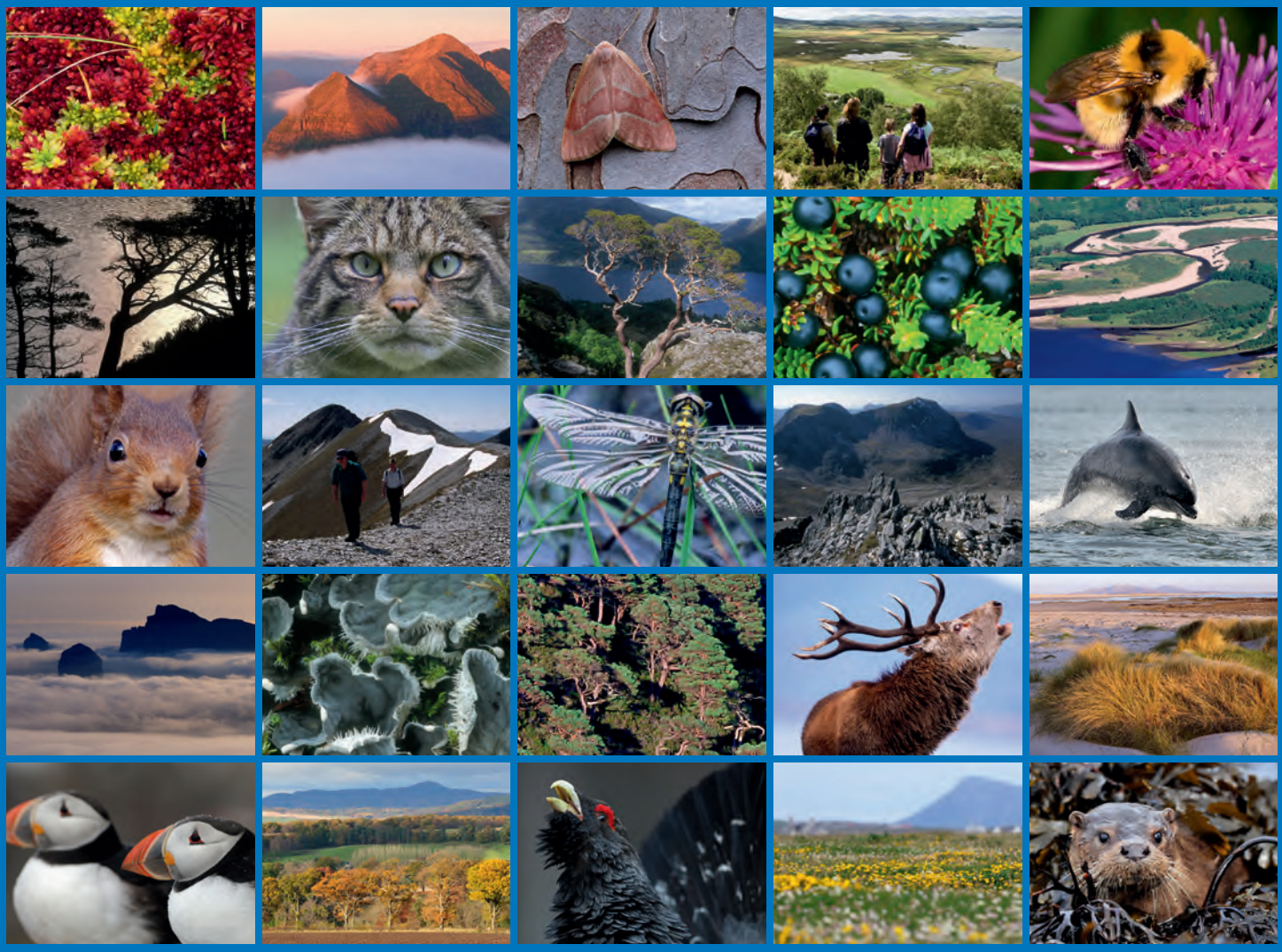
Scottish Natural Heritage
Commissioned Report No. 526

Scoping the economic benefits and costs of wild deer and their management in Scotland



Scottish Natural Heritage
Dualchas Nàdair na h-Alba
All of nature for all of Scotland
Nàdar air fad airson Alba air fad

COMMISSIONED REPORT

Commissioned Report No. 526

Scoping the economic benefits and costs of wild deer and their management in Scotland

For further information on this report please contact:

Alastair MacGugan
Scottish Natural Heritage
Great Glen House
INVERNESS
IV3 8NW
Telephone: 01786 450362
E-mail: Alastair.MacGugan@snh.gov.uk

This report should be quoted as:

Putman, R. (2012). Scoping the economic benefits and costs of wild deer and their management in Scotland. *Scottish Natural Heritage Commissioned Report No. 526*

COMMISSIONED REPORT

Summary

Scoping the economic benefits and costs of wild deer and their management in Scotland

Commissioned Report No.: Report No. 526
Contractor: Putman, R.
Year of publication: 2012

Background

Wild deer are an important part of our natural environment, and they are viewed by the public as one of the most iconic species, thus having significant wider cultural value to the Scottish people. This work attempts to review earlier studies and identify the main costs and benefits arising from the deer populations in Scotland.

Main findings

Costs:

Deer can cause negative impacts to agriculture, commercial forestry, amenity trees or farm woodlands, and to conservation of habitats and species. Attributing accurate costs at a national scale is particularly difficult to do for agriculture and forestry impacts as costs tend to be very site specific. Deer can also be involved in the transfer of diseases, to humans or their livestock, and pose a more direct risk to public safety through their involvement in road traffic accidents.

Benefits:

Deer are an important component of natural ecosystems and wider biodiversity. They have significant wider cultural value to the Scottish people and contribute to the tourist economy. They also provide a significant contribution to the economy in many rural areas, whether for private enjoyment by the landowners and their guests or through leased hunting. Estates are major employers in some rural areas.

Conclusions

There are a wide range of impacts that must be assessed if we are to provide an accurate cost/benefit analysis for wild deer in Scotland. The current data has been explored to provide initial estimates of costs and benefits and identify other data sources that could contribute to our overall understanding of the true costs of both deer impacts and deer management.

It is recognised that most information is currently available at a national scale but the costs and impacts may be better understood at a site level.

Table of Contents **Page**

1. BACKGROUND 1

2. APPROACH 2
2.1 Costs 2
2.2 Economic benefits from deer 2

3. COSTS 4
3.1 Deer in Commercial Forestry 4
3.1.1 General 4
3.1.2 Deer on the Public Forest Estate 5
3.2 Private Forestry 6
3.2.1 European comparisons 7
3.2.2 Deer damage in Amenity Woodlands and Farm Woodland Schemes ... 7
3.2.3 Summary of costs in the Forestry sector 8
3.3 Agriculture 8
3.4 Impacts on Native Biodiversity 11
3.5 Other ecological costs 12
3.5.1 Disease transfer to humans and domestic stock 13
3.6 Deer Vehicle Collisions 16
3.6.1 Deer on the road network 16
3.7 Costs of physical mitigation 17
3.8 Diffuse Costs 17
3.9 Deer on the rail network 18
3.10 Problems caused by deer in urban contexts 18
3.11 Regulation and administration of wild deer 18
3.12 Summary of costs and assessment of quality of data 18

4. BENEFITS 20
4.1 Direct Benefits 20
4.1.1 Stalking 20
4.2 Indirect employment and secondary products 22
4.3 Capital costs/values 22
4.4 Ecotourism 22
4.5 Social benefits 23
4.6 Summary of benefits and assessment of quality of data 23
4.7 Economic Costs and Benefits of Deer under different models of land-ownership 24
4.8 General Conclusions 25
4.8.1 Commercial forestry 25
4.8.2 Agricultural and other costs: 25
4.9 Benefits 26
4.10 Gaps in Knowledge 27
4.11 Knowledge Gaps in the benefits of wild deer 28

5. REFERENCES 28

1. BACKGROUND

Scotland boasts significant populations of red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and sika (*Cervus nippon*) as well as more localised populations of fallow (*Dama dama*). The most recent population estimates (after Ward, 2007; Putman 2010) suggest overall numbers at between 360,000-400,000 red deer, 200,000-350,000 roe deer, 25,000 sika and perhaps 2,000 fallow.

Scottish Natural Heritage (SNH) wishes to commission research to better understand the full range of economic benefits and costs of wild deer and their management in Scotland. This scoping study aims to summarise what information is currently available, but particularly aims to identify gaps in knowledge of the benefits and costs of wild deer and their management in order to identify priorities for future research.

We would note that (as outlined in the SNH paper: Economic Value of Deer Damage in Scotland) there are a number of areas where deer may cause negative impacts – in damage to agriculture, commercial forestry, in damage to amenity trees or farm woodlands or damage to conservation habitats/sites; through implication in the transfer of diseases to humans or their livestock or posing a more direct risk to public safety through their involvement in road traffic accidents. SNH also identifies a more subtle impact through a contribution of wild deer to greenhouse gas emissions.

Some elements of these impacts may be identified, both in terms of the direct costs of damage (where there is significant and measurable economic loss) or at least in the costs of management required to reduce or prevent (some of) these impacts. Others impacts have, in the past, proved rather more intractable in terms of being able to attribute an actual economic cost.

As well as appreciating these more negative impacts (whether economic or ecological), at the same time we also recognise that there are significant benefits to be derived from the presence of deer in the environment at appropriate density. Most obviously, a significant industry associated with deer-stalking (whether for private enjoyment by landowners and their guests, or through leased hunting) provides a significant contribution to the economy in many rural areas. Figures presented by PACEC (2006) estimated this (at that time) as of the order of £105 m per year (although it is noted that of this only £70.4m remained in Scotland).

In addition to this – and perhaps somewhat harder to put an actual financial value on - private stalking Estates are major employers in many of the more remote areas in Scotland, and thus stalking plays an important economic and social role in maintaining communities in these areas, even perhaps to the extent, in some cases, of actually enabling these rural communities to persist.

Deer are an important component of natural ecosystems and wider biodiversity. Deer in Scotland are viewed by the public as one of the most iconic species and thus have significant wider cultural value to the Scottish people (e.g. Stewart 2006). Grazing and browsing by red deer especially (alongside hill sheep) has been one of the most significant factors shaping the entire landscape of much of the Highlands, which is equally viewed by many as having iconic status. In the same vein, both through their own charismatic value and their effect in maintaining the uniquely Scottish landscape, deer contribute significantly to tourist interests in Scotland and the tourist economy, whether indirectly, or more directly through targeted ecotourism (which is becoming a very significant component of tourism in Highland areas).

Once again, while tentative values have been attributed in the past to some of these benefits, many have never really been taken into account in the overall economic balance of cost and benefit.

2. APPROACH

After an initial briefing meeting with SNH staff, further scoping the project and identifying possible issues for inclusion, this review has largely been carried out as a desk top study reviewing the overall benefits and costs of wild deer in Scotland as "headline" figures.

2.1 Costs

We offer an update and expand on data summarised in SNH's own report: "Economic Value of Deer Damage in Scotland" on the negative impacts of deer in Scotland on:

- commercial forestry
- amenity woodlands and farm woodland schemes
- agriculture and horticulture
- biodiversity, in terms of impacts on native fauna and flora.

Deer may also impose costs in terms of risks to public health and safety.
We evaluate:

- the actual risk of deer as possible vectors of diseases to humans and their livestock and assess the probability of any requirement for management intervention in this regard.

We also offer an update on:

- the costs associated with deer-vehicle collisions and costs of mitigation.

Finally we offer some consideration to the problems caused by deer in urban areas.

2.2 Economic benefits from deer

The economic benefits of wild deer are less well studied than their negative impacts. Studies to date have focused on highland stalking (PACEC, 2006); we will also wish to consider economic benefits/costs in other regions. There are many positive aspects of deer presence (public enjoyment; tourism/wildlife watching; provision of opportunities for commercial or recreational stalking); as well as ecological advantages of grazing at low densities – preventing scrub encroachment in open habitats and actively increasing diversity within woodlands where grazing is at comparatively low levels.

In this review we focus principally on the following areas:

- The value of deer as a sporting resource (evaluating and updating the economic values reported in the PACEC studies)
- The current and potential value of venison drawing on the work carried out by BASC and the Scottish Quality Wild Venison Scheme, as well as other sources
- Eco-tourism

We also explore the possible socio-economic value of wild deer in maintaining remote rural communities.

As part of this review we draw on experience of costs of deer and their impacts in other European countries where actual quantitative data are available – as well as the economic benefits derived from deer as a harvestable resource to offer some

comparative context to figures available for Scotland.

It is clear that in many instances both actual benefits and management costs may vary significantly, depending on land-ownership patterns, overall patterns of land-use and the actual management “model” applied (as for example, whether damage to commercial forestry is managed by fencing, or by culling, and whether that culling is carried out by retained personnel, or contractors - and so on).

Even these headline figures of overall costs may thus mask a great deal of internal variation; in terms of informing recommendations or policy to guide future management we feel it important to attempt to compare and contrast the advantages and relative costs of different approaches to management in different contexts. A considerable part of this review therefore focuses on the different costs and benefits of different management models which may be applied, rather than simply focusing on the overall headline figures.

3. COSTS

3.1 Deer in Commercial Forestry

3.1.1 General

Deer may cause damage in commercial forestry by browsing on restock sites (checking growth, or even killing a proportion of planted trees; or reducing stem quality and value through inducing the development of multiple leaders in conifers such as sitka spruce (Welch *et al*., 1991, 1992). Deer may also browse lateral shoots of more established trees or cause damage to stems through bark-stripping (e.g. Szczerbinski, 1959; Staines & Welch, 1984; Ratcliffe, 1989; Gill, 1992a, b; Büchsenmeister and Gugganig, 2004); or by fraying bark in territorial display, or in cleaning velvet from antlers (see reviews by e.g. Prior, 1983; Gill 1992, 2000; Putman, 1994, 2004; Pepper, 1998, Mayle, 1999). In continuous cover forestry systems, dependent on natural regeneration, deer may have a substantial impact on seed reserves and also have negative impacts on rates of subsequent recruitment through browsing of regenerating stems (e.g. Reimoser, 2001, 2003).

Such impacts may lead to significant losses, especially in the establishment phases, and significant economic costs either associated directly with those losses, or in attempting to reduce damage by protection of the crop (fencing or tree guards) or in culling to reduce deer presence.

On the other hand deer in commercial forestry, on both the Public Forest Estate (PFE) and private ground, can provide benefits in terms of guided and leased stalking, venison production and wildlife watching (e.g. Galloway Forest Park). However, over the life cycle of a forest plantation, it seems likely that, except in exceptional circumstances, deer management will always be a net cost for forest management in Scotland.

We had hopes to present a summary headline figure for the estimated total cost for damage to forestry caused by deer in Scotland. However the paucity of data and the age of the data currently available would make such an estimate meaningless. We therefore present a summary of the published data available and an indication of other data that we have identified that would allow such an estimate to be produced in future studies.

3.1.2 Deer on the Public Forest Estate

The most recent published study, Gill et al (2000) developed an analytical method to estimate accumulated bark damage at felling. Their estimates of accumulated damage ranged from 0.7% and 23% for Sitka spruce in Galloway and Argyll respectively and 41% for lodgepole pine in Galloway. They produced a yield which indicated a financial loss of 0.03 to 1.03% for the levels of accumulated bark stripping damage estimated for Galloway and Argyll respectively.

By way of comparison, after adjusting for inflation and exchange rates (1992), estimates of the costs of browsing range from £ 0.73 – 0.98 ha^{-1} yr^{-1} for browsing by moose in Sweden (Jantz, 1982) to £ 85.23 ha^{-1} yr^{-1} for red and roe deer browsing in Germany. Both of these estimates were intended to represent serious, but not catastrophic damage, but the variability in the results serves to underlie the difficulties in accurately assessing the cost.

Browsing on Sitka spruce has been found to impose an average delay in height growth of approximately one year in Scotland. [From studies in Glenbranter forest (Argyll), Welch *et al.* (1992) conclude that overall effects of red deer browsing on sitka spruce in Scotland are equivalent to a check of about one year in the time taken to reach a height of 80cm (beyond which little further browsing damage is experienced); this conclusion is supported by independent evidence from studies of Sitka spruce in enclosures, which at 5 years old, 10 years old etc. were found to have suffered the equivalent of approximately 1 year of growth (Welch *et al.* 1992).] Much longer delays have been recorded on other species and locations. If maintained until the end of a rotation, a one year delay in growth in Sitka spruce could result in a revenue loss of 3.4%.

Leader browsing can result in reduced log size and poor stem form. In addition: affected trees may be more susceptible to wind-shear or fungal attack (Mitchell *et al* 1977) and Sitka spruce trees which have had their leading shoot browsed once are more susceptible to future browsing damage (Iason *et al* 1996) with up to eight leader browsing events evident on some individual trees in Scotland (Welch *et al* 1991). Terminal bud browsing in sitka may also lead to growth of multiple leaders, reducing the economic value of the crop. The loss of revenue will depend on the relative sizes of each forked stem. Sitka spruce in Scotland losses were estimated to range from 0.8-8.4%.

Gill et al. (again following e.g. Welch et al. 1992; Staines, 1995) conclude that browsing is likely to be a more serious form of damage in economic terms, than bark stripping (although it is acknowledged (Staines, 1995) that bark-stripping damage, it may cause a check in growth and extensive wounding may facilitate secondary fungal infection, reducing the value of stained timber. In practice fungal infection is rarely apparent unless wounds exceed 200 cm^2 in area and in practice most wounds (at least on commercial conifers in Scotland) are very much smaller than this. Inevitably the relative loss of revenue from deer damage varies in all cases with stand growth rate, rotation length, and timber product prices.

On the basis of their review, Gill et al (2000) concluded that much of the cost of deer control might be offset against revenue from venison and that culling appeared to be a far more cost effective option than fencing, which could cost in the region of 10-30% of yield for Sitka spruce. Their view then was that the estimates of the cost of browsing on Sitka spruce suggest that fencing is unlikely be a cost-effective measure for preventing damage, unless it is to be applied in an area where little or no deer control can be carried out.

In their report, Gill et al. estimated that the employment costs for damage prevention - predominantly deer management in Scotland - was £1.22m with a venison revenue of £1.26m. The cost was based on the assumption that Rangers spent 60% of their time on deer management and did not include other elements related to deer control.

Forestry Commission Scotland currently manages approximately 660,000 ha of forestry of which only 17% (105,600 ha) is native woodland. In 2009/10 the cost of forest protection in Scotland (predominantly deer management) was £10.5m with an income of £1.1m (Forestry Commission Annual Report 2009/10). This gives a net cost of £9.4m. Further investigation would be required into the apparent difference in costs between the recent report and Gill et al, though we would note that they quote 'employment costs' and the recent report is a global figure.

3.2 Private Forestry

It would appear that there are few comparative figures currently available for the private sector. It would seem likely that the yield losses will be similar to those reported by Gill et al but without an indication of management effort and further impact assessment it is not certain.

It is clear from discussions with both public and private forestry practitioners that factoring in the cost of fencing and its contribution to deer management is problematic. A recent report for DCS (Hambrey et al, 2005) identified that the public cost of deer fencing is now well recorded, and available on request from FCS. Under the Scottish Forestry Grant Scheme from June 16th 2003, until 11 March 2005 the total fencing grant (establishment) paid was £312,616 which grant aided 59,127 meters of fencing. These figures cover a period of nearly two years, and at the start of a new grant scheme, so they should be compared against other figures with due care. A grant was also given for the removal of deer fencing and disposal of it to landfill. At about £1.98/m grant aid for this, the total public cost of removing the fencing described in the table above would be some £117,070.

A summary of the above impacts and costs are summarised at Table 1.

Table 1: Summary of impacts and costs of management

Impact	PFE loss (%)		Private sector		Comment
Browsing	3.4				On sitka spruce
Loss(death) of planted or regenerating stock					Unknown
Check to growth of planted or regenerated stock					Unknown
Multiple leaders etc. affecting economic value of crop	0.8-8.4				On sitka spruce
Bark stripping and fraying	0.03-1.03				In Galloway
Total accumulated damage	0.7 23 41				sitka in Galloway lodgepole pine in Argyll lodgepole pine in Galloway
(£)	Gross	Net	Gross	Net	
Management costs					
Stalking	1.22m 10.5m	-0.4m 9.4m			Based on employment costs only
Fencing Removal of fencing			156k 58k		Annually (2003-5)

We also note that Government grant aid for deer management to reduce deer impacts in the private sector in Scotland is forecast to be £2m in the period 2009-13 (Woodland Grant Activity Statistics to March 2010). This represents a cost to the public sector but clearly is also a benefit to the private sector.

3.2.1 European comparisons

In practice, national inventories of forest damage by ungulates are carried out elsewhere in Europe only in Austria, Hungary, Slovakia, Slovenia, Finland and Sweden (moose only); such surveys assess actual economic value of damage only and do not incorporate any element of management cost (Reimoser and Putman, 2011).

Where national data are available at all, data for forest impacts are variously recorded in different countries in relation to area damaged, number of trees damaged, proportion of damaged trees or/and monetary compensation figures. Some countries apply tolerance limits that should not be exceeded, e.g. Sweden (2 % of main stems per year – top shoot (leader) browsing, stem breaking, and bark stripping), and Switzerland (on 75% of forest area natural regeneration has to be ensured using locally adapted tree species without protective measures).

An alternative approach is to explore the level of compensation for game damage that must be paid by Government or by Hunter's Associations who are granted the game management lease on forest concessions (Reimoser and Putman, 2011). However, in the majority of cases, the actual compensation awarded is not an accurate estimate of true economic cost of damage because (in so many cases) compensation is nowhere near 100%. In Austria it is estimated that only about 20% of the calculated damage is paid by the hunters to the forest owners (F. Reimoser, personal communication).

To try and bring such examples up to the present day: official "assessment tables" (Pollanschütz, 1995) for Austria suggest that the monetary damage to forests by browsing, fraying and barking stripping is of the order of, on average, 218 Euro/ha yearly, with at least 10,000 km2 (25% of total forest area) damaged per year (Reimoser, 2000). Whereas at the countrywide level about 25 % of the Austrian forest area is more or less damaged per year, at a local or land-owner level damage can be much more significant, with up to 100% damaged area in small private forests.

Data from the Swedish National Forest Inventory 2003-2004 (which records primarily damage to Scots pine from moose) indicate a mean level of 12% for the country, with a range of 9-25 % between large regions (National Board of Forestry 2006). This figure means that on average 12 % of the main stems of Scots pine are damaged each winter in young forests (1-4 m tall) and with at least 10 % Scots pine. The accumulated damage level (all damage irrespective of time of the damage) is 40-50 %, i.e. 40-50 % of the pine stems have some damage caused by moose (National Board of Forestry, 2006).

3.2.2 Deer damage in Amenity Woodlands and Farm Woodland Schemes

In a study of damage by fallow deer to Farm Woodland Scheme plantations (Key et al., 1997), browsing damage at sites in Northamptonshire (n = 23 plantations) and Suffolk (n = 74 plantations) showed tremendous variation, with damage to terminal shoots ranging from 0 - 93%. In the Suffolk sites, there was a significant difference in susceptibility of different tree species, with Cherry, *Prunus avium*, the most preferred (72% showing signs of damage), followed by Rowan, *Sorbus aucuparia* (66%), Lime,

Tilia cordata (61%), Oak (37%) and Sweet Chestnut, *Castanea sativa* (25%). Preliminary analyses of these data suggest that the most important determinants affecting degree of damage were species composition, degree of cover and plantation size. Larger plantations had more damage than smaller ones and plantations that contained much cover or were adjacent to good cover were more prone to damage.

In general terms we may assume that amenity and Farm Woodland Schemes include smaller areas of woodland. Mayle (1994) concluded that individual tree protection is generally cheaper than fencing on areas of less than 2 - 5 hectares (where fencing costs are calculated on the basis of construction to Forestry Authority recommended specification; Mayle suggests that costs of whole site fencing fall below those of individual tree protection for fallow deer for areas greater than 0.7 -1 hectare. Clearly the break-point of relative cost will be different when costs of guards are set against costs of cheaper styles of fencing (Putman 2004).

3.2.3 Summary of costs in the Forestry sector

The Forestry Commission have attempted to summarise the costs of deer management for the establishment and protection of forestry and woodlands (Willoughby et al 2005) and provide updated costs which are included in Table 2.

Table 2: Deer control costs (after Willoughby et al, 2005)

Method	Cost per treated ha per operation	Total cost per ha for complete control[1]	Comments
Population control by shooting	£5-10 per year – very variable	£25-700 (5-70 years	Some income from letting stalking and venison sales is possible to offset costs. Cost varies considerably depending on whether stalking is let to third parties or carried out by owner, and the presence of fencing etc. Shooting is often required in any case in addition to other control measures, perhaps throughout the entire rotation, therefore direct comparison of costs may not be valid.
Fencing Permanent Temporary	£4-7 per m £400 (for 25 ha enclosure) £1313 (4 ha) £3200 (0.5 ha) £0.75-1.50 per m £60-120 (25 ha) £197-394 (4ha) £480-960 (0.5 ha)	 £320-400 (25 ha) £1050-1313 (4 ha) £2960-3200 (0.5 ha) £60-120 (25 ha) £197-394 (4 ha) £480-960 (0.5 ha)	The larger the area enclosed the lower the cost of fencing per hectare. Cost effective for large areas and high stocking densities.
Treeshelters	£1.70 per 1.2 m guard/shelter - £4250 per ha £2.20 per 1.8 m guard/shelter - £5500 per ha	£4250 £5500	Cost effective for small areas and low stocking densities.

3.3 Agriculture

There are very few data available on the actual impacts of deer on agriculture in Scotland although there have been a number of past attempts to assess agricultural impacts from deer in England or within the UK more widely (e.g. Putman & Moore, 1998; Putman & Kjellander, 2003; Wilson, 2003a).

Damage may be caused to arable crops or root crops (see Putman, 1986; Putman & Moore, 1998; Langbein & Rutter, 2003; Wilson *et al.*, 2009), but impacts are also of concern where they may reduce productivity of grass crops grown for hay or silage (Trdan & Vidrih, 2008), or where deer may remove the 'early bite' from fertilised grasslands prepared for turn-out of livestock after winter (e.g. Langbein & Rutter, 2003; Wilson, 2003b; Rutter & Langbein, 2005; Wilson et al, 2009).

Deer may also cause damage to more intensively managed crops (orchards and soft fruit, market gardens, nurseries etc). Such damage most commonly involves roe deer (84% of those instances where the species of deer was identified in one official survey within the UK: see Putman 1995; Putman & Moore, 1998), although increasingly reports are received of damage by fallow and red deer. Most horticultural ventures are by their nature relatively small-scale and engaged in the cultivation of high value crops; in consequence, any impact from deer is likely to be significant.

Many of the studies mentioned above, however, do not offer actual estimates of economic loss, reporting rather actual yield loss. More significantly, in relation to agricultural damage, it is recognised that impacts are often highly localised (with serious damage focused on individual farms, or even individual fields (usually those adjacent to close cover), rather than at a wider regional level; see for example Packer et al., 1999; Putman & Kjellander, 2003; Wilson, 2003; also Scott and Palmer, 2000). Thus regional figures for damage (for example) to arable crops will tend to record overall a rather low regional or national cost; yet this may conceal significant losses at individual farm level.

These individual losses are however hard to assess and (Doney and Packer, 1998) farmers themselves prove not the best at assessing this economic loss. It is clear that farmers in Doney and Packer's survey were equally likely to underestimate as to overestimate actual loss.

One part of the reason for this may be that apparent damage may not necessarily equate with actual long-term economic loss (see Putman, 1986; Putman and Moore, 1998, Doney and Packer 1998; Putman and Kjellander, 2003). Winter sown cereal fields in southern England might have 30% of the area of crop field grazed back by roe deer during the vegetative phase; physical damage may also cause sizeable flattened areas within the crop. However, this may in practice prove of no economic significance by harvest. In both Putman's, and Doney and Packer's analyses, damaged areas of the crop showed evidence of a compensatory increase in rate of growth to catch up with ungrazed treatments by the time of harvest. Thus actual economic significance of damage at harvest may be far less than would appear from assessment of the extent of actual damage caused at the outset. Similar results are presented by Kamler *et al.* (2005); Cerkal *et al.* (2006).

A further important consequence of the effective "patchiness" of impacts recorded is that even if it were possible to take available estimates of yield losses measured in individual case-studies, it proves difficult to convert these to economic loss at both a local and a wider landscape scale (because in effect, by definition, losses tend to be assessed on holdings reporting actual loss and cannot be extrapolated over a patchwork of areas of varying impact).

A separate approach towards some estimate of overall economic loss would be to identify threshold densities of deer above which damage to agricultural crops might be expected to be significant on particular farms and assess what proportion of agricultural cover in Scotland supports deer at or above such densities. However,

extensive review (Putman et al, 2011a) has failed to establish such density thresholds, noting, as above, that damage tends to be less related to density *per se* but characteristics of vulnerable fields/farms - especially those where palatable crops are planted close to adjacent cover (Putman et al., 2011a).

Despite the problems, a number of past estimates have been essayed for costs of deer damage to agriculture and Wilson's review (Wilson, 2003b) concluded that deer might be responsible for actual damage to the level of £4.3 million per year, with £1 million each in east and southwest England.

This estimate included the cost of damage caused by deer to cereal crops, grassland, root, fruit and vegetable crops. However estimates were based on costs of damage to cereal alone and extrapolated to other crop types, including vegetable and fruit crops, as no direct estimates were available of the costs of damage to these other crop types. No current data on the amount of damage done by deer to horticultural crops were available to improve the estimate of £4.3 million.

It is difficult to extract from this possible damage costs specific to Scotland. However, to any such costs it is also necessary to add costs of authorisations of out of season and night shooting licences in relation to the protection of agricultural crops. There were 213 Night Shooting Authorisations issued for the year 2009/10. The average cost to SNH for administration of these authorisations is in the region of £20 - £25 per application. This gives a total annual cost of £4260-5325. SNH estimate that the cost of administering out of season shooting licenses is of a similar order (pers comms MacGugan/Watson) giving an annual total of approximately £10,000.

Conclusions above that in general, the effects of deer on agriculture are not of economic significance at a national or regional scale would appear to be true of Europe more generally: where although indeed impacts may be significant at the level of individual farms or even individual fields, ungulates – with the possible exception of wild boar - do not constitute a significant economic problem on a regional or national scale (see Putman & Kjellander, 2003; Reimoser & Putman, 2011).

A review of surveillance systems across Europe (Reimoser & Putman 2011) notes that no European country actually operates a formal programme of monitoring of damage to agricultural crops either at a regional or national level. Some regular level of surveillance is carried out only in France, Finland, Hungary, Slovakia, Slovenia and Switzerland.
In most countries, there is no system of regular or stratified monitoring of agricultural damage and monetary compensation figures are the only available indicators of actual damage levels. Even then, some countries do not have any information about game damage in agriculture; either no compensation is paid to the farmers or such payments are not registered on a regional or country-wide level (e.g. Austria).

In general however, it would appear that damage due to *cervids* is rarely of significance at a national level. This is not to suggest that these animals do not cause significant damage; rather that, as already noted, such damage tends to be extremely patchy and localised – significant on a farm by farm – or even field by field – basis rather than on a larger, regional or national scale.

Even where instantaneous grazing impacts appear high, loss of yield is often negligible due to compensatory growth within the crop (see above). Thus, such published data as are available suggest that *overall,* loss of yield in most arable crops due to grazing of vegetative parts of the plants by roe deer was likely to be insignificant.

In the Czech Republic, loss of vegetative parts of maize crops during the summer months resulted in a decrease in fresh weight of ears at harvest of only 2.6%. Since, in addition, grazing by deer affected less than 0.7% of the crop, the effective loss of yield for the crop as a whole was less than that at 0.15% (Obrtel and Holisova, 1983; Obrtel, Holisova and Kozena, 1984).
Kaluzinski (1982) calculated that despite high densities of roe deer in agricultural areas in western Poland, consumption of vegetative parts of cereal crops outside the growing season was <1% and would not significantly influence yield - and that, although later damage, involving direct removal of ripening ears caused measurable and irrecoverable loss, it was nonetheless an insignificant proportion of the crop as a whole.

Recent data recorded for damage to cereals in different counties in Sweden confirm that here, too, the overall area of crops reported as suffering damage (as a proportion of the area grown in any region) never exceeds 5% and is usually lower than 1% (Putman and Kjellander, 2003). Again however, damage at a local or farm level can be significant, with up to a 26% loss of yield in unprotected oat crops against fenced controls.

In addition, in most of the studies summarised in these paragraphs, we are dealing with damage largely due to red, fallow and roe deer. In Sweden, as elsewhere in Scandinavia, much of the damage recorded is due to the significantly larger moose. Of damage reported here for Sweden, over 98% is attributable to moose - and, as elsewhere in Europe, recorded damage from other species is low).

Finally, we should note that while damage levels reported from deer species (even moose) are comparatively low, far more significant levels of damage may be experienced – and on a wider, regional scale, where there are established populations of wild boar (e.g. Schley and Roper 2003; Arnold, 2005; Wildauer, 2006, 2007a, 2007b; Apollonio *et al*., 2010a).

3.4 Impacts on Native Biodiversity

In considering impacts of deer on native biodiversity we are shifting into a somewhat different dimension, in that these impacts are largely ecological rather than economic - and, as emphasised by Reimoser and Putman (2011) impacts are simply impacts and not intrinsically good or bad.

There may be scope for taking an ecosystem services approach in analysis of what are the more general costs and benefits of the relationship between deer and their ecological environment - in terms of the way they may affect support services - but we suggest this is beyond the scope of the current scoping study.

In practice, impacts become damaging when they are seen to conflict with (human-determined) management objectives for a given site (Reimoser and Putman, 2011). In such context, actual negative impacts (through grazing/browsing and/or trampling) are primarily noted within sites designated as of special conservation interest. Similar impacts - (such as extensive browsing or regeneration of upland birch woodland, for example) - if occurring on sites where conservation is not a major objective, are clearly of less concern to managers and are thus not viewed as necessarily damaging since they do not conflict with management objectives and there is no management cost involved in reducing or mitigating such impacts. We thus restrict consideration in this section to impacts on designated sites.

Red, roe and sika may all have significant impacts within conservation woodlands

(whether broadleaved or coniferous) through suppressing regeneration and/or damaging established trees by browsing, bark-stripping or fraying - although most ecological concerns relate to suppression of regeneration. On open-hill, upland habitats, while there may be some contribution from sika in certain locations, primary concerns are about grazing and trampling impacts of red deer.

By contrast to woodlands, some level of grazing/browsing may be required for maintenance of open communities, explicitly to prevent encroachment by scrub and succession to woodland. Such communities may thus be much more "tolerant" of grazing impacts before these may conflict with wider management objectives - although high levels of grazing and trampling remain a cause for concern in many areas (see for example Callander & Mackenzie, 1991; SNH/DCS, 2002).

In this context, trampling impacts appear to be of more immediate concern than the effects of grazing – which may suggest that damaging impacts may occur at a lower threshold of deer utilisation/ deer density than might be anticipated from consideration of grazing impacts alone (Dayton, 2006). In addition it should be stressed that grazing and trampling impacts may affect different habitats and may not always be co-incident.

In the same way we should note that impact levels which are acceptable for one community-type may be too great (or too low) for maintaining other habitats in the same area in favourable condition, and thus (with deer densities "adjusted" at a landscape level), some compromise may be inevitable. For blanket bog and flushes in particular there may be negative changes resulting from moderate impacts, whereas for grassland communities moderate or low impacts may not be desirable (MacDonald *et al*., 1998).

Apart from an un-quantified impact on ecosystem services (paragraph 6.2), because such impacts are of concern only where they conflict with specific management objectives for a given site, economic costs of prevention or mitigation are typically associated with designated conservation sites (paragraph 6.3). We therefore attempt to summarise costs involved in restoration of SSSIs or SACs which have been classed, during routine Site Condition Monitoring, as being in unfavourable condition due to herbivore impacts (and specifically red deer). Costs of initial Site Condition Monitoring are not included since SNH has a statutory obligation to carry these out anyway; our analysis focuses on follow-up costs where such sites are regarded as being in unfavourable condition.

Recent data released as a result of Parliamentary questions indicates that over the past 5 years (2005-10) there have been 12 Section 7 agreements covering 9887ha. The financial costs to DCS/SNH of implementing these agreements total £721.969k, including £160k for direct assistance in culling operations in Caenlochan. This is an average annual expenditure of £144.4k at a cost of £2.63 per ha. The costs on all 62 Joint working Sites over the same period was £1,247,568 or an average of £249,513 per year or an average cost of £1.68 per ha.

3.5 Other ecological costs

We would note that deer may also have negative impacts on other elements of wider diversity, since effects of grazing and browsing on the structure and species composition of vegetational systems may have knock-on implications on other species of animals and plants dependent on that same vegetation (see for example: Smit and Putman, 2011 for review). Such effects are probably not quantifiable in economic terms.

However the economic costs of non-native species such as the introduced Japanese sika deer may be more tractable. Aside from effects on economic forestry (considered above in Section 4), expanding populations of sika potentially cause a threat to native biodiversity by hybridisation with native populations of red deer (see, for example, recent references: Goodman et al., 1999; Pemberton et al., 2006; Senn and Pemberton, 2009; Perez-Espona et al., 2009).

The extent of current introgression is still debated as is the degree to which hybridisation continues to occur (see for example Perez-Espona et al., 2009). Perhaps more significantly, introgression of sika genes into a native red deer herd is only of significance to the extent that that red deer population is truly of native origin; we know that many populations have been exposed in the past to introductions of individuals from other sources (continental European stock or English park stock) in misguided attempts to try and improve antler quality, and in truth we have no good "handle" on the extent to which this has already compromised the genetic integrity of native populations. Perez-Espona et al (2008) suggest little evidence of non-native genetic markers in red deer populations of the central Highlands, but these studies were largely carried out on maternally-inherited mitochondrial DNA, whereas we know that most introductions were in practice of stags (Perez-Espona et al (2009); see also Linnell and Zachos, 2011).

To an extent, however, this debate is perhaps academic, in that Government has sequentially adopted a policy of trying to contain the expansion of sika populations through targeted cull and subsequently of establishing refugia for "native" red deer on islands, or in other remote and less-accessible areas from which sika can effectively be excluded. Enforcement of this policy will inevitable produce a cost, but will be extremely difficult to calculate and is probably best addressed through the overall costs of wildlife management in the SNH budget.

3.5.1 Disease transfer to humans and domestic stock

Deer are potentially implicated in the transmission of Lyme disease (*Borrelia burgdorferi*) to humans. However we should recognise that their role is somewhat peripheral and deer populations merely contribute to the maintenance of the disease organism and its transfer, by providing a reservoir of infection and providing an abundant alternative host in maintenance of populations of the tick vector (*Ixodes ricinus*).

Pichon et al (1999) suggest a positive link between tick density and deer density in woodland in France, while in England and Wales, increasing incidence of Lyme disease has been attributed to a rise in the deer population (Barbour, 1998), although the evidence in anecdotal. Accordingly, areas with high deer densities are considered high-risk areas for Lyme disease (Barbour, 1998; Pichon et al., 1999). However, more recently published studies suggest that there is no close correlation between tick abundance and abundance of either deer or sheep. Thus in some instances where sheep have been removed from the hill, or stringent efforts have been made to reduce deer populations, abundance of tick does appear to have declined; but in other cases under the same treatment, tick populations have remained unchanged or have shown increased number. Equally, in areas where no reduction has been made in large herbivore populations, tick numbers have declined in some cases and remained constant or increased in others (Scharlemann et al. 2008).

It is apparent that large herbivores are in any case not an obligate part of the system; both tick and spirochaete (*Borrelia*) may be adequately maintained in a narrower host

cycle consisting merely of small rodents or small rodents and medium sized mammals such as hares (e.g. Randolph, 2007; O'Connell, 2007; Ostfeld and Keesing, 2010). **Thus while we explore below the actual costs to the economy of Lyme disease, it is not clear what proportion of that total cost (if any) should be attributed as an actual cost associated with deer.**

Health Protection Scotland have reported that reported cases of Lyme disease (*Borealis burgdorfori*) in Scotland rose from 37 to 605 over the period from 2000 to 2010 (http://www.documents.hps.scot.nhs.uk/giz/10-year-tables/lyme.pdf).

In a study in the US (where mean incidence of Lyme disease is 4.73 cases per 100,000 population; Maes *et al.*, 1998) the cost of illness associated with the cases of Lyme disease in the US was estimated at $2.5 billion over 5 years, equivalent to $500 million per year, including both direct medical and indirect costs. Given an estimated 13,750 cases per annum. The cost of illness associated with each case was $36,372, or £24,248, (£1.00 = $1.50).

A cost benefit analysis of deer in the East of England (White et al, 2004) reported that there were 48 cases of Lyme disease in humans in the East of England over the 13 year period 1986-1998 inclusive, an average of 3.69 per year. Although the personal costs of health care are likely to be higher in the US than in Britain because of the dominance of private sector health care, the overall cost to the nation would be similar.

Using the cost of illness associated with a case of Lyme disease of £24,248, this means that the cost of Lyme disease to humans in the East of England over the period 1986 to 1998 was £1.16 million, or an average of £89,000 per year.

Using the same calculation this would suggest a cost in Scotland for 2010 alone of over £14m. However we would reiterate that these costs cannot be unequivocally attributed to deer. The tick vector life-stage which infect humans is an earlier nymphal stage than those usually present on deer (which are themselves an end-host) and thus usually derives from a small rodent host rather than from a deer. In addition, as above, while deer may be loosely implicated in the maintenance of populations of both disease and vector in the wider environment, both tick and disease organism can persist in the absence of deer (or any other large mammal host (paragraphs 7. 2 and 7. 3 above)).

Similarly, an exploration of the implication of roe deer in the spread of tick-borne encephalitis in continental Europe concluded that although there was some relationship between tick density and prevalence of the disease and roe deer population number, this was a comparatively minor factor compared to changes in vegetational structure that improve habitat suitability for the main TBE hosts (again, small mammals; Rizzoli et al 2009).

A very similar situation attends the possibly implication of deer in maintaining tick populations which may subsequently (again at a different stage in the life-cycle) infest grouse. While it is clear that infestation of chicks by tick is one of the (many) factors contributing to reported declines in grouse populations - which clearly may have considerable economic significance for large parts of the Highlands where grouse-shooting is of major importance - most recently published studies suggest that there is no close correlation between tick abundance and abundance of either deer or sheep (Scharlemann et al, 2008; and above: paragraph 7.2).

Deer may also be implicated in the transfer of diseases to domestic livestock. Thus

deer are known to be variously susceptible to Foot and Mouth disease (FMD; e.g.. Fletcher, 2002). Roe deer are particularly susceptible with high mortality in those cases where the disease is contracted (e.g. Forman and Gibbs, 1974). In practice however deer appear to be terminal hosts, because of relatively low contact rates and transmission rates within populations; Defra concluded that wild deer populations did not pose a significant risk during the most recent FMD outbreak (pers comms Watson/Hartley).

Probably the most significant current risk in terms of disease transmission within the UK is related to the transmission to cattle of bovine tuberculosis (bTB). Risk assessments of the role of wild deer in the spread of bTB to cattle have been commissioned by DEFRA (Risk Solutions 2006; CSL 2006) and a development of these in the form of a modelled quantitative assessment of the risk posed by deer and badgers to cattle in southwest England has been published by Ward *et al*. (2008a).

In this report the authors attempted to calculate the basic reproductive rate of the disease (R_0) in order to model whether a given deer population represented a dead end host (an infected individual would not infect others of any species), a spill over host (infection of the population requires continual re-infection from an external source) or a maintenance host (self-sustaining infection within the population).

Four species of deer (red, fallow, roe and muntjac) were modelled, together with badgers. Deer population densities were based upon the 2007 GWCT/BDS survey and data from the Deer Initiative. The bTB prevalence was taken from Patterson (2008). Ward et al conclude that for red and roe deer, even assuming virtually 100% bTB prevalence, population density would have to exceed 91 km^{-2} for red and 200 per km^2 for roe before maintenance host status would be achieved. In contrast, fallow appeared to be able to act as maintenance hosts at populations as low as 25 km^{-2} when prevalence rates were approaching 100% and at 75 km^{-2} when only 30% were infected.

The authors emphasise that these figures are based upon assumptions of disease transmission coefficients that are uncorroborated and that density limits were set according to maximum densities seen in the field at local rather than landscape density levels. Despite this it seems unlikely that deer population densities in Scotland would ever reach levels at which this might be a real risk.

Finally we offer some consideration to blue-tongue. The bluetongue virus (BTV) is a pathogen that infects both domestic and wild ungulates (Fernández-Pacheco *et al.*, 2008; Ruiz-Fons *et al.*, 2008; Mintiens *et al.*, 2008) in Europe. Since the introduction of the causal agent in Europe and the spread of the disease are comparatively recent, we have only recently had the opportunity to study the infection in wild deer species and the potential pathways for cross-infection. Climate change has been proposed as a reason for the spread of bluetongue (Purse et al., 2005) and measures to control or eradicate bluetongue virus (BTV) from Europe have been widely implemented.

The implication of wild deer as a potential reservoir for the bluetongue and possible agent in dispersal is little studied. BTV is able to replicate in red deer after experimental infection, causing a long-lasting viraemia comparable to that of domestic ruminants (Gortazar *unpublished data* and see Ferroglio et al, 2011). However, there is no work available to date on the dynamics of the disease in free-living deer populations.

3.6 Deer Vehicle Collisions

3.6.1 Deer on the road network

It is estimated that in Europe as a whole there are currently between 0.5 and 1 million traffic accidents involving deer each year (Langbein *et al*., 2011). Within the UK alone, there are between 42,500 and 74,000 deer-vehicle collisions per year, resulting in some £17 million of material damage plus additional economic impacts near £30M incurred annually from between 400 to 700 deer-related road traffic accidents involving human injuries (Langbein & Putman, 2006; Langbein 2007) . Given that, of the estimated total number of deer-vehicle collisions per year within GB, 18-20% occurs in Scotland, we may assess total cost of material damage and human injury to be of the order of £9.4 million.

Table 3 shows cost levels up-rated to 2009. These figures incorporate allowances for various components such as 'lost output', medical and ambulance and human costs, and police, insurance etc.; but we are as yet unclear as to how they are calculated.

Within the UK a detailed survey of deer-vehicle collisions at a national scale was initiated over the period 2003-2005, in Scotland (Langbein & Putman, 2006) and in England (Langbein, 2007) collecting information from a wide range of potential sources. Monitoring has continued since in England for 2006 to 2011, and was later recommenced in Scotland (2008 to 2011), focusing on a more restricted set of information sources (such as trunk road up-lifts, human injury accidents, call to animal welfare organisations to attend to injured deer at roadsides) in order to maintain an index of change between years and identification of local hotspots (Langbein, 2009).

Table 3: Average Value of Prevention per reported Casualty and per reported road Accident: GB 2009 (Road Accidents Great Britain 2009)

£June 2009

Accident/casualty type	Cost per casualty	Cost per accident
Fatal	1,585,510	1,790,200
Serious	178,160	205,060
Slight	13,740	21,370
Average for all Severities	47,740	68,320
Damage only		1,880

Since the re-start of the project in Scotland in May 2008, one of the most significant increases in records are the numbers of DVC reports obtained from Trunk Road Operating Companies. In the Tables below it is apparent that although in 2003-2005 there was almost no input for the SE-Scotland, even if we exclude that region from all comparisons, the average numbers of trunk incidents reported by NE+NW+SW in 2009 (487) was over 50% higher than in 2005 (322); and for just all 4 trunk road

regions puts together the project is now receiving around 700 records a year. What part of that increase is through greater success in recording/ extracting these data from the trunk companies and what represents an actual increase in DVCs is difficult to say, but it very likely that it is at least part due to a real increase in incidents.

Costs of accidents in Table 2 do not incorporate extra losses through diffuse impacts or indirect costs such as costs of carcase recovery, or attendance at injured animals by vets or the SSPCA; lost venison (and potentially trophy) income.

In 2008 and 2009 SSPCA reported an average of 305 call-outs a year relating to RTAs compared to just average of 160 per year in 2004 & 2005; even at this average of 305 incidents per year the SSPCA calculate that this incurs a cost of £30,500. Clearly this is a minimum estimate overall since SSPCA are involved only in a proportion of cases where injured deer may be attended at the roadside.

In terms of other costs these were estimated by Langbein in an (unpublished) presentation to the Mammal Society Conference on "Mammals on Roads" in 2003, as Collection & Disposal of carcases: £0.75m; Lost venison £1m, over the UK as a whole.

Given that, of the estimated 42,500 and 74,000 deer-vehicle collisions per year within GB, 18-20% occur in Scotland (pers comms Langbein/Watson) we may thus derive an estimate for these additional costs of RTAs for Scotland alone as £315-350k.

3.7 Costs of physical mitigation

Transport Scotland (pers comms Corby/Watson) are trying to identify the costs of routine physical mitigation employed on the Trunk Road network. We currently have no data available.

We are aware that in 2009/10 there were 3 roads classified as Priority Sites and each had panels set up under Section 5 of the Deer Act. These were: A835 Garve; A87 Lochshiel; and the A82 Glencoe. Each ran for 18 months and SNH estimate that their direct costs for these Priority Site operations was £8k. A number of physical mitigation measures were deployed including signage and fencing at a capital cost of £47k; in addition there was some vegetation clearance carried out by Trunk Road contractors for which costings were not available and a small amount of targeted deer control done by FC Scotland and Atholl Estates. SNH estimate that the total for these Priority sites over the 18 month period was in the order of £60k.

3.8 Diffuse Costs

In addition to the direct and indirect costs identified above there are a number of more diffuse costs that can be attributed to delays caused by DVCs, such as lost productivity, stress etc. A parallel review for SNH is investigating this issue for the Scottish Trunk Road Network (Steiner et al, 2011). The draft conclusions suggest that there are well established techniques to quantify the value of wasted time, increased accident risks and to estimate the increased vehicle operating costs. Other costs (such as stress or lost productivity) require a detailed understanding of the nature of each individual's journey. In the report they used four case studies to show, amongst other information, that a single DVC occurring on a busy part of Scotland's road network can have substantial consequences. Three of the case studies examined would generate quantified indirect costs following a four-hour closure of a main link of the Trunk Road network of at least £75,000.

3.9 Deer on the rail network

Deer are implicated in collisions with trains but anecdotal evidence has suggested this was a relatively minor issue. However the recent severe winter has highlighted the potential scale of the problem in the UK. We have identified approximately 200 reports of incidents for the period 2008 to early 2010 in Scotland (pers comms Langbein/Watson). In parts of the country there may well be mitigation measures (such as fencing) in place which are helping to keep deer off the network and reduce the risk to operators, passengers and deer, but we are not currently aware of the distribution and effectiveness of these. There are clearly costs resulting from the loss of hunting opportunities and the resulting venison and in addition there are financial implications from the delays to railway services. Whilst we have data for the number and distribution of incidents, there is currently no data available for the costs, but such data could be obtained in the future.

3.10 Problems caused by deer in urban contexts

Deer are increasingly becoming established within urban areas in the United Kingdom, where their impacts may cause potential conflict with human activity. In addition conflicts are occurring in areas where human activities and habitation impinge on historic and current deer range. There has been increasing colonisation of larger towns and cities over recent decades by, in particular, roe deer which are now established well within the centres of cities such as Glasgow and Edinburgh, with a range of impacts including deer-vehicle collisions (above) and damage to gardens (see, for example, Chapman *et al*., 1994; Coles, 1997), and cemeteries. There may also be issues related to animal welfare, with the physical condition of deer established within urban sites often being poor by comparison to deer within more natural habitat (Green, 2008).

Little formal analysis has been made of this aspect of deer impact, although some work is now being undertaken in an attempt to collate some information (Dandy et al. 2009). In general damage to gardens is addressed by individual homeowners electing to plant less palatable species or individually fencing their properties; however there may be significant incidental costs associated with attempted capture and removal of deer from gardens or industrial premises. To our knowledge these are largely borne by the private sector and have not been quantified.

We are aware that approximately 30-40% of the SSPCA call-outs relate to non-RTA deer related incidents. The two major causes of incidents are dog attacks and the general public finding or removing 'orphan' deer. SSPCA have indicated that the average cost for each incident is in the order of £100 pers comms) giving a total annual cost of up to £12k. As indicated above this cost is currently funded through general charitable donations.

3.11 Regulation and administration of wild deer

Until recently the Deer Commission was charged with regulating and administering the system of wild deer management in Scotland. In 2009/10 the cost of this work was £1.8m. We have identified in Section 6.8 that these costs were directly attributable to Section 7 authorisations, other Joint working and the Priority site process. These costs have now been absorbed into the SNH budget. We believe that it is appropriate to incorporate the remaining costs of the DCS function into any discussion of the costs and benefits of wild deer.

3.12 Summary of costs and assessment of quality of data

In Table 4 we have summarised the costs of non-forestry impacts set out above that we have identified under the headings above.

Table 4: Summary of non-forestry related impacts and costs.

Area	Impact	Costs	Comment
Agriculture	Loss of crops Authorisations	N/K £10k	 annually
Biodiversity	Ecosystem impacts Authorisations	N/K £250k	 annually
Other Ecological impacts	Hybridisation Policy Enforcement	N/K N/K	
Disease	bTB testing Lyme disease	N/k £14m	 In 2010 however the percentage of this figure that can be directly attributed to deer is uncertain
DVCs on the road	**Human injuries** *Vehicle Damage* **Collection & Disposal** **Lost venison** SSPCA call outs **Priority sites 2009-10** Physical mitigation SNH costs Diffuse costs	£28m >£11m £135-150k £180-200k £30k £47k £8-13k N/K	Based on on-going study, so assumed to be timely and accurate.
DVCs on the rail network		N/K	
Deer in the urban context	**SSPCA call outs** Police call outs	£12k	Annually
Monitoring, regulation and administration	**SNH/DCS costs**	£1.8m	Includes authorisations for protected sites

4. BENEFITS

The brief for this project indicates that in understanding the economic benefits of wild deer and their management in Scotland, SNH are interested in the widest definition of economic benefit. As noted at paragraphs 1.5-1.7 there are many positive aspects of deer presence (public enjoyment; tourism/wildlife watching; provision of opportunities for commercial or recreational stalking).

Both red and roe deer are species native to Scotland and thus part of the wider natural biodiversity. Deer of all species (native and non-native) play an important part in maintaining those native plant communities which require grazing, browsing and disturbance to maintain or promote diversity. Deer may also play an important role as seed dispersal vectors and therefore facilitate the colonisation processes and populations of various plant species (Eycott *et al*., 2007). Without recourse to some form of ecosystem services approach however it is difficult to attach economic value to these ecological roles.

As noted at paragraph 2.7, in this review we focus principally on the following areas:

- The value of deer as a sporting resource
- The current and potential value of venison
- Eco-tourism

We also examine the wider socio-economic value of wild deer in maintaining remote rural communities, and the cultural importance of deer (as an iconic emblem of wild land) to the Scottish public, although these, also, are aspects to which it is more difficult to attach an actual economic value.

4.1 Direct Benefits

4.1.1 Stalking

Red deer, in particular, make a significant contribution to the economy of a number of land-holdings in the North and West of Scotland, often comprising the major form of land use over wide areas and making a significant contribution to the fragile economies of remote communities. More recently, sika stags have also become a valuable sporting asset, currently commanding higher prices than red stags in some places. The majority (90%) of respondents to the PACEC study who manage deer do so in order to ensure the deer population does not exceed the resources of their habitat. Culling for the primary purpose of selling the meat is less common. The report suggests that venison production is generally a by-product of deer management, although it produces a significant income stream. In conclusion PACEC considered the total value of stalking to the Scottish economy to be of the order of £105 m per year (paragraph 1.5). It is noted however that of this total only an estimated £70.4 million remains in Scotland.

The value of wild venison to the Scottish economy can be estimated using published venison sale figures collated by the DCS (DCS, 2006) of around 50,000 carcasses.

Based on an average of carcass weight of 40 kg priced at £1/kg, the annual value of venison sales is approximately £2 million (MacMillan *et al*. (2008)). If downstream processing is included, the contribution of venison to the Scottish economy rises to £10 million. We are aware that the introduction of the Game Meat Hygiene Regulations allowed exempt sales of venison in England and Wales and a proportion of venison shot in Scotland is sold in England.

In 2004 BASC estimated that 85% of red deer but only 38% of roe deer carcasses

are sold to AGHEs. This suggests that there is significant scope for increasing the income generated through venison sales.

Figures in MacMillan *et al*. (2004) indicate that 54% of all red deer stags and 18% of all hinds are shot by paying clients, and based on average fees of £500 per stag and £100 per hind, would suggest an annual aggregate revenue in Scotland of £5.2 million from let stalking.

The report subsequently commissioned by ADMG (PACEC 2006) examined the contribution of deer management to the Scottish economy. This was expressed in terms of employment (FTEs) and economic value. The report looked at both direct and indirect impacts of deer management, including the range and extent of relationships between deer management and other sectors of the economy. The report recognises that deer management in Scotland is undertaken for population control, environmental reasons and for sport and separates the employment and economic benefits into 'Sporting Shooting of Deer' and 'Deer Management (not for sport). The authors suggest that direct employment for deer management in the private sector (both sporting and non-sporting was 966 FTEs. PACEC also suggest that deer management indirectly employs 1554 FTEs. This suggests an overall total of 2520 jobs in Scotland associated with deer management.

This is summarised in Table 5:

Table 5: Deer Management in Scotland: Scottish Employment arising from Deer Management in Scotland (FTEs)(from PACEC 2006)

	Sporting Shooting of Deer	Deer Management (not for sport)	Deer Management (including sport)
Direct employment	840	126	966
Indirect employment	1,440	114	1,554
Total jobs in Scotland	2,280	240	2,520

This provides Gross Value Added (GVA) totals of £15.7m direct and £55m indirect.

The other relevant key findings from the report are related to individual sites and include:

- An average of 1.8 stalkers (or 0.9 Full Time Equivalents) are required per shoot site (where the average size of shoot site was 7,984 ha) in order to carry out the necessary deer management.
- The average (mean) operational expenditure per site was £54,468 per annum, of which £25,726 (47%) was spent on staff (including sub-contractors).
- The typical operational expenditure (including wages) relating to deer management (not for sport) per site was £27,430 per annum, with £26,184 staying in Scotland.
- The typical (median) capital expenditure relating to deer management (not for sport) per site is £2,240 per annum, with £948 staying in Scotland. On average, each year £520 is spent per site on fencing alone.
- The average (mean) income per site for the sale of deer carcasses, processed venison and other deer products is £6,372. In addition, respondents estimated that an average of £4,537 was saved per site on the prevention of damage to crops, horticulture woodlands and the natural environment as a result of deer management.

In more Central or lowland areas, roe stalking (primarily in commercial forestry) may also provide considerable economic benefits to landowners Traditionally the value of roe stalking, in common with other shooting activities, has been calculated on a 'per hectare' basis and this continues to be the case in private sector with ground being leased by agents for at least £3.50 per ha and in some cases depending on accessibility and the likelihood of other species (red, sika) being present dictating the final price. Prices in excess of £10 per hectare are not unknown. However the Forestry Commission currently give guide prices for stalking leases based on the required/expected cull. The current value is £100 per deer.
This variation of methodology in setting lease prices and the variation in market response makes any accurate external assessment of the value of individual and aggregated leases extremely difficult and we would suggest the PACEC totals may give the best indication of the current overall contribution of this growing area.

4.2 Indirect employment and secondary products

The PACEC report outlines a model economic framework to identify and quantify upstream and downstream impacts of deer management in Scotland. We were specifically asked to look at income from secondary products such as horn, but the research suggests that there is only a minor income from other carcass related products (such as antlers) which currently equates to less that 2% of the income from venison. This would suggest an annual income to estates of approximately £40k.

4.3 Capital costs/values

Red deer are especially important in terms of their contribution to the capital value of sporting estates. The Deer Commission for Scotland (DCS) estimated that, on average, every stag shot on a sporting estate adds approximately £22,000 to the capital value of the estate, and every hind £2200 (DCS, 2000). Based on average annual cull figures of around 50 000 over the last 10 years, and an average stag to hind ratio of 1:1.9 (17 000:33 000), the capital value of red deer managed for sport in Scotland in 2000 was therefore in the region of £450 million; this figure includes all stags shot, including those by the owner, employees and paying clients (MacMillan *et al*. (2008)).

4.4 Ecotourism

The value of wild deer in relation to non-consumptive activities is difficult to judge.

A recent report commissioned by SNH (Bryden et al 2010) recognises that conceptually it is possible (though very difficult) to assess the impact of a single feature (e.g. deer) – i.e. visitors could be asked whether their visit to Scotland were in any way related to the presence of deer, but to ask them to imagine Scotland without the countryside and landscapes in which deer can been seen would not be possible.

However, using this approach Bryden et al concluded that the total visitor spend attributable to nature based tourism was £1.4bn with an associated 39,000 FTEs and an associated income from employment of £0.8bn. Of that total 'wildlife watching' generated an economic contribution of £138m and supported 3943 FTEs (by comparison the totals for field sports were £147.3 and 4209 FTEs).

However a recent report by DCS (*Challenges and Opportunities of Deer Watching as a commercial activity: A Critical Review*) looking specifically at 'deer watching' as the sole focus of an activity or included as part of a wider "package" of wildlife watching could only identify 40 potential 'deer watching' providers. Of the 14 respondents who offered dedicated deer-watching activities, 43% described the demand for these

activities as high, 29% described as medium demand and 29% felt the demand was low. Participants were asked to provide information about the numbers of people taking part in deer watching activity throughout the year and about the average spend per head. Using these figures we estimate that revenue generated by these enterprises is approximately £107-113k annually.

The disparity between the two reports highlights the complex nature of nature tourism and Bryden suggests that specialist wildlife watching and committed field sports participants could be considered as the most dedicated nature based tourists and whilst it is clear if there were no deer, the hunters would not come, it is difficult to assess the impact of fewer or no deer on the wider nature tourism industry.

4.5 Social benefits

Both consumptive and non-consumptive exploitation of wild deer populations offer direct benefits in terms of providing employment, whether such employment is retained and permanent (Forestry Commission rangers, retained stalkers /gamekeepers on private Estates), through contractors, or in the provision of self-employed opportunities (eco-tourist enterprises).

Perhaps more significant than the actual overall economic value of all such deer-related employment, the employment which is provided is focused heavily within remote rural communities which may have few other job-opportunities, and in such areas may make a significant contribution to the overall level of employment - in effect keeping a reasonable number of jobs in these more fragile remote communities and thus helping to sustain the viability and social structure of the entire community. Employment of at least some members of such communities within the deer sector also brings to, or retains within those communities a range of transferable rural skills and a valuable knowledge base, which may contribute to wider social benefit, even beyond the immediate local community. [Thus for example, many mountain rescue services, or other local emergency response teams depend on volunteer support from professional stalkers or rangers, who have intimate knowledge of the local geography and terrain].

However we are not aware of any work that has attempted to allocate costs to these diffuse benefits.

4.6 Summary of benefits and assessment of quality of data

Table 6 summarises the available data on the benefits derived from deer and their management in Scotland and also identifies where data is unavailable.

Table 6: Summary of benefits derived from deer and their management at a national level.

Benefit	Area	Value	Comment
Stalking	Land values Leasing Direct Employment Indirect employment	£450m £5.2m £15.7m £55m	 Annually 966 FTEs 1554 FTEs
Venison	Primary production Processing By-products	£2m £8m £40k	Annually Annually Annually
Eco-tourism	Wildlife watching Deer watching	£138m £107-113k	But difficult to dis-aggregate the value of individual species Annually
Social benefits	Rural employment		

4.7 Economic Costs and Benefits of Deer under different models of land-ownership

In preparing this report we were asked to see what information might be available on the different balance of costs and benefits of deer and their management under different models of land management - and specifically in relation to public or private ownership of land.

It would indeed be informative to consider both costs and benefits of deer and deer management in Scotland separately in relation to whether land is in:

- private ownership vs.
- public ownership (e.g.. FC, SNH or others)
- community ownership (Assynt Crofters' Trust, Assynt Foundation, Eigg, Knoydart etc.)
- ownership of other NGOs (e.g. JMT, RSPB/ other NGOs)

Certain costs clearly remain the same under any model of management (costs which may be charged for leased stalking; value of ecotourism, value of venison product). Given the major elements of cost and benefit identified above, it might therefore be appropriate in such analysis to consider in particular differences in terms of:

- the number of people employed (per 100 ha?)
- inward investment into local communities
- differences in relation also to sustainability of management

In such analysis we would note that the PACEC study suggests that currently an average (mean) of 1.8 stalkers (or 0.9 Full Time Equivalents) are required per shoot site (Estate) [where the average size of shoot site (Estate) was 7,984 ha] in order to carry out the necessary deer management.

It seems clear to us that the cost benefit framework is complex, and further complicated by the current financial incentives provided by the public sector to support some private sector activities. As for example forestry (capital costs of fencing etc., plus annual management grant); open hill deer management subsidised by moorland management grant; management on conservation grounds often additionally subsidised through specific Management Agreements with SNH or under Rural Stewardship schemes/ Natural Care Schemes. We believe therefore that it

may also be useful to take an approach based on an analysis of public sector v private sector inputs at an appropriate scale while separating also benefits gained from such investment by private and public interest.

4.8 General Conclusions

It is clear that there are a wide range of impacts that must be assessed if we are to provide an accurate cost/benefit analysis for wild deer in Scotland. In the sections above we have set out these areas, summarised the current data available and attempted to identify what other data is available but is un-published or is not yet collected and could add to a better understanding of the true costs of both deer impacts and deer management.

4.8.1 Commercial forestry

Where data has been published much of the work is dated. The most recent comprehensive review of forestry impacts and management (Gill, 2001) is based on data from 1991. Yet we know more recent data is collected by the FC for the PFE to support business planning. Similar date may be available from the private sector but it is not yet clear whether this data would be available in a format that would be useful for comparisons between the public and private sector. We do know that FCS manages approximately 40% of commercial forestry in Scotland and whilst management effort may vary, data on impacts and management costs should allow extrapolation to provide a reasonably accurate indication of the cost of deer impacts on commercial forestry. What is lacking however is sufficient data to allow comparison between management costs in public and private sectors.

Information on amenity and farm woodlands is even more elusive. Costs for fencing and other deer management based on grants may be the only method available for identifying costs and these should be available from SRDP; such data should be sought in any follow work to this scoping study.

One area which we had hoped to explore in more detail was the role of fencing (both temporary and permanent) at different scales and the relative costs and benefits of fencing vs. culling, however even FC are unable to separate out in their own costs the effect of fencing on overall net costs of deer management.

4.8.2 Agricultural and other costs:

We have been unable to identify any published material relating to agricultural impacts in Scotland. Work in other countries including England and Wales suggests that the costs are likely to be insignificant at a national level though there may be high localised costs, particularly with high value vegetable crops are involved. As suggested at paragraph 5.8 a separate approach towards some estimate of overall economic loss would be to identify threshold densities of deer above which damage to agricultural crops might be expected to be significant on particular farms and assess what proportion of agricultural cover in Scotland supports deer at or above such densities. However, extensive review has failed to establish such density thresholds, noting, as above, that damage tends to be less related to density *per se* but characteristics of vulnerable fields/farms - especially those where palatable crops are planted close to adjacent cover (Putman et al., 2011a).

There are few data available on the economic impacts of deer on natural biodiversity, in terms of impacts on native fauna and flora and other ecological costs beyond the site scale. New “ecosystem services” approaches may allow some estimate of

positive value of biodiversity and economic costs of ecosystem damage. For now, however we have had to restrict analysis to costs involved in administration and regulation of management agreements in designated sites of conservation priority.

Whilst animal disease outbreaks such as FMD have the potential to inflict significant coats on the Scottish economy it is clear that the risk is low and the on-going costs are limited. Clearly the legal requirement to submit samples for bTB testing imposes a cost for testing and this should be identified as part of any further study.

The most obvious cost associated with human disease is treatment for Lyme disease and the disease (or the reporting and recording of the disease) has increased significantly over the last ten years. However although much literature suggests an important role for deer in this increase, we would emphasise that there is no evidence of a direct link and it is clear (para 7.3) that that large herbivores are in any case not an obligate part of the system; both tick and spirochaete (*Borrelia*) may be adequately maintained in a narrower host cycle consisting merely of small rodents or small rodents and medium sized mammals such as hares. Therefore costs we have included in our analysis should be treated with extreme caution.

The area for which we have most recent published data is DVCs and this is a reflection of the on-going work by Langbein et al. This valuable accumulated dataset allows a comprehensive review of the direct and indirect costs associated with accidents on the road and coupled with the work of Steiner et al. (2010) provides a framework for future analysis of costs associated with DVCs. It is clear that the rise in urban and peri-urban deer is bringing deer and humans into closer contact and this is reflected in the SSPCA call outs. However in relative terms the economic cost of these incidents is still relatively small (though the animal welfare implications are not).

We have included in the costs for wild deer and their impacts a headline figure for regulation and administration for which we used the last annual cost of the DCS. We believe that this is appropriate though we recognise that in future it may be less visible as a consequence of the merger with SNH.

4.9 Benefits

When looking at the benefits deriving from deer both direct and indirect, the original report by PACEC (2006) gives a valuable 'global' view and our own subsequent analysis of other available data suggests that the conclusions offered by PACEC remain broadly appropriate. The PACEC report however did not include any analysis of local variations, so does not allow us to explore different models of land ownership and the cost/benefit balance.

In addition PACEC focuses on the Highland private sector and there is a danger that this underestimates the value of lowland stalking. Whilst it should be reasonably easy to evaluate this benefit on the PFE (though we do not yet have the data), the commercial sensitivity of stalking leases makes it difficult to confirm the anecdotal evidence we have for the range of lease prices. It is further complicated by the 'grey' market of cash payments for stalking which may not be identifiable. We therefore believe that the commercial sensitivity of lease/stalking right costs makes local data collection problematic and aggregation at a larger scale except through anonymous sampling (such as PACEC) extremely unreliable.

The value of stalking and related activities to the Scottish economy was probably pretty accurately assessed by PACE (2006) as of the order of £105m per annum

(paragraph 1.5 and 12.1).

The value of wild venison to the Scottish economy can be estimated (as at paragraph 12.2 and after MacMillan et al., 2008)) at approximately £2 million. If downstream processing is included, the contribution of venison to the Scottish economy rises to £10 million.

The recent SNH report on nature tourism highlights the value of both stalking and eco-tourism and suggests that there is a balance between stalking and ecotourism with both adding significantly to the Scottish economy. But we believe that there is the potential for overestimating the role of deer in visiting Scotland and this is highlighted by the DCS report on deer watching which indicates that there is currently a very small market for deer watching as a specialist activity.

4.10 Gaps in Knowledge

Our approach has also identified significant gaps in the current understanding of the economics of deer management. In this section we suggest methods to help fill some of these gaps. We examine these in relation to the most significant areas of economic impact, as identified in earlier sections.

It is clear that whist the economic benefits of deer management have been well summarised at a national scale the costs associated with the various impacts are better understood at a site level and aggregation of the results is extremely problematic, especially taking into account the significant regional variations especially in the forestry sector, e.g. browsing on lodgepole pine.

Tables 7 & 8 summarise the areas within the forestry and non-forestry sector in which we believe there are significant gaps in our knowledge. We have also tried to summarise in the same tables possible methods of addressing these gaps to inform any subsequent work which may be undertaken to follow this scoping study.

Table7: Summary of forestry related knowledge gaps and possible methods of addressing the gaps.

Impact	**Knowledge Gap and methods of addressing the gaps**				
Browsing	To be investigated – but likely to require new sample survey work				
Loss(death) of planted or regenerating stock	As above				
Check to growth of planted or regenerated stock	As above				
Multiple leaders etc. affecting economic value of crop	As above				
Bark stripping and fraying	As above				
Total accumulated damage					
	Public sector		Private sector		Knowledge gap and methods of addressing the gap
	Gross	Net	Gross	Net	
Management costs					New data collation
Stalking					New data collation
Fencing Removal of fencing					New data collation

Table 8: Summary of non-forestry related knowledge gaps and priorities for research.

Area	**Impact**	**Knowledge gap and methods of addressing the gap**
Agriculture	Loss of crops	unfeasible to assess, because damage highly localised. Unlikely to be significant at a national, rather than local level
Biodiversity	Ecosystem impacts	No reliable landscape scale data Identify a methodology for either aggregating site specific data or measuring impacts on a wider scale.
Other Ecological impacts	Hybridisation Policy Enforcement	Unknown SNH to record expenditure on enforcement action
Disease	Lyme disease	Determine the percentage of Lyme disease that can be directly attributed to deer is uncertain
DVCs on the road	Routine Physical mitigation Diffuse costs	Transport Scotland may have data on routine deer mitigation but we have been unable to access such data. GIS based approaches should be used to identify and record such mitigation in relation to DVCs.
DVCs on the rail network		Unknown
Deer in the urban context	Police call outs	Unknown

4.11 Knowledge Gaps in the benefits of wild deer

It is clear that whist the economic benefits of deer management have been well summarised at a national scale we are missing significant data at a local scale particularly in relation to lowland stalking values. This links to our relative lack of knowledge of the economic and social benefits from different management strategies, which makes accurate comparisons between approaches problematic. Significant gaps exist in our knowledge of forest lease values and rural employment.

5. REFERENCES

Anon. 2006 / 2010. *Deer and Fencing*, Forestry Commission Scotland: Guidance Note 11 (2006, revised March 2010).

Apollonio, M., Andersen, R. & Putman, R.J. (eds). 2010. *European Ungulates and their Management in the 21st century.* Cambridge University Press. ISBN 978-0521-76061-4.

Arnold, W. 2005. Schwarzwild – Hintergründe einer Explosion. *Österreichs Weidwerk* 1(supplement), 8 - 11.

BASC. 2004. Deer Stalking Survey, unpublished report.

Bryden, D.M., Westbrook, S.R., Burns, B., Taylor, W.A. & Anderson, S. 2010. Assessing the economic impacts of nature based tourism in Scotland. *Scottish Natural Heritage Commissioned Report No. 398.*

Büchsenmeister, R. & Gugganig, H. 2004. Stammschäden im Österreichischen Wald. Bundesamt und Forschungszentrum für Wald, Wien, *BFW-Praxisinformationen* 3, 12-14.

Callander, R.F. & Mackenzie, N.A. 1991. *The Management of Wild Red Deer in Scotland.* Scottish Rural Forum; Perth.

Chapman, N.G., Harris, A. & Harris, S. 1994. What gardeners say about muntjac. *Deer* 9, 302-306.

Cerkal, R., Dvorak, J., Kamler, J. & Vejrazka, K. 2006. Poskozovani porostu jecmene bylozravei [Game damage to barley]. In: J. Zimolka (ed) *Jecmen – formy a uzitkove smery v Ceske Republice.* Profi Press, Prague; pp 120-125.

Coles, C.L. 1994. Damage to gardens by deer. *Deer* 9, 161-3.

Coles, C.L. 1997. *Gardens and Deer: A guide to damage limitation.* Swan Hill Press.

CSL (Central Science Laboratories). 2006. *A quantitative risk assessment on the role of wild deer in the perpetuation of TB in cattle*. Project report SE3036. Defra, London.

Dandy, N., Ballantyne, S., Moseley, D., Gill, R. & Quine, C. 2009. *The management of roe deer in peri-urban Scotland.* Forest Research Report, Forestry Commission, UK. May 2009.

Dayton, N. 2006. An Assessment and Evaluation of Herbivore Impacts on Blanket Bog Habitat in the Monadhliath Special Area of Conservation. *Scottish Natural Heritage Commissioned Report 165* [ROAME No F02AC202/3].

Deer Commission for Scotland. 2009. *Challenges and Opportunities of Deer Watching as a Commercial Activity: a critical review*. Deer Commission for Scotland.

Doney, J. & Packer, J. 1998. An assessment of the impact of deer on agriculture. In: C.R. Goldspink, S.King and R.J.Putman (eds) *Population Ecology, Management and Welfare of Deer*. British Deer Society/Universities' Federation for Animal Welfare, 38-43.

Eycott, A.E., Watkinson, A.R., Hemami, M.R. & Dolman, P.M. 2007. The dispersal of vascular plants in a forest mosaic by a guild of mammalian herbivores. *Oecologia* 154,107-118.

Fernández-Pacheco, P., Fernández-Pinero, J., Agüero, M. & Jiménez-Clavero, M.A. 2008. Bluetongue virus serotype 1 in wild mouflon in Spain. *Veterinary Record* 162, 659-660.

Ferroglio, E., Gortazar, C. & Vicente, J. 2011. Wild ungulate diseases and the risk for livestock and public health: Chapter 7 in Putman, R.J., Apollonio, M. & Andersen, R. (eds) *Ungulate Management in Europe: Problems and Practices.* In press with Cambridge University Press.

Fletcher, T. J. 2002. *Diseases of deer relevant to Scotland*. Contract Report to the Deer Commission for Scotland, Inverness. Contract ref. RP/22. 60pp.

Forman, A.J. & Gibbs, E.P.J. 1974. Studies with foot-and-mouth disease virus in British deer (red, fallow and roe) I. Clinical disease. *Journal of Comparative Pathology* 84, 215-220.

Gill, R.M.A. 1992a. A review of damage by mammals in north temperate forests. I. 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 by the Forest Research Agency, Wrecclesham, UK.

Goodman, S., Barton, N., Swanson, G., Abernethy, K. & Pemberton, J.M. 1999. Introgression through rare hybridization: A genetic study of a hybrid zone between red and sika deer (Genus *Cervus*) in Argyll, Scotland. *Genetics* 152 , 355-371.

Green, P. 2008. *Disease, health and other animal welfare issues arising*: presentation at the British Deer Society Seminar on Urban Deer, 21 October 2008.

Hambrey *et al*. 2005. *Developing a policy framework for managing diffuse deer impacts*, Landwise Scotland for the Deer Commission for Scotland, Project RP35c.

Iason, G.R., Duncan, A.J., Hartley, S.E. & Staines, B.W. 1996. Feeding behaviour of red deer (*Cervus elaphus*) on Sitka spruce *Picea sitchensis*): the role of carbon-nutrient balance. *Forest Ecology and Management*, 88, 121-130.

Jantz, K. 1982. What does elk damage cost? *Sver. Skogsvardsforb. Tidskr*. 4, 41-42.

Kaluzinski, J. 1982. Composition of the food of roe deer living in field and the effects of their feeding on plant production. *Acta Theriologica* 27, 457-70.

Kamler, J., Homolka, M., Heroldova, M. & Dvorak, J. 2005. Volne zijici bylozravei a poini plodiny [Free living ungulates and field crops] *Folia Venatoria* 35, 205-210.

Key, G., Moore, N.P. & Hart, J. 1997. 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.), pp. 44-47, British Deer Society/Universities' Federation for Animal Welfare.

Langbein, J. 2003. *The Economics of mammals on roads.* Unpublished presentation to the Mammal Society's Autumn Symposium Mammals on Roads, November 2003.

Langbein, J. 2007. *National Deer-Vehicle Collisions Project: England 2003-2005.* Final Report to the Highways Agency. The Deer Initiative, Wrexham.

Langbein, J. 2009*. Deer Initiative Research Report 09/3*, Deer Vehicle Collisions in Scotland Monitoring Project 2008-2011, The Deer Initiative, Wrexham.

Langbein, J. & Putman, R.J. 2006. National Deer-Vehicle Collisions Project; Scotland, 2003-2005. *Report to the Scottish Executive, June 2006.*

Langbein, J. & Rutter, S.M. 2003. Quantifying the damage wild deer cause to agricultural crops and pastures. In: E. Goldberg (ed) Proceedings of the conference *The Future of Deer*, English Nature Research Reports 548, English Nature, Peterborough, pp. 32-39.

Langbein, J., Putman, R.J. & Pokorny, B. 2011. *Road traffic accidents involving ungulates and available measures for mitigation.*

Linnell, J.D.C. & Zachos, F.E. 2011. Status and distribution patterns of European ungulates: genetics, population history and conservation . Chapter 2 in: *Ungulate Management in Europe: Problems and Practices* (eds R.J. Putman, M. Apollonio & R. Andersen. Cambridge University Press, *in press*.

MacMillan, D.C. 2004. Tradeable hunting obligations – a new approach to regulating red deer numbers in the Scottish Highlands? *Journal of Environmental Management* 71, 261–270.

MacMillan, D.C. & Phillip, S. 2008. Consumptive and non-consumptive values of wild mammals in Britain. *Mammal Review* 38, 189–204.

MacDonald, A., Stevens, P., Armstrong, H., Immirzi, P. & Reynolds, P. 1998. *A Guide to Upland Habitats – surveying land management impacts.* Scottish Natural Heritage, Perth.

Maes, E., Lecomte, P. & Ray, N. 1998. A cost-of-illness study of Lyme disease in the United States. *Clinical Therapeutics* 20, 993-1008.

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

Mayle, B.A. 1999. Managing Deer in the Countryside, *Forestry Commission Practice Note 6,* H.M.S.O.

Mintiens, K., Méroc, E., Mellor, P.S. *et al*. 2008. Possible routes of introduction of bluetongue virus serotype 8 into the epicentre of 2006 epidemic in north-western Europe. *Preventative Veterinary Medicine* 87, 131-144.

Mitchell, B., Staines, B.W. & Welch, D. 1977. *Ecology of Red Deer: A Research Review relevant to their Management.* Institute of Terrestrial Ecology; Cambridge.

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.

O'Connell, S. 2007. Lyme borrieolosis, presentation to Deer Initiative Deer, Habitats and Impacts Conference, Buxton, www.thedeerinitiative.co.uk/pdf/18_lyme_disease_sue_oconnell.pdf

Ostfeld, R.S. & Keesing, F. *The natural regulation of zoonotic diseases in wildlife communities*; Wildlife Society of America 17th Annual Conference, Snowbird, Utah.

PACEC (Public and Corporate Economic Consultants, Cambridge). 2006. *The Contribution of Deer Management to the Scottish Economy.* Report commissioned by the Scottish Association of Deer Management Groups.

Packer, J.J., Doney, J., Mayle, B.A., Palmer, C.F. & Cope, M. 1999. *Field and Desk Studies to Assess Tolerable Damage Levels for Different Habitats and Species of Deer.* Report to the Ministry of Agriculture, Fisheries and Foods, on project VC 0315. MAFF, London.

Patterson, A. 2008. *Report of the 2006 – 2007 South-west England and Cotswolds Survey of Tuberculosis in Deer Defra Tuberculosis Programme*. Report to Defra: www.defra.gov.uk/animalh/tb/index.htm (page expired).

Pemberton, J., Swanson, G., Barton, N., Livingstone, S. & Senn, H. 2006. Hybridisation between red and sika deer in Scotland. *Deer* 13, 22-26.

Pepper, H.W. 1998. The Prevention of Mammal Damage to Trees in Woodland. *Forestry Commission Practice Note 3, H.M.S.O.*

Perez-Espona, S., Perez-Barbiera, F.J., McLeoad, J.E. *et al*. 2008. Landscape features affect gene flow of Scottish Highland red deer (*Cervus elaphus*). *Molecular Ecology* (2008) 17, 981–996.

Perez-Espona, S., Pemberton, J.M. & Putman, R.J. 2009. Red and sika deer in the British Isles, current management issues and management policy. *Mammalian Biology* 74, 247-262.

Pichon, B., Mousson, L., Figureau, C., Rodhain, F. & Perez-Eid, C. 1999. Density of deer in relation to the prevalence of Borrelia burgdorferi sl in *Ixodes ricinus* nymphs in Rambouillet forest, France. *Experimental and Applied Acarology*, 23, 267-275.

Pollanschütz, J. 1995. Bewertung von Verbiss- und Fegeschäden, Hilfsmittel und Materialien. *Mitteilungen der Forstlichen Bundesversuchsanstalt Wien*, 169 pp.

Prior, R. 1983 / 1994. Trees and Deer. Swan Hill Press.

Purse, B.V., Mellor, P.S., Rogers, D.J. *et al*. 2005. Climate change and the recent emergence of bluetongue in Europe. *Nature Reviews Microbiology* 3, 171-181.

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. 1994. Effects of grazing and browsing by mammals in woodlands. *British*

Wildlife 5, 205-213.

Putman, R.J. 1995. *Status and Impact of Deer in the Lowlands and Options for Management*. Technical review, contract VC 0316, MAFF, London.

Putman, R.J. 2004. *The Deer Manager's Companion: A Guide to Deer Management in the wild and in parks*. Swan Hill Press ISBN 1-904057-03-9.

Putman, R.J. 2010. Ungulates and their management in Great Britain and Ireland. In: *European Ungulates and their Management in the 21st century.* (eds M. Apollonio, R. Andersen & R.J. Putman), Cambridge University Press, pp 129-164.

Putman, R.J., Langbein, J., Green, P. & Watson, P. 2011. *Identifying threshold densities for wild deer in the UK above which negative impacts may occur*. In press.

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

Putman, R.J. & Kjellander, P. 2002. Deer damage to cereals: economic significance and predisposing factors. In: *Conservation & conflict – Mammals and farming in Britain.* (eds Tattersall, F. & Manley, W..) Linnean Society Occasional Publications: 186-197.

Randolph, S.E. 2007. *Tick-borne diseases–wild deer and the future,* a presentation to Deer Initiative Deer, Habitats and Impacts Conference, Buxton, www.thedeerinitiative.co.uk/pdf/17 ticks_sarah_randolph.pdf

Ratcliffe, P.R. 1989. The control of red and sika deer populations in commercial forests. In: *Mammals as Pests* (ed. Putman, R.J.), Chapman and Hall; London. pp.98-115.

Reimoser, F. 2000. *Income from hunting in mountain forests of the Alps*.

Price, M.F. & Butt, N. (eds) Forests in Sustainable Mountain Development: A State-of-Knowledge Report for 2000. *IUFRO Research Series, no* 5, CABI Publishing, New York, 346-353.

Reimoser, F. 2001. Forest ungulate damage: Integrating wildlife and forest management practices. In: *Wildlife, Land, and People: Priorities for the 21st century* (eds Field, R., Warren, R.J., Okarma, H. & Sievert, P.R.), The Wildlife Society, Bethesda, Maryland, USA. pp.172-176.

Reimoser, F. 2003. Steering the impacts of ungulates on temperate forests. *Journal for Nature Conservation* 10, 243-252.

Reimoser, F. & Putman, R.J. 2011. Impact of large ungulates on agriculture, forestry and conservation habitats in Europe. Chapter 6 in: Putman, R.J., Apollonio, M. & Andersen, R. (eds) *Ungulate Management in Europe: Problems and Practices*. Cambridge University Press, *in press*.

Rizzoli, A., Hauffe, H.C., Tagliapetra, V., Neteler, M. & Rosa, R. 2009. Forest structure and roe deer abundance predict tick-borne encephalitis risk in Italy. *Plos One* 4, e4336.

Ruiz-Fons, S., Reyes-Garcia, A.R., Alcaide, V. & Gortázar, C. 2008a. Spatial and temporal evolution of bluetongue virus in wild ruminants, Spain. *Emerging Infectious*

Diseases 14, 951-953.

Rutter, S.M. & Langbein, J. 2005. *Quantifying the damage wild deer cause to agricultural crops and pastures.* Contract report VC0327 to the Department of Environment, Food and Rural Affairs, London.

Szczerbinski, W. 1959. The problem of stands with bark stripped off by game animals and consideration of methods suitable for studying the effects of damage in pine and spruce stands. *Sylwan*, 103, 73-90.

Scharlemann, J.P.W., Johnson, P.J., Smith, A.A., Macdonald, P.W. & Randolph, S.E. 2008. Trends in ixodid tick abundance and distribution in Great Britain. *Medical and Veterinary Entomology* 22, 23-247

Schley, L. & Roper, T.J. 2003. Diet of wild boar *Sus scrofa* in Western Europe, with particular reference to consumption of agricultural crops. *Mammal Review 33*, 43-56.

Scottish Natural Heritage/Deer Commission for Scotland. 2002. *Wild Deer In Scotland and Damage to the Natural Heritage.* Scottish Natural Heritage.

Scottish Natural Heritage (no date): *Economic Value of Deer Damage in Scotland.* Unpublished Report.

Senn, H.V. & Pemberton, J.M. 2009. Variable extent of hybridisation between invasive sika (*Cervus nippon*) and native red deer (*Cervus elaphus*) in a small geographic area. *Molecular Ecology* 18, 862-876.

Smit, C. & Putman, R.J. 2011. Large herbivores as "environmental engineers". In: *Ungulate Management in Europe: Problems and Practices* (eds Putman, R.J., Apollonio, M. & Andersen, R. Cambridge University Press, *in press*.

Staines, B.W. 1995. *Impact of red and roe deer browsing on commercial conifer forests in Scotland*. Presentation to Symposium on Ungulates in Temperate Forest Ecosystems, Wageningen, The Netherlands, 23-27 April 1995.

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

Steiner *et al*. 2011. *The Indirect Costs of Deer Vehicle Collisions*: Interim Report to SNH.

Stewart, D. 2006. *Scottish Biodiversity List Social Criterion: results of a survey of the Scottish population.* Scottish Executive Social Research, Research Findings. No 26. www.scotland.gov.uk/socialresearch

Trdan, S. & Vidrih, M. 2008. Quantifying the damage of red deer grazing on grassland production in southeastern Slovenia. *European Journal of Wildlife Research* 54, 138-141.

Trout, R.C. & Pepper, H.W. 2006. *Forest fencing*, Forestry Commission Technical Guide, Forestry Commission, Edinburgh. i.vi + 1-50 pp.

Ward, A.I. 2007. *Trends in deer distribution and abundance within the UK*.

Presentation to “Deer, Habitats and Impacts”, the Deer Initiative Conference, Buxton UK, 23rd March 2007.

Ward, A.I., Etherington, T.R. & Smith, G.C. 2008. *Exposure of cattle to Mycobacterium bovis excreted by deer in southwest England: a quantitative risk assessment.* Consultancy report to TB Programme, Food and Farming Group, Department of Environment, Food and Rural Affairs, London.

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- 30.

White, P.C.L., Smart, J.C.R., Böhm, M., Langbein J. & Ward, A. I. 2004 *Economic impacts of wild deer in the East of England*, a report for the Forestry Commission.

Wildauer, L. 2006. *Wildschwein (Sus scrofa) und Reh (Capreolus capreolus) in den Bezirken Zentral und Ostösterreichs seit 1950: Abschuss- und Bestandsentwicklung, mögliche Einflussfaktoren, Wildschweinschäden in der Landwirtschaft.* Diploma Thesis, University of Veterinary Medicine, Vienna.

Wildauer, L. & Reimoser, F. 2007a. Wild boar (*Sus scrofa*) damage in agriculture - relation between farmers and hunters in past and present. XXVIIIth International Union of Game Biologists Congress, Uppsala, p. 225.

Wildauer, L. & Reimoser, F. 2007b. *Wild boar* (Sus scrofa) *management - what can we learn from history?* XXVIIIth International Union of Game Biologists Congress, Uppsala, Sheden, p. 42.

Willoughby, I. *et al*. 2004. *Reducing pesticide use in forestry.* Forestry Commission Practice Guide. Forestry Commission, Edinburgh. i–iv + 1–140 pp.

Wilson, C.J. 2003a. *Current and Future Deer Management Options.* Report on behalf of Defra European Wildlife Division, December 2003. Department of Environment, Food and Rural Affairs, London.

Wilson, C.J., Britton, A. & Symes, R. 2009. An assessment of agricultural damage caused by red deer (Cervus elaphus L.) and fallow deer (Dama dama L.) in Southwest England. *Wildlife Biology in Practice* Vol 5, 104-114.

Wilson, C.J. 2003b. *A Preliminary Estimate of the Cost of Damage Caused by Deer to Agriculture in England.* Defra Rural Development Service. Department of Environment, Food and Rural Affairs, London.

Wilson, C.J., Britton, A. & Symes, R. 2009. An assessment of agricultural damage caused by red deer (*Cervus elaphus* L.) and fallow deer (*Dama dama* L.) in Southwest England. *Wildlife Biology in Practice* 5 (2),104-114.

www.snh.gov.uk

ISBN: 978-1-85397-886-9

Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

You can download a copy of this publication from the SNH website.

recycle

Scottish Natural Heritage
Dualchas Nàdair na h-Alba
All of nature for all of Scotland
Nàdar air fad airson Alba air fad