1990).

Winter feeding of wild and free-ranging animals is carried out for a variety of reasons, but mostly associated with maintaining high densities of animals for hunting, improving trophy quality, or in offsetting possible damage to forestry resulting from the maintenance of high deer densities (e.g. Raesfeld, 1920; Raesfeld & Lettow-Vorbeck, 1965; Wagenknecht, 1980; Hofmann & Kirsten, 1982; Glaser, 1983; Bubenik, 1984; Onderscheka, 1986, 1991; Raesfeld & Reulecke, 1988; Sackl, 1992; Wieselmann, 1994). Feeding of red deer is perhaps most widespread in Germany, Austria and Hungary. Peek *et al.* (2002) note that it is in these three countries that red deer densities reach their highest levels in continental Europe and, in all three countries, winter feeding is obligatory by law (Gill, 1986).

Attitudes to winter feeding of deer and other game within the USA and Canada are more polarized: between those States believing that where high densities of animals are maintained for hunting, winter feeding is required on ecological or welfare grounds, and those that believe any form of intervention is in some sense 'artificial' and so detracts from 'wildness' (Peek *et al.*, 2002). As an illustration of this variation in attitude, permanent feeding grounds for wapiti or elk *Cervus e. canadensis* are promoted in Idaho, Utah, Washington State and Wyoming and feeding is undertaken in Colorado during emergencies such as especially severe winters. In contrast, New Mexico strongly discourages supplemental feeding and advocates reduction in deer populations when problems occur. Montana and Nevada have no established feeding programmes and promote habitat improvement or acquisition as alternatives (Smith, 2001; Peek *et al.*, 2002).

Feeding in the USA of other species: white-tailed deer *Odocoileus virginianus*, mule deer *O. hemionus* or black-tailed deer *O. h. columbianus*, has usually been undertaken in response to particularly severe winter conditions, rather than as a routine measure, although animals

are fed regularly in restricted 'feed-yards' in some northern states, and see Baker & Hobbs (1985) for further review.

One important distinction between winter feeding programmes in Europe and the USA is that, in the US, supplementary feeding is the responsibility of, and carried out by each State's fish and game department, with expenses recovered from licensing fees charged for hunting. Only where State policy is actually against supplementation will any feeding that is seen as necessary on welfare grounds be carried out by private individuals. In contrast, supplementary feeding of red and roe deer in Europe is typically paid for directly by the landholders within a hunting area (*revier*) or by the subscriptions of members of the local hunting association.

THE REASONS FOR FEEDING DEER

The reasons given for feeding deer are broadly summarized by Peek *et al.* (2002) as follows: winter feeding substitutes for lost natural winter range (through enclosure or habitat change), prevents winter starvation, increases range carrying capacity, increases density of trophy males, antler points and weights, controls animal movements and may be aimed at preventing agricultural or forest damage. We may usefully add some detail to these more general objectives and insert a few additional justifications. (For the present, these objectives of feeding are simply listed in terms of reasons given for such practice; actual effectiveness in satisfying those objectives is considered separately in the main body of the text.)

In almost all cases feeding is associated with the desire to maintain artificially high densities of deer on open range in support of hunting interests. Winter feeding may be carried out simply to sustain animals at densities higher than those which would be supported by the carrying capacity of available natural forage. It may be carried out in order to substitute for lost winter range – lost through enclosure by fencing or because of habitat modification. It may be carried out to support, on wintering areas, concentrations of animals which have been prevented from undertaking traditional seasonal migrations between discrete winter and summer ranges (because of man-made barriers such as large-scale fencing, or motorway construction, or because of loss of dispersal corridors through habitat fragmentation or urbanization).

Winter feeding is also carried out where deer are on restricted range in hunting parks (e.g. Groot Bruinderink, Lammertsma & Hazebroek, 2000) or in deer parks (e.g. Putman & Langbein, 1990, 1992a,b; Langbein & Putman, 1992). Such feeding of wild or impounded animals may seem even more advisable if animals are artificially maintained at high densities on winter ranges where environmental conditions may be severe or extreme (e.g. Karns, 1980; Schmidt, 1992). By analogy, winter feeding is often advocated as a mechanism to reduce mortality in areas where populations are subject to high levels of overwinter mortality either on a regular or on an occasional basis.

In addition to its role in simple maintenance of high population densities of game, maintenance of body condition, or reduction of overwinter mortality, feeding may also be carried out in an attempt to offset environmental damage which might result from maintenance of high densities of animals in a localized area. While in many instances this may be explicitly designed in some diversionary way, in order to draw animals away from areas which it is desired to protect (forest plantings, regeneration areas, vulnerable agricultural crops, areas of high conservation value which would suffer from especially heavy impact of grazing or browsing), such feeding may also be used to reduce damaging impacts simply in the provision of part of the forage intake requirements of the animal population, thus reducing the extent of natural foraging required by wintering concentrations of deer in sensitive areas.

Further objectives of winter supplementation are targeted specifically at males or females within the population. Thus, feeding may be targeted deliberately towards enhancing body condition of females to maintain body weights and high reproductive performance (e.g. Kozak, Hudson & Renecker, 1994) as well as milk production of lactating females the following summer (Kozak *et al.*, 1995). Feeding of females (**hinds**) may also be used in an attempt to increase the numbers of breeding females held in a particular area (or on any one particular hunting estate), either to improve recruitment overall or to provide a focal population of resident females which will in due course attract males in the autumn rut and thus provide increased numbers of trophy males as quarry in the hunting season.

Winter feeding of males (**stags**) is also claimed to improve body condition and in particular to improve antler quality (and thus hunting value) (Raesfeld, 1920; Glaser, 1983; Gossow & Dieberger, 1989). Success of this may depend in part on actual foods provided, the quantities of feed provided in relation to actual daily nutritional requirements, and even-ness or inequality of apportionment of food between individuals (Wiersema, 1974; Linn, 1987; Schmidt, 1992; Seivwright, 1996), as well as the degree to which antler development is in practice limited by availability of food/minerals in the first place. Feeding is also widely practised in continental European countries to 'hold' stags onto particular estates or reviers for hunting and encourage range fidelity (as with hinds). The success of this practice in improving sporting opportunities will of course depend on the degree of synchrony between the period of winter feeding and the actual hunting season (restricted by law in Scotland to late summer and autumn).

FEEDING PRACTICE

Feed offered varies from place to place in type, quality and amount. In some instances animals are offered only hay, or hay supplemented with feeder blocks (e.g. Rumevite) aimed at increasing the digestibility of poor-quality forages. Other bulk feeds commonly provided included silage, root crops (turnips/swedes, carrots, potatoes, etc.) or maize. A variety of commercial pelleted rations are now available based on alfalfa, grass nuts, barley or other cereals, and some are specifically formulated for deer. Baker & Hobbs (1985) describe a ration specifically formulated for feeding to mule deer and white-tailed deer in winter feeding programmes.

Most feeding stations on hunting reviers in Germany, Austria and Hungary are located where little natural winter forage is available (Glaser, 1983; Sackl, 1992), so that here the objective is to provide the deer with nearly all their daily energy demands throughout winter and specific feeding tables are available for different feeding stuffs. However, feeding practice may differ from theory. A survey of deer that were given supplementary feed in deer parks within the UK (Langbein & Putman, 1992) concluded that amounts of winter food provided varied widely in the proportion of metabolizable energy requirements satisfied. Even if supplements were actually apportioned equally among all members of the herd, the actual nutritional value provided by average intake ranged from only 0.1% to 80% of individual maintenance requirements. The type of food provided varied widely from hay only, to hay plus silage, or root crops, corn, and concentrated compound feeds. While total quantities of wet weight of feed offered per deer seemed to be of a similar order in many of the parks, once the actual dry matter content and nutritional values were taken into account wide differences became apparent.

Some authorities suggest that hay alone (if of good quality) will support red deer throughout winter (e.g. Kimball & Wolfe, 1985; Wolfel, 1986; Kozak *et al.*, 1994); others do not recommend this (e.g. Putman & Langbein, 1990) or suggest that it should at least be sup-

ported by provision of mineral/urea blocks (such as Rumevite) to increase digestibility. In experimental trials, Kozak *et al.* (1994) found that wapiti hinds supplemented with hay lost more weight overwinter (December to March) than did those supplemented with alfalfa-barley pellets although differences were not statistically significant. Hinds not receiving any supplementation lost 16% of peak December weight by March; animals supplemented with hay lost 9% of peak December weight over the same period while animals supplemented with pellets lost 6% and showed little change in weight over the winter as a whole (November to April), even in a particularly severe winter.

Furthermore, it is suggested that while good-quality hay may on its own be sufficient to maintain body condition overwinter if provided *ad libitum*, hay alone will not prevent forest damage (Raesfeld, 1920; Ueckermann, 1986; Onderscheka, 1991). Likewise, supplementary feeding consisting exclusively of concentrates is not recommended, as it does not provide adequate fibre and may adversely affect water balance. Pfeiffer & Hartfiel (1984) suggest that stripping of bark by red deer in Austria was a response to a shortage of forage containing both fibre and high levels of digestible nutrients; many authors have noted that stripping of bark, particularly from coniferous species, is higher in areas where supplementary food is offered to (hunted) deer populations overwinter, where that supplement is primarily fed as grain, potatoes or other root crops and thus deficient in fibre (e.g. Ueckermann, 1984; Nahlik, 1995). Most continental European authors recommend feeding silage, turnips, beer draff or distiller's grains, apple draff or potatoes as juicy feed (Hofmann & Kirsten, 1982; Nerl, 1985; Furst, 1987), alongside good-quality hay fed *ad libitum* with enough that some will be left over at the next feeding. Water is also regarded by some authors as an absolute necessity at feeding stations especially if animals are maintained on hay alone or a diet mainly of concentrates (Wagenknecht, 1992; Wieselmann, 1994). However, Ueckermann (1986) and Raesfeld & Reulecke (1988) suggest that red deer rarely drink water during winter and snow as well as silage, containing approximately 80% water, should be sufficient to satisfy water requirements.

Most authorities stress that supplementary feeding should be commenced immediately after the rut, particularly if the aim is to retain stags on the rutting grounds and delay or prevent dispersal to disjunct wintering areas. Earlier provision of feed also enhances the opportunity for males in particular to regain condition after the rut, before the commencement of winter. Recorded intakes of supplementary feeds actually increase as ambient temperatures decline (Bubenik, 1984; Nerl, 1985; Onderscheka, 1986; Furst, 1987) so that the amount of food offered should gradually increase from October to April. This contrasts with natural declines in appetite and feed intake in winter which reflect endogenous periodicity in response to lower quality and quantity of natural forage (e.g. McEwen *et al.*, 1957; Mitchell, Staines & Welch, 1977; Kay, 1979; Kay & Staines, 1981).

All authorities also stress the importance of maintaining supplementation during late winter and spring. (In most Austrian provinces it is a legal requirement to continue feeding until April or May; J. M. Peek & K. T. Schmidt, unpublished). Putman & Langbein (1992a,b) also note that it is often at the end of winter when feeding is most required. In general, it is suggested that feeding should be gradually phased out as availability of spring growth increases, ending 1 month after the flush of natural vegetation in spring. Rapid switches to newly sprouting, lush, natural forages may cause diarrhoea and rumen dysfunction (Butzler, 1986; Onderscheka *et al.*, 1989).

Food at feeding stations is inevitably temporally and spatially concentrated. There is intense competition for access to food and feed distribution is typically uneven (Wiersema, 1974; Schmidt, 1992; and see below). Where the intention is to feed females as well as, or in

preference to males, male dominance will result in stags displacing hinds from feed and separate feeding stations for hinds and stags have been recommended (e.g. Raesfeld, 1920; Bubenik, 1984; Butzler, 1986). In addition, the concentration of high numbers of animals in a limited area may cause local damage to vegetation through trampling and poaching of the ground or increase incidental damage to forestry (e.g. Schmidt & Gossow, 1991; Nahlik, 1995). For all these reasons it is strongly recommended that feed is distributed at a number of locations rather than presented in one or a few sites. It is also suggested that each site should present many individual troughs and/or hay racks distributed over a large area, together with hay heaps on the ground and, if appropriate, creep-feeders, to ensure simultaneous access by all individuals (Raesfeld, 1920; Hofmann & Kirsten, 1982; Nerl, 1985; Raesfeld & Reulecke, 1988).

EFFECTIVENESS OF WINTER FEEDING PROGRAMMES

1. Effects on body condition and reproductive performance

Body weight

In multivariate analysis of factors affecting late winter body weights in park deer, Putman & Langbein (1992b) showed that supplementary feeding had a significant effect on body mass. In multiple regression analysis, weights of both stags and hinds showed a consistent negative relationship with levels of winter rain/snow and positive correlation with levels of feed supplementation. For yearling stags (the group of animals with least variance around mean cohort weight), differences between sites in winter precipitation and amount of energy supplied in supplementary winter feed together accounted for 54.7% of the variance in dressed carcase weight. (R^2 for levels of precipitation alone 44.8%; R^2 for precipitation plus supplementary feeding together 54.7%. This may be interpreted as suggesting that weights of yearling stags will fall significantly in wet winters, but that the degree of reduction can be compensated for by supplementary feeding.)

In experimental conditions, food-supplemented wapiti hinds also maintained body condition and body mass overwinter better than unsupplemented animals (Kozak *et al.*, 1994, 1995). Biweekly body weights were recorded for two groups of hinds and calves on native aspen parkland in Alberta: one group unsupplemented and the other supplemented with feed pellets containing alfalfa and barley. In a subsequent trial, body weights of an unsupplemented group of hinds on native pasture were compared against those of animals supplemented with pellets as above, or straight alfalfa hay. In all cases unsupplemented animals showed significant weight loss from peak weights in November or December, till March. Animals offered hay *ad libitum* lost some 9% of peak body weight, while in both trials, pelleted animals showed no significant weight loss over the experimental period as a whole (Kozak *et al.*, 1994). Similar results are reported by Oldemeyer, Robbins & Smith (1993), but note that such results are derived from studies where significant supplementation is provided. Where only a small amount of supplementary feed is provided, animals may regularly lose condition (see below).

Peek *et al.* (2002) summarize data from a number of continental European studies of the effects of feeding wild red deer. With an increase in supplementary winter feeding of some 50% from 1975 to 1981, carcase weights of (yearling) red hinds increased in one study by 9.8% (from 46.8 to 51.4 kg) and carcase weights of calves increased from 30.1 to 36.9 kg (Ennemoser, 1983). In other areas, carcase weights of yearling females remained relatively low despite intensive feeding programmes and showed no significant increase (Sackl, 1992); Groot Bruinderink *et al.* (2000) found no significant differences in body weight or fecundity of red deer in the Veluwe area of the Netherlands following cessation of winter supplementation.

In some resolution of these contradictory results Glaser (1983) suggests that effects of supplementary feeding on body weight depend on sex and age class, type of feed provided, and also whether feeding occurred at a feeding station on open range, or inside a winter enclosure in which deer were confined until spring. On open range, in Glaser's studies, average adult hind weight increased by 3.1% after 6 years of intensive feeding (from 54.3 to 56 kg) and that of female calves, by 6.9% (from 38.4 to 41 kg). Weight of supplementally fed stags in contrast showed significant decrease, with mean weights of adult stags falling from 68.7 to 55.9 kg and that of male calves from 43.9 to 41.5 kg. When confined on more restricted range within a wintering enclosure (a strategy adopted in some areas to reduce risk of damage to woodland by concentrations of wintering deer), both sexes of adults gained weight over the same 6-year period (stags: 4%, from 77.4 to 80.5 kg; hinds: 2.9%, from 50.6 to 52.1 kg); both male and female calves, however, showed a loss of weight and condition (Glaser, 1983).

Fecundity

Despite its effects in maintaining hind body weights, there is no evidence to suggest that even high levels of supplementation increase reproductive rates. Indeed such feeding may even be accompanied by a significant decline in fecundity because of its effects in maintaining populations at artificially high density, in turn resulting in an increase in resource limitation over the spring and summer months and a density-dependent reduction of reproductive rates. Smith (2001) reports a decline in summer recruitment rates in Grand Teton National Park (where half the wapiti from the National Elk Refuge in Jackson, Wyoming, spend the summer), since supplementary winter feeding began at the Jackson Refuge in 1990.

Bailey (quoted in Smith, 2001) further found no difference in foetal growth rates between wapiti given supplementary feed and free-ranging wapiti in the National Elk Refuge (Jackson, Wyoming) and at the rates and duration for which supplemental feeding occurs in this population, winter feeding did not produce calves with greater birth weights than those reported for animals which are not given supplementary feed (Smith, Robbins & Anderson, 1997). However, Kozak *et al.* (1995) have shown that food supplementation overwinter could also increase milk production of lactating hinds the following summer, thus calf growth rates may be improved. Calves in populations of wapiti that were given supplementary feed in the National Elk Refuge in Wyoming had higher winter survival rates than calves in populations which were not fed (Smith, 2001), possibly as a result of increased lactation of dams as well as direct access to the food supplement.

Antler weights

Winter feeding of stags, as noted above, is also often aimed at increasing antler size and quality. Many proprietary supplements contain specific mineral 'loads' aimed at improving antler growth. After 20 years of supplementary feeding in one area of Austria, between 1960 and 1980, Glaser (1983) and Gossow & Dieberger (1989) reported that the number of medal-winning trophies more than doubled. The weight of cast antlers increased more than 100% (Rossler, 1983). Antler weight also increased relative to body weight and may achieve 6.3% of live body weight (8.3% of carcass weight) at the beginning of the rut (Glaser, 1983). Groot Bruinderink *et al.* (2000), however, found no changes in antler morphology, growth rate or body weight of red stags even 10 years after cessation of winter feeding in the Netherlands. The effects of supplementation in this case must depend greatly on the period of supplementation, amounts fed and type (mineral content) of the ration, as well as the extent to which antler growth in a given population was, in the first place, actively restricted by a shortage of minerals in natural forage.

2. Effects on overwinter survival

The effectiveness of winter food supplementation in reducing mortalities, or more specifically reducing risk and frequency of major mortality events, is more controversial. While winter mortality of red deer calves has been shown to be highly density dependent (e.g. Clutton-Brock, Major & Guinness, 1985, Clutton-Brock *et al.*, 1987), once past this neonatal hurdle, levels of overwinter mortality of mature animals were found to be principally affected by late summer rainfall and temperature in early winter (November/December). Although adult mortality of both stags and hinds on Rum tended to rise as density increased (and thus individual body condition declined), this effect was not large. Of the annual variation in hind mortality 72% was explained by the amount of rainfall in late summer and the temperature in early winter (Albon & Clutton-Brock, 1988); these same two variables accounted for 49% of the variance in stag mortality between years.

The direct importance of climatic conditions in determining levels of overwinter mortality is clear; other analyses of the factors influencing levels of adult mortality among Scottish red deer elsewhere in the Highlands also identify winter weather conditions as the major factor (e.g. Watson, 1971; Albon, 1983) although the precise climatic variable (rainfall, temperature, days of snow) may differ in different regions (Clutton-Brock & Albon, 1989). In such analysis, the potential for supplementary feeding to reduce mortality may be presumed to be limited. Despite this, it is clear that the effects of winter weather conditions are to some extent interactive with poor body condition among the deer. Clutton-Brock *et al.* (1985, 1987) did note for their study population on Rum that mortality levels did rise as densities increased. Such interaction, with mortality controlled by density-independent factors, but exacerbated among populations already stressed by resource limitation, is further illustrated by Putman & Langbein's studies of winter mortality among red deer in deer parks. Their analyses showed that winter mortality among (park) red deer populations was significantly higher if autumn body weights were low (Putman & Langbein, 1992a,b).

In this case, supplementary feeding, *if offered early enough to improve body weights of animals going into the winter*, might indeed act to reduce mortality. This is clearly illustrated by the comparison of mortality levels over an 8-year period from 1981 to 1989 in two deer parks in London (Richmond and Bushy Parks) both containing mixed populations of red and fallow deer and situated within 5 km of each other so clearly subject to comparable climatic conditions (Table 1). Mortality levels were very high only in 1 year when late winter temperatures were particularly low – and only in Richmond Park where little or no supplementary feed was provided. Note, however, by comparison of mortality levels between years within that park, that even though there are other years leading up to the die-off in which little supplementary feeding was carried out, heavy mortalities were only sustained following this single severe winter. Animals in populations at high densities, fed a lower level of winter supplements, or entering winter with low body weights, may survive equally well in relatively mild winters and major mortality events even among such susceptible populations occur only sporadically (Putman & Langbein, 1992a). Such complex interaction between winter severity and critical thresholds of body condition may explain why other published data on the efficacy of supplementary feeding in reducing adult mortality overwinter appear somewhat inconclusive or even contradictory (Smith *et al.*, 1997).

It is also quite clear that to be effective in reducing mortality, any supplementation is required early in the season and not simply in response when heavy mortalities are already being experienced. If provision of supplementary foods is delayed until animals are perceived already to be in poor condition, such feeding may have little effect. It takes some time for rumen structure and microflora to adjust from coping with the high fibre natural forages of

Table 1. Mortality levels and associated characteristics in Richmond and Bushy Parks, between 1981 and 1989

Year	Bushy Park				Richmond Park			
	January/February temperature (°C)	Supplementary feed (MJ per stock unit)	Grazing pressure (stock units/ha)	Total mortality (% population)	Supplementary feed (MJ per stock unit)	Grazing pressure (stock units/ha)	Total mortality (% population)	
1981/2	4.6	5.4	2.6	1.5	0.1	2.6	1.7	
1982/3	4.9	5.2	2.7	0.2	0.1	2.7	1.3	
1983/4	4.7	6.4	2.2	0.5	0.2	2.4	1.8	
1984/5	2.4	6.7	2.1	1.6	0.1	2.6	1.0	
1985/6	2.0	5.9	2.4	0.5	0.1	2.8	11.3	
1986/7	3.0	5.7	2.5	0.8	5.4	2.2	3.9	
1987/8	5.8	6.2	2.2	0.6	1.9	2.2	1.0	
1988/9	6.3	7.5	1.8	1.4	3.9	2.1	0.5	

In interpretation of the table, remember that these two London parks are very similar in character; both have mixed populations of red and fallow deer at approximately the same densities and are subject to similar levels of public access. Because of their geographical proximity, they are also exposed to similar climate (from Putman & Langbein, 1992b; overall grazing pressure is calculated as 2 units = 1 red deer = 2 fallow deer).

winter, low in nutrient quality and digestibility, to the structure and microbial composition appropriate to digestion of artificial feedstuffs. Furthermore, the physiology of the use of bodily reserves of fat and protein is complex. Deer overwintering on such bodily reserves will first utilize the energy stored in fat deposits; only later will they start to use up body protein. Increased catabolism of protein materials in late winter as fat stores become exhausted results in impaired glycconeogenesis with hypoglycaemia and a resultant ketosis. The deer probably reach an irreversible stage of starvation some considerable time before death and supplementary feeding at this stage is unable to prevent death (Denholm, 1979). Experiences of deer starving to death with abundant supplementary food all around them are a well-documented characteristic of emergency operations that attempt to prevent deaths in wild deer populations where animals are found in malnourished condition in late winter and emphasize the importance of early, prophylactic feeding well *before* animals are observed to be in weakened condition (Giles & McKinney, 1968; Pearson, 1968; Denholm, 1979).

3. Effectiveness of supplementary winter feeding in protection of forestry and agriculture

One of the foremost goals of supplementary feeding in both Europe and the USA has become the prevention of environmental damage, particularly damage to commercial and native forests, while maintaining deer populations at huntable densities (Peek *et al.*, 2002). However, evidence for effectiveness in this regard is equivocal. Schmidt & Gossow (1991) for example note that, in Germany and Austria, there is no close correlation between food supplementation and reduction of forest damage, citing instances where supplementary feeding did indeed reduce damage to adjacent forestry interests, but others where significant levels of damage were recorded in areas of high supplementary feeding.

In an elegant analysis of the various different factors associated with browsing damage in a number of commercial forests in Hungary, Nahlik (1995) concluded that the single factor most significantly correlated with levels of damage by red deer was provision of supplementary food in winter – with highest damage levels recorded in those areas where regular winter feeding occurred. Aggregation of animals around feeding stations produced extremely high local densities resulting in a significant increase in forest damage.

Pheiffer & Hartfiel (1984) suggest that stripping of bark by red deer in Austria was a response to a shortage of forage containing both fibre and high levels of digestible nutrients. Many other authors have noted that stripping of bark, particularly from coniferous species, is increased in areas where supplementary food is offered to deer populations overwinter, where that supplement is fed as grain, potatoes or other root crops and so is deficient in fibre (e.g. Ueckermann, 1984). Prevention of agricultural and forest damage remains a major motivation for many supplementary feeding programmes in the USA (Musclow, 1984; Peek *et al.*, 2002), but few objective studies have been undertaken to assess effectiveness in either context.

Overall, the objective evidence available both for and against any effect of winter feeding on increasing body weights, reproductive performance, antler weight, or in helping to decrease problems of environmental damage resulting from high wintering densities of deer, is summarized in Table 2, where an attempt is also made to try and explain the circumstances of conflicting data.

PROBLEMS ASSOCIATED WITH SUPPLEMENTARY FEEDING

Whatever may be the effectiveness of winter feeding in achieving its main objectives, such feeding may also have significant disadvantages. Inevitably, however well-managed, such

Table 2. Evidence for effects of winter feeding in increasing or decreasing animal body weights, fecundity, antler weight of stags, overwinter survival and in reduction of environmental damage

Parameter	Measured effect	Source	Comments
Body weight			
Adult male	+	Putman & Langbein (1992b)	Enclosed
	+	Glaser (1983)	Enclosed
	-	Glaser (1983)	Open range
Adult female	+	Putman & Langbein (1992b)	Enclosed
	0	Kozak <i>et al.</i> (1994, 1995)	Experimental
	+	Ennemoser (1983)	Open range
	+	Glaser (1983)	Open range
	0	Sackl (1992)	Open range
	0	Oldemeyer <i>et al.</i> (1993)	Open range
Male calf	-	Glaser (1983)	Open range
Female calf	+	Ennemoser (1983)	Open range
	+	Glaser (1983)	Open range
	-	Glaser (1983)	Enclosed
Fecundity			
Adult female	0	Groot Bruinderink <i>et al.</i> (2000)	
	-	Smith (2001)	
Antler weight			
	+	Glaser (1983)	Effects seem to depend on timing and quantity of feed provided, and must also be influenced by degree of mineral limitation in normal diet
	+	Rossler (1983)	
	+	Gossow & Dieberger (1989)	
	0	Groot Bruinderink <i>et al.</i> (2000)	
Overwinter survival			
	0	Denholm (1979)	Effective only if feed levels are high and feeding is commenced early enough
	+	Putman & Langbein (1992a)	
	+/-	Smith <i>et al.</i> (1997)	
Achieves reduction in environmental damage			
	+	Ueckermann (1986)	
	+	Schmidt & Gossow (1991)	
	-	Pheiffer & Hartfiel (1984)	
	-	Schmidt & Gossow (1991)	
	-	Nahlik (1995)	

+, positive effect; -, negative effect; 0, nil effect demonstrated.

feeding results in high concentrations of animals around feeding stations. As a result of this there is often reported extensive (even if local) poaching of the ground (e.g. Doman & Rasmussen, 1944; also common experience); if feeding stations are located in areas of high conservation value, or areas otherwise particularly vulnerable, this may result in unacceptable local damage. It is clear, also, that despite its intended function in reducing damage to commercial forestry, the provision of supplementary feed may have quite the opposite effect. In many cases it is clear that levels of forest damage (browsing, bark-stripping) are increased in areas where winter feeding is provided (Schmidt & Gossow, 1991; Nahlik, 1995) due to its effects in concentrating animals in particular areas at artificially-elevated density. One partial solution to this latter problem may be to combine the artificial feeding of deer herds over winter with actual enclosure, temporarily confining the animals over winter into a more restricted area, with fences, to try and minimise damage outside that fenced area (Schmidt & Gossow, 1991; Peek *et al.*, 2002).

In addition to any such impacts on the local or more general environment, winter feeding may also have direct and damaging effects on the condition and welfare of the deer themselves, directly counter to its actual intentions.

One of the most apparent problems associated with the provision of regular supplementary feed over the winter period is that those animals that come to use the feeding stations may become 'lazy', developing an increasing reliance on the food supplement and reducing intake of natural forages to near zero (Doman & Rasmussen, 1944; Staines, 1969; Wiersema, 1974). This is a particular problem in areas where food is provided on a daily basis and not left in excess so that there is always food available. At such daily feed sites it is common experience that the deer begin to congregate just before the regular feed time, consume as much of the supplement as they are able, and then withdraw only a few metres to ruminate, waiting until the next feeding session. Little or no foraging on any remaining natural, fibrous vegetation may occur among these dependent individuals.

If the supplement offered is in the form of a concentrated ration, or otherwise low in fibre, this may lead to rumen dysfunction and may, as noted, lead to increased bark-stripping damage if feeding sites are adjacent to forest shelter-belts. More seriously still, if natural foraging is decreased in this way to near zero, then animals may lose rather than gain body weight and condition as the result of the supplementary food, unless feed is provided *ad libitum* and provides 100% of metabolisable energy and nutritional requirements. Although in continental European deer 'forests', feed supply may attempt to provide 100% of dietary needs, this is probably rarely achieved in practice and feeding in many areas, certainly in the UK, never approaches the levels required to provide for complete nutritional needs. In consequence, animals developing total reliance on artificial feeds may regularly lose, rather than gain condition – and it is common experience in Scottish hill conditions, where hinds may come to feed at stations maintained primarily for stags, that these feeding hinds and any calves that accompany them may suffer higher rather than lower overwinter mortality.

This situation is further exacerbated where feeding sites are in open or exposed areas. Animals attracted to the feed increase energy losses through standing about in exposed areas waiting for the small amount of feed they obtain. By coming in to feeding stations the animals are by definition not able to adopt the alternative strategy of conserving energy through lying up in shelter. However, the increased energy costs of coming in to feeding stations may not be offset by the small amount of energy gained from the additional food obtained.

This deterioration of condition, of hinds in particular is in some measure due to the fact that they may be excluded from free access to the food provided because of competition from mature stags. This may also be true for younger stags who may also be denied access to the feed. Many studies have been undertaken of dominance relationships at feeding stations and the intensification of competition which may result (e.g. Wiersema, 1974; Linn, 1986, 1987; Schmidt, 1992; Seivwright, 1996). It is clear from studies such as these that, where food is limited or presented over a limited area, mature stags dominate other feeders and individual intake of food is skewed.

Perhaps the clearest illustration of this comes from the studies of Wiersema (1974) studying the behaviour of deer at supplementary feed at the Glenfeshie Estate, Central Highlands. Results are of particular relevance and are thus worth considering here in some detail. Wiersema maintained continuous watches at three main feeding sites on the Estate, observing behaviours in different months from December to February. (Feeding, mostly in the form of commercial deer cobs, had been provided at these sites since October, at a rate of between 50 and 75 kg per day.) Wiersema noted that not all animals in a given area came to the feeding station. Based on wider counts of the immediately local population in each area, he estimated that at the most frequented stations (Larder and Middle stations, regarded as one site) the proportion of the local population coming to the feed was between 46% and 82% (with

numbers declining from the peak in December where 82% of animals came to the feeding station, to 46% in February). At the other station (Ponybridge) that was less frequented overall, proportions of the local population of animals attending the site were between 19% and 22%. A proportion of animals even in the immediate vicinity of feeding stations thus never benefit from the food provided at all.

More pertinently, a significant number of those animals considered regular attenders at the feeding stations were never observed to consume any of the feed. At the Larder and Middle sites, actual *feeders* comprised from 64% to 88% of the individuals regularly attending feed stations (with the highest proportion of non-feeders recorded in December); at Ponybridge, only 38% of animals attending the feeding station actually received food. Feeding animals were predominantly mature stags; most 'associated feeders', coming to the station but never observed to feed directly, were hinds, calves and yearling males (Wiersema, 1974). If regular attendance at feeding stations may indeed imply a reduced inclination to feed on natural forage available (Doman & Rasmussen, 1944), those attending but not feeding are inevitably compromised. Finally, even among those animals observed actually to obtain food at the feeding stations, intake rates showed a notably skewed distribution: using a threshold chewing time of 210 seconds (equivalent to a consumption of approximately 15 cobs), Wiersema showed that of 69–71 animals at each of the three sites, 29 stags, 41 stags and 45 stags (respectively 41%, 59%, 65% of feeders), actually ingested 15 cobs or more; so, clearly the intake by other deer fell short of this amount.

The importance of *early* feeding is also stressed by most European authors, where feeding commonly commences shortly after the rut and continues to April or even May. Problems are likely to result where feeding is irregular, is inconsistent or is for too short a period (starting too late or finishing too early). Additional problems also result if the practice of regular winter feeding is discontinued after a period of some years. The problems associated with 'crisis-management' and the offering of supplementary food only in emergencies have already been mentioned (see above and Denholm, 1979). Similar problems result where feeding is inconsistent; animals become accustomed to coming to a feeding station, become dependent on the artificial food offered (dispensing partially or completely with any effort at natural foraging) and then find food withdrawn or not maintained. In such cases, levels of forestry or other environmental damage may be extremely high, where high concentrations of animals have aggregated around feeding sites, but no food is provided.

Similar problems result when supplementary feeding as a practice is stopped altogether after a period of some years. If animals have become familiar with regular winter feeding, at traditional sites and are used to expecting feed overwinter, they will continue to attend the feeding stations even when food is no longer provided, may, again, not bother to forage widely on any remaining natural vegetation and may rapidly lose condition. High mortalities often attend the cessation of established patterns of winter feeding; it is notable that such mortalities are concentrated among older stags.

One final potential problem associated with the extremely high local densities resulting from concentration of animals around even successful feed stations is the potential for increased communication of parasites and diseases. One of the major reasons that free-ranging, wild deer appear to suffer fewer problems of disease than park or farmed populations is that they generally occur at much lower densities and contact rates are low (Putman, 1988). At feed stations, local densities may be extremely high and the potential for disease transmission increased. In the USA, Smith & Roffe (1994) reported that brucellosis, pasteurellosis and scabies were the three diseases closely associated with winter mortalities of wapiti on the Jackson Hole National Elk Refuge. Brucellosis is clearly the greatest

Table 3. The potential disadvantages associated with provision of supplementary winter feed

Risks associated with feeding	Source
Animals become dependent on feed supply only intended as a supplement	Doman & Rasmussen (1944); Wiersema (1974)
Feed is distributed unequal and results in strong competition	Wiersema (1974); Linn (1986, 1987); (1987); Schmidt (1992); Seivwright (1996)
Evidence of loss, rather than gain in condition	Doman & Rasmussen (1944); and others
Increased risk of disease/parasitic infection	Smith & Roffe (1994)
Increased local environmental damage around feed site	Doman & Rasmussen (1944); and others
Increased environmental damage in more general area	Schmidt & Gossow (1991); Nahlik (1995)
Cost-effectiveness	Peek <i>et al.</i> (2002)

problem because of the potential for onward transmission to domestic livestock. Significantly, brucellosis is limited as an important disease in North American wapiti to those animals regularly attending supplementary feed-grounds in north-western Wyoming. The incidence of brucellosis in mature female wapiti at Jackson Hole is approximately 50%. Pasteurellosis has been implicated in major mortalities in deer parks in the UK and is typically associated with high densities of animals in poor condition (Davidson, Putman & Goldspink, 1991).

A summary of the potential dangers attending the provision of winter feed is provided in Table 3.

COSTS AND COST-EFFECTIVENESS

From the data reviewed so far it is clear that under certain circumstances, winter feeding at high levels of provision can be effective in maintaining or improving body weights, improving antler quality in males, and may also be effective in reducing overwinter mortality. Such a conclusion is perhaps not surprising, as long as feed levels are sufficient: after all, deer are maintained at high density and on restricted range in zoos, farms or other private collections where nutritional requirements are supplied virtually entirely through artificial feeding. In effect, in such extremes, natural foraging is not 'supplemented', but entirely replaced by the rations provided.

However, it is apparent that there are quite considerable problems associated with the practice of winter feeding of animals on open range. In order to be effective it is necessary to provide substantial quantities of food (up to 100% of maintenance requirements, and with provision maintained *ad libitum*). It is clear that feeding must be maintained over a considerable period (from late October through until March or April), and that to overcome problems of competition and dominance at feeding stations, there should be clearly separated feeding sites for males and females, there should be numerous small feeding stations widely distributed over the entire area (as opposed to one or two major feeding sites) and that even at these small stations there should be some variation in the disposition of feed (with some in feeders, or troughs, some in small dumps on the ground, potentially some in creep-feeders for access by calves).

Thus, to be wholly effective, winter feeding is an expensive undertaking (and we would reiterate the problems associated with incomplete or inconsistent feeding; above). J.M. Peek & K.T. Schmidt (unpublished) estimate that on average, feeding costs are approximately 12 Austrian schillings per deer per day in Austria (equivalent to US\$1.2). In general, the feeding

period will extend for 150–200 days, depending on the area and the severity of winter. If some natural feeding is available, feeding costs (feed costs plus labour) are approximately 800 AS (US\$80) per deer per winter. In western Austria, where supplementary feeding may be maintained for 180 days each winter, costs are 2500 AS (US\$250) per deer, and in enclosures, where artificial feed provision is the only source of food, feeding costs may be very much higher. By comparison, a prime trophy stag sold to a trophy hunter may fetch approximately 100 000 AS (approximately US\$10 000) (F. Volk, in Peek *et al.*, 2002).

Cost-effectiveness of programmes of supplemental feeding for American wapiti are also presented by Peek *et al.* (2002). Smith & Robbins (1984) estimated the costs of feeding a pelleted ration to wapiti in the National Elk Refuge to be 23.4 cents per day; assuming a (short) feeding period from 1 December to 31 March, or 120 days, the cost per elk per year would be approximately US\$28.00 (at 1984 prices). The net economic value of a wapiti hunting trip was estimated at about the same time at *c.* US\$100 (Sorg & Nelson, 1986). In these terms the costs of supplemental feeding of one animal for 1 year are well below its economic value. But such calculations do not take account of the number of years for which an animal must be supplemented before it may be shot, the proportion of supplemented animals which actually are available to hunters – and the actual increase in basic survival rates achieved by providing winter supplements rather than just leaving the population unsupplemented.

THE SITUATION IN SCOTLAND

There have been rather few studies of the extent or effects of supplementary winter feeding in Scotland. Those that have been carried out have been largely academic rather than applied in nature and have tended to focus on social interactions, dominance relationships and rates of aggression at feed sites (Seivwright, 1996; Schmidt & Seivwright, 1997; but see also Wiersema, 1974). Earlier Annual Reports of the Red Deer Commission (now DCS) make mention of surveys of the extent of supplementary feed provision in Scotland carried out in 1969 and between 1977 and 1979. However, details are scant. A more recent analysis of supplementary feeding practice within Scotland was carried out by questionnaire survey in 1995 (Trenkel *et al.*, 1998).

In this case 358 returns were received from a postal questionnaire, with returns relatively evenly distributed between different geographical regions (Trenkel *et al.*, 1998). The proportion of landholdings surveyed that supplied supplementary feed overwinter ranged from some 17% in the Western Isles to about 50% in the central regions and the North. Only 3% of the holdings that did supply feed overwinter provided only hay/silage. Thirty-three per cent provided Rumevite/feed blocks with (7%) or without hay/silage (26%). Nine per cent of holdings supplied only root crops or pelleted feed; 6% provided root crops/pellets and forage crops (hay/silage). Seventeen per cent of holdings provided concentrated foods and feed blocks, and 29% provided hay/silage, feed blocks and concentrates/roots (Trenkel *et al.*, 1998).

In an attempt to assess the current status and distribution of supplementary winter feeding in Scotland, a questionnaire was prepared for circulation to individual estates and landholdings throughout Scotland (Putman & Staines, 2003). Landholdings within the 122 returns received ranged from 24 to 58 300 ha, with the actual area available to deer ranging between 24 and 47 773 ha. Censused deer numbers ranged between: stags: 4 and 1721; hinds: 95 and 2367; hinds plus calves: 358 and 3011; and average annual stag culls from zero to 270 stags per year. Land-use interests also showed considerable variation, with four returns coming from holdings managed with vegetation conservation as their primary

objective and four from areas managed by Forest Enterprise holdings, where policy in both cases is such that deer are reduced wherever possible to minimum presence and actively discouraged. Of the entire sample we determined 100 estates to have primarily sporting interests.

Of the 122 estates/landholdings responding to the questionnaire, 66 (84%) offered some form of supplementary feeding. Of the 56 (16%) holdings that did not offer winter feed, five estates had previously offered winter supplementation but had recently stopped; this number was balanced by those that had only commenced winter feeding in recent years. Of the 100 estates considered by us to be primarily sporting estates, 64 offered supplementary winter feeding while 36 did not do so.

Those who do not feed offered a number of reasons. As noted above, a number were estates or holdings managed primarily for conservation or for forestry, who did not seek to sustain high numbers of deer on the ground – who indeed sought to reduce deer populations rather than to encourage them. Others, smaller estates or those with low stocking rates, argued that numbers or densities of deer on their ground were not sufficient to require supplementary feeding; even some with quite high resident deer populations felt that their estate offered good natural forage and shelter so that supplementation was not necessary. A small number noted that provision of winter feeding produced artificial concentrations of animals in local areas which caused damage to vegetation on their own ground, or produced complaints of damage from neighbours; four specifically commented that such concentrations had in the past encouraged poachers to their ground.

Feeding practice

Of the 66 estates offering some supplementary food overwinter, 27 offered feed to stags only; the remaining 39 estates fed both stags and hinds. While this might be an artefact of small numbers of hinds coming to feed offered primarily for stags, this did not appear to be the case. Only four or five estates having mixed feeding had fewer than 30 hinds coming to the feed, and at the other extreme with numbers of hinds coming to the feed as high as 600. A few estates even maintained separate feeding stations for stags and hinds.

Of those estates offering some form of supplementary food overwinter, the majority (40) fed a mixture of feedstuffs. Twenty-six fed hay or silage plus other feedstuffs (roots, pellets and/or feeder blocks); 12 provided pellets and feeder blocks. Blocks, when fed, were commonly put out for sheep rather than necessarily specifically for deer. Feed was generally put out at more than one location. The number of feed stations used varied between one and 10, with an average number of four locations on each estate.

It appeared possible that the feed types offered might relate to the size of an estate/holding with larger holdings more easily able to provide hay/silage from their own resources, and smaller estates perhaps needing to rely more heavily on concentrated rations. The average size of holdings which included hay or silage within feeds offered to the deer was 16498 ha while the average for holdings where hay/silage were not part of the ration was 7250 ha. Differences, however, were not statistically significant ($F = 6.5$; d.f. = 1, $P = 0.17$).

Feeding of cobs or pellets was also not related to holding size. The average size of holdings feeding only pellets was 8087 ha (against a holding average overall of 7805 ha) while the average size of holdings which included pellets within the ration (either alone or in combination) was not significantly different from those that did not ($F = 2.0$, d.f. = 1, $P = 0.17$). Similarly use of feed blocks as part of the ration showed no relationship with holding size ($F = 0.18$ d.f. = 1 $P = 0.68$) while estates providing only blocks had an average area of 8994 ha, again not significantly different from the overall average for all holdings surveyed.

Timing of feed provision

Most estates commenced feeding in late October or November and continued to March or April. A small but significant number of estates did not commence feeding till late winter (January or February), thus feeding in direct response to immediate need.

Reasons for feeding

Respondents were offered a series of potential reasons for offering supplementary winter feed and asked to indicate which reasons applied to their own decision to offer such supplementation. Including those responses where owners/managers offered a combination of reasons for feeding, we may summarize (out of 66 respondents) the number identifying each reason as at least one of their objectives as:

Necessary to sustain high densities of deer overwinter	16
Helps improve condition and fecundity of hinds	27
Helps improve condition and antler quality of stags	39
Helps reduce dispersal of stags	36
Helps hold stags in vicinity of Lodge, or in certain areas for stalking	3
Diversionsary feeding	29

(to move deer away from areas sensitive to heavy browsing impact such as forestry blocks, areas set aside for natural regeneration, or areas of high nature conservation interest).

Effectiveness of supplementary feeding

Fifty-eight of 66 respondents offering winter feed considered that feeding was effective in achieving their declared objectives; none felt that feeding was not effective and only eight did not volunteer an opinion or were uncertain. Only 43 respondents, however, felt that feeding was cost-effective (cf. above, a total of 58 who considered it effective overall). Four felt that it was definitely not cost-effective and a further 19 felt uncertain.

CONCLUSIONS AND IMPLICATIONS FOR WINTER FEEDING PRACTICE IN SCOTLAND

In practice, even when high levels of supplementary feed are provided (approaching 80% of maintenance or more), evidence from continental studies is, to say the least, 'equivocal' about any effects of feeding on body weights of stags, with marginal improvements reported at best, sometimes zero benefit or even weight loss. There is likewise little or no evidence to suggest that even high levels of feeding have any real effect on hind body weight or fecundity; there is indeed some evidence that it has a counterproductive effect particularly on younger animals (calves/yearlings). There is perhaps some circumstantial evidence that high levels of feeding over an extended period (October to March/April) may improve overwinter survival, and that feeding of mineral-loaded rations may contribute to an increase in antler quality in stags on otherwise mineral-deficient ground.

We should note, however, that these are the effects (or non-effects) of feeding at extremely high levels; if even feeding at these high levels achieves relatively little benefit, then feeding at the levels more usually offered within UK will be unlikely to achieve significant improvement at least in terms of body weight, antler quality or fecundity. Furthermore, such is the skew in feed intake, where only limited feed is provided, that any benefits achieved are likely to be evident only within a very small proportion of the population as a whole.

We also know from studies in UK and elsewhere that it is when only limited feed is provided that the various potential disadvantageous effects become most exaggerated. Competition between individuals for what food is provided means that some individuals commandeer most

of the feed and others get little or none; when combined with the behavioural dependence that becomes associated with the 'handout' (and the resultant reduction in natural foraging) this may result in a significant proportion of animals losing rather than gaining in condition. It is also evident from various continental studies that it is precisely under these same conditions, when animals become accustomed to receiving artificial feed (and thus tend to congregate in significant numbers in a relatively small area) but where the amounts of feed provided are insufficient, that significant problems may result in terms of increased damage to timber crops and the natural heritage.

Winter feeding in general is thus a management measure to be approached with caution. However, our review has suggested a number of specific situations in which some such supplementation might be considered.

Body weights and condition

If the main aim of winter feeding is to increase body weights, reproductive success or antler growth, there is currently little evidence to suggest that traditional forms of supplementary feeding are likely to be either effective or cost-effective, and it would appear likely that the potential disadvantages greatly outweigh any perceptible advantage. We note, however, that while provision of additional *food* is in itself unlikely to have any positive effect on body weights, fecundity or general condition, the feeding of urea blocks may have some utility.

Because they can be widely distributed (and easily distributed at some distance from roads/permanent trackways required to support tractor delivery of bulk feeds), they suffer few if any of the disadvantages of feeding at regular feed sites. Thus:

1. wide distribution among natural forage means animals are not concentrated at artificial feeding sites, so minimizing any risk of local poaching of ground, or concentrations of animals leading to unacceptable impacts on conservation vegetation, agriculture, native woodlands, etc.;
2. likewise, wide distribution and persistent nature of blocks means there is unlikely to be a problem with inequitable division among 'feeders', or competitive displacement of some animals from feed; and
3. because they can be widely distributed and do not in themselves constitute a direct food source, they will not cause problems of animals 'hanging about feed sites' waiting for a specific and time-limited distribution of artificial rations and in consequence not bothering to eat what natural forage remains available.

However, at the same time their mode of action is to enhance the digestibility of what natural forage is available overwinter, increasing the nutritional value derived from it and as such they may indeed have some benefit in maintaining higher condition.

Antler growth and quality

While, as before, we remain convinced that at the population level, supplementary feeding at levels currently provided in Scotland has little or no effect on body weights, fecundity, antler weights and quality, it is certainly true that antler development in wild stags is restricted by nutritional plane (and particularly mineral availability). In the Scottish Highlands, the majority of red deer populations live on peaty and minerally deficient soils and various lines of evidence make it abundantly clear that antler development of stags is genuinely restricted by mineral availability.

This restriction, particularly through lack of available phosphorus (Mitchell *et al.*, 1977) or calcium, is abundantly obvious in many sites, where stags gnaw on cast antlers to retrieve the minerals they contain. Furthermore, there are many anecdotal reports (summarized in Lowe,

1961) of dramatic improvements in antler growth of Scottish hill stags translocated to areas of better feeding – such as to deer parks or farms. Clearly the genetic potential for larger antlers was always there; it simply was not realized on the open hill because of restricted resources.

In this case again, while it is unlikely that a general, low, supplementation of food intake will have any demonstrable effect on antler growth and development, specific feeding of mineral-loaded rations, or preferably, mineral blocks, might indeed have some effects. While mineral-enriched feeds would occasion the same problems attending artificial feeding in general (and would in any case, because of the pronounced skew in intake of such supplementary rations, benefit relatively few individuals), provision of mineral blocks, as with the wide distribution of urea blocks above, could be accomplished without all the associated disadvantages usually associated with actual feed supplementation, because blocks are small, portable and can be distributed over a very wide area.

Overwinter survival

There is some evidence to suggest that (adequate) feeding over a prolonged period overwinter (October to March/April) may help reduce winter mortality; this, in order to be effective, should be at levels approaching 80% of maintenance, and must also be provided for a much longer period than is the norm at present in this country. It is clear that the benefits of such feeding will be restricted to certain years only – due to the dominating effects of climatic factors on observed mortality rates in any year, and the clear interactions between winter weather and general body condition; however, continuing high levels of supplementation may help to enhance survival in bad years. Further work is clearly required, and such regular feeding at such levels is likely to be extremely expensive.

Feeding as a diversionary tactic

There is some anecdotal evidence that supplementary feeding at feed stations in non-sensitive areas may be effective in keeping winter pressure off more vulnerable areas, or may even be used (if the feed site is gradually moved over a period of some years) to draw wintering concentrations of stags from some traditional wintering ground where they are causing damage, to another site where the vegetation is less sensitive. There are as yet few formal data on which to base an objective judgement on the potential of this as a management measure, but it does carry with it the risk of creating a subsequent dependency on the rations provided, and introducing to another site all the potential problems associated with regular supplementary feeding.

Further work is perhaps required on all these four areas, but it seems likely that, with these possible exceptions, supplementary feeding in general is of little benefit to open range populations of wild red deer in the UK. This is not, however, to suggest that those currently providing winter supplementation should immediately cease to do so. Older animals within the populations, having become accustomed over the years to the provision of food overwinter, will still tend to congregate in former feeding areas awaiting the usual supplement traditionally provided for them. If no feed is provided, extensive local damage may be experienced to natural vegetation and adjacent timber. In addition, experience has shown that where animals have been accustomed to some winter supplementation and this is summarily withdrawn, it has resulted in major mortality among 'habitual' feeders. The cessation of supplementation should thus be performed gradually, and is best achieved by beginning to spread the feed provided over a number of sites, rather than concentrating it within a few

major feeding stations, and thereafter gradually reducing the amount of food provided over a period of some years.

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