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DAMAGE BY DEER TO AGRICULTURE AND FORESTRY

Report to Deer Commission for Scotland

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Executive Summary

SECTION A: DEER DAMAGE TO AGRICULTURE

BACKGROUND

- A brief review of the interactions between deer and agriculture revealed that historically the “red deer problem” was mainly caused by deer marauding agricultural ground. Since the formation of the RDC in 1959 this problem has been viewed as less serious than the threat of deer to forestry and the need to reduce the population size on deer forest ground.

- The DCS has the necessary powers and duties to carry out action to protect enclosed agricultural ground as defined in the Deer (Scotland) Act 1996.

REVIEW OF CURRENT INFORMATION

- The only systematically collected data available to us on the extent of deer damage to agriculture is the number of out-of-season shooting Authorisations held on the DCS database. Additional information was collected by a postal questionnaire to the secretaries of each Deer Management Group and phone conversations with staff from the DCS and the National Farmers Union.

- It seems likely, from the literature, that damage by deer to agricultural fields will be confined to fields immediately adjacent to woodland or other suitable cover. Further more, most damage will be on the boundary edges of fields close to woodland. Within fields damage tends to be patchy and within a distinct ‘zone’ of utilisation.

- No Scottish study has researched the direct effect of deer damage on agricultural crops.

- The timing of damage dictates if serious economic loss will ensue. Winter and spring grazing of cereals may actually lead to greater tillering and potentially greater yield. Grazing damage just prior to harvesting may have economic consequences but damage by animals trampling and flattening cereals may be less than perceived due to modern harvesting machines.

- Winter damage to root crops can have serious economic consequences. Most studies have concluded that damage to crops by roe deer is not economically significant. Although not measured, deer grazing of early spring grass could cause reduced milk production for dairy farmers.

- In Scotland marauding red deer come down off open hill ground in winter and spring to raid crops, but can be shot legally by agricultural owners and occupiers.

- Woodland within or adjacent to farmland is also an important habitat for deer, using it for cover and to lie up during the day.

- Use of farm crops is seasonal in Scotland with fields of cereals, grasslands and oilseed rape important in spring, peas and beet in summer and root crops important in autumn and winter. Stubble fields are important in autumn and winter but use of these fields may depend on the type of crop recently harvested.

- Cereals have been shown to be an important component of roe deer diet in Scottish farmland. Despite little research on the diet of other deer species in agricultural land in Scotland evidence from other countries suggests that grasses would form a large proportion of the diet. These grasses might well include species found in improved grassland.

- The use of damage categories changed during the lifetime of the Out-of-season Shooting Authorisation database making a proper analysis difficult and we are unable to present annual trends on a regional basis.

COSTS OF PROTECTION AND DAMAGE

- In the ADAS questionnaire of farmers from lowland England culling was perceived to be the most effective form of damage prevention. In the same questionnaire the costs of protection for farm holdings was less than £500 in most cases.

- Most farmers in lowland England attributed a cost of less than £500 per annum to deer damage.

- Estimated costs of damage by rabbits and Greylag geese are currently much greater than those for deer.

CONCLUSIONS

- A closer monitoring of the “agricultural cull” could be useful for estimating the “size” of the “agricultural problem” as authorisations *per se* do not give an adequate estimate of the problem.

- Farmers` perceptions on cost of damage could be collected by a questionnaire. In some areas this may also help increase farmers awareness about the DCS and its role.

- The European policies of removing farmland from production and replacing them with woodland is bound to lead to an increase in deer on farmland and could potentially lead to greater damage.

SECTION B: DEER DAMAGE TO FORESTRY

- Despite seemingly making up little of the annual diet of deer a high proportion of young conifers are eaten during winter and spring with one study suggesting increased use in summer as well.

- So far as we know tree bark has never been found in any of the dietary studies of red and sika deer in this country, and the study of Jackson (1977) is the only instance we found where bark was found in the diet of fallow. This suggests that bark-stripping is an insignificant element of deer diet, yet it is without doubt the main concern of foresters.

EFFECTS OF BROWSING

- Different tree species have varying susceptibility and periods of vulnerability to leader browsing. Most browsed Sitka spruce are smaller than 80 cm despite deer species being able to reach much higher.

- The effect of browsing on leading shoots is generally believed to be more serious than on side shoots. Crops may have their growth checked, become deformed by multiple stemming or structural defects to timber may occur.

- Growth of trees is checked by browsing and the length of time a species is checked depends partly on trees species.

- The more times trees are browsed in early life the greater the chance that these trees will become permanently multiple stemmed.

- Multiple stemmed trees have similar survival but poorer growth compared with single stemmed trees. Although many multiple stemmed trees ultimately become single stemmed as weaker trunks die, many still remain deformed at harvesting.

EFFECTS OF BARK STRIPPING

- Tree species have different vulnerability to bark stripping, with Norway spruce and Lodgepole pine particularly vulnerable. Wound size also varies between species with Norway spruce receiving both more and larger wounds than Sitka spruce.

- Wounds are generally restricted to the bottom 1.5 m of stems. Once a tree has been damaged it is likely to be damaged again thus reducing the overall impact of bark stripping.

- At Glenbranter most wounds on Sitka spruce are small and heal within 8 years, and only 1% of Sitka showed signs of rot on wounds compared with 11% for Norway spruce.

- Loss of growth following bark stripping may happen in some species. In many species damaged trees have similar survival to undamaged tree but Lodgepole pine are particularly prone to stem breakage at the point of wounding.

- Norway spruce is particularly vulnerable to development of stain and rot following bark stripping. Most research on Sitka spruce suggests it does not suffer severe stain and decay

- From an initial estimate that 27% of Sitka spruce trees at Glenbranter would be bark stripped by the time of harvesting, this figure was reduced to only 14 % of the best trees, as mainly it is the small less valuable trees that are damaged. A stand value at the time of felling estimated site losses of between 9-11% in value. Because only large wounds have a potential economic impact at the time of harvesting, down grading estimates based on rejection rates of sawn timber and timber strength tests meant the actual financial loss would be only 2-3% of stand value.

EFFECTS OF FRAYING

- Fraying damage is generally regarded to be economically less serious than the other forms of deer damage.

COSTS OF PROTECTION AND DAMAGE

- In 1991-92 the cost of employing forest rangers was £2.03 million while venison returns brought in £1.26 million in that year. Rangers do not spend all their time on deer control and if 60% of their time was spent on this task the cost would have been £1.22 million.

- Current costs of fencing are between £4-10 per metre depending on terrain and type of fencing. The costs of other methods such as chemical repellents and individual protection are even more cost prohibitive.

- For trees planted since 1978 in Glenbranter we estimate using current figures that the losses due to deer damage will range from 7.8% to 17.3% for yield class 12 Sitka spruce the most common yield class in the forest. (Yield class being an estimate of stem volume per ha per year).

- More data are required on the economic costs of damage both for more tree species and from a wider selection of forests.

CURRENT ISSUES

- Current issues identified include deer fencing, regeneration of semi-natural woodland and increased planting of farm woodlands.

SECTION A: DEER DAMAGE TO AGRICULTURE

1. A brief review of the interactions between deer, agriculture and The Red Deer Commission up to 1996.

The background and main factors that led to the formation of the Red Deer Commission have been reviewed in more detail by Callander & MacKenzie (1991). In this section we restrict ourselves to reviewing interactions with agriculture and will deal with forestry in Part B of this report.

As far back as 1872 a Government Inquiry noted that in Scotland damage to the crops of farmers and crofters by red deer was incurring economic costs, generally in the construction of deer fences. Following on from that, various inquiries into "The Red Deer Problem" took place as and when the intensity of debate increased. For example, The Killing Deer (Scotland) Order, 1917, gave agricultural occupiers the right to kill deer damaging their grazings or crops.

The 1954 Report of the Committee on Close Seasons for Deer in Scotland and its Minority Report led to several years of negotiations and the creation of the RDC as part of the Deer (Scotland) Act 1959. In the 1959 Act the RDC was given overall responsibility for the *conservation* and *control* of wild red deer. There were some amendments made to the Act between 1959 and 1996. Following the Deer (Amendment) Scotland Act 1982 the powers of the RDC were extended to include sika deer and other species and amongst other things introduced night shooting.

The very first RDC Annual Report reviewed the then current situation and highlighted that the urgent need for increased livestock production during two world wars had led to a large increase in stocks of sheep and cattle in the Highlands, and in particular in the deer forest areas. This increase in sheep numbers was maintained following World War 2. At the same time the sporting value of deer did not keep pace with costs and landlords tended increasingly to supplement income by use of suitable deer forest grazings for livestock (RDC, 1961).

For the purposes of *control* the Commission was given limited emergency powers to deal with marauding deer and more fundamental powers to deal with resident stocks of deer whether "colonised" or on recognised deer forest. The criterion for any such action was damage caused to agriculture or forestry. Marauding deer are animals which come down off the hills and raid crops, pasture or woodland and the action of the Commission in this situation was reactive, acting on a complaint and instigating remedial action. The biggest issue seen by the Commission was in dealing with colonised deer. However, the conflicting interests of agriculture, forestry and deer forests made this a difficult task, but the Commission identified that the problem of colonised deer had to be considered in direct relation to the deer forests from where they had spread. One major cause was over-stocking and the Commission took the view that numbers needed to be kept at manageable levels on recognised deer ground. "When an operation has to be performed to remove a growth, it is bad practice not to deal with the root of the trouble at the same time" (RDC, 1961).

Thus the Commission promoted the increase in the red deer cull in the belief that this long-term strategy would reduce the overall deer population and the damage done to agriculture and forestry.

No overall assessment of the losses caused by red deer to agriculture was made by either the Department of Agriculture and Fisheries for Scotland (DAFS) or the RDC in the following 30 year period (Callender & MacKenzie, 1991). Furthermore there was no adequate indicator of the level of damage. Thus while at times the RDC reported increased and more intense individual complaints from farmers and crofters it did not view the number of complaints as a full reflection of the problem (Callender & MacKenzie, 1991). A possible reason for this is that complaints, and therefore out-of-season authorisations, are very localised. In a six year period 50% of agricultural authorisations came from just two RDC counting blocks (Callender & MacKenzie, 1991).

The annual red deer cull includes a part termed the “protection cull” and this was estimated to be about a quarter of the total cull (RDC, 1989). Most of the protection cull is carried out under the automatic right of owners and occupiers, or their authorised nominees, to shoot wild red deer at any time of year on enclosed land to prevent damage. Much of this protection cull is the “forestry cull”, which was increasing steadily in the period 1976 – 1989. In that period the “agricultural cull” by farmers and crofters, although it fluctuated from year to year, was only higher than the forestry cull in one year (Callender & MacKenzie, 1991).

Callander and MacKenzie (1991) point out that the price of venison rose in the 1970s and farmers and crofters may have been less inclined to complain, as deer were possibly shot as “compensation” for the damage they caused. These authors also suggest that a slump in venison prices could lead to increased complaints but not necessarily change the level of damage.

With regard to the agricultural sector, the RDC mainly carried out its statutory duties of authorising out of season shooting, and since 1982, night shooting. On occasion the RDC was involved in the setting up of voluntary control schemes and culling regimes following increased complaints from farmers of damage (RDC, 1983, 1992, 1993, 1995).

A Consultation Paper on deer legislation in Scotland (SOAFD, 1992) stated there was a growing recognition that wild deer were not only a threat to forestry and agriculture but were also damaging to the natural heritage. Deer grazing was preventing the regeneration of native Scots pine (*Pinus sylvestris*) and other semi-natural woodland, and also altering the composition of mountain vegetation. There were also concerns that the welfare of deer may be adversely affected where populations were above the carrying capacity of that habitat.

It was felt that since the 1959 Act there had also been significant changes in both land use and policy objectives. Increased forestry planting had reduced ‘traditional’ red deer range and provided alternative habitat for deer. Food surpluses in the agricultural sector had led to reduced government support to encourage production by farmers and crofters (SOAFD, 1992). All these issues needed to be addressed and the 1959 Act required updating to reflect these changes.

The Deer Commission for Scotland was created in the Deer (Scotland) Act 1996 with wider functions, duties and powers.

2. Relevant duties and powers of the DCS with respect to Agriculture

In the 1996 Act the **duties** of the DCS are to further the *conservation*, *control* and *sustainable management* of all deer species in Scotland and to keep under review all matters, including *welfare*, relating to deer. In exercising these functions the DCS has to take into account the size and density of the deer population and its impact on the natural heritage, the needs of agriculture and forestry and the interests of owners and occupiers of land.

The **powers** of the DCS are fairly similar to those of its predecessor:

Control Agreement
The DCS may draw up a control agreement where it is **satisfied** that, on any land, deer **have caused**, **are causing**, **or are likely to cause damage** to **agricultural production**, and that for the **prevention of further damage** the deer in that locality should be reduced in number.

Agricultural damage includes any crops or foodstuffs, injury to livestock, whether by serious overgrazing of pastures, competition with any such livestock for supplementary feeding, or otherwise.

Control Scheme
Where the DCS is **satisfied** that it is not possible to secure a control agreement or that a control agreement is not being carried out, and deer **have caused and are causing serious damage to agricultural production**, **whether directly or indirectly**, it shall initiate a scheme to carry out such measures as it considers necessary to **prevent such serious damage**.

Emergency Measures
Where the DCS is **satisfied** deer **are causing serious damage to agricultural production** and **none of the other powers** of the DCS **are adequate** to deal with the situation, and that killing of deer is necessary to **prevent further damage** it shall identify the land those deer come from and request that the person having the rights to shoot deer on that land complies with the terms of the request.

Night Shooting
The DCS **may authorise** an occupier of agricultural land **where it is satisfied** the taking or killing is necessary **to prevent serious damage** to crops, pasture or animal foodstuffs.

Rights of occupiers
Occupiers **may out of season**, **on agricultural land**, kill deer **to prevent serious damage** to crops, pasture or human or animal foodstuffs.

3. Review of current information

For the purposes of this review we have restricted ourselves to agriculture on enclosed land.

3.1 Relevant data sets

Scottish data

The RDC and DCS have been authorising out-of-season shooting on red deer since 1959 and since 1983 for sika and roe deer. This probably represents the best long-term information on agricultural damage by deer and is the only major Scottish data set. However, because agricultural occupiers can legally shoot deer damaging their crops on enclosed land without having to obtain authorisation from DCS, this data by no means quantifies the actual scale of agricultural damage but should be seen as an indicator of the problem.

For further information on agricultural damage we sent a small questionnaire (Appendix 1) to the secretary of each of the Deer Management Groups (DMGs`) (obtained from the DCS database). As time was short and we could not be certain that groups would be meeting between early January and mid-February we asked the secretary of each group to reply, based on their experience and knowledge from management group meetings. We also contacted the Policy Section of the National Farmers Union (NFU) by phone to get an indication of Scottish farming opinion.

Other relevant data

A search of the literature found 3 relevant data sets for England and Wales. Between 1985 and 1989 requests for assistance or advice received by the MAFF Wildlife and Storage Biology Section of the Agriculture Development and Advisory Service (ADAS) were entered into a national database. Entries on the COSTER database (**Co**mputerised **S**ummary of **Te**chnical **R**eports) recorded the reason for enquiry, and in the case of reported damage caused by any species of wildlife information was also recorded on the type of damage, crop type and the species believed responsible by the enquirer. Only 1% of enquiries related to deer damage (Putman & Moore, 1998). This project was discontinued in 1989.

The second data set is from the Wildlife and Conservation Research Branch of the Forestry Authority (FA), who between 1992 and 1994 undertook a national postal questionnaire survey to assess the extent of damage occurring in agriculture and forestry due specifically to Fallow deer. Some of the results are reported in Mayle (1994).

As part of a MAFF initiative on lowland deer populations, in 1995 ADAS undertook a postal questionnaire survey of four land user sectors with an interest in deer: agriculture, forestry, conservation and sporting/recreation. The survey covered four regions of lowland England: Suffolk/Essex, Glocestershire/Somerset, Northamptonshire and parts of Yorkshire. The questionnaire included details of economic consequences of damage caused by deer and the costs and types of damage prevention measures taken (Packer et al., 1998). The response rate from the agricultural sector was 46%, a high return compared with the expected response of 20-30%, which indicated that many farmers were aware of deer in the agricultural landscape and took an interest in the issues involved. A follow-up study was carried out to assess the significance of damage on winter wheat, the crop being chosen because of its national economic importance, its well understood physiology and the results of the questionnaire survey (Doney & Packer, 1998).

These data sets probably represent the best available for England and Wales although other data may exist of which we are not aware.

3.2 Types of damage

Damage to farmland takes several forms including grazing, flattening by rolling, lying and trampling of crops, damage to fences or hedges and damage to trees. Doney & Packer (1998) report that 69% of farmers reporting deer present on their land also reported that deer caused damage. The most commonly perceived type of damage in their survey was grazing (34% of farm holdings) followed by damage to trees (24%), flattening of crops (23%) and damage to fences (11%). Mayle (1994) found that grazing damage by fallow deer accounted for 65% of returns, with and flattening of crops (21%) was also seen as important.

3.3 Selectivity in damage

In Scotland, red, roe and sika deer account for most requests to the DCS for out-of-season shooting Authorisations. In discussion with DCS Deer Officers and Liason Officers pasture, silage fields root crops and potatoes were cited as crops that were damaged, although none felt that there was a serious problem in their area.

We sent questionnaires to 52 DMG secretaries and by the time of writing had received 46 responses, of which 36 replied “yes” to damage occurring on farmland in their area. Of the 6 respondents recording “no” damage 4 reported no farmland within their area. Four respondents did not know if damage to farmland occurred. As most DMG areas are in the Highlands and islands where most of the red deer population is our data is clearly biased geographically, but the results are valuable none the less.

Table 3.1 Deer species perceived as causing agricultural damage as a percentage of respondents that answered yes to having damage present (n=36).

	Red	*Roe*	*Sika*	*Fallow*
%	97	36	9	3
n	(35)	(13)	(3)	(1)

Our DMG questionnaire found that agricultural damage was primarily associated with red deer, 97% of respondents with damage reporting them, either as the only species or in combination with other species (Table 3.1). Of the other species roe were the next most reported as causing damage but always in combination with another species, usually red deer.

Table 3.2 The proportion of crop types reported as being damaged.

	Cereals	*Grass*	*Root crops*	*Vegetables*
%	17	89	40	3
n	(6)	(32)	(14)	(1)

Most damage was to grassland followed by root crops and cereals with just one report of damage to vegetables (Table 3.2). Grassland also included silage fields. The highest proportion of grasslands and farmland is found in Highland region (Appendix 3) where many DMG areas occur. The region with the largest proportion of cereals, oilseed rape and other crops is Northeast Scotland which also has the second largest area of farmland.

Other data

Putman and Moore (1998) found that most agricultural damage in England and Wales was due to fallow, red and roe deer and most reports of damage were to pasture or cereals, with oilseed rape, nursery and orchard crops also frequently damaged. However, because of differences in ecology and distribution, different deer species were implicated in different types of damage, in relation to geographical patterns of crop type. Thus damage caused by red deer was primarily associated with loss of yield of pasture and silage grassland in southwest England, an area which is largely non-arable and has the highest proportion of grass cover of all the MAFF regions and the largest concentration of red deer. Fallow deer were mostly associated with damage to arable agriculture, 65% of complaints relating to cereal damage, the majority of which were in east England, which has the highest fallow concentrations and is the largest cereal growing region (Putman & Moore, 1998)

Similar results were found by Doney & Packer (1998), with cereals perceived to be the most damaged crop followed by trees, grass, root crops, fruit, vegetables and oilseed rape. Roe deer were the most commonly reported species seen followed by fallow, muntjac and red deer (Packer et al., 1998). But 58% of farmers with fallow present on their land thought they were causing damage compared with 56% for red, 54% for roe and 34% for muntjac. Mayle (1994) also reported that damage to grass and cereal crops were the main cause of concern to farmers in her survey, which was restricted only to damage done by fallow deer.

3.4 Occurrence and significance of damage

In its most recent annual reports the DCS suggests that deer damage on agricultural land in Scotland, as perceived through the number of Authorisations for out-of-season shooting, is falling (DCS, 1998, 1999). This perception is the opposite of what is believed to be happening in the rest of Britain. In a recent review on the impact of deer in lowland England and Wales, it was noted that there was a perception by farmers that damage levels in agriculture were rising, although there were no quantifiable data on the scale of impact (Putman & Moore, 1998).

Some research on roe deer in farmland has been done in Scotland, but there is little or no equivalent research on the impact of red and sika deer on agricultural crops. This is certainly somewhat surprising for red deer, because as previously stated their raiding of crops was part of the original “deer problem”. It could also suggest that research groups and the RDC/DCS have never viewed it as a serious problem compared with damage to forestry.

Other British and European studies tend to have concentrated on damage by roe deer in agricultural land, and only a few studies have been done on other deer species. In Britain, studies tend to be localised geographically, most research on sika and fallow deer having been done in Hampshire, whereas most research on roe deer has been done in the northeast and east of Scotland.

Occurrence of damage
Damage to crops is generally very variable with certain fields remaining undamaged even though neighbouring fields under the same crops are heavily used (Calder, 1994; Putman, 1986). Similarly, damage is patchy within fields (Calder, 1994; Putman, 1986). However a relationship between distance from cover, usually woodland, and damage intensity has been observed by several studies (Obrtel & Holisova, 1983; Obrtel et al., 1984; Calder, 1994; Muri & Stammbach-Geering, 1995; Kjostvedt et al., 1998).

In northeast Scotland, Calder (1994) recorded 20% damage to winter barley immediately adjacent to woodland but less than 1% at 50 m away, and no detectable damage one field away from cover. Obrtel & Holisova (1983) found that damage to maize was concentrated within a 12 m zone at the edge of their study field. Similarly, damage to sugar beet was concentrated within a 20 m strip away from continuous tree and shrub cover (Obrtel et al., 1984).

These observations are backed up by studies of habitat use on farmland by deer. Boag et al (1990) in east Scotland observed most roe deer within 75 m of woodland during winter. Idris (1990), working in northeast Scotland using both visual observations and radio-tracking, showed that fields adjacent to woodland were the most heavily used by roe deer and use of fields four or more away from woodland was never recorded. In a Polish study, use of farmland was confined within a distance of 500 m from woodland cover, most deer being seen between 100 – 200 m from the forest edge (Aulak & Babinska-Werka, 1990).

- It seems likely, from the literature, that damage by deer to agricultural fields will be confined to fields immediately adjacent to woodland or other suitable cover. Further more, most damage will be on the boundary edges of fields close to woodland. Within fields damage tends to be patchy and within a distinct ‘zone’ of utilisation.

With no data available on the effects of deer damage on crops in Scotland we rely on studies from other parts of Britain, Europe and North America to gauge the overall significance of damage.

Significance of damage
The significance of damage to crops is thought to be partly dependent on the timing of damage. Winter-sown wheat and barley fields in Hampshire had up to 30% of the crop grazed back by roe deer in spring but recovered by harvest time with no significant loss in yield (Putman 1986). However, there appears to be no other British study to have investigated this, despite its obvious importance for potential economic

loss. In Devon, Salter (1972) saw groups of up to 28 roe deer in his field of winter oats in spring but despite this the harvested crop was the best he had ever grown. Winter and spring grazing by deer may actually help cereal crops by promoting tillering and so increase yields (Marshall, 1970; Salter, 1972).

Pronghorn (*Antilocapra americana*) grazing on winter wheat in Colorado did not reduce grain yields and damage was confined to green shoots in winter and spring (Torbit et al., 1993). An assessment of roe deer damage to maize in Czechoslovakia showed that overall loss of ears affected at most only 0.15% of the total crop. But damage was restricted to a 12 m zone at the edge of the field where 5% of plants were damaged and direct damage to maize ears affected 0.7% - 1.7% of plants (Obrtel & Holisova, 1983).

Damage caused to ripening cereal crops by deer crushing stems in bedding sites or by rolling or trampling is probably not as serious as perceived because modern harvesting machinery cut quite close to the ground and can recover the majority of such bent stems (Putman & Moore 1998).

Some root crops such as turnips and swedes remain in fields during winter and damage at that time of year can allow frosting, causing them to rot (Salter, 1972). Generally, only the tops of carrots, swedes and turnips are eaten by deer (Coles, 1997; Salter, 1972), and usually just a few bites occur on a single plant, but many plants can be damaged. Deer damage to sugar beet leaves was concentrated in a 20 m broad strip at the edge of fields close to cover and affected at most 10% of plants and loss of leaf area did not exceed 2% (Obrtel et al., 1984). This loss was considered to be negligible in view of the regenerative ability of sugar beet plants.

One of the most frequent crops noted as damaged by deer in our questionnaire, and in the COSTER, ADAS and FA databases, was pasture and silage grasslands, yet these are the most difficult to quantify, and there are no published studies on the economic significance of such damage. Grazing of early spring grass by deer is believed to be of potential economic significance. Dairy farmers rely on the ‘early bite’ to increase milk yield following the winter months. It is believed that the increase in milk production due to this ‘early bite’ is as much as 20% per day (Marshall, 1970). Thus the losses to a farmer could be quite substantial if deer were competing for, or removing, the new growth of grass.

- No Scottish study has researched the direct effect of deer damage on agricultural crops.

- The timing of damage dictates if serious economic loss will ensue. Winter and spring grazing of cereals may actually lead to greater tillering and potentially greater yield. Grazing damage just prior to harvesting may have economic consequences but damage by animals trampling and flattening cereals may be less than perceived due to modern harvesting machines.

- Winter damage to root crops can have serious economic consequences. Most studies have concluded that damage to crops by roe deer is not economically significant. Although not measured, deer grazing of early spring grass could cause reduced milk production for dairy farmers.

3.5 Ecology of deer on farmland

At the start of the 20th century woodland cover was only 3% but with the formation of the Forestry Commission in 1921 there began a major increase in afforestation. In more recent times Government initiatives such as the Woodland Grant Scheme, the Farm Woodland Scheme and the Farm Woodland Premium Scheme have encouraged the development of woodland on previously cultivated land (The importance of these schemes with regard to deer will be discussed in Part B of this report). Thus there has been a large increase in woodland in the last 100 years and currently woodland accounts for about 10% of land cover.

In our DMG questionnaire we asked if deer causing damage to farmland came from surrounding deer forest and commercial forestry or lived permanently in farmland. We have split the data into two groups, the first is for situations where red deer only are cited as causing damage and the second where more than one species was recorded as causing damage.

The data are somewhat confounded because of the proportions of different land types available within a DMG and in an earlier question we asked for a simple ranking of the three land types available within the DMG area, with 1 indicating the greatest area (Appendix 1). We show the mean rank for each land type present. While not ideal it does give an index of occurrence of land types.

When deer forest was present the likelihood was that red deer would raid agricultural ground, but in every DMG area with deer forest present it was the major land type (Table 3.3). Farmland was the next most common land type and we had 1 response suggesting red deer were resident on farmland. Forestry was less common than farmland but just over half the responses suggested red deer raided crops from this land type.

Table 3.3 Percentage of respondents indicating that only red deer raided agricultural crops from deer forest and forestry or were resident in farmland, based on the presence of that land use type within their area. By definition farmland must be present.

	Deer Forest	*Farmland*	*Forestry*
%	85	6	53
n	(19)	(20)	(19)
rank	1.0	2.4	2.5

Of 14 responses where more than 1 deer species was reported to damage crops, 10 of these respondents reported damage by both red and roe deer. Deer forest, when present, was not always the primary land type, but a similar proportion of respondents as in table 3 perceived that deer (presumably red) raided crops from this land type. The major difference was in the proportion of respondents who thought that deer causing damage were resident on farmland, which had a higher ranking than in table

3.3. In every response with deer resident on farmland roe were one of the species causing damage and we infer from this that roe deer were resident in farmland in some areas. The percentage of animals raiding from forestry also increased, possibly because more forestry occurs in these DMG areas.

Table 3.4 Percentage of respondents indicating that more than 1 deer species raided agricultural crops from deer forest and forestry or were resident in farmland, based on the presence of that land use type within their area.

	Deer Forest	*Farmland*	*Forestry*
%	83	64	85
n	(12)	(14)	(13)
rank	1.4	2.1	2.2

3.5.1 Habitat use on farmland

Woodland

Most damage to crops tends to be restricted to fields nearest to woodland or scrub areas which provide shelter, and many studies have found that deer spend much of their time within these wooded areas (see Section 3.4). In Scotland, radio telemetry studies of roe deer showed that woodland was highly preferred during the day (Idris, 1990; Reynolds & Tapper, 1991). Use of agricultural land peaked during dawn and dusk, but woodlands were still preferred by most deer at night, although use of crop fields was greater than during the day (Idris 1990). The same author found that in his study area of small fragmented farm woodland all woods of less than 8 ha had signs of roe deer occupancy.

Red deer stags in Exmoor National Park spent much of their time in woodland and used improved pastures during the night (Langbein, 1997). Hinds in this study tended to prefer upland heath during the day but also selected pasture during the night. In their study of red deer in lowland Hungary, Szemethy et al. (1998) found that of 31 radio tagged animals only 2 stags and 8 hinds used agricultural land, moving from a large forested area in spring and most not returning until autumn. During this time animals made much use of maize and cereal fields. These authors note that red deer had colonised new habitats in the last 40 years following intensive agriculture, increased field sizes and forest plantation.

Fallow deer made extensive all year round use of closed woodland in agricultural areas in Hampshire and Northamptonshire (Thirgood, 1995; Staines et al., 1998) and made extensive nocturnal use of open habitats (Thirgood, 1995). Chapman & Chapman (1975) also found that fallow needed cover and shelter but such woods need not be large, 5 ha being sufficient if they had plenty of undergrowth and were interspersed with agricultural land.

In the DCS study at Scaniport on sika deer, animals spent much of their time during the day inside woodland cover (Colin McLean, pers comm). Similarly at Purbeck forest in Dorset sika deer had a pronounced diurnal cycle of activity throughout the year, using thicket conifer forest by day and foraging in adjacent heathland and agricultural fields at night (Mann & Putman, 1989a).

Many other European studies cite woodland and scrub as important to deer utilising farmland (Strandgaard, 1972; Maublanc, 1986; Cibien et al., 1995; Marchal et al., 1998).

Agricultural crops

Use of winter cereal fields in northeast Scotland by roe deer peaked in autumn and winter and declined in spring and summer (Idris, 1990). Other studies have also found increased use of cereal fields by roe deer in winter (Zejda & Homolka, 1980; Boag et al., 1990; Cibien et al., 1995; Marchal et al., 1998). Reduced use of cereal crops during summer was also found by Putman (1986) and Marchal et al. (1998), although damage to cereals in Hampshire was restricted to spring (Putman 1986).

Roe deer use of other crop fields such as peas (summer), kale (autumn), fodder roots (winter), turnips (autumn & winter) and sugar beet (summer & autumn) are strongly related with the time period they were available (Strandgaard, 1972; Putman, 1986; Idris, 1990; Cibien et al., 1995; Marchal et al., 1998). Roe deer also eat beets when they are put out as fodder (Strandgaard, 1972; Holisova et al., 1986). However, Idris (1990) never saw roe deer in potato fields, even when they were next to woodland cover. However, the leaves of potatoes are known to be poisonous. Oilseed rape fields were most used in spring (Idris, 1990; Reynolds & Tapper, 1991), and grass fields were rarely used, except in spring (Strandgaard, 1972; Putman, 1986; Idris, 1990). Strandgaard (1972) saw many roe deer in grass fields when they were immediately adjacent to woodland in one year, but the following year when these fields were planted with wheat and grass fields were further away he saw very few roe deer in fields of grass.

Stubble fields were highly preferred by roe deer in autumn and winter in Northeast Scotland (Idris, 1990), but were not a preferred habitat in East Scotland (Boag et al., 1990). In both studies fallow and ploughed fields were little used. In France Cibien et al. (1995) found stubble and ploughed fields (cereal and sugar beet) were important in autumn and winter. Ploughed cereal fields in autumn and ploughed sugar beet fields in winter were of major importance to roe deer in Czechoslovakia (Zejda & Homolka, 1980; Holisova et al., 1986). Shallow ploughing of cereal fields causes scattered grains to germinate and the young sprouting plants become sought after, and post-harvest remains of sugar-beet roots abound after ploughing and are present throughout winter.

In our questionnaire data red deer were often reported as causing damage in grass fields and less so on root crops. Red deer in Exmoor also used improved pasture and cultivated land, which comprised 45% of the study area (Langbein, 1997). However, Langbein (1997) states that such areas were underused relative to their area. Probably this is because red deer spent much time in cover. Fallow deer showed little seasonal variation in patterns of habitat use at various sites in Hampshire, and although they made extensive use of grassland and arable fields during spring and summer overall these habitats were underused in comparison with their availability (Thirgood, 1995). Sika deer in Dorset also made use of improved pasture throughout the year (Mann & Putman 1989a).

- In Scotland marauding red deer come down off open hill ground in winter and spring to raid crops, but can be shot legally by agricultural owners and occupiers.

- Woodland within or adjacent to farmland is also an important habitat for deer, using it for cover and to lie up during the day.

- Use of farm crops is seasonal with fields of cereals, grasslands and oilseed rape important in spring, peas and beet in spring and root crops important in autumn and winter. Stubble fields in Scotland are important in autumn and winter but use of these fields may depend on the type of crop recently harvested.

The use of farmland fields by deer should also be reflected in their diet, which we describe in the following section.

3.5.2 Diet

Clearly as deer make use of crop fields in the Scottish agricultural landscape, their dietary requirements are of paramount importance and may well control what and when damage to cultivated plants occurs. However, the use of certain fields does not necessarily mean that crops are being eaten, as agricultural weeds may also form an important part of the diet.

The Scottish studies on roe deer in farmland found that cereals are an important component of the diet in winter and spring when plants are young and green (Boag et al., 1990; Calder, 1994). These findings are similar to those found elsewhere in Europe (Holisova et al., 1982; 1984; 1986; Kaluzinski, 1982; Maublanc, 1986; Putman, 1986; Cibien et al., 1995). However substantial use of cereal grains by roe deer in summer has also been reported (Holisova et al., 1984).

In Denmark rye formed a small part of the winter diet of red deer, and cereals (mainly grains of oats, wheat and rye) constituted 12% of the summer diet and 5% of the annual diet (Jensen, 1968). Only one British study has found any evidence of cereals in the diet of fallow deer (Caldwell et al, 1983).

Most diet studies failed to find commercial grasses such as perennial rye grass (*Lolium perene*), and only one study from Poland (Kaluzinski, 1982) reported finding clover (*Trifolium spp*), both of which are indicative of improved pasture. Probably this failure to find individual grass species is because they can be difficult to identify, and in many studies get lumped into larger groupings. However, in Scotland most of the forage obtainable from permanent grass swards, and much of that from sown swards, is produced by species of bents *Agrostis spp*, *Holcus spp*, meadow grasses *Poa spp*, red fescue *Festuca rubra*, and many other indigenous grasses (Hubbard, 1984).

In his study in Northeast Scotland Calder (1994) found that wild species of grass accounted for 7% of roe deer diet in both winters of his study, and 28% of the summer diet. However, it is impossible to say whether these grasses came from pastures or not. The winter diet of roe deer in East Scotland contained only 2% grass (Boag et al., 1990). Grasses were most important in spring, but formed only 3% of the annual diet of roe deer in Poland (Kaluzinski, 1982), and similarly grasses were only a small part of roe deer diets in Czechoslovakia (Holisova et al., 1982, 1984, 1986).

Grasses comprise much of the diet of red (Mitchell et al., 1977) and fallow deer (Caldwell et al., 1983; Putman et al., 1993). The diet of red deer stags and hinds in Exmoor comprised a large proportion of grasses reflecting use of improved pastures (Langbein, 1997). The autumn and winter diet of fallow deer inhabiting farmland and small woods in Essex contained 80% grass (Caldwell et al., 1983). In Denmark, red deer with access to agricultural land ate very little of the agricultural forage grasses, the diet being dominated by wavy hair grass (*Deschampsia flexuosa*) a species characteristic of woodland clearings and open moorland.

Kale has been shown to induce goitre and kale poisoning in domestic ruminants but was rarely reported in wild deer. In Scotland there has been a marked decrease in the area of kale grown but the planting of oilseed rape (*Brassica napus*) has dramatically increased in the last 20 years. In Europe, Onderscheka et al. (1987) and Seifert & Robbelen (1988) reported oilseed rape poisoning to roe deer caused by double low varieties of oilseed rape. In Scotland it took a diet of 60% oilseed rape for roe deer to display signs of poisoning in experimental feeding trials, but red deer seemed unaffected (Sibbald et al, 1995). Oilseed rape contributed 16% of the annual diet of Polish roe deer Kaluzinski (1982), being most important in the winter.

Root crops, fruit and vegetables made up only a small number of complaints in both the COSTER and ADAS data sets (Putman & Moore, 1998; Packer et al., 1998) but their importance in deer diet seems much more variable. Thus in France peas and other vegetables accounted for 33% of the summer diet of roe deer (Cibien et al., 1995), but in other studies contribute little. Sugar beet was an important part of the winter diet of roe deer in the studies of Holisova et al. (1984; 1986) and Cibien et al., (1995). Small quantities of turnips, swedes, cabbage, carrots and potatoes were found in the diet of Danish red deer (Jensen, 1968).

Of all the deer species in Scotland, roe deer are the most widespread and are clearly resident on agricultural land. A recent review comparing the diets of roe deer in woodland and farmland concluded that the variation in food intake of this species was mainly explained by the habitat in which they live (Cornelis et al., 1999). Thus roe deer seem well able to adapt to a diet of cultivated plants. Red, sika and fallow deer generally have very high proportions of grasses in their diets, even in more agricultural situations, and generally there is little evidence from the few published studies that agricultural crops constitute a major part of their diets.

- Cereals have been shown to be an important component of roe deer diet in Scottish farmland.

- Despite little research on the diet of other deer species in agricultural land in Scotland evidence from other countries suggests that grasses would form a large proportion of the diet. These grasses might well include species found in improved grassland.

4. Analysis of the DCS Authorisations database

Detailed quantitative data on the incidence and severity of damage on agricultural land in Scotland are lacking, but within certain limits the pattern of out-of-season Authorisations issued under the terms of the Deer (Scotland) Act 1996 may be used as an index of the incidence of problems with deer, but not the severity of damage. This section presents an analysis of the DCS Authorisations database as at 16th February 2000 (3100 records –total numbers in tables are less than this owing to missing data). Regional breakdowns of the number of Authorisations by damage categories, sections of the Act and deer species are presented, together with the distribution of deer species by damage category and section of the Act. Annual trends are highlighted where appropriate.

4.1 Methods

Regional analyses other than of deer species are straightforward percentages within each category for each region and over all of Scotland. Regions are based on Scottish local authority boundaries, but in the east, central lowlands and south, these were grouped into four regions: Northeast (Moray, Aberdeenshire and City, Angus), East (Perth & Kinross, Stirling, Clackmannanshire, Fife), South (all Ayrshire, Dumfries & Galloway, South Lanarkshire and Scottish Borders) and Central Belt (all remaining authorities between Inverclyde and East Lothian).

Analyses of deer species show the percentage occurrence of each deer species on Authorisations within each region or category, and as more than one species can be cited on an Authorisation, the species may sum to more than 100%.

In accordance with DCS Annual Reports, we have defined the year as commencing 1st April. It must be remembered when interpreting the findings, that the years 1996/97 and 1999/2000 are incomplete (from October 1996 and up to February 2000 respectively), and in particular annual trends in numbers of Authorisations should be regarded with caution.

Preliminary analyses indicated that there appeared to have been a change in the application of damage categories during the lifetime of the database. ‘Agric/Wood’ was not assigned after 1996/97, and ‘Wood/Agric’ appeared from 1997/98 onwards. ‘Agricultural’ appeared in all years except the incomplete 1999/2000. We have combined these three categories under the single heading ‘Agricultural’. However, the picture regarding damage categories may still be distorted, as ‘Wood/Agric’ increased from 42% of all Authorisations in 1998/99 to 89% in 1999/2000, and ‘Woodland’ decreased from 32% to 3% respectively.

4.2 Regional distributions of Authorisations by damage category and section of the Act

Authorisations for the Central Belt (32) and for the Western Isles (14) were too few to permit meaningful analyses, especially on an annual basis; percentages are shown in tables, but not generally discussed.

The overall dominance of ‘Agriculture’ and ‘Woodland’ (57% and 38%) in Authorisations was reflected throughout all the regions (Table 4.1). Only Highland, with 66% ‘Agriculture’, and the South, with 60% ‘Woodland’ differed substantially from the countrywide figures. ‘Natural Heritage’ approached 10% in the East and Northeast, but was otherwise poorly represented, and ‘Public Safety’ Authorisations were negligible in all regions.

Table 4.1 Percentage distribution of Authorisations across damage categories by region, October 1996 – February 2000

	Agriculture	*Natural Heritage*	*Public Safety*	*Woodland*	*n*
Argyll & Bute	54	3		44	325
Central Belt	50			50	32
East	57	9	<1	33	460
Highland	66	4	<1	30	1280
Northeast	51	8	1	41	343
South	40			60	492
Western Isles	71	14	7	7	14
ALL	57	4	<1	38	2946

On the basis of the definitions adopted here (but see the caveat above), ‘Agriculture’ Authorisations have increased dramatically from 30% in 1996/97 to 89% in 1999/2000, accompanied by a decrease for ‘Woodland’ from 69% to just 3%. As it is not clear to what extent this represents changes in assignment of the categories or a real increase in the incidence of deer problems on agricultural land, annual trends on a regional basis would be inappropriate.

Table 4.2 Percentage distribution of Authorisations across sections of the Deer (Scotland) Act 1996 by region, October 1996 – February 2000

	5(6)	*10(2)*	*10(4)*	*18(2)*	*19(2)*	*26(2)*	*n*
Argyll & Bute	4			39		57	325
Central Belt				25		75	32
East	14		2	28		57	458
Highland	6	<1	<1	44		50	1276
Northeast	15			41		44	343
South	1			32		68	492
Western Isles	21			29	7	43	14
ALL	7	<1	<1	38	<1	54	2940

5(6) - unenclosed woodlands, natural heritage and deer in public places

10(2) - emergency powers: deer killed on land by person with right to kill

10(4) - emergency powers: deer followed and killed on land where the person with right to kill is unable or unwilling to kill.

18(2) - night shooting

19(2) – use of vehicle for taking deer

26(2) - daylight shooting on agricultural crops and enclosed woodlands

The national proportions of 38% of Authorisations issued under section 18(2) of the Act and 54% under section 26(2) varied very little across the regions (Table 4.2), indicating that night shooting is of roughly the same importance in all areas. Likewise, these figures differed very little between years, with Authorisations under section 18(2) varying annually between 35 and 42%, and under section 26(2) between 51 and 58% on a national basis,

4.3 Occurrence of deer species on Authorisations

Red deer appeared on 79% of all Authorisations, roe on 34% and sika on 22% (Table 4.3), but there was considerable geographical variation. Authorisations including red deer were considerably lower in the South and the Northeast than in the East, Highland and Argyll & Bute, which largely reflects the known range of the species, in which Deer Management Groups are well established. Red deer accounted for all but one of Authorisations in the Western Isles, but were relatively infrequent in the Central Belt. The national and regional percentages differed little between years, with no obvious trends.

The distribution of roe deer Authorisations was complementary to that of red deer, with the highest incidences in the South and Northeast. Whether this reflects possible competition between the two species, or different habitat preferences, with roe more abundant in the agricultural land of the South and Northeast is open to question. However, in contrast to red deer, roe deer Authorisations increased from 13% in 1997/98 to 65% in 1999/2000, and this increase occurred in all five principal regions. Roe deer were clearly the most important species in the Central Belt.

Authorisations for sika deer were highest in Argyll & Bute and lowest in the Northeast. As for roe deer, there was a sharp increase from 4% in 1997/98 to 50% in 1999/2000, and this occurred in all principal regions except the Northeast.

Fallow deer Authorisations clearly reflect their very limited distributions in Scotland, although there were increases, particularly in the South and East (to 12 and 20% respectively in 1999/2000).

Table 4.3 Percentage occurrence of deer species in Authorisations by region, October 1996 – February 2000

	Red	*Roe*	*Sika*	*Fallow*	*Unknown*	*n*
Argyll & Bute	94	30	42	0	2	325
Central Belt	22	78	6	3	0	32
East	85	31	16	9	2	460
Highland	89	26	22	0	4	1280
Northeast	61	51	4	0	3	343
South	54	46	31	3	3	493
Western Isles	93	7	0	0	0	14
ALL	79	34	22	2	3	2947

All three principal deer species appeared more frequently on Authorisations issued to cover damage to 'Agriculture' than to 'Woodland', but the difference was substantially more for roe and sika deer than for red deer (Table 4.4). Red deer also differed from the other two species in occurring on all but 6% of Authorisations issued to cover damage to 'Natural Heritage'. Although the occurrence of roe and sika deer increased under all categories during the four years, the increase was most marked for both species under 'Agriculture', with roe deer reaching 68% occurrence by 1999/2000, and sika deer 52%.

Table 4.4 Percentage occurrence of deer species in Authorisations by damage category, October 1996 – February 2000

	Red	*Roe*	*Sika*	*Fallow*	*Unknown*	*n*
Agriculture	81	47	33	3	2	1682
Natural Heritage	94	21	21	2	0	126
Public Safety	100	13	25	0	0	8
Woodland	74	16	7	0	5	1131
ALL	79	34	22	2	3	2947

Over the whole period, the occurrence of red, roe and sika deer was similar for the two most frequent sections of the Act (Table 4.5), although red deer were somewhat higher for Authorisations under section 26(2) than under section 18(2). The pattern for red deer varied little over the four years, but in 1999/2000, roe deer were cited on 66% and 70% of Authorisations under sections 18(2) and 26(2) respectively, and likewise sika deer on 49% and 54%. Thus by 1999/2000, roe deer were approaching the same frequency on Authorisations as red deer. Authorisations under section 5(6) were dominated overall by red deer, but roe and sika were increasing under this section too, albeit not as rapidly as under sections18(2) and 26(2).

Table 4.5 Percentage occurrence of deer species in Authorisations by section of the Deer (Scotland) Act 1996, October 1996 – February 2000 (see Table 4.2 for description of sections)

	Red	*Roe*	*Sika*	*Fallow*	*Unknown*	*n*
5(6)	93	20	19	3	0	210
10(2)	100	0	0	0	0	2
10(4)	100	0	0	0	0	8
18(2)	72	37	22	2	3	1125
19(2)	100	0	0	0	0	1
26(2)	82	34	23	2	3	1594
ALL	79	34	22	2	3	2940

- The use of damage categories changed during the lifetime of the Out-of-season Shooting Authorisation database making a proper analysis difficult and we are unable to present annual trends on a regional basis.

5. Costs of protection and damage

5.1 Protection

In our questionnaire we asked if agricultural damage was a serious problem (Appendix 1) and gave respondents a choice of 5 statements to describe the efficacy of the cull in their area, in no response was damage a major problem. Several respondents commented that quite frequently the boundary between agricultural ground and deer forest was fenced which reduced problems and others also commented on the right of agricultural owner/occupiers to shoot deer also reducing the problem.

In the ADAS questionnaire study, farmers were asked the type of damage prevention measures undertaken and its associated costs. These are the only data from Britain of which we are aware that gives the farmers' perception of how successful they believe prevention methods to be. Only 29% of agricultural respondents who had deer present on their land took any measures to prevent deer from causing damage (Packer et al., 1998). The most effective protection as perceived by farmers was regular culling or culling in response to damage. Fencing, electric fencing and occasional culling were believed to be less effective and repellents and scarers the least effective (Packer et al., 1998).

The costs of damage prevention increased with the size of the agricultural holding (Packer et al., 1998); over half (55%) the holdings of less than 500 ha in size (n=356) had no cost in prevention methods and over 90% of holdings had costs of £500 or less per annum. No cost included those who took measures at no cost and those who took no measures. On holdings larger than 500 ha (n=28) 39% incurred no cost and 82% of holdings had costs of £500 or less. Only three holdings had estimated costs of more than £5000, one being less than 500 ha in size.

Mayle (1994) did not distinguish between protection methods against fallow used by foresters and farmers, but did report one instance where woodland rides were mowed during August to improve grazing available on them, and thus draw deer away from neighbouring fields. However, the respondent did not say how successful this had been.

- In the ADAS questionnaire of farmers from lowland England culling was perceived to be the most effective form of damage prevention. In the same questionnaire the costs of protection for farm holdings was less than £500 in most cases.

5.2 Economic costs of damage

As regards agricultural damage by deer in Scotland the one group from whom we do not have an opinion is farmers. The NFU in Scotland believes that deer damage is not a general problem, although localised damage may occur (Craig Campbell, NFU Policy Section, pers comm). Because there is no national estimate of deer damage in Scotland clearly there is no estimate on the cost of that damage. Only the ADAS questionnaire data have estimates on the cost of damage, both for all farm holdings and for holdings whose main activity was growing cereal crops. These costs are based on farmers` perceptions rather than direct measures. Because ADAS undertook a follow up study on damage to cereal crops there are also some estimates as to how accurate they believed farmers perceptions to be.

As with cost of protection perceived losses generally increased with holding size but 86% of farm holdings had either no loss to deer damage or losses less than £500 per annum (Packer et al., 1998).

For farms growing mainly cereal crops 17% claimed no annual cost of deer damage and a total of 85% claimed the annual cost to be £500 or less for the whole farm (Doney & Packer, 1998). There was little agreement between the perceptions of damage from the questionnaire and the ADAS damage assessments with 40% of farmers reporting a higher level of economic damage than was found in the ADAS assessment and 53% reporting a lower cost of damage (Packer et al, 1998). Farmers over- estimated the cost of damage when they perceived high levels of damage and conversely under-estimated when they perceived low levels of damage.

To try and put deer damage into some sort of perspective, we make comparisons with national estimates of damage costs for other wildlife pests, such as rabbits (*Oryctolagus cuniculus*) and geese. In Britain rabbits are seen as one of the major wildlife pests and the cost of damage nationally was estimated at over £100 million annually (Mills, 1986). In lowland England losses of winter wheat are about 1% per rabbit per hectare at densities of up to 40 per ha. This represents a loss of 65 kg of grain per rabbit or £7.50 per rabbit. Yield loss of grass is about 0.5% per rabbit per ha at densities of up to 15 rabbits per ha and is estimated to cost £2.00 per rabbit (McKillop et al., 1997).

Spring grazing by greylag geese (*Anser anser*) in Northeast Scotland affected 7,700 ha of farmland and delayed grass growth causing loss of “early bite” at an estimated cost of £141,000 (Soler et al., 1997).

In comparison with both rabbits and geese, the densities of deer that occur on farmland are generally much lower, and whereas both rabbits and geese may graze in open farmland during the day, as a rule deer do not. Increasing the amount of woodland within the agricultural landscape may well lead to greater deer densities in the future and increased damage could ensue.

- Most farmers in lowland England attributed a cost of less than £500 per annum to deer damage.

- Estimated costs of damage by rabbits and greylag geese are currently much greater than those for deer.

6. Conclusions

Agricultural damage by deer in Scotland is currently not perceived as economically serious at a national level, although it may be at a local level. This view is generally held by the NFU, DCS staff involved in authorisations and DMG`s, although we have no direct information on farmers perceptions. The fact that so little research has been done in this area is also another indicator that the problem is not widespread or serious, although it may become more important if deer were to increase in number and range throughout Scotland. One possible reason could be that agricultural owners and occupiers have a legal right to kill deer causing agricultural damage on enclosed land. Another possible reason is that when serious damage is perceived at a local level the DCS has the necessary powers to try and resolve the problem.

The use of DCS authorisations was of limited value because of changes in the use of certain categories and it was not possible to present meaningful data on the geographic spread of damage.

Despite little research on the effects of deer damage on agricultural crops in Scotland the overwhelming evidence from studies in other parts of Britain and Europe suggests that it has minimal affect on crop yields and in the case of some cereals may actually increase yield. However, this may not necessarily be the case for grasslands where the loss of the “early bite” is perceived to cause serious economic loss, and this area certainly merits investigation as grasslands were identified as the most commonly damaged crop in our questionnaire. Similarly, a study or survey on the occurrence of deer damage to root crops might also be illuminating.

With no national estimate of agricultural damage by deer, other than through DCS out-of-season Authorisations, perhaps this should also be taken more seriously. Changes in policy, especially in the increase of farm woodland, may provide some deer species with more suitable habitat within which to proliferate and spread.

An increase in deer numbers in the agricultural landscape would have other consequences, especially in lowland Scotland, with likely increase in the number of road traffic accidents involving deer. A similar problem is recognised by MAFF. Indeed the current concerns of farmers about deer reported to the NFU is about this very matter (Craig Campbell, pers. comm).

Closer monitoring of the “agricultural cull” is an initial step to following changing densities of deer. A postal questionnaire may also be another method employed on an *ad hoc* basis to get farmers perceptions, especially out with the traditional areas of DCS counting blocks and more recently DMGs. A further advantage in questioning farmers would be that in some parts of the country this could raise awareness about the DCS and its role.

There was certainly a belief from some DCS staff that agricultural owner/occupiers in central and southern Scotland were less aware of the DCS and the law with regard the taking of deer. The large number of small holders in this area of Scotland could be taking many deer annually and if venison is not sent to game dealers (as happens elsewhere) there will be a much larger “agricultural cull” than perhaps is currently believed.

- A closer monitoring of the “agricultural cull” could be useful for estimating the “size” of the “agricultural problem” as authorisations *per se* do not give an adequate estimate of the problem.

- Farmers` perceptions on cost of damage could be collected by a questionnaire. In some areas this may also help increase farmers awareness about the DCS and its role.

- The European policies of removing farmland from production and replacing them with woodland is bound to lead to an increase in deer on farmland and could potentially lead to greater damage.

SECTION B: DEER DAMAGE TO FORESTRY

1. Introduction

Large-scale afforestation began in this country following the formation of the Forestry Commission (FC) in 1920, and was instigated because of timber shortages during World War 1. To prevent damage to young trees, large areas within the red deer range in the Highlands were deer-fenced. In other parts of Scotland where red deer were not present afforestation went ahead using stock fencing.

In the first RDC Annual Report (1961) a brief review of concerns with FC operations highlighted the exclusion of deer by deer fences as having had, on occasion, drastic effects on local red deer populations. Following meetings between the two organisations, the FC agreed to consult with the RDC whenever forestry operations were planned involving deer fencing.

At that point in time little concern seems to have been voiced over the potential spread of red deer into commercial forests beyond traditional deer range, despite worries that the population as a whole was being under culled, and therefore increasing. Furthermore, while the problem of red deer breaking into fenced plantations and causing damage had been long recognised by foresters (Maxwell, 1967), it was little realised that red deer were resident in many plantations in Scotland.

It was not until the late 1970's that growing concerns about resident deer populations in forestry plantations led to a major research initiative by the FC, the Institute of Terrestrial Ecology (ITE) and the RDC.

2. Deer diet

As a means of putting into context how important conifer browse and bark are to deer species, we present a review of deer diets in Scottish plantation forestry.

In summer, grasses form the main component of the diet of red deer in Scottish conifer forests and typically occupy 30-70% of rumen volume (Staines & Welch, 1984; Staines et al., 1985; Latham et al., 1999). However there is obvious variation between forests in the proportions of different plant groups eaten. These differences are mainly due to the ground flora, with red deer diet at individual forests being similar to the proportions of different ground flora present there (Latham et al., 1999). The winter diet of red deer shows a marked decrease in the utilisation of grasses and increase of heaths, mainly heather (*Calluna vulgaris*) and some blaeberry (*Vaccinium myrtillus*), in the diet (Staines & Welch, 1984; Staines et al., 1985; Latham et al., 1999).

At Glenbranter, Argyll the red deer spring and autumn diets both had large proportions of grasses, very similar to the summer diet. However, there are some obvious seasonal trends in the other components. The proportion of conifer material in the diet was greatest in spring and fell in summer to a fraction of the diet in autumn before increasing in winter. The use of heather was least in summer rising in autumn to a peak in winter before falling again in spring (Staines et al., 1985).

Roe deer eat predominantly forbs (herbaceous plants) during summer and a mixture of heaths, conifers and forbs in winter (Staines & Welch, 1984; Staines et al. 1985; de Jong et al., 1995; Latham et al., 1999). Roe deer are more selective in their feeding, showing differential use of grasses and forbs relative to their availability (De Jong et al., 1995; Latham et al., 1999). Thus grasses form a smaller proportion of the diet.

At Glenbranter the annual diet of roe deer also showed clear seasonal differences; forbs were most important in the summer decreasing in autumn to a minimum in winter before increasing in spring. The pattern of use of conifer was similar to that of red deer with a peak of use in winter and spring decreasing in summer and autumn. The use of heather showed the opposite pattern to the use of forbs, and was least in the summer increasing in autumn to a peak in winter before decreasing in spring (Staines et al., 1985).

For both red and roe deer, ferns form part of the diet at all times of year in Scottish studies (Staines et al., 1985; De Jong et al., 1995; Latham et al., 1999).

The winter diet of sika deer from five commercial coniferous forests in Scotland was found to be similar, both between forests and between years. In all cases grasses composed more than 70% of the diet with heather comprising a further 20-30% (Mann & Putman, 1989b).

Fallow deer are also preferential grazers, and in most populations studied in Britain, grasses make up more than 60% of the spring – autumn diet (Chapman & Chapman, 1975; Jackson, 1977; Putman et al., 1993). Dwarf shrubs and tree browse also make up a substantial part of the diet at certain times of year. In the New Forest, Jackson (1977) found conifer browse an important part of the winter diet. He also found freshly ingested tree bark in most months of the year, although it never formed a large part of the diet.

- Despite seemingly making up little of the annual diet of deer a high proportion of young conifers are eaten during winter and spring with one study suggesting increased use in summer as well.

- So far as we know tree bark has never been found in any of the dietary studies of red and sika deer in this country, and the study of Jackson (1977) is the only instance we found where bark was found in the diet of fallow. This suggests that bark-stripping is an insignificant element of deer diet, yet it is without doubt the main concern of foresters.

3. Scoping study on deer damage and financial implications

Deer damage takes three main forms: firstly the browsing of leading and lateral shoots, secondly bark-stripping by teeth and thirdly damage from thrashing or fraying by deer antlers. It is widely believed that roe deer do not bark-strip trees, but all deer species will browse and fray trees.

3.1 Browsing damage

Damage to trees varies widely both within and between forests and species (Staines & Welch, 1989). Melville (1980, quoted in Staines & Welch 1989) reported 'substantial' and 'extensive' leader browsing in West Scotland where deer fencing was not general policy, although some damage could be attributed to sheep. Browsing of Japanese larch (*Larix kaempferi*) and Douglas fir (*Pseudotsuga menziesii*) was more severe than on Sitka spruce (*Picea sitchensis*). In the north where fencing is commonplace, damage was less common with Grand fir (*Abies grandis*) and Lodgepole pine (*Pinus contorta*) being more often browsed than Sitka spruce.

Not only do tree species have seemingly different vulnerability to browsing, they also have differing periods when they are susceptible to leader browsing (Melville, 1980; Staines & Welch, 1984). Most leader browsing of Sitka spruce at Glenbranter occurred during the first 6 years of growth (Welch et al., 1992). On younger stands of Sitka spruce the taller trees are browsed and in older stands the smaller. Both in Glenbranter and Fetteresso, Kincardineshire, browsing of Sitka spruce peaked when trees were 40-55 cm tall with few taller than 80 cm suffering leader browsing, despite both red and roe deer being able to browse much higher (Welch et al., 1988a, 1991).

Browsing damage to the leading shoots of conifers has a marked seasonal pattern, with consistent peaks over several years during winter (Miller et al., 1982; Cummins & Miller., 1982; Mitchell et al., 1982., Welch et al., 1991), and at the time of the spring flush of growth (Welch et al., 1988a, 1991). At Fetteresso Forest, leader and lateral browsing by roe deer at the time of the spring flush of growth was shown to peak in early June, about 10 days after bud burst (Welch et al., 1988a). The selection for young tender shoots in spring and older shoots in winter was also found in the diets of both red and roe deer at Glenbranter (Staines & Welch, 1989).

The incidence of browsing is very variable and tends to be spatially clumped (Mitchell et al., 1982, Staines & Welch, 1989; Welch et al., 1988a, 1991), but has also been shown to be more severe on the edge of forest compartments adjacent to older stands (Thirgood & Staines, 1989). Browsing incidence is also believed to be greater on sites with better tree growth (Melville, 1980; Welch et al., 1992).

The main concerns of foresters with regard to leader and lateral browsing are that growth of young trees may be impaired causing a delay or failure of the crop, trees become deformed by multiple stemming, or that structural defects to timber may have occurred.

We first consider if browsing causes a delay or failure of tree crops. Several conifers including Sitka spruce respond to browsing by either dormant buds developing on the current years growth of the main stem or by side shoots 'flagging' up and assuming apical dominance. Flagging up occurs throughout the year, and so damaged leaders can be replaced relatively quickly, reducing the overall loss in tree height (Welch et al., 1991).

A delay of 1 year was found for Sitka spruce reaching a height safe from leader browsing despite deer densities of 20-30 km^{-2} (Staines & Welch, 1989; Welch et al., 1992). Furthermore, this check in growth was observed in the girth of these trees in later years (Welch et al., 1992). At Keilder Forest tree growth was held back by 5 years or more due to roe deer (Staines & Welch, 1989). Adams (1986) reported a reduction in mean height of 17 cm between grazed and ungrazed Sitka spruce over 7 years and at Inverliever Forest, Argyll the difference in average height between fenced and unfenced areas was only 17 cm after 5 years (Staines & Welch, 1989).

Other species respond less well to leader browsing. Norway spruce (*Picea abies*) can be held in check for many years when heavily browsed (Rowe, 1982) and the regeneration of Scots pine (*Pinus sylvestris*) is well known to be suppressed by overgrazing (Mitchell et al., 1977; Staines, 1995). Less is generally known about the response of other conifers to browsing.

It is usually assumed that browsing of lateral shoots is less serious than leader browsing. However, the growth of Norway spruce was significantly reduced by lateral browsing, even when the leaders were left intact (Kampmann, 1983), and leader length of Scots pine is reduced by severe winter browsing of laterals (SCF Palmer, unpublished data)

Compensatory growth following defoliation is well known to occur in many plant species. However, the evidence for trees is varied, and limited by a lack of long-term studies (Gill, 1992b). Evidence of compensatory growth in young Sitka spruce was found by Welch et al. (1992), with greater response in browsed trees 50-95 cm in height.

We next consider the deforming effects of browsing, the most serious of which is multiple stemming. When a browsed leader is replaced by either new shoots or side shoot flagging up, often several new leaders develop and in time the tree may become multiple-stemmed. This deformation of the tree is believed to be a more serious consequence of browsing than check in growth, and has financial implications both through loss of timber volume and timber defects. From a practical point of view multiple-stemmed trees are often difficult to fell.

Many damaged trees become multiple leadered following browsing (Welch et al., 1992), although not all multiple leaders are a direct consequence of deer browsing (Gross, 1983; Staines & Welch, 1989; Welch et al., 1992). The more often a tree is browsed the greater the chance that it will become ultimately multiple stemmed (Gill, 1992b; Welch et al., 1992). Similar results have been shown from experimentally clipped Norway spruce (Eiberle, 1978; Mitscherlich & Weise, 1982) and for Silver fir (*Abies alba*), Douglas fir, and Scots pine (Eiberle, 1978).

In Scots pine the strongest of the multiple leaders that develop after browsing normally becomes dominant over time, producing a single trunk, the other leaders ‘flag’ down to become side branches but retain a double-curve S-shape (Molski, 1970). The flagging down of leaders also occurs in Sitka spruce but not on a sufficient scale to reduce the incidence of multiple stemming significantly (Welch et al., 1992).

Formerly in Britain, foresters would have removed many multiple stemmed trees from conifer plantations during thinning operations, thus minimising their frequency in the final crop. Thinning is less common now and many stands of conifers are likely to be harvested without having been thinned previously (Rollinson, 1987). The frequency and consequences of multiple stemming in conifers has been little studied but Barszcz (1989) reports on the incidence of 'forking' in Polish stands of Norway spruce, Silver fir, Scots pine and Larch. Staines & Welch (1989) report that FC studies at Inverliever suggested appreciable proportions of multiple stemming, even in deer free exclosures. In British Columbia 17% of Sitka spruce trees in 26 year-old stands were 'forked' (Alfaro & Omule, 1990).

In the long-term study on damage to Sitka spruce at Glenbranter, multiple stemmed trees had similar survival to single-stemmed trees. Multiple stemming declined mostly in stands aged between 18-45 and was caused by the weaker stems dying off. On average multiple stemmed trees had poorer growth than single-stemmed trees, the loss in girth increment being roughly 10%. Generally few of the best trees in the crop were multiple stemmed, but those that were tended to have the most reduced growth (Welch et al., 1995).

Stands planted around 1978 in Glenbranter have currently 40-65% of trees multiple stemmed and it is predicted that by the time these stands are ready to be harvested they will still contain 10-30% multiple stemmed trees. Stands originally older than 29 years in 1978, and since felled, had between 3-8% multiple stemmed trees at harvesting. The predicted difference in the proportion of multiple stemmed trees in the final stage of the crop is attributed to an increase in deer numbers since the 1950's (Welch et al., 1995).

With almost 40 years elapsing between the time of damage and harvesting, the ultimate financial impact of deer browsing remains unknown. However, the long-term data from the ITE research at Glenbranter will give an opportunity in several years time to put an estimate on the costs of multiple stemming caused by deer.

- Different tree species have varying susceptibility and periods of vulnerability to leader browsing. Most browsed Sitka spruce are smaller than 80 cm despite deer species being able to reach much higher.

- The effect of browsing on leading shoots is generally believed to be more serious than on side shoots. Crops may have their growth checked, become deformed by multiple stemming or structural defects to timber may occur.

- Growth of trees is checked by browsing and the length of time a species is checked depends partly on trees species.

- The more times trees are browsed in early life the greater the chance that these trees will become permanently multiple stemmed.

- Multiple stemmed trees have similar survival but poorer growth compared with single stemmed trees. Although many multiple stemmed trees ultimately become single stemmed as weaker trunks die, many still remain deformed at harvesting.

3.2 Bark-stripping

Bark stripping of conifer species peaks in late winter to early spring (McIntyre, 1972; Welch et al, 1987). Bark in spring and summer may be easily peeled as this is the time when cambial tissues are growing and are less rigid and more easily torn than in the non-growing seasons, when they are tough and strongly attached to the bark and wood tissue.

There are obvious differences in the susceptibility of tree species to bark-stripping, several studies suggesting that both Norway spruce and Lodgepole pine are particularly vulnerable (Mitchell et al., 1977; Gill, 1992a; Staines & Welch 1989). Norway spruce received more and bigger wounds on average than Sitka (Welch et al., 1988b) and in a mixed stand all the Lodgepole pine were damaged (D. Scott, unpublished data).

At Glenbranter forest the rate of bark stripping of Sitka spruce by red deer was less than 1% per annum. The accumulated rate of damage over the whole rotation of the tree crop was estimated to be 27% (Welch et al., 1987). However, the occurrence and severity of damage is very variable but tends to be clustered (McIntyre, 1975; Welch et al., 1987). Such “hot spots” of damage may persist for only a short period of time, These authors suggest that damage within their forest might be at most 30 damaged trees per ha per year out of an estimated stocking density of 3000 trees per ha.

Bark stripping was confined to the bottom 1.5 m of trunk in Sitka and Norway spruce at Glenbranter, which would only affect the bottom log at harvesting, assuming no staining of timber.

Bark-stripped trees are selected on their size (Hildebrandt, 1959; McIntyre, 1975; Welch et al., 1987; Scott, 1998). Thus when the mean girth of a stand is small the trees selected tend to be larger than average; conversely when the mean girth is large trees smaller than average tend to be selected. The girth at which this selection changes is estimated at 10 cm for Lodgepole pine and 20 cm for Sitka spruce (McIntyre, 1975; Welch et al., 1987). A reason for this difference is due to bark thickness which increases with age more rapidly in Scots and Lodgepole pine than in Norway or Sitka spruce (Pellew, 1968; McIntyre, 1975). Gill (1992a) points out that bark on suppressed trees is thinner than on dominants and that the thickening of bark restricts stripping. Therefore stands that are not thinned for their entire rotation might be susceptible for longer than thinned stands.

Individual trees suffer repeat bark stripping more often than might be expected by chance (McIntyre, 1975; Welch et al., 1987). However, most repeat damage of Sitka and Norway spruce trees occurred within 2 years of initial damage and over a seven-year period about a quarter of damaged trees accumulated three or more wounds with half receiving a single wound (Welch et al., 1987). As a result of repeat bark stripping and selection of smaller trees for much of the period when trees are vulnerable the impact on the tree crop is diminished. Thus it is suggested for Glenbranter that just 14% of the best crop trees would suffer bark stripping (Welch et al., 1987).

From the foresters` point of view, bark-stripping wounds, of any size, allow rot to develop within the tree, affect tree growth and survival, or may weaken timber strength. Thus the long-term response of trees to bark stripping is important in assessing any economic loss that may be incurred.

We first consider wound size. Clearly the larger the wound the greater the effects are likely to be. Bark stripping involves the loss of tissues that have protective (bark), growth (cambium) or translocation (phloem and xylem) functions and exposes the sapwood to potential attack from fungal infections. Furthermore, we need to know how big wounds have to be before they cause timber degrade and just how frequently wounds of that size occur.

There is a relationship between wound size and tree size, with larger trees receiving larger wounds (Welch et al., 1988b; Scott, 1998). However, in relation to girth, wounds have proportionally less extent on older, larger trees. On Sitka and Norway spruce most wounds tend to be small with few exceeding 100 cm^2, although pole stage trees had a greater proportion of large wounds than other growth stages (Welch et al., 1988b).

Most wounds on trees expose the xylem and produce resin. Two years after damage new bark begins to develop on Sitka spruce trees and after 8 years many wounds are completely healed (Welch et al., 1997). Wounds on young trees heal more quickly than on older trees. Larger wounds have xylem exposed for longer and are slower to heal than smaller ones, as the bigger the wound area the further that the peripheral phloem and cambium have to grow to effect occlusion. 10% of wounds had not healed 14 years after wounding (Welch et al., 1997).

Only about 1% of wounds on Sitka spruce became visibly rotten, none of them small. On average rot was first detected 6-7 years after wounding. However the tree with the largest recorded wound showed signs of rot within 18 months of being damaged, yet a similar sized wound was still rot free 12 years after wounding (Welch et al., 1997). Norway spruce is known to be much more vulnerable to infection (Loffler, 1975; El Atta & Hayes, 1987) and Welch et al. (1997) reported 11% of wounds developing rots.

We next consider the effect of bark stripping on tree growth and survival. Gill (1992b) shows that the effect of damage on subsequent growth was variable and depends much on the design of studies and methods used, but he concluded that probably a negligible loss in growth occurs and wound size relative to tree size was an important factor.

In Sitka spruce only a weak relationship was found between wound size and subsequent growth; even trees with very large wounds were inconsistent in reaction. But subsequent growth of bark stripped trees was reduced in stands older than 8 years by 0.1-0.2 cm in girth per annum in comparison with undamaged trees (Welch & Scott 1998).

Complete girdling has been reported as relatively rare and more likely to occur on the most susceptible trees or species (Gill, 1992a; Scott, 1998). However, the majority of trees survive partial girdling (Faber & Thorson, 1996; Welch et al., 1997; Scott, 1998), but when 66% or more of a stem has been girdled then deaths can occur (Lewis, 1980; Miquelle & Van Ballenberghe, 1989). Gill (1992b) notes that death from partial girdling may occur as a result of breakage of the stem at the point of wounding, citing Lodgepole pine as being particularly vulnerable to this.

There was no difference in survival between damaged and undamaged Sitka spruce trees except in the pre-thicket stage where bark stripped trees had better survival than undamaged trees (Welch et al.,1997). This was because larger trees tended to be damaged, and were less likely than smaller trees to succumb to competition from other neighbours.

Finally we consider the effects of bark stripping on timber quality, principally the development of stains and rots and physical damage causing reduced timber strength, and their effect on the final economic value of timber. The most important forms of timber degrade following wounding are the development of stain or timber rot. Staining generally causes discoloration but not structural deterioration of wood and may be caused by either a reaction from the tree or by micro-organisms. Rot involves structural deterioration as well as staining and is caused by decay-causing micro-organisms.

Most studies of the development of stain and rot have focussed on spruces because they appear to be more seriously affected than other timber producing species (Gill, 1992b). There is a relationship between the development of rot and wound size, which has been shown for Norway spruce in several studies (Loffler, 1975; Hansen & Hansen, 1980; El Atta & Hayes 1987) and Sitka spruce (Hennon & DeMars, 1997). However, rot development is usually found on the wound surface rather than inside the stem (Gregory, 1986; Welch et al., 1997; Welch & Scott, 1999).

There are clear differences in susceptibility between species. Norway spruce suffers greater staining and rot after wounding than Sitka spruce (Pawsey & Gladman, 1965; Gregory, 1984, 1986; Gill, 1992b; Welch & Scott, 1999). Norway spruce generally receives larger bark-stripping wounds, which are slower to heal, compared with Sitka. Gregory (1986) concluded that bark stripping of Sitka spruce by deer was unlikely to lead to severe stain and decay.

Although bark wounds gradually heal by callus formation a fissure is formed below the callus, which breaks when the stem is sectioned into planks. This weakness is confined to the wound area and timber loss is proportional to the size of wound and age of tree when damaged. Wounds inflicted when trees are young or old are likely to be the least serious as they are, respectively, small or near the periphery of the stem (Gill 1992b). In strength tests of sapwood, wound wood was weaker compared with other wood, but for intermediate wood and heartwood the differences between wound wood and other wood were small. Large wounds had weaker sapwood than small wounds (Welch & Scott 1999).

Calculations based on the rejection rate of logs for structural use, judged by visual grading after sawing-up and on timber strength tests, estimated Net stand values were reduced to only 2% for 28-29 year-old sites and 3% for 34-39 year-old sites. These were much less than the reductions of 9% and 11% respectively, estimated for these two ages of site by stand valuation. This suggests stand valuations over-estimate the importance of bark stripping wounds on Sitka spruce, and accordingly under-value the price of the crop (Welch & Scott, 1999).

- Tree species have different vulnerability to bark stripping, with Norway spruce and Lodgepole pine particularly vulnerable. Wound size also varies between species with Norway spruce receiving both more and larger wounds than Sitka spruce.

- Wounds are generally restricted to the bottom 1.5 m of stems. Once a tree has been damaged it is likely to be damaged again thus reducing the overall impact of bark stripping.

- At Glenbranter most wounds on Sitka spruce are small and heal within 8 years, and only 1% of Sitka showed signs of rot on wounds compared with 11% for Norway spruce.

- Loss of growth following bark stripping may happen in some species. In many species damaged trees have similar survival to undamaged tree but Lodgepole pine are particularly prone to stem breakage at the point of wounding.

- Norway spruce is particularly vulnerable to development of stain and rot following bark stripping. Most research on Sitka spruce suggests it does not suffer severe stain and decay

- From an initial estimate that 27% of Sitka spruce trees at Glenbranter would be bark stripped by the time of harvesting, this figure was reduced to only 14 % of the best trees, as mainly it is the small less valuable trees that are damaged. A stand value at the time of felling estimated site losses of between 9-11% in value. Because only large wounds have a potential economic impact at the time of harvesting, down grading estimates based on rejection rates of sawn timber and timber strength tests meant the actual financial loss would be only 2-3% of stand value.

3.3 Fraying

This type of damage is caused by the rubbing of antlers up and down tree stems, and is sometimes termed thrashing. Sika deer damage trees by scoring their trunks with the points of their antlers and this causes a deeper and potentially more serious wound. Fraying is usually done to remove velvet from antlers but may also be done for marking territories or during the rut. Generally the trees damaged are relatively young and often on the edge of forests.

Frayed Sitka spruce trees were found in the establishment, pre-thicket and thicket stages of forest growth, with most damaged recorded in establishment and least in thicket (Welch et al., 1988). These damaged trees had smaller girths than bark-stripped trees at the equivalent growth stage but similar sized wounds. Fraying wounds had a lower incidence of recovery, and often the damaged tree or trunk died. But fraying wounds that did begin to heal usually became completely healed in the next 5 or 6 years, whereas about 10% of bark-stripped wounds had not healed 14 years after wounding (Welch et al., 1997).

The incidence of fraying reported in Gill (1992a) varied from 3% to 30% of stems being damaged. But in Scotland, foresters do not view this type of damage as economically important. The Glenbranter study shows that frayed trees tend to be smaller than average, and if not killed by fraying may well die later on as part of the natural self thinning of the tree crop, when competition between trees becomes more intense.

- Fraying damage is generally regarded to be economically less serious than the other forms of deer damage.

3.4 Costs of protection and damage

Protection

In 1991-92 Forest Enterprise spent approximately £2.03 million on forest rangers and their equipment which has been costed at about £2.30 per ha of forest (Gill et al., 2000). Income from venison sales amounted to £1.26 million in that year but as pointed out by Gill et al.(2000) forest rangers do not spend all their time on deer control and estimate that if rangers spent 60% of their time on this task the cost of protection was £1.22 million for that year. The cost of control incurs a net loss but is mainly offset by the sale of venison.

In the Forest Authority Guidance Note (1999 draft) on deer, natural regeneration and fencing the estimate for providing a fully trained and equipped woodland stalker is about £10,000 per annum, plus overheads and that there is an annual net loss incurred by forest protection.

Fence costs vary depending on the terrain and the standard of fencing to be used, the price range being within £4-10 per metre. The cost of dismantling a fence is put at £0.5-1.0 per metre although some material might be reusable. New proposals for temporary and reusable fencing could in theory reduce costs. However these net fences are not designed with red deer in mind and would also be impractical in areas where woodland grouse are present.

Current roe deer management aims at Keilder Forest are to allow the establishment of Sitka spruce without fencing. The cost of deer fencing in 1994-95 added between £150-400 per ha to the cost of establishing alternative more vulnerable conifer species, and further additional cost would have been needed to protect broadleaved trees because of damage by field voles (*Microtus agrestis*) (McIntosh, 1995). Thus sometimes the costs of fencing can influence the types of trees planted.

Similarly Gill et al. (2000) demonstrate that at a cost of £7 per metre the cost to fence a 10 ha block was £885 per ha and £280 per ha for a 100 ha block. This latter figure is within the range given for fencing in Kielder forest above. Gill et al. (2000) also estimate that the cost of fencing as a percentage of revenue gained would be 9.6% for a 100 ha block after 45 years for an unthinned stand of yield 12 Sitka spruce.

Another area of forest protection has been the limited use of chemical repellents. North American researchers have shown far more interest in this area, although Mayle (1994) recommended that Aaprotect can be used against winter browsing. However this particular chemical is toxic to plants (phytotoxic) and cannot be used during the growing season. Wright & Milne (1996) conducted experiments on the efficacy of denatonium benzoate (Bitrex) as a browse deterrent, concluding it could be useful where there was a choice of other foods but was not effective when no other food source was available.

Even if repellents are effective many of those commercially available are very expensive and do not persist needing “booster sessions”. Cheaper home-made alternatives such as human hairballs and soap have been found to be effective.

Table 3.1 Variation in cost of chemical repellents (excluding labour costs).

Chemical Repellent	*Cost per Hectare ($)*
Big Game Repellent	990.00
Thiram	555.98
Hinder	75.98
Magic Circle	74.50
Miller Hot Sauce	26.20
Hairballs	25.00

Source Hartley et al. (1998)

It is unlikely that chemical repellents will form an important part in large-scale forest protection but they may be useful in smaller vulnerable areas.

Similarly the use of shelters and tree guards are particularly useful in protecting broad-leaved tree species in small areas such as stream sides or farm forestry. However, protecting large crops in this way is uneconomic and there is also some evidence to suggest that tree shelters and guards reduces early growth in Sitka spruce (Mayhead & Jenkins, 1992).

- In 1991-92 the cost of employing forest rangers was £2.03 million while venison returns brought in £1.26 million in that year. Rangers do not spend all their time on deer control and if 60% of their time was spent on this task the cost would have been £1.22 million.

- Current costs of fencing are between £4-10 per metre depending on terrain and type of fencing. The costs of other methods such as chemical repellents and individual protection are even more cost prohibitive.

Damage
In a recent review on the economic implications of deer damage for the DCS Gill et al. (2000) provide estimates for the losses incurred by different types of damage. In this section we use their estimates and some of our own to predict the final cost of deer damage for trees planted in Glenbranter around 1978 and due for harvesting in 2023, assuming a 45 year rotation.

Our data suggests that there is a 1-year delay in growth at Glenbranter caused by browsing. Gill et al. (2000) estimate for 1 ha of Sitka spruce at 2 m spacing with a no thin regime that a 3.4% loss in yield will ensue for both yield classes 12 and 16 (Yield class is an estimate of stem volume per ha per year). At Glenbranter the most common yield class is 12 with a smaller number having yield class 16. As Gill et al. point out this estimate is speculative and to us seems quite high, as 1 year represents 2.2% of 45 years.

YIELD CLASS 12	ASSUMPTION	EXPECTED LOSS
Browsing	1 year delay (Glenbranter)	
Delayed Growth		3.4%
Multiple stemming	25% (Within expected range for Glenbranter)	
Assuming main stem 15% smaller		1.4%
Assuming main stem 30% smaller		2.1%
All multiple stems used as pulp		7.1%
Bark stripping	All trees damaged	
1.13 m affected stump		4.5%
1.40 m affected stump		6.8%
Bark stripping	Estimated using data from Welch & Scott (1999)	
2 m log	Stand valuation	11%
2 m log	Visual grading	3%
Cost of browsing	Gill et al. (2000) estimates	Range 4.8% to 10.5%
+ *Cost of bark stripping*	Gill et al. (2000) estimates	Range 9.3% to 17.3%
+ *Cost of bark stripping*	Welch & Scott (1999) estimate.	
	Stand Valuation	Range 15.8% to 21.5%
	Visual grading	Range 7.8% to 13.5%

The estimate of 25% multiple stemming in the calculations of Gill et al (2000) is within our predicted range for Glenbranter of 10-30% at harvesting.

YIELD CLASS 16	ASSUMPTION	EXPECTED LOSS
Browsing	1 year delay	
Delayed Growth	3.4	3.4%
Multiple stemming	25% (Within expected range for Glenbranter)	
Assuming main stem 15% smaller		1.5%
Assuming main stem 30% smaller		3.3%
All multiple stems used as pulp		8.4%
Bark stripping	All trees damaged	
1.13 m affected stump		5.6%
1.40 m affected stump		6.2%
Bark stripping	Estimated using data from Welch & Scott (1999)	
2 m log	Stand valuation	11%
2 m log	Visual grading	3%
Cost of browsing	Gill et al. (2000) estimates	Range 4.9% to 11.8%
+ *Cost of bark stripping*	Gill et al. (2000) estimates	Range 10.5% to 18.0%
+ *Cost of bark stripping*	Welch & Scott (1999) estimate.	
	Stand Valuation	Range 15.9% to 22.8%
	Visual grading	Range 7.9% to 14.8%

There are some differences in the estimates of Gill et al. (2000) and Welch & Scott (1999) but these probably reflect the different methods and criteria used. In the assumptions of the former all stained sections are sold as pulp and all remaining sawlogs are graded as ‘green’, the apportionment of sawlog or pulp log is based on a yield model. The data from Welch & Scott use data from Glenbranter collected from stand valuations and visual grading of sawn logs, including stain and rot assessment, as well as timber strength measurements of wounds. In the latter assessment downgrading of ‘green` sawlogs did not always result in a pulp log as some were re-graded as red logs and losses were estimated at 2% and 3% for the different stand ages. The percentages of green and red logs downgraded from stain and rot visible at sawing up ranged from 2.2 to 5.2%. In contrast the stand valuation gave much higher losses of 9% and 11% depending on stand age (Welch & Scott, 1999). For the purposes of the estimates of cost of bark stripping we have used the higher figure for both stand valuation (11%) and visual grading (3%) however these figures are for 34-39 year-old stands and the figures may possibly be slightly higher for a 45 year-old stand.

Using the Glenbranter stand valuation for bark stripping gives the highest estimate of loss but it was felt that this method over estimated the significance of damage compared with visual grading (Welch & Scott, 1999). Therefore comparing the estimate ranges predicted from Gill et al. (2000) with that using visual grading give reasonably similar results. Using the 2 estimates the broad range of expected loss is 7.8% to 17.3% for yield class 12 trees and 7.9% to 18% for yield class 16.

Much work still needs to be done on the actual economic cost of deer damage, as we have no direct measure on the effects of check in early growth on final yield although in the long term this could be available for Glenbranter. Similarly long-term data are required on the loss in yield caused by multiple stemming which again could be available for Glenbranter. However such data may not be available for at least 15 years or more and clearly estimates based on yield models are the best we have currently. There are already some direct measurements of the cost of bark stripping but clearly more are needed from different forests and tree species.

- For trees planted since 1978 in Glenbranter we estimate using current figures that the losses due to deer damage will range from 7.8% to 17.3% for yield class 12 Sitka spruce the most common yield class in the forest. (Yield class being an estimate of stem volume per ha per year).

- More data are required on the economic costs of damage both for more tree species and from a wider selection of forests.

4. Review of current issues

In this section we review the current issues and trends in the interaction between deer and woodlands. The most important issues include international certification standards for forestry, the impact of deer fencing, regeneration of semi-natural woodlands, increasing farm forestry and damage done to them and community and urban woodland. However many of these issues are inter-linked and the DCS is actively involved in some of these issues.

The international forest products market is increasingly demanding assurance about the quality and environmental impacts of forest management. One way of providing this assurance is by independent verification against a published standard, which defines appropriate and effective management. The recent introduction of such a Certification Standard under the United Kingdom Woodland Assurance Scheme (UKWAS) sets out the requirements which forest and woodland owners and managers and certifying bodies should adhere to. Although the scheme is voluntary without certification many markets could be closed to timber producers. Following initial evaluation by a certifying body the certified enterprise will be reassessed after 5 years (UKWAS, pre publication text).

With regard to deer management, Section 5 (Protection and maintenance) provides the standard. The requirement of the standard is that deer management is based on a written strategy identifying management objectives, aimed at regulating the impact of deer. This requirement may involve the setting up of cull targets and would involve the membership of a DMG where appropriate. Verification of the requirement would be through the documented strategy and evidence of cull targets and achievements.

Much of the commercial forestry in northern Scotland was fenced to prevent incursions by red deer. Similarly areas of semi-natural woodland have also been protected in this way. The Life programme is a recent European initiative launched in 1992 which provides funding to promote the implementation of the Fifth Environmental Action Programme. The ideals of the programme are to achieve an acceptable balance between human activity, economic development and environmental protection and enhancement. In Scotland the Life programme has funded work on the restoration of native pine and oak woods. Much of this restoration work has been through reducing both deer and sheep numbers and deer fencing.

However the effects that deer fences have on populations of woodland grouse in Scotland has only recently come to light (Catt et al., 1994) and much research has gone into finding ways of reducing bird collisions against fences. The obvious way to do this is to have no fencing but this brings into conflict the need to protect trees and the need to conserve rare birds such as the capercaillie (*Tetrao urogallus*) and black grouse (*T. tetrix*). In a study looking at deer impact following fence removal of a 22 year old woodland block high levels of bark stripping were reported initially (Scott, 1998). Furthermore the Forestry Authority is under increasing pressure to reduce its reliance on deer fencing.

Forestry Authority (Scotland) (FAS) guidelines on fencing areas of natural regeneration states that “it is FA policy only to use deer fencing only when no other reasonable alternative is appropriate”. In these guidelines it is suggested that fencing should be used as a short-term (5-15 years) solution over small areas (<2 – 300 ha), and it can be used to "kick-start" regeneration during the critical early stages (FAS, 1999 draft report). A programme of fence monitoring with a view to their removal is envisaged as important for the management plan of the area

Whether fencing is used or not, the guidelines suggest that plans should be made to reduce deer densities to a level "compatible with the regeneration of the forest". Forestry Bulletins 71 (Red deer) and 105 (Roe deer) are suggested as an approach to simple population modelling for deciding culling levels. The target audience for the fencing guidelines include FAS staff who provide guidance on Woodland Grant Schemes (WGS) as well as the staff of Forest Enterprise, Scottish Natural Heritage, RSPB and the DCS.

The guidelines mentioned above have been agreed between DCS and FAS and are to be adopted by DCS when determining the interaction between deer and WGS and will form the basis for advice on deer plans for inclusion by FA in grant conditions. The DCS will be responsible for assessing the impact of woodland schemes and calculating the reduction in local deer populations required to minimise pressure on fencing, adjoining habitat and deer welfare.

The WGS provides incentives to create and manage woodlands on sites all over Britain. The FA pays grants for establishing and managing woodlands and forests. The scheme is tied in with the Farm Woodland Premium Scheme (FWPS), which provides annual payments to farmers to compensate for agricultural income foregone in the conversion of agricultural land to woodland either by new planting or natural regeneration. However applications for FWPS must satisfy the environmental and silvicutural standards of the WGS before approval.

The geographical spread of FWPS sites shows distinct clumping in the Northeast and East of Scotland and in Dumfries & Galloway and Scottish borders (Fig. 1), not surprisingly areas of lowland farming. In May 1995 a total of 875 holdings had planting approval covering 14,272, ha at an average of 16.3 ha per holding. Almost half the holdings planted less than 5 ha and this represented only 7% of the total area planted. Only 13% of farms planted more than 40 ha, some individual planting exceeding 200 ha and this accounted for 55% of the total area planted (Crabtree et al 1997). In WGS the DCS are asked for their advice only when areas >50 ha are planted and presumably in the vast majority of FWPS their advice is not sought.

Research on farm woodland in northeast Scotland suggests that roe deer select all woodlands >8 ha and prefer woods >4 ha of mixed structure with clearings. An example of roe deer using small woodlands is shown in figure 2**.** The impact of deer on farm woodlands has also attracted some interest recently (Calder, 1994; Key et al., 1998; Staines et al., 1998).

The likelihood of increased farm woodland will undoubtedly lead to an increase in roe deer numbers, and damage to some farm woodlands are reported in the out-of-season Authorisations. Increased roe numbers and perhaps other species may in time cause more agricultural damage and combined with fewer fields (relatively speaking) and greater occurrence of field/woodland boundaries could increase the significance of damage (given our findings in Part A, Section 3.4).

There is currently increased interest in the protection and expansion of community and urban woodlands in Scotland with many bodies such the Forestry Commission providing funding and guidance for full time management of these areas. Much interest is focussed in the central belt with towns such as Cumbernauld and Livingston actively involved.

Presumably deer are present in many of these woodlands and potentially several areas of conflict with man may occur. Such conflicts could include damage to young trees, increased damage to surrounding agriculture, damage to nearby gardens, increased number of deer involved in road accidents and an increase in poaching. In North America control and regulation of "urban" deer has sparked off heated controversy with animal right groups and has led to the development of contraceptive methods of control. Clearly public safety is paramount if such deer populations were to require controlling and undoubtedly public opinion in these areas is unlikely to be pro culling. Although we are not yet aware of any serious conflict, without doubt there is potential for it.

- Current issues identified include deer fencing, regeneration of semi-natural woodland, increased planting of farm woodlands and community and urban woodland.

5. Relevant powers and duties of DCS with respect to Forestry

Out of Season Authorisations
The DCS **may authorise** the owner or occupier of land, or any nominated person, where they are **satisfied** that the taking or killing of deer is necessary **to prevent serious damage** to any unenclosed woodland which forms part of that land.

Control Agreement
The DCS may draw up a control agreement where they are **satisfied** that, on any land, deer **have caused**, **are causing**, **or are likely to cause damage** to **woodland**, and that for the **prevention of further damage** the deer in that locality should be reduced in number.

Agricultural damage includes any crops or foodstuffs, injury to livestock, whether by serious overgrazing of pastures, competition with any such livestock for supplementary feeding, or otherwise.

Control Scheme
Where the DCS are **satisfied** that it is not possible to secure a control agreement or that a control agreement is not being carried out, and deer **have caused and are causing serious damage to woodland**, **whether directly or indirectly**, they shall make a scheme to carry out such measures as they consider necessary to **prevent such serious damage**.

Emergency Measures
Where the DCS are **satisfied** deer **are causing serious damage to woodland** and **none of the other powers** of the DCS **are adequate** to deal with the situation, and that killing of deer is necessary to **prevent further damage** they shall identify the land those deer come from and request that the person having the rights to shoot deer on that land complies with the terms of the request.

Night Shooting
The DCS **may authorise** an occupier or any person nominated to sell ot otherwise dispose of any deer on woodland **where they are satisfied** the taking or killing is necessary **to prevent serious damage** to crops, pasture or animal foodstuffs.

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REFERENCES

Adams, S.N. 1986. Sheep performance and tree growth on a grazed Sitka spruce plantation. Scottish Forestry. 40, 259-263.

Alfaro, R.I. & Omule, S.A.Y. 1990. The effect of spacing on Sitka spruce weevil damage to Sitka spruce. Canadian Journal of Forest Research. 20, 179-184.

Aulak, W. & Babinska-Werka, J. 1990. Use of agricultural habitats by roe deer inhabiting a small forest area. Acta Theriologica. 35, 121-127.

Barszcz, A. 1989. Analysis of the frequency of occurrence of wood defects in standing coniferous trees as an extension to evaluations of the quality of the raw material base. Sylwan. 133, 31-38.

Boag, B., Macfarlane Smith, W.H. & Griffiths, D.W. 1990. Observations on the grazing of double low rape and other crops by roe deer. Applied Animal Behaviour Science. 28, 213-220.

Calder, C.J. 1994. Population performance and feeding ecology of roe deer in farm woodland. PhD. Thesis, University of Aberdeen.

Caldwell, J.F., Chapman, D.I. & Chapman, N. 1983. Observations on the autumn and winter diet of fallow deer (*Dama dama*). Journal of Zoology. 201, 559-563.

Callender, R.F. & MacKenzie, N.A. 1991. The management of wild red deer in Scotland. Rural Forum, Perth.

Catt, D.C., Dugan, D., Green, R.E., Moncrieff, R., Moss, R., Picozzi, N., Summers, R.W. & Tyler, G.A. 1994. Collisions against fences by woodland grouse in Scotland. Forestry. 67, 105-118.

Chapman, D. & Chapman, N. 1975. Fallow deer: their history, distribution, and biology. Terence Dalton Ltd. Lavenham.

Crabtree, J.R., Bayfield, N.G., Wood, A.M., Macmillan, D.C. & Chalmers, N.A. 1997. Evaluating the benefits from farm woodland planting. Scottish Forestry. 51, 84-92.

Cibien, C., Bideau, E., Boisaubert, B., Biran, H. & Angibault, J.M. 1995. Seasonal diet and habitat use in field roe deer (*Capreolus capreolus*) in the Picardie region. Gibier Faune Sauvage. 12, 37-49.

Coles, C. 1997. Gardens & Deer. A guide to damage limitation. Swan Hill Press. Shrewsbury.

Cornelis, J., Casaer, J. & Hermy, M. 1999. Impact of season, habitat and research techniques on diet composition of roe deer (*Capreolus capreolus*): a review. Journal of Zoology. 248, 195-207.

Cummins, R.P. & Miller, G.R. 1982. Damage by red deer (*Cervus elaphus*) enclosed in planted woodland. Scottish Forestry. 36, 1-8.

DCS Annual Reports 1998,1999

De Jong, C.B., Gill, R.M.A., Van Wieren, S.E. & F.W.E. Burlton. 1995. Diet selection by roe deer *Capreolus capreolus* in Keilder Forest in relation to plant cover. Forest Ecology and Management Special Issue: Keilder – The ecology of a man-made spruce forest. 79, 91-97.

Doney, J. & Packer, J.J. 1998. The impact of deer on agriculture: interim results of a questionnaire and subsequent validation. In Population ecology, management and welfare of deer. Eds. Goldspink, C.R., King, S. & Putman, R.J. Manchester Metropolitan University, Manchester.

Eiberle, K. 1978. The consequences of simulated browsing damage on the development of young forest trees. Schweiz. Z. Forstwes. 129, 757-768.

El Atta, H.A. & Hayes, A.J. 1987. Decay in Norway spruce caused by *Stereum sanguinolentum* Alb. & Sch. Ex Fr. developing from extraction wounds. Forestry. 60, 101-111.

Faber, W.E. & Thorson, E.M. 1996. Bark stripping of young *Pinus sylvestris* by *Alces alces* on the individual, stand and landscape level in Sweden. Canadian Journal of Forest Research. 26, 2109-2114.

Gill, R.M.A. 1992a. A review of damage by mammals in north temperate forests: 1. Deer. Forestry. 65, 145-169.

Gill, R.M.A. 1992b. A review of damage by mammals in north temperate forests: 3. Impact on trees and forests. Forestry. 65, 363-388.

Gill, R., Webber, J. & Peace, A. 2000. The economic implications of deer damage. A review of current evidence. Unpublished report to the Deer Commission for Scotland.

Gregory, S.C. 1984. Micro-organisms isolated from wounded stems of *Picea sitchensis*. Transactions of the British Mycological Society. 83, 683-686.

Gregory, S.C. 1986. The development of stain in wounded Sitka spruce stems. Forestry. 59, 199-208.

Gross, H.L. 1983. Injuries to terminal shoots cuase multiple-leadered nursery seedlings. Department of the Environment Information Report 0-X-347, Canadian Forestry Service.

Hansen, F.R. & Hansen, H.R. 1980. Microorganisms which invade Picea abies in seasonal stem wounds. European Journal of Forest Pathology. 10, 321-339.

Hartley, S.E., Young, C., Thurlow, M., Truscott, A., Scott, D. & Hanley, M. 1998. Natural compounds as repellents to deer browsing: The relationship between the chemical composition of trees and shrubs and their palatability to deer. Unpublished report to MAFF.

Hennon, P.E. & DeMars, D.J. 1997. Development of wood decay in wounded Western hemlock and Sitka spruce in southeast Alaska. Canadian Journal of Forest Research. 27, 1971-1978.

Hildebrandt, G. 1959. (The distribution of bark-scaling damage by deer in Norway spruce stands). Allgemeine Forst-und-Jagdzeitung. 130, 213-218.

Holisova, V., Kozena, I. & Obrtel, R. 1984. The summer diet of field roe deer bucks (*Capreolus capreolus*) in Southern Moravia. Folia Zoologica Brno. 33, 193-208.

Holisova, V., Obrtel, R. & Kozena, I. 1982. The winter diet of roe deer (*Capreolus capreolus*) in the Southern Moravian agricultural landscape. Folia Zoologica Brno. 31, 209-225.

Holisova, V., Obrtel, R. & Kozena, I. 1986. Seasonal variation in the diet of field roe deer (*Capreolus capreolus*) in Southern Moravia. Folia Zoologica Brno. 35, 97-115.

Hubbard, C.E. 1984. Grasses. Aguide to their structure, identification, uses and distribution in the British Isles. 3rd Edition. Penguin books.

Idris, A.B.H. 1990. The ecology of roe deer (*Capreolus capreolus* L.) inhabiting farmland in north-east Scotland. PhD. Thesis, University of Aberdeen.

Jackson, J. 1977. The annual diet of the Fallow deer (*Dama dama*) in the New Forest, Hampshire, as determined by rumen content analysis. Journal of Zoology. 181, 465-473.

Jensen, P.V. 1968. Food selection of the Danish red deer (*Cervus elaphus* L.) as determined by examination of the rumen content. Danish Review of Game Biology. 5, 1-44.

Kaluzinski, J. 1982. Composition of the food of roe deer living in fields and the effects of their feeding on plant production. Acta Theriologica. 27, 457-470.

Kampmann, H. 1983. Investigations on the effects of gnawing side shoots by roe deer on the growth of spruce trees. Zeitschrift fur Jagdwissenschaft. 29, 235-243.

Key, G., Moore, N. & Hart, J. 1998. Impact and management of deer in farm woodlands. In Population ecology, management and welfare of deer. Eds. Goldspink, C.R., King, S. & Putman, R.J. Manchester Metropolitan University, Manchester.

Kjostvedt, J.H., Mysterud, A. & Ostbye, E. 1998. Roe deer *Capreolus capreolus* use of agricultural crops during winter in the Lier valley, Norway. Wildlife Biology 4 23-31.

Langbein, J. 1997. The ranging behaviour, habitat-use and impact of deer in oak woods and heather moors of Exmoor and the Quantock hills. British Deer Society. Fordingbridge.

Latham, J., Staines, B.W. & Gorman, M.L. 1999. Comparative feeding ecology of red (Cervus elaphus) and roe deer (*Capreolus capreolus*) in Scottish plantation forests. Journal of Zoology. 247, 409-418.

Lewis, C. 1980. Simulated cattle injury to planted slash pine: Girdling. Journal of Range Management. 33, 337-340.

Loffler, H. 1975. The spread of wound rot in Norway spruce. Forstwissenschaft Centralblatt. 94, 175-183.

Mann, J.C.E. & Putman, R.J. 1989a. Patterns of habitat use and activity in British populations of sika deer of contrasting environments. Acta Theriologica. 34, 83-96.

Mann, J.C.E. & Putman, R.J. 1989b. Diet of British sika deer in contrasting environments. Acta Theriologica. 34, 97-109.

Marchal, C., Gerard, J.F., Delorme, D., Boisaubert, B. & Bideau, E. (1998). Space and habitat use by field roe deer (*Capreolus capreolus*) in mid-winter and mid-growing season. Gibier Faune Sauvage. 15, 737-746.

Marshall, F. 1970. Deer and the farmer. Deer. 2, 514-516.

Maublanc, M.L. 1986. Utilisation de l`espace chez le chevreuil (*Capreolus capreolus*) en millieu ouvert. Gibier Faune Sauvage. 3, 297-311.

Maxwell, H.A. 1967. Red deer and forestry with special reference to the Highlands of Scotland. Deer. 1, 126-130.

Mayhead, G.J. & Jenkins, T.A.R. 1992. Growth of young Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and the effect of simulated browsing, staking and treeshelters. Forestry. 65, 453-462.

Mayle, B.A. 1994. Falling foul of fallow. Timber Grower. (Autumn), 34-36.

Melville, R.C. 1980. A survey of red deer damage in west and north Scotland to assess relative vulnerability of different tree species and crop type. Unpublished closure report Y14/50. Forestry Commission. Alice Holt Lodge.

McIntosh, R. 1995. The history and multi-purpose management of Kielder forest. Forest Ecology and Management Special Issue: Keilder – The ecology of a man-made spruce forest. 79, 1-11.

McIntyre, E.B. 1972. Barkstripping – a natural phenomenon. Scottish Forestry. 26, 43-50.

McIntyre, E.B. 1975. Barkstripping by ungulates. Ph.D. Thesis, University of Edinburgh.

McKillop, G., Dendy, J. & Fox, S. 1997. The costs of rabbit damage to crops. Abstract 48. First European Vertebrate Pest Management Conference. University of York.

Miller, G.R., Kinnaird, J.W., & Cummins, R.P. 1982. Liability of saplings to browsing on a red deer range in the Scottish Highlands. Journal of Applied Ecology. 198, 941-951.

Mills, S. 1986. Rabbits breed a growing controversy. New Scientist, 6 March, 50-54.

Mitchell, B., McCowan, D. & Willcox, N.A. 1982. Effects of deer in a woodland restoration enclosure. Scottish Forestry. 36, 102-112.

Mitchell, B., Staines, B.W. & Welch, D. 1977. Ecology of red deer. A research review relevant to their management in Scotland. Institute of Terrestrial Ecology, Cambridge.

Mitscherlich, G. & Weise, U. 1982. Growth restriction (simulated browsing) trials with spruce in Abtsgmund and Crailsheim. Allgemeine Forst-und-Jagdzeitung. 153, 97-104.

Miquelle, D.G. & Van Ballenberghe, V. 1989. Impact of bark stripping on aspen-spruce communities. Journal of Wildlife Management. 53, 577-586.

Molski, B. 1970 (Replacement of leading shoots of *Pinus sylvestris* damaged by game). Roczn. Dendrol. Polsk. Tow. Bot. 24, 43-60.

Muri, H. Von. & Stammbach-Geering, K. 1995. (Rape as a factor of habitat in Central Switzerland). English summary. Zeitschrift fur Jagdwissenschaft. 41, 126-137.

Obrtel, R. & Holisova, V. 1983. Assessment of the damage done to a crop of maize (*Zea mays*) by roe deer (*Capreolus capreolus*). Folia Zoologica Brno. 32, 109-118.

Obrtel, R., Holisova, V. & Kozena, I. 1984. Deer damage to sugar beet leaves. Folia Zoologica Brno. 33, 99-108.

Onderscheka, K., Tataruch, F., Steineck, T., Klansek, E., Vodnansky, M., Wagner, J. & Echsel, H. 1987. Roe deer losses through the consumption of 00-rape. English summary Zeitscrift fur Jagdwissenschaft. 33, 191-205.

Packer, J.J., Doney, J., Mayle, B., Palmer, S.C.F. & Cope, M. 1998. Field and desk studies to assess tolerable damage levels for different habitats and species of deer. Unpublished report to the Ministry of Agriculture Fisheries and Food

Pawsey, R.G. & Gladman, R.J. 1965. Decay in standing conifers developing from extraction damage. Forestry Commission Forest Record No. 54.

Pellew, R.A. 1968. Barkstripping: a problem in the integrated management of red deer and forestry. Unpublished Honours Thesis. University of Edinburgh.

Putman, R.J. 1986. Foraging by roe deer in agricultural areas and impact on arable crops. Journal of Applied Ecology, 23, 91-99.

Putman, R.J., Culpin, S. & Thirgood, S.J. 1993. Dietary differences between male and female fallow deer in sympatry and allopatry. Journal of Zoology. 229, 267-275.

Putman, R.J. & Moore, N.P. 1998. Impact of deer in lowland Britain on agriculture, forestry and conservation habitats. Mammal Review, 28, 141-164.

RDC Annual Reports for 1961, 1983, 1989,1992,1993,1995

Reynolds, J. & Tapper, S. 1991. Roe deer and oilseed rape: the first winter. The Game Conservancy Review of 1990. p98-102. The Game Conservancy, Fordingbridge.

Rollinson, T.J.D. 1987. The yield of unthinned Sitka spruce in Great Britain. Scottish Forestry. 41, 265-272.

Rowe, J. 1982. Roe research in relation to management in British woodlands. In. Roe and Red deer in British Forestry. 25-41. The British deer Society and the Forestry Commission.

Salter, H.B. 1972. Deer in my corn. Deer. 2, 815.

Scott, D. 1998. Impact of red deer on a Scots pine plantation after removal of deer fencing. Scottish Forestry. 52, 8-13.

Sibbald, A.M., Iason, G.R., Bristow, I.A. & Davidson, G.C. 1995. The consequences for deer of ingesting oilseed rape (*Brassica napus*): feeding experiments with roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*). Journal of Zoology, 235, 99-111.

Seifert, H.S. & Robbelen, G. 1988. Production of 00-rapeseed varieties and its effect on wildlife. In Double low rapeseed forum. 62-64. National Institute of Agricultural Botany, Cambridge.

SOAFD. 1992. Consultation paper on deer legislation in Scotland. Deer. 8, 489-491.

Soler, E., Fuchs, R.M.E. & Slee, W. 1997. The impact on agriculture of Greylag geese roosting at the Loch of Schene. Abstract 82. First European Vertebrate Pest Management Conference. University of York.

Staines, B.W. 1995. The impact of red deer on the regeneration of native pinewoods. In: Aldhous, J.R. (ed.) *Our Pinewood Heritage*. Forestry Commission; The Royal Society for the Protection of Birds; Scottish Natural Heritage, Inverness, pp. 107-114.

Staines B.W., Palmer S.C.F., Wyllie I., Gill R. and Mayle B. 1998. Desk and limited field studies to analyse the major factors influencing regional deer populations and ranging behaviour. Report to the Ministry of Agriculture, Fisheries and Food.

Staines, B.W. & Welch, D. 1984. Habitat selection and impact of red (*Cervus elaphus*) and roe (*Capreolus capreolus*) deer in a sitka spruce plantation. Proceedings of the Royal Society of Edinburgh. 82B, 303-319.

Staines, B.W. & Welch, D. 1989. An appraisal of deer damage in conifer plantations. In Deer and Forestry. R. McIntosh (ed). ICF, Edinburgh, 61-75.

Staines, B.W., Welch, D., Catt, D.C., Scott, D. & Hinge, M.D.C. 1985. Habitat use and feeding by deer in sitka spruce plantations. Annual Report of the Institute of Terrestrial Ecology 1982. 12-16.

Strandgaard, H. 1972. The roe deer (Capreolus capreolus) population at Kalo and the factors regulating its size. Danish Review of Game Biology. 7, 205pp.

Szemethy, L., Heltai, M., Matrai, M. & Peto, Z. 1998. Home ranges and habitat selection of red deer (*Cervus elaphus*) on a lowland area. Gibier Faune Sauvage. 15, 607-615.

Thirgood, S.J. 1995. The effects of sex, season and habitat availability on patterns of habitat use by fallow deer (*Dama dama*). Journal of Zoology. 235, 645-659.

Thirgood, S.J. & Staines, B.W. 1989. Summer use of young stands of restocked Sitka spruce by red and roe deer. Scottish Forestry. 43, 183-191.

Torbit, S.C., Gill, R.B., Alldredge, A.W. & Liewer, J.C. 1993. Impacts of pronghorn grazing on winter wheat in Colorado. Journal of Wildlife Management. 57, 173-181.

Welch, D., Chambers, M.G., Scott, D. & Staines ,B.W. 1988a. Roe-deer browsing on spring-flush growth of Sitka spruce. Scottish Forestry. 42, 33-43.

Welch, D. & Scott, D. 1998. Bark-stripping damage by red deer in a Sitka spruce forest in Western Scotland. IV. Survival and performance of wounded trees. Forestry. 71, 225-235.

Welch, D. & Scott, D. 1999. Timber degrade in Sitka spruce (Picea sitchensis) due to bark-stripping. Unpublished report to the Scottish Forestry Trust.

Welch, D., Scott, D. & Staines, B.W. 1997. Bark-stripping damage by red deer in a Sitka spruce forest in Western Scotland. III. Trends in wound condition. Forestry. 70, 113-120.

Welch, D., Scott, D. & Staines, B.W. 1995. Survival rates and performance of multi-trunked trees in even-aged stands of Sitka spruce in western Scotland. Forestry. 68, 245-253.

Welch, D., Staines, B.W., Scott, D. & Catt, D.C. 1987. Bark-stripping damage by red deer in a Sitka spruce forest in Western Scotland. I. Incidence. Forestry. 60, 249-262.

Welch, D., Staines, B.W., Scott, D. & Catt, D.C. 1988b. Bark-stripping damage by red deer in a Sitka spruce forest in Western Scotland. II. Wound size and position. Forestry. 61, 245-254.

Welch, D., Staines, B.W., Scott, D., French, D.D. & Catt, D.C. 1991. Leader browsing by red and roe deer on young Sitka spruce trees in Western Scotland. I. Damage rates and the influence of habitat factors. Forestry. 64, 61-82.

Welch, D., Staines, B.W., Scott, D. & French, D.D. 1992. Leader browsing by red and roe deer on young Sitka spruce trees in Western Scotland. II. Effects on growth and tree form. Forestry. 65, 309-330.

Wright, I.A. & Milne, J.A. (1996) Aversion of red deer and roe deer to denatonium benzoate in the diet. Forestry. 69 1-4.

Zejda, J. & Homolka, M. 1980. Habitat selection and population density of field roe deer (*Capreolus capreolus*) outside the growing season. Folia Zoologica Brno. 29, 107-115.

Appendix 1.

DEER DAMAGE TO AGRICULTURE QUESTIONNAIRE

For the purposes of this questionnaire farmland refers to enclosed fields of crops or grassland.

1. Which deer species are in your management area. (Please circle)

   Red Roe Sika Fallow

2. Please rank in order of area (1 = greatest area) the following land use types within your management area.

   Deer Forest Farmland Forestry

3. Does damage to farmland occur within your area. (Please circle) If the answer is NO or DON'T KNOW please turn to the comments section.

   YES NO DON'T KNOW

4. Do farmers, crofters and land-owners inform your group of problem areas. (Please circle)

Tennant Farmers	YES	NO
Crofters	YES	NO
Estates	YES	NO
Farm owner/occupiers	YES	NO

5. Which crop types are damaged. (Please circle)

   Cereals Grasslands Root crops Vegetables Soft fruits

   Other (Please specify)

   Don't Know

6. Which species of deer cause damage to crops. (Please circle)

   Red Roe Sika Fallow

(PTO)

7. Is this damage done by marauding deer from deer forests and/or deer resident in farmland (e.g. animals living in farm woodlands) or commercial woodland. (Please circle)

    Deer Forest   Farmland   Forestry

8. Is damage to agriculture a serious problem in your area. Please circle the statement that you think best describes the problem in your area.

   The culling regime in our area prevents any major problem for farmers/crofters.

   We occasionally get complaints from farmers/crofters but these are quickly dealt with.

   We get sporadic outbreaks of damage

   We have problems every year usually in the same areas.

   Damage to farmland is a major problem in this area.

Thank you for completing this questionnaire, your assistance in this matter is much appreciated. I hope you found the questions easy to understand if not or if you wish to comment on or clarify any of your answers please feel free to do so.

Comments:

Appendix 1 (contd)

		Cereal	Grass	Roots	Veg	Deer Species		
Aberfoyle	Y	✓	✓			Red	Roe	
Arran	?							
Blackmount	N							
Borders sika	Y		✓	✓		Roe	Sika	
Cabrach/Strathdon	Y	✓	✓	✓		Red	Roe	
Cairngorms/Spey	Y	✓	✓	✓		Red	Roe	
Cowal	Y		✓			Red	Roe	
Ardnamurchan	Y		✓	✓		Red		
E. Glen Lyon	Y		✓			Red		
E. Grampian	Y	✓	✓	✓		Red	Roe	
E. Loch Ericht	?							
E. Loch Sheil	Y		✓			Red		
E. Ross	N							
E. Sutherland	Y		✓	✓		Red		
Gairloch	Y		✓			Red		
Galloway	N							
Glenartney	Y		✓			Red		
Glenelg	N							
Harris/Lewis	Y					Red		
Inverary/Tyndrum	Y		✓			Red		
Islay	Y	✓	✓	✓		Red		
Skye	Y		✓		✓	Red		
Jura	Y		✓			Red		
Kincardineshire	?							
Knoydart	Y		✓			Red	Roe	
W. Argyll	Y		✓	✓		Red	Sika	
Mid West Assoc	Y					Red		
Moidart	Y		✓			Red		
Monadhliaths	Y			✓		Red		
Morvern	N							
Mull	Y		✓			Red		
N. Ross	Y		✓			Red		
NW. Sutherland	Y		✓			Red		
Northern	?							
S. Loch Tay	Y		✓	✓		Red	Roe	
S. Perthshire	Y		✓	✓		Red	Roe	
Strathconon/bran	Y	✓	✓	✓		Red	Roe	
SW. Ross	Y		✓			Red	Roe	
Affric S.Ross	Y		✓			Red	Roe	Sika
W. Sub gp. S. Ross	Y		✓			Red		
Strathtay	Y			✓		Red		
W. Grampian Tay	Y		✓	✓		Red	Roe	Fallow
Lochaber	Y		✓			Red		
West Rannoch	Y		✓			Red		
W. Sutherland	Y		✓			Red		
Loch Arkaig/GG	N							

Appendix 2.

Data sources for Agricultural review

MAFF	England & Wales	1985-1989	National database of reports on agricultural damage by wildlife.
FC		1992	Questionnaire on damage by Fallow deer.
ADAS	4 regions of Lowland England	1995	Questionnaire on damage by all species of deer.
RDC/DCS	Scotland	1963-1999	Authorisatons for out-of-season Shooting of Red deer
		1983-1999	Authorisations for out-of-season Shooting of Sika & Roe deer.
ITE	Deer Management Groups, Scotland.	2000	Questionnaire on agricultural damage by deer (for this report).

Appendix 3

	Agricultural Land by Type of Use			
Crop type	Orkney, Shetland & Western Isles	Highland	NE Scotland	Tayside
	Area as % of Scotland			
Cereals	0.9	6.9	31.9	19.2
Potatoes	0.9	3.6	22.4	43.0
Oilseed Rape	+	5.2	37.0	23.5
Peas	+	6.4	5.6	24.2
Stockfeed	3.4	12.1	29.4	14.0
Other Arable	0.5	7.0	32.0	21.2
Grassland <5yrs	4.5	10.4	29.4	9.2
Other grassland	4.0	36.6	7.8	10.5
Vegetables	0.2	1.2	15.6	39.5
Fruit	+	2.0	5.0	78.6
Farmland	4.0	30.9	12.4	11.8

	Agricultural Land by Type of Use			
Crop type	Fife	Lothian	Scottish Borders	Dumfries & Galloway
	Area as % of Scotland			
Cereals	8.8	8.7	12.8	3.7
Potatoes	9.9	7.7	7.6	1.4
Oilseed Rape	10.7	7.7	12.2	0.2
Peas	6.0	30.6	25.7	+
Stockfeed	3.5	3.9	16.0	9.3
Other Arable	5.0	13.0	8.0	5.3
Grassland <5yrs	2.9	3.1	9.9	13.5
Other grassland	0.6	1.4	6.2	8.9
Vegetables	22.0	5.8	13.1	0.3
Fruit	6.9	2.4	0.5	0.2
Farmland	1.9	2.5	7.3	8.5

	Agricultural Land by Type of Use			
Crop type	East Central	Ayrshire	Argyll & Bute	Clyde Valley
	Area as % of Scotland			
Cereals	2.5	1.9	0.4	2.2
Potatoes	0.3	2.6	0.2	0.4
Oilseed Rape	2.8	+	0.0	+
Peas	+	+	+	+
Stockfeed	1.6	1.5	1.8	3.5
Other Arable	1.0	1.5	0.2	5.2
Grassland <5yrs	3.0	5.4	2.7	6.1
Other grassland	3.8	4.8	10.5	4.3
Vegetables	+	0.6	+	1.1
Fruit	+	0.4	0.1	3.1
Farmland	3.5	4.4	8.7	4.1

Source: The digest of Agricultural Census Statistics United Kingdom 1997.