Centre for Ecology and Hydrology
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# MANAGEMENT OF DEER IN WOODLANDS
## Literature reviews of woodland design, and techniques for assessing populations and damage

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## EXECUTIVE SUMMARY

### Review of practical woodland design

- A literature review of practical woodland design to facilitate deer control was done.

- The creation of deer glades is vital for aiding deer control.

- Two to five small glades per 100 ha which provide security of cover and available browse for deer should be adequate and in total about 5% of plantable land should be used as deer glades. Ideally, deer glades should be linked together by stalking paths.

- To this should be added areas normally left unplanted such as streamsides, forest rides, roadsides and other linear features such as power lines. The principles for creating glades are all the same: breaking up linear features, providing greater diversity by planting species (deciduous trees & shrubs) other than the main crop, giving a forest edge of variable shape, size, width, height and density of planting.

### Review of techniques used to assess deer populations and damage

- A literature review of techniques for assessing deer populations and damage was undertaken.

- Static census, Aerial census, Spotlighting and Index counts are considered unreliable as techniques for estimating deer populations in woodlands and are not recommended.

- Drive counts and thermal imagery are expensive techniques and are not recommended because of cost. Future developments might make the latter technique more suitable for population assessment in woodland. Open hill counts and CIR counts are best suited to open range situations and are not recommended for woodlands. Vantage point counts are only suitable in areas of hilly terrain but the technique tends to underestimate population size.

- We suggest that direct counts are not suitable for forest or woodland and that indirect methods should be used. We recommend that faecal pellet group counts should be used for assessing deer populations in woodland.

- Using life tables for reconstructing cull data are not recommended.

- We strongly recommend that more use be made of cull data, including aging and collecting reproductive data, and suggest cohort analysis for reconstructing population data.

- We recommend nearest neighbour techniques for assessing damage to commercial woodland.

## Review of the techniques used to assess deer populations and damage to woodland.

- Consistent and comparable data should be collected within an estate, between estates (at the Deer Management Group level) and collated across Scotland.

- Personnel involved in culling these species should be trained in estimating ages based on eruption and tooth wear patterns. The material on which training is based should be based on known aged animals or from animals where the annuli in the cementum have been measured.

- For red deer, there is a need to calibrate tooth wear and annuli counts in deer from forests. Most guides were developed for deer from open hill. DCS should provide this?

- Hunters/stalkers should be trained centrally in ageing and assessing reproductive rates from the reproductive tract. This should be combined with population estimate techniques and cohort analysis training so that data collection is seen as a pre-requisite in the setting of culling targets and therefore essential to the management of deer. Courses are available from BDS (and colleges of Further Education? Thurso?)

# 1. Review of practical woodland design

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"*It may seem that if deer were fully recognized as a site factor before plantations were attempted, then properly planned deer control, including concessions in the lay-out of the plantations could accommodate the deer problem*" (Cooper & Mutch 1979).

The aim of this section is to compile a literature review of practical woodland design to facilitate deer control. Much of the review is relevant to multi-purpose commercial forestry, as this is often regarded as lacking sufficient investment in deer control areas.

By the end of World War I there was a severe shortage of timber and as a result the Forestry Commission (FC) was set up in 1921 to increase timber growing and production. Later, tax incentives and grant schemes aimed at increasing the amount of private forestry land were introduced. Government policy was to produce the maximum amount of timber at the least cost, and little consideration was given to any other form of land management. Because of this philosophy taking account of deer management requirements in the design of woodlands has for the most part been ignored until recently.

Ideally the needs of deer management should be identified along with those of other uses of woodland including recreation, visual amenity, conservation and water management. Attributes such as deer glades can then be incorporated in a forest plan before planting. The person responsible for deer control should be involved in planning, preparing and maintaining deer glades (Ratcliffe 1985). The same principles still hold if improving established plantations or redesigning before replanting clearfelled or windthrow areas. Any concessions must be justified as having a major contribution to forest protection, venison production or trophy heads (Prior 1983).

## 1.1 Deer Glades

The provision of glades, whether by openings, clearings, streamsides, rides or woodland edge is recognised as vital and recommended for the control of all deer species (RDC 1979; Prior 1983, 1995; Springthorpe & Myhill 1985; Ratcliffe 1985; McLean 1992; Mayle 1999). Woodland deer may be reluctant to leave forest cover during the day and glades will provide increased shooting opportunities.

Within any woodland natural openings (glades) will occur. Ideally glades to be used for deer control should be located in areas preferred by deer and where damage to trees is occurring (McLean 1992) or is likely to occur. Suitable sites include well-drained knolls and rich flushes, grassy clearings, areas of remnant mature hardwoods, south facing heathery slopes and streamsides (Prior 1983; Springthorpe & Myhill 1985; Ratcliffe 1985). These areas are usually on more fertile ground where better tree growth might be expected. However, the benefits in aiding culling, reducing damage and returns from venison sales should outweigh potential loss of timber income from such areas (Prior 1983), especially as the trees will be prone to greater deer damage. Natural sites on rides, by roadsides, along power lines, in checked areas or adjacent to afforested sites should also be used (Prior 1983; Springthorpe & Myhill

1985; Ratcliffe 1985). Avoidance of exposed unplantable areas of heather and blaeberry is recommended (Ratcliffe 1985).

Improvements to natural glades are usually for access and visibility for shooting (McLean 1992). Bracken control or removal of dead vegetation may be beneficial but the costs of fertilizing or liming might be greater than the benefits (Ratcliffe 1985; McLean 1992). Some natural glades become apparent later in the rotation and may be improved by brashing or high pruning (McLean 1992). Heavily browsed trees in such areas should be kept to provide food and cover (Ratcliffe 1985; McLean 1992).

In some forests there may be a lack of suitable natural glades, such as in large blocks of thickets intersected by narrow rides with poor quality vegetation, and glades will have to be created by re-seeding. This is easier and less costly if planned in advance and done after clear felling and prior to planting (Ratcliffe 1985). More usually it is done as an afterthought to aid culling in reaction to increased deer damage. Glades can be created within the woodland adjacent to a ride, by linking two rides or within a woodland block (Warren & Fuller 1990). Detailed information on creating deer glades is given in Ratcliffe (1985).

Within a cleared glade either one or several small patches of between 0.05 ha and 0.5 ha are selected for seeding (Ratcliffe 1985). Ratcliffe suggests the use of grass mixes or grass clover mixes, and while reseeding on mineral soils is preferable, good results have been obtained on peat. He also suggests removal of the field layer of vegetation and screefing or scarifying to remove needles and dead vegetation to create a suitable bed for germination. On pure heather sites the application of lime a year prior to treatment may also be required to increase soil alkalinity and kill heather. Ratcliffe recommends sowing in April, May or September, though in wet summers anytime between May and September may be acceptable. He notes that periodic maintenance of the grass sward may be necessary, as might additional applications of fertiliser.

Woodland deer prefer to remain secluded in cover and creating a fringe of ‘open woodland’ around a glade may be necessary to give cover and security for deer and sufficient open space for shooting (McLean 1992). This can be done by thinning and high pruning or brashing a band of trees about 30 metres wide around a glade, or on very open areas it may be necessary to plant clumps of trees resilient to deer damage, such as Sitka spruce (Ratcliffe 1985). Providing alternative scrub for fraying and browsing may also increase usage by deer and help reduce damage (Prior 1983; Ratcliffe 1985). Prior suggests species such as willow, ash, rowan and Norway spruce to provide fraying stock for roe deer.

In large conifer blocks Prior (1983) suggests planting patches of larch at intervals where the soil permits. Such patches would be large enough not to attract serious damage and he suggests a minimum of 2 ha. These patches should adjoin an access path to allow a silent approach for stalking. At the appropriate time the larch are thinned, and in time a field layer develops and the stand becomes a feeding area and potential glade without loss of crop. Brashing and subsequent thinning would further improve such sites.

Optimum sizes suggested for glades are fairly similar: 0.5 ha (Prior 1995), 0.2 to 1.0 ha (Ratcliffe 1985; McLean 1992) and 0.25 ha to 2 ha (Springthorpe & Myhill 1985).

Many small, scattered glades are preferable to a single large open space with, ideally, between 2-5 glades per 100 ha of forest (Ratcliffe 1985; Springthorpe & Myhill 1985).

Glades are more effective when linked by forest roads, stalking rides or paths thus allowing continuous stalking (Springthorpe & Myhill 1985; Ratcliffe 1985; McLean 1992; Mayle, 1999). It is more cost effective if glades, approach paths and carcase extraction routes are selected prior to planting or replanting (Ratcliffe 1985). Ideally a linked series of glades could be viewed from vantage points to increase efficiency in locating deer. Stalking can then commence along prepared routes quickly and effectively (Ratcliffe 1985). Stalking paths should be wide enough to allow free passage with a rifle in wet weather and ideally should bend occasionally (Mayle 1999). This can be done by simply brashing two adjacent lines of trees to head height (McLean 1992). Glades and their associated access paths need to be maintained but the limited maintenance costs can be repaid in terms of venison sold, damage prevented and sporting rent (Prior 1983).

As forest structure alters so use of glades changes. Monitoring the effectiveness of individual glades is recommended (Ratcliffe 1985) and an element of flexibility is foreseen where glades will be tried, adapted or abandoned either temporarily or permanently (Prior 1983; Ratcliffe 1985). Ratcliffe suggests periodic assessment of deer use of glades can be by dung counts, from evidence of browsing, grazing and trampling or, where possible, regular viewing from vantage points. He recommends recording all visits to glades, the number of animals seen and or shot, and just as important the number of unsuccessful visits.

Authors suggest that in a large forestry block between 2-5% of plantable land should be given over purely for deer control (Prior 1983; Rose, cited in Wigan 1992). To this should be added other unplanted ground not initially designed for deer control, such as streamsides, roadside verges, power lines, firebreaks etc. Improvements in such habitats may be primarily for water management, landscape design or conservation, but in effect can create extra glades for deer control. Rose suggests up to 15% of the forest area be left open for deer control (Wigan 1992). The UK forestry standard sets a target of 10-20% open space, including roads and rides and edge habitats adjacent to streams (Forest Authority 1998; Ferris & Carter 2000). In forests seeking accreditation it may be necessary to increase the amount of open ground, some of which can be utilised by deer management. Areas where natural colonisation is preferred may have more open ground, sometimes as much as 50% and usually at least 20% (Rodwell & Patterson 1994).

### 1.2 Streamsides

The management of watercourses in woodland areas has several specific aims including reducing acidification, sedimentation, soil and stream erosion and preventing pollution. The FC has published guidelines, aimed at woodland owners and managers, on how to protect and enhance the water environment. The standards set out in these guidelines must be met in Woodland Grant proposals and felling licence applications. Deer managers and stalkers can take advantage of the woodland design requirements of the 'Forests and Water Guidelines' because it creates open spaces in areas likely to be preferred by deer.

Advice on managing watercourses includes the provision of 'buffer zones'. The buffer zone is left uncultivated to protect the watercourse and the ground immediately adjoining (riparian zone) from discharges off adjacent land, particularly from drains (FC 2000). The width of the buffer area is determined by the risk of sediment movement. Suggested widths vary from 5 metres on either side of a headwater stream, with a channel up to 1 metre wide, to 10 metres on either side of a stream, with a channel of 1 to 2 metres wide, to 20 metres on either side of a stream with a channel over 2 metres wide. In areas with easily eroded soils these widths should be doubled (FC 2000). The buffer width should vary and is intended to take account of the landscape. Ground vegetation is crucial in trapping sediment and should not be shaded out (FC 2000).

Riparian zones tend to be more sheltered and have better soils than the surrounding ground and are recognised as good habitats for deer (Prior 1983; Springthorpe & Myhill 1985; Ratcliffe 1985; FC 1990, 1994, 2000). The management of riparian vegetation not only meets the requirements for water, nature conservation and landscape design guidelines it can also benefit deer control (Patterson 1991).

McLean (1992) reports that to aid control of sika deer stream sides were widened to 30-50 m, though this was less successful for culling than small glades. Under the water guidelines about half the length of a watercourse should be maintained open to sunlight with the remainder under dappled shade from light-foliaged trees and shrubs (FC 2000). Therefore it is possible to create a succession of glades by either opening up the watercourse and removing undesirable trees or planting trees and shrubs as required. Such planting will have to take account of the water guidelines and may have to meet landscape design and conservation guidelines as well (FC 1990; 1994; 2000). Glades selected should be well used by deer and should need only improvements for access and safe shooting. Periodic cutting may be necessary to keep the balance between open and shaded areas but as this is required for water management it should not be a cost to deer management. Suggested length for streamside glades is between 100 and 200 metres long, with a succession of glades screened from each other by groups of trees (Lucas 1991; FC 1994).

### 1.3 Forest rides, roads and other linear features

Modern practice is to make use of roads, streams, crags and other natural features as compartment boundaries in forests (FC 1994), or to increase diversity in new native woodlands (Rodwell & Patterson 1994). However, most large woods have a network of rides which are maintained principally to aid timber extraction or act as firebreaks. Long straight linear features such as rides and power lines can be improved to help deer control. In small woodlands the wide rides recommended for game coverts are also ideal for deer management (Prior 1983). Very wide rides may be too open, and by planting blocks of trees at right angles to the direction of the ride and about 150 metres apart a series of glades can be created. Consideration can also be given to the provision of other browse species (Prior 1983). Glades can easily be created at the intersection where two rides cross, allowing the maximum amount of glade for the minimum amount of tree felling (Warren & Fuller 1990; Ferris & Carter 2000). Such junctions can be further improved by making the glades asymmetric (Lucas 1991).

Best design for a ride is to curve gently, and by varying the width a series of linked glades can be created (Lucas 1991; Ferris & Carter 2000). Mayle (1999) suggests an average ride width of 20 m. Cutting bays or scallops in the edges of older rides will increase the amounts of sunlight received. The amount of solar radiation received is related to slope, aspect, tree height, orientation of rides and latitude (Ferris & Carter 2000).

The width of corridor that forest roads pass through should allow direct sunlight and wind to dry the road surface (Ferris & Carter 2000). They suggest that for road maintenance purposes it may be necessary to cut back the tree edge 10-30 metres from the middle of the road, particularly on roads with an east-west orientation where tree shade from the southern side can lead to deterioration. Prior (1983) suggests leaving about 8 m either side of a track unplanted. Roadside glades can be created in the same way suggested for rides.

Landscaping improvements to corridors for power lines, pipelines or other services can also be useful for deer management. Under forest landscape design guidelines the forest edge of these corridors can be designed to create irregular spaces with irregular tree heights, often using broadleaved trees and shrubs to give variable width to the corridor (Lucas 1991; FC 1994). Woodland edge can also be designed to create glades by avoiding abrupt external edges, establishing irregularly spaced and sized groups and individual trees, re-spacing and early thinning to reduce edge density (ref).

### 1.4 Crop protection

Although not strictly forest design the protection of trees may well be part of the deer management strategy. The likely damage from deer may determine what trees are planted and whether individual trees or stands need protecting (Pepper 1992). Already mentioned above is the use of alternative browse for either food or as fraying stock. Often however these scrub or tree species will need protection from damage in early life. Alternatively if there is existing browse then consideration can be given to improving it by coppicing (Prior 1983).

If damage is believed to be potentially serious then consideration should be given as to what species to plant (Prior 1983; McIntosh 1995). McIntosh describes the tree choices made at Kielder Forest, which was, for commercial purposes, mainly Sitka spruce. The choice of other species was mainly on the grounds of visual amenity or conservation.

Ratcliffe and Pepper (1987) suggest, that in general individual tree protection should be used on areas less than 4 ha with fencing being more cost effective in larger areas. Individual protection of trees needs to take account of what species of deer are present, the following sizes of tree guard are recommended by Hodge and Pepper (1998): 1.2 m for roe and 1.8 m for red sika and fallow deer.

Although large-scale fencing is generally out of favour at the moment, its use in protecting smaller vulnerable areas continues. The cost of permanent fencing makes it an expensive protection option (Prior 1983) and from a commercial viewpoint would need to be compensated for from any extra value gained from the final crop (Pepper 1992). Increased culling, choice of a different tree species or individual protection should first be considered first (Pepper 1992). For conservation purposes foresters trying to regenerate native woodlands have the dilemma that while fencing helps establishment of trees it has adverse impacts on game birds due to accidental collisions (Catt et al. 1994). With greater emphasis on planting broadleaves now prevalent the need to protect young trees will mean that short-term fencing could be considered as useful.

Mayle (1999) recommends fencing a maximum area of 10-15 ha for 10-15 years in lowland woodlands, and that whole woods should not be fenced. The Forest Authority Scotland Guidance Note (Deer, natural regeneration and fencing) recommends fencing areas of 2 to 300 ha for between 5-15 years. Even if deer are not originally in a fenced area, when they break in they need to find a way out. The incorporation of deer leaps which allow animals to escape, but not enter a fenced area is recommended by various authors (Prior 1983; Pepper 1992). In small areas of plantings if deer have broken in they will soon become obvious and can be dealt with.

Recently the development of temporary and reusable fencing, aimed at excluding roe, fallow and muntjac deer has been investigated (Pepper 1999). The principal aims of this research were to reduce fencing costs while maintaining efficiency. The costs of materials account for 50% of the initial establishment cost of a traditional post and wire fence (Pepper 1999). Using new lightweight fencing materials, Pepper claims that savings of 25% - 30% are attainable. However practical experience with this system is limited, but the potential for reusing fencing material must be of benefit to some foresters. It should be noted that Pepper's recommendations do not cover red and sika deer, for which heavy gauge fencing is still recommended.

### 1.5 Summary

**The creation of deer glades is vital for aiding deer control. Two to five small glades per 100 ha which provide security of cover and available browse should be adequate and in total about 5% of plantable land should be used as deer glades. Ideally, deer glades should be linked together by stalking paths. To this should be added areas normally left unplanted such as streamsides, forest rides, roadsides and other linear features such as power lines. The principles for creating glades are all the same: breaking up linear features, providing greater diversity by planting species (deciduous trees & shrubs) other than the main crop, giving a forest edge of variable shape, size, width, height and density of planting**.

## 1.6 References


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

Chadwick, A. H., Ratcliffe, P.R. & Abernethy, K. (1996). Sika deer in Scotland: Density, habitat use and fertility – some comparisons with red deer. *Scottish Forestry* 50 8-16.

Cooper, A.B. & Mutch, W.E.S. (1979). The management of red deer in plantations. In *The ecology of even-aged forest plantations*. Eds. Ford, E.D., Malcolm, D.C. & Atterson, J., pp 453-462. Institute of Terrestrial Ecology, Cambridge

Ferris, R. & Carter, C. (2000). *Managing rides, roadsides and edge habitats in lowland forests*. Forestry Commission Bulletin 123. Forestry Commission, Edinburgh.

Forest Authority. (1998). *The UK Forestry Standard: The governments approach to sustainable forestry*. Forestry Commission, Edinburgh.

Forestry Commission. (1990). *Forest nature conservation guidelines*. HMSO, London.

Forestry Commission. (1994). *Forest landscape design guidelines*. HMSO, London.

Forestry Commission. (2000). *Forests and water guidelines 3rd edn*. HMSO, London.

Hodge, S. & Pepper, H. (1998). *The prevention of mammal damage to trees in woodland*. Forestry Commission Practice Note 3. Forestry Commission, Edinburgh.

Lucas, O.W.R. (1991). *The design of forest landscapes*. Oxford University Press, Oxford.

Mayle, B. (1999). *Managing deer in the countryside*. Forestry Commission Practice Note 6. Forestry Commission, Edinburgh.

Mayle, B.A., Peace, A.J. & Gill R.M.A. (1999). *How Many Deer? A field guide to estimating deer population size*. Field Book 18. Forestry Commission, Edinburgh.

McIntosh, R. (1995). The history and multi-purpose management of Kielder Forest. *Forest Ecology and Management*, 79, 1-11.

McLean, C. (1992). Sika deer control. *Red Deer Commission Annual Report 1992*. HMSO, Edinburgh.

Pepper, H. (1992). *Forest fencing*. Forestry Commission Bulletin 102. HMSO, London.

Pepper, H. (1999). *Recommendations for fallow, roe and muntjac deer fencing: new proposals for temporary and reusable fencing*. Forestry Commission Practice Note 9. Forestry Commission, Edinburgh.

Prior, R. (1983). *Trees and Deer.* B.T Batsford Ltd, London.

Prior, R. (1995). *The Roe Deer*. Swan Hill Press, Shrewsbury.

Ratcliffe, P.R. (1985). *Glades for deer control in upland forests*. Forestry Commission Leaflet 86. HMSO, London.

Ratcliffe P.R. & Pepper, H. (1987). *The impact of roe deer, rabbits and greys quirrels on the management of broadleaved woodlands*. Occasional Paper 34. Oxford Forestry Institute.

Red Deer Commission. (1980). Fuinary project: formation of deer control clearings. *Red Deer Commission Annual Report 1979*, HMSO, Edinburgh.

Rodwell, J. & Patterson, G.S. (1994). *Creating new native woodlands*. Forestry Commission Bulletin 112. HMSO, London.

Springthorpe, G.D. & Myhill, N.G. (eds) (1985). *Wildlife Rangers Handbook*. Forestry Commission, Edinburgh.

Warren, M.S. & Fuller, R.J. (1990). *Woodland rides and glades: their management for wildlife*. Nature Conservancy Council, Peterborough.

## 2. Review of techniques used to assess deer populations and damage

The need to base woodland deer population estimation on sound data collection and scientific method (Ratcliffe 1987a) has meant that techniques used for research purposes have been introduced for use in practical deer management. This has introduced such concepts as stratification and sampling, understanding of which are crucial to the use of many techniques. Furthermore, the use of sophisticated computer modelling techniques, or equipment required for some techniques may well be daunting to some, and expensive for others. A major requirement for any practical method will be cost of collecting the data or information. In many forestry situations expenditure on assessing deer populations and damage will have to be justified as financially beneficial. If deer managers and their staff are to use these techniques they should be properly trained so that the standards applied to any given technique are the same wherever that technique is used.

There have been several recent reviews of techniques used to assess deer populations (Buckland 1992; Cederlund et al 1998; Macdonald, Mace & Rushton 1998; Mayle, Peace and Gill 1999). There are many techniques available and 21 were reviewed by Mayle et al. (1999), for which there is some practical experience of use in this country. Techniques, used exclusively in North America or Europe, are not reviewed. We first consider techniques used for assessing deer populations from direct, indirect methods and cull data before looking at damage and impact assessments.

### 2.1 Direct Methods

Methods of population assessment may be classed as 'direct' if they depend on animal sightings, and as 'indirect' when based on animal tracks, signs or products. Direct counts are influenced by forest habitat succession (Gill 1994), and in large dense forest habitats are not considered effective (Buckland 1992; Mayle et al. 1999). However, given the variability in woodland size, structure and occurrence in the landscape some direct methods are still of value to the deer manager.

#### *2.1.1 Drive counts*

Drive counting is relatively simple in concept; the idea being to flush all deer from cover and into the open so they can be counted by carefully positioned observers from vantage points (Mitchell & McCowan 1980 1981; Mayle et al. 1999). In enclosed woodland, where it is not possible to drive deer into the open, beaters count the numbers of deer that break back between them. For a successful drive count the area should be naturally well defined, such as a small area of woodland. The main requirement is to have sufficient numbers of beaters and observers. The use of well-trained dogs to flush animals may also be necessary. Coordination and organisation are critical, especially in dense forest and difficult terrain and accurate recording of animal details, times of sightings, and direction of movement is essential to reduce the problem of double counting. The main assumption is that all animals present within the area being driven are counted once. Results are only specific to the drive day and are influenced by such things as disturbance and seasonal changes in deer behaviour and weather. Underestimation occurs if animals remain hidden in dense vegetation and are not counted. Disturbance can be great and drive counts are not recommended for nature reserves (Macdonald et al 1998).

Tests against populations of known size have found marked underestimates using drive counts (Mitchell & McCowan 1981; van Laere et al. 1998). Mitchell and McCowan generally got better results for red deer than for roe deer. The proportions of animals detected from averages of their best and poorest counts were 74% and 21% for red and 41% and 29% for roe deer. The individual red deer most frequently missed were calves. Mayle et al (1999) report on a drive count of 3 $km^2$ of thicket to estimate red deer density. A total of 96 beaters and observers were used and the minimum population estimated was greater than that suggested from pellet group counts. In Poland drive counts gave higher density estimates of red deer than spotlighting and static census counts (Dzieciolowski et al. 1995), and higher estimates for red, roe and fallow compared with snow track counts (Pucek et al. 1975).

- Drive counting is more suitable to small areas and for larger species such as red deer than for smaller species but needs large numbers of personnel and repeat-counts to be useful. While they can be reliable and effective if well organised, drive counts are likely to underestimate deer numbers by unknown amounts.

### *2.1.2 Static census, Vantage point and Open Hill counts*

Static census is similar to drive counting using observers at vantage points. In this method, the animals are not driven but observers are placed at suitable locations around the woodland area to be counted prior to dusk and dawn, the periods when greatest deer activity is thought to occur. Observers record deer as they move into the open to feed. It is assumed that all deer within the woodland block come out to feed in the open during daylight. The method relies on a large number of observers and on weather conditions allowing good visibility. It requires fewer people that drive counting. In this country the method is thought to be best suited to early spring (March/April) when vegetation doesn't obscure visibility so much (Mayle et al. 1999).

In Poland static census counts of woodland red deer were compared with those of three other methods: spotlighting, drive counting and track counting. Both static census and spotlighting underestimated deer density compared with the other two (Dzieciolowski et al. 1995). In a Danish study on woodland roe deer the entire population was exterminated, the total number killed was nearly three times the size estimated by static census (Andersen, 1953). The same author quotes another example for a population of fallow deer inhabiting a small island, where the population removed was 50% bigger than that estimated.

Cederlund et al. (1998) consider methods such as drive counts and static census as unreliable for management purposes. They require large numbers of people with inevitably different observational skills and double counting can occur, especially at high population densities. Mayle et al (1999) also consider static census inappropriate for assessing overall deer population sizes.

- Static census is generally thought to be an unreliable technique for estimating deer population size. It requires relatively large numbers of people and usually underestimates population density by an unknown amount.

In upland areas it may be possible to use vantage point counts. The whole area to be counted is first stratified into different habitats and representative large contiguous blocks of between 40-120 ha selected randomly. From the vantage point the observer marks on a map areas that can and cannot be seen into easily. The delineated area is then scanned methodically for deer using binoculars and telescope for ageing and sexing. Sightings are recorded on a map along with details of time, sex and age class of animals seen and direction of movement. To reduce double counting new groups are not added unless their composition and time of emergence into open areas suggest conclusively that they haven't been counted previously. Deer moving into the scan area from outside are not counted. Because animals are most likely to be seen when feeding, counts last between 2-3 hours. This allows the completion of rumination cycles and the onset of feeding activity, increasing the chances that any deer present in the scan area at the start of the observation period will be counted. Counting is best done after dawn and before dusk. April and May are suggested as the best months for doing vantage point counts (Ratcliffe 1987a; Ratcliffe & Mayle 1992).

At the end of a count the minimum number of animals seen is related to the area scanned and expressed as a density per unit area. Three or four repeat counts are needed to reduce problems with factors such as weather influencing deer movements. The maximum count recorded in a single period is used for the density estimate. Fresh counts are then made on adjacent areas of similar structure, and other habitat types present. Mean densities for each habitat type are applied for the area as a whole. Counts are specific to the observation day and seem better suited for more sedentary species such as roe deer (Ratcliffe & Mayle 1992). Observer bias in classifying sex and age classes may occur. Counts are affected by deer behaviour (Staines & Ratcliffe 1987). Vantage point counts used to estimate red (Ratcliffe 1987a 1987b) and sika deer (Mayle et al. 1999) populations consistently underestimated density. Ratcliffe (1987b) felt the technique too imprecise for indicating population changes over time. The method is therefore thought to be less useful than pellet group counts.

- Vantage point counts can only be used in hilly terrain, requires repeated counts and may be imprecise. This technique consistently underestimates population density and is not thought to be as useful as faecal pellet group counts.

In many estates with mixed use, open hill counts are likely to be used either for estimating the estates red deer population or as part of the DCS technique for counting red deer and populations of open range sika deer. The method is best used in large areas of open range and requires defined sections of ground to be counted by a census team within a day. Only a minimum population can be estimated and results are specific to count days. Counts are influenced by observer bias in age and sex estimation, the weather and changes in deer behaviour (Mayle et al 1999).

- Open hill counts are used for red and sika deer and as a technique is suitable for counting populations occupying large areas of open range. Only a minimum population can be estimated.

### *2.1.3 Population Indices*

Index methods assume that standardised observations detect a consistent fraction of the population. This assumption is unlikely to be met (Cederlund et al. 1998). An index can only be used to estimate the size of a population if it is calibrated against known populations. The problem with these kinds of data is that they are much more difficult to standardise for between-area than for within-area comparisons (Mitchell & McCowan 1980). One advantage of this approach is that it requires fewer people. For example, a forest ranger could collect data (animals seen along given routes, or map records of animal sightings over defined periods) for population monitoring in the course of other work such as during hunting (McIntosh, Burlton & McReddie 1995).

Casual visual observations within a 20 ha enclosure, which contained known populations of both red and roe deer, found a ratio of 20 red deer observations: 1 roe deer observation, although there were only twice as many red as roe (Mitchell & McCowan 1981). In a 5-year study at Kielder forest it was noted that the number of roe deer observed per hour of hunting effort indicated a similar pattern in population trend to that found by pellet group counting and it was concluded that observational data might be useful in determining long-term population trends (McIntosh et al. 1995).

- Index counts consistently underestimate population density because the assumption that observations detect a consistent fraction of a total population is unfounded. The technique is thus unreliable.

### *2.1.4 Change in ratio (CIR) estimates*

Any estimation technique that takes advantage of changes in observed sex or age ratios is a CIR method. The basic concept of CIR estimates is that one sex or age class (such as females) is culled more heavily than another and this selective removal will be reflected in differences between pre-hunt and post-hunt ratios. If the pre-hunt and post-hunt ratios can be estimated along with the number of animals culled, both the pre-hunt and post-hunt populations can be calculated from published formulas (Mayle et al. 1999).

The effectiveness of the CIR estimate is dependent on a high degree of accuracy in both cull and the herd sex or age classification data. Whereas it might be expected that a small error in the pre-hunt ratio would be inconsequential, such errors are magnified by the CIR formulas (Connolly 1981). CIR estimates assume that non-hunting mortality between pre-hunt and post-hunt counts affects all age and sex classes equally, animals of different sex or age classes are seen with equal probability, and that the herd classification data are from precisely the same population from which the cull is removed, ie a closed population. Often these assumptions are not valid. Because each of the values used in calculating population sizes are estimates they also have a sample variance. Therefore, variance and confidence limits can be calculated and used to predict the level of precision likely to be achieved with any given sampling effort (Connoer, Lancia & Pollock 1986).

CIR estimates have been widely used in North America (Connolly 1981). An example of using this technique in Britain gave widely differing results and both seasonal deer behaviour and misclassification were thought to be responsible for this (Mayle et al

1999). Staines and Ratcliffe (1987) suggest the method may not suitable for many red and roe deer populations. They point out that red deer stags use very different areas during the summer and autumn hunting season than in winter.

- Change in ratio estimates are thought more suitable for use in large open hill areas and could provide a check on open hill count bias. The technique is influenced by observer bias in classifying age and sex classes and deer behaviour.

### *2.1.5 Spotlighting*

Deer can be easily observed at night using a spotlight as it picks up eye reflection from animals facing the light source. Spotlights (100 Watt) are capable of picking up ‘eyeshine’ from 300-350 metres away. Usually spotlighting is done from a vehicle with a driver, observer and possibly a third person for recording deer seen. Specific areas are visited or selected routes driven. Animals seen are recorded, either by searching from set locations for a period of time or by driving slowly until animals are sighted then stopping to record. To ensure consistency, initial locating of animals should be by spotlight with the naked eye and good binoculars used to confirm identification. Spotlighting should begin about an hour after sunset. The method is affected by the weather with mist, heavy rainfall and snow, reducing visibility and snow depth, temperature and availability of food influencing counts (McCullough 1982; Progulske & Duerre 1964). Spotlighting is not recommended on bright moonlit or wet foggy nights. Counts are time specific and are best done in areas with good road or track systems.

Distance sampling (Buckland et al. 1993) can be used to estimate population density from the number of deer seen and confidence limits can be calculated. This relies on the calculation of a detection function from the distances measured between animals sighted and the transect line. The detection function gives the probability of seeing a deer at a given distance from the transect line and allows an estimate of deer density to be made (Mayle et al 1999). Distance estimation can be made using a range finder or recording animal location on a map relative to some physical feature (Gill, Thomas & Stocker 1997).

Experience from the forest of Chizé in France, using spotlighting to count roe deer, showed that following a 30% reduction in population the resulting density recorded suggested no significant change (van Laere et al. 1998). Other authors also report that spotlight counts underestimate population density (Dzieciolowski et al. 1995; Farfarman & DeYoung 1986; Kie & Boroski 1995). At Glenbranter Forest in Argyll, both red and roe deer were seen more during the night than during the day in restocks. However, differential use of restock areas was observed with more roe than red observed during the day and more red than roe during the night (Thirgood & Staines 1989).

- Spotlight counts are believed to be of limited use for estimating population size, as they tend to underestimate deer densities.

### 2.1.6 *Thermal imagery*

Thermal imaging technology has recently received interest as a potential method for counting numbers of deer in this country (Gill et al. 1997). All objects with temperatures above absolute zero emit radiation at the far-infrared end of the spectrum, with the intensity varying with the temperature of the source. Sensors convert far-infrared energy into visible light by focusing thermal radiation onto an array of super-cooled detectors (Boonstra et al. 1994). Two types image-forming sensors have been used in counting deer, infrared line-scanning devices and thermal imaging systems. Infrared line-scanners have been used in aerial census studies (Croon et al. 1968; Graves, Bellis & Knuth 1972; Wiggers & Beckerman 1993). Line-scanners scan a series of narrow strips perpendicular to the direction of flight building an image as the instrument is moved over a specific area. In contrast, thermal imagers scan both vertically and horizontally giving a higher quality image (Boonstra et al. 1994).

The method is similar to that for spotlight counting and involves selecting specific areas to be visited or routes to be driven or walked (Gill et al 1997). As with spotlight counting, distance sampling can be used with thermal imaging. It is suggested that to get a sufficiently accurate 'detection function' at least 70 distance measurements are required (Mayle et al. 1999). Some thermal imagers incorporate a range finder. Population density can then be calculated using the DISTANCE program, which is available on the Worldwide Web (Mayle et al. 1999). Thermal imaging has an advantage over spotlight counts in that more animals can be seen (Naugle, Jenks & Kernohan 1996). The equipment does not work well in heavy rain and visibility is severely limited in range in areas of dense thicket. Distinguishing between species can be difficult and although modern thermal imaging equipment gives high resolution, a red deer 2 km away appears as a pin prick (Macdonald et al. 1998). Sexing can only be done if animals are in velvet (Mayle et al. 1999).

An extensive network of roads, tracks, paths or firebreaks is needed to allow adequate coverage of a forest. Logistically these routes are easier to follow as transect lines. Sampling of the forest edge adjacent to fields and other open areas may also be necessary (Gill et al. 1997). The portable thermal imager used in field trials by Gill et al. cost £44,000, with an expected lifespan of 10-15 years. But the costs in time spent collecting data were favourable in comparison with other methods. For thermal imaging, vehicle censuses took on average 0.39 man-nights $km^{-2}$ and walked censuses 0.78 man-nights $km^{-2}$ compared with an average of 1.23 man-days $km^{-2}$ to search pellet group plots and 17.6 man-days $km^{-2}$ for drive counts (Gill et al. 1997). While it is not inconceivable that the price of the equipment may fall, it is not a method currently in widespread use. The methodology requires training in the use of the equipment, the sampling methodology and data analyses.

Pioneering research in North America established many of the problems associated with the technology. Some 30 years later these technical failings do not seem to have been improved upon, and cost remains prohibitive (Mayle et al 1999). The method is thought best suited to open woodland or open areas (Gill et al 1997; Mayle et al 1999), but is likely to underestimate numbers by a variable amount (Gill et al. 1997).

- Used in combination with an internal range finder, and in conjunction with distance sampling, thermal imaging is potentially suitable for estimating deer densities in forest habitats. However, the equipment is very expensive and the method has had limited use in this country.

### *2.1.7 Aerial counting*

In North America, aerial counts of ungulate species are routinely made (Connolly 1981). Counts are usually done in winter when visibility is enhanced by snow cover. While flying predetermined transects over the count area an observer counts and records the number of animals seen (White et al. 1989), aerial photographs can be used to aid counting large groups or as a check on counts (Kufeld, Olterman & Bowden 1980). Large areas of ground can be surveyed relatively quickly, as can less easily accessed areas. Aerial surveys often provide gross under-estimates of animal density because observers fail to see some of the animals (Caughley 1974; White et al. 1989). Accuracy of aerial counts decreases progressively with increasing width of transect, cruising speed and altitude. While the biases inherent in aerial surveys cannot be eliminated, they can be measured and estimates corrected accordingly (Caughley 1974; Connolly 1981). American experience shows that aerial counts in dense vegetation are impractical (Connolly 1981). Unpredictable weather in hilly terrain might restrict the usefulness of this technique in this country.

- Aerial census counts are best suited for to flat areas of open ground and are not suitable for counting animals in dense cover. Undercounting is a serious problem. Light aircraft and helicopters are expensive to hire the latter giving greater disturbance, especially to red deer.

Aerial counting using thermal imaging is also very expensive and prone to disruption by the weather. A military helicopter fitted with thermal imaging equipment took 3 days (approx. 9 hours flying time) to census the deer population of a Scottish estate. A certain amount of double counting was thought to have occurred. Bad weather dictated the heights and speed of helicopter operation and the location of counts. Strong winds made thermal imaging difficult due to excessive vibration. The mountain terrain prevented night flying and together with the weather conditions gave rise to greater aircrew fatigue than normally experienced. The operating height of the aircraft was also influenced by tree canopy; the denser the wood the greater the reduction in thermal image and the lower the aircraft had to operate. This inevitably produced more noise and encouraged deer movement (Anon 1999). The DCS and SNH carried out trials to evaluate airborne thermal imaging from a helicopter in open range red deer counts. The results were compared with those from simultaneous ground counts and extremely close agreement was found between the two methods (RDC 1993).

- Use of thermal imagery in aerial census increases the probability of detecting deer. Although infrared penetration is poor in very dense forest canopies it may be suitable for open range. The Scottish weather and hilly terrain might restrict use of this method, as will the current prohibitive costs.

## 2.2 Indirect methods

There is general acceptance that visual census techniques are impractical and inaccurate in the context of woodland habitats and so indirect methods are more commonly used. The tracks, signs and faeces of animals have been used in various ways as estimators, or indicators of their population density, each approach having its own advantages and limitations. One difficulty in using animal tracks and signs is that quantitative measures usually reflect the combined effects of population density and animal activity, leading to questions of interpretation.

### *2.2.1 Track counts*

Although not widely used in this country, track counts are used as an index of deer activity in parts of Europe (Dzieciolowski 1975; Pucek et al. 1975; Dzieciolowski et al. 1995) and North America (D'Eon 2001) where snowfall is more prevalent and reliable. Because of the unpredictability of snowfall in this country such snow track counting is not recommended. However, two variations of the method have been used in Britain.

The number of deer track-ways crossing woodland boundaries can be counted and an average per unit length calculated as an index (Mayle, Putman & Wyllie 2000) or the number of slots formed in prepared ground over a specified period of time can be counted (Mayle et al 1999). This latter method is similar to snow track counting. In the former study track-way and pellet group counts were undertaken at a large number of sites with either fallow or roe deer as the main species present. Although species such as foxes, badgers and hares also create track-ways this did not pose a problem in this study. A highly significant correlation was found between track-way and pellet group counts for sites with roe deer as the main species. The correlation for sites with fallow deer as the main species was poorer (Mayle et al. 2000). These authors argue that as a herding species, a number of fallow deer will use the same track-ways when leaving or entering a wood and this could account for the weaker correlation between track-ways and pellet group counts, whereas roe deer are more likely to use track-ways specific to themselves. An index is given where low density (<5 deer $km^{-2}$) equalled up to 2 track-ways per 100 m, medium density (5-15 deer $km^{-2}$) equalled 2-5 track-ways and high density (>15 deer $km^{-2}$) had >5 track-ways per 100 m. They suggest this is a quick and easy method, applicable at all times of year and provides a useful index, but if more accurate estimates were required then other methods should be used (Mayle et al. 2000).

- One of the main assumptions of track counting is that animals pass through the same place on consecutive days. Because this assumption is not always true track counts are best used as an index rather than an estimate of deer numbers.

### *2.2.2 Faecal pellet group counts*

Faecal pellet group counts are widely used as a method of estimating deer population densities in woodland (Mayle et al 1999). The method allows direct conversion from the number of pellet groups (an index of abundance), to a number of animals per unit area (Mayle 1996). In theory the method can be used for estimating population densities of large areas of deer range, or for assessing occupation by deer (the product of density and time) of relatively small sites within an area of deer range. The main advantages of this method are that pellet groups can be sampled by standard plot or transect techniques and that it provides estimates of average abundance over time rather than a day-specific estimate. Variants of the method are available, each having their own advantages and disadvantages, but in order to use the method successfully some knowledge of sampling procedures is required. The two types of pellet-group counting are the faecal accumulation method and standing crop counts. Most of the topics in the following text are relevant to both forms of counting method.

The applicability of the faecal pellet group count methods depends on:

i) defecation rates of deer in different habitats and in relation to the main kinds of forage available.

Defecation rates are required as part of the calculation for getting deer density from pellet group density. Very few studies have been undertaken to estimate defecation frequencies for deer in Britain (red deer: Mitchell, McCowan & Campbell 1983; Mitchell & McCowan 1984; roe deer: Mitchell et al. 1985; fallow: Mayle et al. 1996; sika: Mayle et al. 1999). Most estimates have been carried out on captive animals, although usually some comparison between habitat types has been undertaken (Mitchell & McCowan 1984; Mitchell et al. 1985). A criticism of using captive deer is that because of dietary differences their defecation rates could be different from those of wild deer (Macdonald et al. 1998). Defecation rates have been found to vary by season, with forage quality, habitat and with sex and age within a species (Mitchell et al 1985; Mayle et al. 1996).

The average daily defecation rate is usually suggested for estimating population density (Mayle et al. 1999). Use of these average rates does not take account of site quality and will potentially overestimate deer density in very rich sites and underestimate in poor sites. Mayle et al. (1999), suggest the following daily defecation rates: red (25), sika (25), fallow (21.4) and roe (20). However, most authors seem to agree that bias in estimating defecation rates is less problematic than bias in estimates of decay lengths (Neff 1968; Mitchell et al. 1980; Buckland 1992; Marques et al. 2001).

ii) the rate of faecal decomposition in relation to habitat and climate.

The assumption of a steady relationship between deer density and the density of faeces is unlikely to be always true because of the variability in the rate of decomposition of faecal material. It is necessary to derive correction factors to remove the effects of decomposition. Rates of decomposition vary in relation to differences in habitat and climate, and one of the prerequisites of using standing crop counts is knowledge of site-specific decay rates (Ratcliffe & Mayle 1992). Published average decay rates are available but it is suggested that local decay rates be measured (Ratcliffe & Mayle 1992; Mayle et al. 1999). Spring is believed the best time for pellet group counting, and decay plots should be set up in autumn in sites representative of different forest habitats. Specifics on estimating defecation rates are given in Ratcliffe & Mayle (1992) and Mayle et al. (1999). It is suggested that pellet groups with more than 40 pellets are set out, with about six pellet groups in each habitat being assessed. Decay is monitored during the winter and considered complete when fewer than six pellets remain (Ratcliffe & Mayle 1992). Decay may take just a few months in rich deciduous habitats and up to 15 months in coniferous acidic ones.

iii) rates of search and success in finding faeces in different vegetation types.

Most counts will underestimate actual pellet group density because pellet groups can be missed because of overgrowth of vegetation, partial decay of dung and inadequate searching (Neff 1968). Tests have been conducted using pellet groups in known positions to calculate the proportions found under different vegetation types (Mitchell & McCowan 1980; Welch et al 1990). Mitchell and McCowan had very high success in finding deer pellet groups in 'easy' ground with short vegetation and poorer success in 'difficult' ground with tall vegetation. Greater success in finding pellet groups is found at the end of winter than in late summer (Mitchell & McCowan 1984; Welch et al. 1990). Time spent searching plots is related to the ground vegetation present (Mitchell & McCowan 1984). Differences in finding pellet groups from species that produce large individual pellets compared with species that produce smaller pellets have also been found Welch et al. (1990).

iv) ease in identifying faeces when two or more herbivore species are present.

There is overlap in the size, shape and appearance of faecal pellets between many species and soft dung is especially difficult to identify. Tests on roe deer pellets showed they could shrink slightly or swell considerably depending on the substratum, and after 10 days on a wet surface pellets almost doubled in volume (Mitchell et al. 1985). In field trials on red and roe deer pellet groups using pairs of observers, Welch et al. (1990) recorded that about 5% of groups were misclassified as to species and concluded that on balance results were unaffected. Prior to fieldwork observers should familiarise themselves with the different species present using known pellet groups (Welch et al. 1990).

v) whether or not defecations are spread evenly over time and if the number found are proportional to the amount of time deer spend in different parts of their home range or territory.

Herbivores, unlike carnivores and lagomorphs, distribute their faeces widely over the ground they occupy with no obvious tendency to select special sites, such as latrines. However, there is a tendency for deer pellet groups to have a clumped distribution (Neff 1968). Red deer mainly defecate when feeding (Mitchell et al. 1983), and consequently do not defecate evenly over time. Therefore the number of pellet groups accumulating at particular sites mainly reflects the amounts of feeding activity. This conclusion is backed up by findings from radio tracking, which showed different habitat preferences for red deer compared with those from pellet group counts at the same site (Catt & Staines 1987). Mayle et al (1996) also report the tendency for fallow deer pellet groups to have a clumped distribution.

Other practical considerations of sampling include the size and shape of plots, the intensity of sampling and defining a pellet group. One criterion for choosing plot size is the density of pellet groups in the sample area. Thus, at low deer pellet group density sample plots may need to be large in order to detect sufficient groups (Neff 1968). From a practical point of view moderately sized plots (50-200 $m^2$) are preferable for obtaining reasonable numbers of pellet groups per plot as they maximize the time spent searching at the expense of travel time between plots

(Mitchell et al 1985 +). Small plots (<50 $m^2$) are less preferred because many more are needed and they increase the likelihood of zero returns, which are of little value. Large plots (>200 $m^2$) are difficult to search efficiently and take much longer (Mitchell et al 1985). The plot sizes that have been recommended by Forest Research are 7 x 7 m for counts by a single person and 10 x 10 m for counts by 2 people. However, some authors have found that in practice these shapes of plot are not easy to use.

The choice of plot size and shape has an affect on observer error. One such error is interpreting groups that are partly in or out of the plot. Plot counts require detecting all pellet groups within sample areas and clear rules about edge groups must be defined if bias is to be avoided. Long narrow plots have a relatively large proportion of edge to area. This increases the probability of pellet groups being located near or on the edge. Batcheler (1975) showed that varying estimates due to plot size could be explained by the 'edge effect' problem of defining groups. Pellet groups outside the plots influence counts, and this influence is proportional to plot size and area over which pellet groups are scattered. This suggests that there may be no such thing as an ideal plot size. Batcheler showed that the high estimates from very small plots are even more biased than the low estimates from bigger plots because of the 'edge effect'. He suggested a plotless distance method, in which the distance from a random point to the nearest pellet group is measured. However, this does not get over the need to determine the location of a pellet group and is wasteful because of the time needed to find the `closest` group (Buckland 1992). Buckland suggests that conventional plot counts or line transect methods will be more efficient.

More recently the use of line transect sampling, whereby the number of pellet groups is modelled as a function of the perpendicular distances of detected pellet groups from the transect line, has been suggested (Marques et al 2001). Using this method it is not necessary to detect all pellet groups and thus the bias from edge effects is eliminated. However, problems can arise when trying to establish the midpoints of strewn-out or scattered pellet groups (Connelly 1981).

Defining what constitutes the minimum size of pellet group to be counted also introduces potential for miscounting. Various figures have been used, from 4 to 16, with lower figures used where authors are concerned with missing decaying groups and higher figures where authors worry about double counting (Mitchell et al.1985); Welch et al 1990; Mayle et al 1999; Marques et al 2001). Although all these figures are completely arbitrary it would make sense that the minimum number used to constitute a group is also used for defining decay. Thus Forest Research use <6 pellets to signify disappearance of a pellet group (Ratcliffe & Mayle 1992) and 6 pellets as the minimum for a pellet group (Mayle et al 1999).

Putman (1984) notes that most authors have stressed the many potential sources of inaccuracy and expressed reservations about application of faecal pellet group counting. He concluded that most of these are problems with sampling and that many of the potential sources of error are insignificant in practice.

Using the faecal pellet group count technique requires sampling the area of interest and calculating the sample size needed to achieve the required precision. Mayle et al. (1999), suggest that population size be measured to ±20% and to achieve this at least a hundred pellet groups must be counted. The number of plots required will depend on the expected mean number of pellet groups per plot. This in turn depends on deer density and defecation and decay rates. Pilot surveys may be needed to estimate the survey effort required to meet a desired level of precision (Mayle et al. 1999). Stratification of the area may also be necessary because of likely variation in the factors being measured, such as rate of decomposition, or detection rates if using distance sampling. This can be done by defining forest types by age and vegetation, using broad characteristics likely to be important to deer (Welch et al. 1990). The extent of each stratum can be calculated and the number of sample plots allocated proportionately (Welch et al. 1990).

Mayle et al. (1999), suggest a minimum of six plots for each habitat type, and ideally these should be allocated at random within a habitat. These authors give greater detail on sampling, estimating sample size, stratification and the formulae used for calculating deer density for the following different methods.

#### *2.2.3 Clearance counts*

Clearance counts require a minimum of two visits. In the first permanent plots are marked out using a tape measure and pegs and searched carefully for dung. All pellet groups encountered are removed from the plots. The plots are revisited some time later, and. the numbers of pellet groups accumulating on each plot are counted. Timing of the second visit depends on prior knowledge of decay rates and ideally should occur just before expected decay time and any potential change in population due to culling or natural mortality. The best time of year for doing faecal accumulation counts is late winter and early spring. At this time of year the effects of faecal decay and the problems of not detecting pellet groups are minimal (Mitchell et al 1985; Welch et al. 1990). Buckland (1992) comments that if the primary aim is to estimate absolute abundance and there are adequate resources then this is the most preferable method. Pellet group clearance counts have been used successfully to monitor the effects of long-term hunting pressure on roe deer at Kielder forest (McIntosh et al 1995). The method is considered best used at high deer density (Buckland 1992; Mayle et al. 1999).

- Clearance plots are thought to be best suited for use in areas with high densities of deer (>30 $km^{-2}$). The method is more reliable than the standing crop method and is not sensitive to decay rate bias. At least 2 visits are required and may be more time consuming than other methods.

#### *2.2.4 Standing crop plot counts*

Rather than measuring a rate of accumulation over two visits standing crop counts are a density measure requiring only one visit per site. Counts are usually done during the spring. Knowledge of daily defecation rates and the rate of decomposition of faecal pellet groups is needed for calculating deer densities. Dung decay rates should be determined locally (Ratcliffe & Mayle 1992). In the field, plots are delineated to reduce edge effect problems, carefully searched, and the number of pellet groups counted. Deer density is calculated using published formula (Mayle et al. 1999). The method is considered best used at medium deer density (Buckland 1992; Mayle et al. 1999).

- The standing crop plot count method relies on precise measurement of faecal decay rates for different habitats. However, with only one visit less effort is required compared with plot clearance. Standing crop counts are thought to be most suitable for medium deer density (10-30 $km^{-2}$).

### *2.2.5 Index of deer presence*

A relatively quick method to provide an index of deer presence is to use a specified number of plots or length of transect within representative areas of habitats present. Plots are allocated at random within habitats while transects can be allocated either at random or systematically. Each plot or transect is searched and the standing crop of pellet groups recorded, if possible identifying to species level. Either totals or means for each habitat can be calculated for each species and compared between habitats, within and between sites, to give an index of presence. An example is given in Mayle et al (1999) but this technique does not seem to be in widespread use.

- A relatively quick technique that can be done by 1 person to provide an index of deer use in different sites and habitats.

### *2.2.6 Strip transects*

This method uses long thin sampling plots of 500-2000 m x 1 m and is thought most suited to sites with low deer density (Mayle et al 1999). For each habitat a representative compartment should be selected. If confidence intervals are required then more that one compartment for each habitat should be sampled. The length of transect used will depend on the precision of the estimate required. Longer transects will give a more precise estimate. Transects should not run parallel to features which may influence deer habitat use, such as streams or rides. A compass bearing is walked recording all the pellet groups found in each 10 m section of a transect. A 1 m cane or rule is used to measure the transect width, and it is easier for determining ‘edge’ groups if the transect line is delineated. Potentially this is a quicker method than standing plot counts, especially in habitats with little or no ground vegetation, but where there is ground vegetation search times will be similar (Mayle et al. 1999).

Because this is a standing crop method faecal decay rates are required and the same equation as for the standing crop plot count can be used to estimate deer density in each habitat and provide an overall deer density (Mayle et al. 1999).

- Strip transects are most useful in areas of low deer density (1-10 $km^{-2}$) and large areas can be sampled relatively quickly, especially if ground vegetation cover is sparse. Because only narrow strips are searched the method is prone to observer bias of pellet groups found on the transect edges.

### *2.2.7 Line transects*

In line transect sampling the number of pellet groups seen are counted, using distance sampling, while traversing a predetermined line of known length. An advantage of this method is that it is not necessary to find all pellet groups, but it is assumed that all pellet groups at zero distance are detected (Marques et al. 2001). Buckland et al. (1993) state “the importance of meeting this assumption cannot be overemphasised”.

Many short transects lines are preferable, giving better spatial coverage and reliable estimates of precision (Marques et al 2001). These authors used a 50 m transect, searching a 2 m strip, on a high density sika deer population and recommend at least 10-20 separate transect lines within each area of land for which a separate estimate is required. In areas of low deer density, transects longer than 50 m may be more appropriate. Precise distance measurement of pellet groups from the transect line are required to avoid rounding up problems which are difficult to model accurately. Computer models are used to calculate detection functions and encounter rate estimates for the different strata to provide pellet group density estimates. The length of time to pellet group decay (the reciprocal of the decay rate) for each habitat is used to estimate deer density from pellet group density (Marques et al 2001). A potential source of bias was found when sampling sloping ground. However, the correction was so small that it made no appreciable difference to the population estimate (Marques et al 2001). These authors suggest that adjustments may be required in areas of steep terrain. The method is considered best used at low deer density (Buckland 1992; Marques et al 2001).

- Line transects are thought to well suited to areas with low or moderate deer density and may be more cost effective than using plots. But at high deer density clearance plots should be preferred. The use of specialist computer software to analyse data might limit the use of this method.

## 2.3 Cull data

Data collected from the annual cull can be used either to reconstruct a deer population so that a retrospective estimate of numbers can be made, or in simple models that can predict changes in the population. The information required comes from estimates of population dynamics. That is reproduction, mortality, immigration and emigration. It is only possible to estimate reproduction and mortality, although emigration that results in a net loss to the population can be considered as mortality (Ratcliffe & Mayle 1992).

Reproduction and mortality (or its compliment, survival) are the two most important aspects of population dynamics and both are age dependent (Caughley 1977). The structure of the population by age and sex is fundamentally important in deriving the cull target (Mitchell, Staines & Welch 1977; Mayle et al. 1999). The age of culled females will provide information on the number of adults that can reproduce. Pregnancy rates (based on counting corpora lutea/foetuses) will provide maximum potential recruitment (Ratcliffe 1987a, 1994). Summer calf:hind / kid:doe ratios indicate calf or kid mortality when compared with pregnancy rates (Ratcliffe & Mayle 1992; Mayle et al.1999). Data collected from culled animals are therefore invaluable as a means of retrospectively calculating population size, and for predicting future changes in population size.

### *2.3.1 Life tables*

Life tables are a means of summarising survival and mortality data about animal populations. Life tables for deer are based on the ages of dead animals. Assumptions are that the age composition of dead animals mirrors that of the population, the population is stable and survival rates are constant from year to year. These assumptions are rarely true for deer populations. A further limitation of life tables is that they give no information on reproduction (Macdonald et al 1998).

- Life tables are not recommended for use because the main assumptions of this technique are rarely true for deer populations.

### *2.3.2 Cohort analysis*

A cohort is a collective name for all the animals born in a particular year. If the age of each deer shot during the year's cull can be reliably determined then the year of birth for each animal can be calculated. Accuracy of the technique will increase if non-cull deaths are recovered. The ages of individual animals are determined using tooth eruption and wear from jawbones collected. It is therefore important that measures of age are accurate. Practical difficulties have been identified in ageing roe deer, in that once they have replaced their milk teeth accurate age determination is only then possible by counting annual growth lines in the dental cementum of cut teeth using a microscope (Ratcliffe & Mayle 1992).

Cohort analysis is a means of recording and accumulating the number of deer born in a particular year. It is possible to estimate the total minimum population by calculating the number of adults required to produce the number of young in a particular year. An Excel program has been developed for this (Helen Armstrong pers. comm.). Several years` data are required before the technique starts producing results, but it is believed to be valuable in providing a factual retrospective check on minimum population size (Ratcliffe 1987a; Ratcliffe & Mayle 1992). A major assumption of the technique is that immigration and emigration are in balance.

Cohort analysis has been carried out for red deer in Carrick forest in Galloway (Ratcliffe 1987b). Estimates were made on the number of calves born per year, the number of breeding age hinds and the number of yearlings and a minimum population size reconstructed for a particular period. Ratcliffe considered cohort analysis an essential component of deer management.

- The Forestry Commission recommend cohort analysis as a useful deer management tool for reconstructing minimum population size. It is dependent on accurate aging of individual deer and may be of particular use in areas where most deaths are from culling.

### *2.3.3 Population modelling*

Estimated deer density, recruitment and mortality data can be used to model predicted changes in the population and to set cull targets relative to management objectives (Ratcliffe 1987a; Ratcliffe & Mayle 1992). This can be done more quickly with the aid of a computer, but may also be done by hand. Leslie Matrix models have been used to estimate post breeding population levels of red (Ratcliffe 1987b) and roe deer (Mayle 1996). Use of this model showed that it was more sensitive to changes in survival than fertility and that survival of the youngest age class should be estimated more precisely than fecundity (Mayle 1996).

A Leslie Matrix model was used to simulate roe deer populations at Glen Righ, using faecal pellet group counts for estimating population density and birth rate and survival from the previous cull. A change in management objectives meant that establishment of Scots pine, larch and broadleaves without the use of fencing was sought for some areas of restock. The roe deer population of 25 deer $km^{-2}$ was considered too high for this to be successful and a target density of 15 deer $km^{-2}$ was set. Mayle (1996) reports that the results from the Leslie Matrix simulations on females suggested a 20% cull would maintain the original density and an increase in this effort would reduce the population. As a result restocking was postponed until the target density was reached and a higher cull was introduced to reach the target density within 3 years. Faecal pellet group counts were used to monitor progress.

Mayle et al. 1999 state that population modelling has become an integral part of deer management by Forest enterprise. Leslie Matrix models are relatively simple and more complex models, which can include habitat quality influences on fertility and mortality, are becoming available (Mayle et al. 1999).

- Population modelling is in current use and has been used successfully for establishing cull targets. It requires estimates of current population density and fecundity and mortality based on age classes.

### 2.3.4 Summary

**Static census, Aerial census, Spotlighting and Index counts are considered unreliable as techniques for estimating deer populations in woodlands and are not recommended.**

**Drive counts and thermal imagery are expensive techniques and are not recommended because of cost. Future developments might make the latter technique more suitable for population assessment in woodland. Open hill counts and CIR counts are best suited to open range situations and are not recommended for woodlands. Vantage point counts are only suitable in areas of hilly terrain but the technique tends to underestimate population size.**

**We suggest that direct counts are not suitable for forest or woodland and that indirect methods should be used. We recommend that faecal pellet group counts should be used for assessing deer populations in woodland.**

**Using life tables for reconstructing cull data are not recommended.**

**We strongly recommend that more use be made of cull data including aging and collecting reproductive data and suggest cohort analysis for reconstructing population data.**

| | Advantages | Disadvantages |
|---|---|---|
| **Direct Methods** | | |
| Drive counts | Species composition and sex and age classes can be estimated. Can be used for woodland counts. | Large numbers of people required. Needs good planning and coordination. Results specific to day of count. Only minimum population estimated. Observer bias in classifying animals. Causes disturbance. |
| Thermal imaging | Species composition can be estimated. Sex and age classes can be estimated if animals in velvet. Only 1-2 people required. Relatively quick. | Equipment expensive and availability limited. Training required for using equipment, sampling method and data analysis. Survey woodlands need good road and ride network. Results specific to day of count and can be influenced by weather and deer behaviour. Specialist software required for data analysis. |
| Vantage point counts | Species composition and sex and age classes can be estimated. Only 1-2 people required. | Only suited to hilly terrain. Needs good visibility. Results specific to day of count and can be influenced by weather and deer behaviour. Only minimum population estimated. Observer bias in classifying animals. |
| Change In Ratio | Sex and age classes can be estimated for individual species. Suitable for large areas. Only 1-2 people required. Low equipment costs. | Large numbers of observations needed. Observer bias in classifying animals. Two separate surveys needed. May be influenced by seasonal deer behaviour. More suited to open hill. |
| Open hill counts | Species composition and sex and age classes can be estimated. Suitable for large areas. Relatively quick. | Only suited to open ground. Large numbers of people required. Needs good planning and coordination. Results specific to day of count and can be influenced by weather and deer behaviour. Only minimum population estimated. Observer bias in classifying animals. |
| **Indirect methods** | | |
| Track counts | Only 1-2 people required. Low equipment costs. Applicable to woodland and open habitats. Species composition can be estimated. Relatively quick. | Provides only an index of presence or activity. Sex and age classes cannot be estimated. Dense vegetation may obscure tracks. |
| Faecal clearance counts | Only 1-2 people required. Low equipment costs. Applicable to woodland and open habitats. Not restricted by weather, except snow. Population estimate for specific time period can be calculated. Estimate more accurate than standing crop counts. | Two separate surveys needed. Sex and age classes cannot be estimated. Species identification sometimes difficult. Habitat and species-specific faecal decay rates required. Species-specific defecation rate needed. 2-3 month delay in obtaining results. |
| Standing crop | Only 1-2 people required. Low equipment costs. One count needed. Applicable to woodland and open habitats. Not restricted by weather, except snow. Population estimate can be calculated for period equal to decay length. | Sex and age classes cannot be estimated. Species identification sometimes difficult. Habitat and species-specific faecal decay rates required. Species-specific defecation rate needed. |
| Index | Only 1-2 people required. Low equipment costs. Quick. One count needed. Applicable to woodland and open habitats. Not restricted by weather, except snow. | Provides only an index of presence or activity. Sex and age classes cannot be estimated. |

| contd | Advantages | Disadvantages |
|---|---|---|
| | | |
| Strip transects | Only 1-2 people required. Low equipment costs. One count needed. Relatively quick. Applicable to all woodland and open habitats. Not restricted by weather, except snow. | Habitat and species-specific faecal decay rates required. Species-specific defecation rate needed. Sex and age classes cannot be estimated. |
| Line transects | Only 1-2 people required. Low equipment costs. One count needed. Applicable to all woodland and open habitats. Not restricted by weather, except snow. | Species-specific defecation rate needed. Sex and age classes cannot be estimated. Specialist software required for data analysis. Dependent on accurate measurement of distances from transect line to pellet groups. |
| **Cull data** | | |
| Cohort analysis | Sex and age classes can be estimated for individual species. Only 1-2 people required. Low equipment costs. Applicable to all woodland and open habitats. Can be used to check other methods retrospectively. | Bias in aging animals and not finding all dead animals. A closed population is assumed. Gives retrospective estimates. Requires several years of data collection. Needs careful record keeping. |
| Population modelling | Sex and age classes can be estimated for individual species. Only 1-2 people required. Applicable to all woodland and open habitats. Predictive. Can test culling scenarios. | Depends on accuracy of initial population estimate, aging of animals, fertility estimates and mortality data. Specialist software required for data analysis. |

## 2.4 Damage assessments

In this review for convenience we have taken the view that impact assessments and damage assessments are in essence the same. Impact assessments are generally used as an index of deer occupance. Implicit with this is an assumption that a high impact equates to a high population size and conversely low impact will equate to a low population, even though the relationship may not be linear. Usually ground vegetation or under-storey of a wood is assessed, perhaps using preferred species as an indicator. Damage assessments in a strict forest sense will relate to direct damage of the tree crop either through browsing, thrashing/fraying, or bark stripping. However, it may still be that a high level of damage will prompt some response to the deer population. With all these assessment methods an important assumption is that observers can differentiate deer damage from that of other species.

### *2.4.1 Impact assessments*

No simple relationship has been found between deer numbers and impact levels on vegetation. There does appear to be a threshold density, for any habitat, below which only minor damage occurs and above which damage is more noticeable (Gill 1992). For this reason impact assessments are used as an index of deer presence, for example high, medium or low.

Such an index has been used by Scottish Natural Heritage using a 3-point index (Heavy, Moderate, Light) to describe the 'current' state of habitats in terms of various forms of impact using field indicators (MacDonald et al. 1998). Initially the index was difficult to use as impact could vary markedly within the sample unit area chosen (0.25 $km^{-2}$) and field workers added intermediate points on the index scale. Also, the whole area had to be assessed, rather than sample areas, which meant the technique was expensive. An alternative methodology for rapid assessment of impacts has been developed, in which a random sample of each habitat is assessed, and extrapolation made to the whole region of interest. This technique has been carried out on some open hill red deer range. Sampling intensity is not done proportionally to habitat area. This is to avoid over-sampling of extensive less preferred vegetation types and under-sampling less extensive but more preferred vegetation types. Following field assessment the overall impact class for each vegetation type is calculated as the mean impact class from the relevant sample squares. This mean is used to classify the remaining areas not sampled. Using this method only between 10% and 25% of 0.25 $km^{-2}$ squares need be sampled as beyond this sampling intensity the gains in improved accuracy are outweighed by increased costs (Macaulay Institute 2002).

Mitchell and Kirby (1990) review the impacts of herbivores on the flora and fauna of semi-natural woodland. They provide an outline index for grazing level indicators concluding that moderate grazing is most beneficial for conservation interests. There are potential problems with impact assessments if they are to be used to guide deer management, as impacts from other herbivores are usually not separated from those of deer. The use of impact assessments highlights areas of different use and can clearly demonstrate increases in impact, but it is unclear how sensitive they are to reductions. Recovery from severe damage may take many years but it is unclear how sensitive some impact assessments will be to this change if vegetation response is slow. For example if using heather condition based on shape of bushes then changes from normal to bushed or carpet may be obvious but it may take many years for bushed or carpet heather to return to normal. A method that includes an estimate of grazing may therefore be more appropriate.

In France the browsing index has been used to monitor roe deer populations. A systematic sampling procedure based on a permanently marked 200 m grid network was used to obtain an annual measure of winter off-take of woody plants. At each grid cell a 40 $m^2$ plot was sampled in spring before vegetation growth starts. All woody species, except ivy, less than 1.2 m, and having live parts that could be eaten by deer, were checked for browsing on twigs. A woody plant was considered as consumed if >5% of available twigs were browsed. An annual index was then calculated using a statistical technique that includes information from the previous year (Morellet et al 2001). The results were compared with those of another technique, the Kilometric Index. This is an index of the number of deer observed per kilometre of transect sampled on foot (Vincent et al. 1991). It was found that the browsing index closely tracked the fluctuations of the roe deer population over time and that changes in browsing pressure were partly accounted for by changes in the size of the deer population. Morellet et al. (2001) conclude that the browse index is a useful tool for monitoring the browse-deer interaction. This method is more useful in deciduous woodland with an understorey than in dense conifer woodland.

- Impact assessments provide only an index of deer presence and impacts from other herbivores may be difficult to separate from those of deer. Recovery from severe damage may take many years but it is unclear how sensitive some impact assessments will be to this change if vegetation response is slow. An index involving some measure of browsing or grazing may be more sensitive.

### *2.4.2 Nearest neighbour assessments*

The nearest neighbour method has been suggested by the Forestry Commission as a simple and quick assessment technique for estimating wildlife damage in plantation forests. The method is best applied when a single damage assessment is needed on a particular compartment. Separate assessments are required for compartments with different tree species or ages of tree. Generally damage assessments on leader browsing, fraying and bark stripping are undertaken (Pepper 1998). From the point of view of deer management it is critical that damage attributable to deer can be identified as such, this might require training, although there is published guidance (Mayle 1999; +).

The details of the method are given in Melville, Lee and Rennolls (1983) and Pepper (1998). A series of parallel lines are paced and cluster points located systematically throughout the compartment. This helps identify regions with different damage intensities. Around the cluster point a predetermined number of trees (cluster) are assessed for damage. Prior to assessment the accuracy required, the total number of trees to be sampled, the number of trees in a cluster, the number of clusters and the distance between clusters are all needed. The accuracy required may depend on the age, crop value and compartment size. High accuracy of ±5% might be justified assessing a large compartment of a high value crop near felling age, whereas less accuracy might suffice for a small recently planted compartment. Accuracy is also related to the number of trees sampled. Formulae for calculating the total number of trees to sample, the number of clusters and distance between clusters are published in

Melville et al. (1983) and Pepper (1998). These authors also suggest that the number of trees in a cluster would normally range from 4 to 7 with 5 trees per cluster recommended. They also suggest a minimum of 20 clusters are assessed to be of value.

Bias may occur from deliberate selection of cluster points, either in areas of damage or no damage. Because in this technique the proximity of nearest neighbour trees to the cluster point is not physically measured, subjective selection for damaged or undamaged trees can occur. Choice of cluster trees must therefore be independent of damage.

A measure of the stocking density of the compartment is essential for putting estimated damage into context. The fewer the trees there are the less a forester can accept damage. An estimate of stocking density can be made at the same time as the damage assessment this time using fixed sized plots. It is possible to set a required level of accuracy and number of plots required, as done for the damage assessment. Alternatively, it is advised that at least 20 plots are recorded.

### 2.4.3 Summary

**We recommend nearest neighbour techniques for assessing damage to commercial woodland.**

## 2.5 References


Andersen, J. (1953). Analysis of a Danish roe-deer population (Capreolus capreolus (L.)) based upon the extermination of the total stock. *Danish Review of Game Biology*, 2, 127-155.

Anon (1999). A deer census of the Balmoral estates. Unpublished draft report, 665 Squadron 5 Regiment Army Air Corps.

Batcheler, L. (1975). Development of a distance method for deer census. *Journal of Wildlife Management*, 39, 641-652.

Boonstra, R., Krebs, C.J., Boutin, S. & Eadie, J.M. (1994). Finding animals using far-infrared thermal imaging. *Journal of Mammalogy*, 75, 1063-1068.

Buckland, S.T., Anderson, D.R., Burnham, K.P. & Laake, J.L. (1993). *Distance sampling: estimating abundance of biological populations*. Chapman & Hall, London.

Catt, D.C., & Staines, B.W. (1987). Home range use and habitat selection by red deer (Cervus elaphus) in a Sitka spruce plantation as determined by radio-tracking. Journal of Zoology, 211, 681-693.

Caughley, G. (1974). Bias in aerial survey. *Journal of Wildlife Management*, 38, 921-933.

Cederlund, G. (1983). Home range dynamics and habitat selection by roe deer in a boreal area in central Sweden. *Acta theriologica*. **28:** 443-460.

Cederlund, G., Bergqvist, J., Kjellander, P., Gill, R., Gaillard, J.M., Boisaubert, B., Ballon, P & Duncan, P. (1998). Managing roe deer and their impact on the environment: maximising the net benefits to society. *The European roe deer: the biology of success* (eds R. Andersen, P. Duncan and J.D.C. Linnell.). Scandinavian University Press, Oslo. 337-372

Conner, M.C., Lancia, R.A. & Pollock, K.H. (1986). Precision of the change-in-ratio technique for deer population management. *Journal of Wildlife Management*, 50, 125-129.

Connolly, G.E. (1981). Assessing populations. *Mule and black-tailed deer of North America* (ed. O.C. Wallmo). University of Nebraska Press.

Croon, G.W., McCullough, D.R., Olson, Jr, C.E. & Queal, L.M. (1968). Infrared scanning techniques for big game censusing. *Journal of Wildlife Management*, 36,875-884.

D`Eon, R.G. (2001). Using snow-track surveys to determine deer winter distribution and habitat. *Wildlife Society Bulletin*, 29, 879-887.

Dzieciolowski, R., Goszczynski, J., Wasilewski, M. & Babinska-werka, J. (1995). Numbers of red deer in the Slowinski National Park, Poland. *Acta Theriologica*, 40, 45-51.

Farfarman, K.R. & DeYoung, C.A. (1986). Evaluation of spotlight counts of deer in south Texas. *Wildlife Society Bulletin*, 14, 180-185.

Georgii, B. (1980). Home range patterns of female red deer (*Cervus elaphus* L.) in the alps. *Oecologia (Berl.)* **47:** 278-285.

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

Gill, R.M.A., (1994*). The population dynamics of roe deer (Capreolus capreolus L.) in relation to forest habitat succession*. Phd Thesis, The Open University.

Gill, R.M.A., Thomas, M.L. & Stocker, D. (1997). The use of thermal imaging for estimating deer population density in forest habitats. *Journal of Applied Ecology*, 34, 1273-1286.

Graves, H.B., Bellis, E.D. & Knuth, W.M. (1972). Censusing white-tailed deer by airborne thermal infrared imagery. *Journal of Wildlife Management*, 36, 875-884.

Kie, J.G. & Boroski, B.B. (1995). Using spotlight counts to estimate mule deer population size and trends. *California Fish and Game*, 81, 55-77.

Kufeld, R.C., Olterman, J.H., & Bowden, D.C. (1980). A helicopter quadrat census for mule deer on Uncompahgre Plateau, Colorado. *Journal of Wildlife Management*, 44, 632-639.

Macaulay Institute. (2002). Rapid assessment of grazing and trampling impacts on upland habitats. *Macaulay Institute Annual Report 2001*, Macaulay Institute, Aberdeen.

MacDonald, A., Stevens, P., Armstrong, H., Immirzi, P. & Reynolds, P. (1998). A guide to upland habitats. Surveying management impacts. Volume 1, Background information and guidance for surveyors. Scottish Natural Heritage, Battleby.

Macdonald, D.W., Mace, G. & Rushton, S. (1998). *Proposals for future monitoring of British mammals*. Department of the Environment, Transport and the Regions, London.

Marques, F.F.C., Buckland, S.T., Goffin,D., Dixon, C.E., Borchers, D.L., Mayle, B.A. & Peace, A.J. (2001). Estimating deer abundance from line transect surveys of dung: sika deer in southern Scotland. *Journal of Applied Ecology*, 38, 349-363.

Mayle, B.A. (1996). Progress in predictive management of deer populations in British woodlands. *Forest Ecology and Management*, 88, 187-198.

Mayle, B.A., Doney, J., Lazarus, G., Peace, A.J., & Smith, D.E. (1996). Fallow deer (Dama dama L.) defecation rate and its use in determining population size.

Mayle, B.A., Peace, A.J. & Gill, R.M.A. (1999). *How many deer? A field guide to estimating deer population size.* Field book 18. Forestry Commission, Edinburgh.

Mayle, B.A., Putman, R.J. & Wyllie, I. (2000). The use of trackway counts to establish an index of deer presence. *Mammal Review*, 30, 233-237.

McIntosh, R., Burlton, F.W.E. & McReddie, G. (1995). Monitoring the density of a roe deer *Capreolus capreolus* population subjected to heavy hunting pressure. *Forest Ecology and Management*, 79, 99-106.

McLean, C. (1992). Sika deer control. *Red Deer Commission Annual Report 1992*. HMSO, Edinburgh.

Melville, R.C., Tee, L.A. & Rennolls, K. (1983). *Assessment of wildlife damage in forests*. Forestry Commission Leaflet 82. HMSO, London.

Mitchell, B. & McCowan, D. (1980). Estimating and comparing population densities of red deer *Cervus elaphus* L. in concealing habitats. *Institute of Terrestrial Ecology Annual Report 1979*. ITE, Cambridge.

Mitchell, B. & McCowan, D. (1981). Experimental drive-counts of deer in a woodland enclosure. *Institute of Terrestrial Ecology Annual Report 1980*. ITE, Cambridge.

Mitchell, B. & McCowan, D. (1984). The defecation frequencies of red deer in different habitats. *Institute of Terrestrial Ecology Annual Report 1983*. ITE, Cambridge.

Mitchell, B., McCowan, D. & Campbell, D. (1983) Feacal depositions as indicators of site use by red deer. *Institute of Terrestrial Ecology Annual Report 1982*. ITE, Cambridge.

Mitchell, B., Rowe, J.J., Ratcliffe, P. & Hinge, M. (1985) Defecation frequency in roe deer (*Capreolus capreolus*) in relation to the accumulation rates of faecal deposits. *Journal of Zoology*, 207, 1-7.

Mitchell, F.J.G. & Kirby, K.J. (1990). The impact of large herbivores on the conservation of semi-natural woodlands in the British uplands. *Forestry*. 63, 333-353.

Morellet, N., Champley, S., Gaillard, J.M., Ballon, P. & Boscardin, Y. (2001). The browse index: new tool uses browsing pressure to monitor deer populations. *Wildlife Society Bulletin*, 29, 1243-1252.

Neff, D.J. (1968). The pellet-group count technique for big game trend, census, and distribution: a review. *Journal of Wildlife Management*, 32,597-614.

Pepper, H. (1998). *Nearest neighbour method for quantifying wildlife damage to trees in woodland*. Forestry Commission Practice Note 1. Forestry Commission, Edinburgh.

Pucek, Z., Bobek, B., Labudzki, L., Milkowski, L., Moro, K. & Tomek, A. (1975). Estimates of density and number of ungulates. *Polish Ecological Studies*, 1, 121-136.

Putman, R.J. (1984). Fact from faeces. *Mammal Review*, 14, 79-97.

Ratcliffe P.R. (1987a). *The management of red deer in upland forests*. Forestry Commission Bulletin 71. HMSO, London.

Ratcliffe P.R. (1987b). Red deer population changes and the independent assessment of population size. Zoological Society London, Symposium 58, 153-165.

Ratcliffe, P.R. & Mayle, B.A. (1992). *Roe deer biology and management*. Forestry Commission Bulletin 105. HMSO, London.

Red Deer Commission. (1993). Thermal imagery. *Red Deer Commission Annual Report 1993/94*. HMSO, Edinburgh.

Staines & Ratcliffe (1987)

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

van Laere, G., Maillard, D., Boutin, J.M. & Delorme, D. (1998). Le suive des populations de chevreuils – methodes traditionnelles d'estimation aux indicateurs biologiques. *Proc XXIeme Colloque francophone de Mammalogie*, Amiens, Oct. 1997. *Arvicola*.

Welch, D., Staines, B.W., Catt, D.C. & Scott, D. (1990). Habitat use by red (*Cervus elaphus*) and roe (*Capreolus capreolus*) deer in a Scottish sitka spruce plantation. *Journal of Zoology*, 221, 453-476.

White, G.C., Bartmann, R.M., Carpenter, L.H. & Garrot, R.A. (1989). Evaluation of aerial line transects for estimating mule deer densities. *Journal of Wildlife Management*, 53, 625-635.

Wiggers, E.P. & Beckerman, S.F. (1993). Use of thermal infrared sensing to survey white-tailed deer populations. *Wildlife Society Bulletin*, 21, 263-268.

# 3 A review of the techniques used to assess deer populations and damage to woodland.

From the tender specification:-

"Literature review to inform the production of Field Guides on each of the recommended data collection techniques. The recommended techniques will be justified by demonstrating how the information collected can be used to inform decision-making.

1. Measuring damage in woodland
2. Estimating population density
3. ageing deer
4. collecting reproductive data"

## 3.1 Aim

To devise an appropriate culling target to achieve the required deer population density.

### *3.1.1 Pre-requisites to achieve this aim*

1. Assessment of damage to trees by deer and target for damage reduction.

2. Current Population density and target future population density to achieve the reduction in tree damage. This requires:-

3. Knowledge of the population dynamics of the deer. Fecundity and survival are the 2 most important aspects of population dynamics and both are age dependent (Caughley, 1977). A practical approach to population dynamics is to conduct a cohort analysis, which depends on ageing the culled individuals and provides a minimum population size. Cohort analyses only give meaningful results after 3-4 years of collecting good data on age and fecundity (Ratcliffe, 1987, Mayle, 1999).
    - Age of Culled females will provide information on the number of adults that can reproduce. The structure of the population by age and sex is fundamentally important in deriving the cull target (Mitchell, Staines & Welch, 1977, Mayle, 1999)
    - Pregnancy rates (based on counting corpus lutea/foetuses) will provide maximum potential recruitment (Ratcliffe, 1987, 1994).
    - Counts of calf:hind ratios in summer will indicate the calf mortality when compared to the pregnancy rate (Mayle, 1999).

Data from 3 above will allow cohort analysis (Mayle, 1999) and this will provide:-

1. A minimum population size.
2. The level of recruitment to the population.
3. the number of animals that need to be culled to achieve the required effect on the population set out in 2 above.

**It has been shown in a number of studies that recruitment and adult mortality can have the biggest effects on population size. Roe deer are good example of this**

**because there is a lot of variation between areas in the number of calves and yearlings that reproduce and they may have 1 or 2 calves (Gill, 1994).**

### 3.2 Ageing deer in Scotland.

Two main methods have been used on all the four deer species present in Scotland. Both depend on collecting the lower jaw of the culled individual ensuring that it is labelled with a code that identifies the individual carcass along with date shot, location, sex and weight data (Ratcliffe, 1994). The first is based on tooth eruption patterns in young animals and on cheek teeth wear patterns in older animals assessed by examination of the lower jaw after removal from the culled animal. (For red deer, Lowe, 1967, Brown & Chapman, 1991a, for roe deer, Aitken, 1975, fallow deer, Chapman & Chapman, 1975, Brown & Chapman, 1990, & sika deer, Hrabe et al., 1989). The second is based on counting the annual rings laid down in the cementum of either the molars or the incisiform teeth extracted and sectioned in specialised laboratory.(For red, Mitchell, 1963, 1967, Brown & Chapman, 1991, roe, Aitken, 1975, fallow, Brown & Chapman, 1990 & sika, Hrabe et al., 1989).

For practical reasons the first method is the most readily used because age can be assessed at the time of slaughter and recorded along with other data relating to individual carcasses.

Ideally, age assessment, based on tooth eruption and wear, should be calibrated against age assessment based on counting annual rings from teeth extracted from the same jaws. This has been done for all four species of deer (for refs see above) and forms the basis of several guides and technical papers have been published over the years (for example, Mitchell & Youngson, 1969). The ease of counting annual rings is thought to vary with species. For example, in one study, annuli in sika were more difficult to distinguish than those in red deer (Hrabe et al., 1989). Also, in forest dwelling red deer, annual rings may be difficult to detect because density of the rings is related to dietary checks in the winter and forest dwelling animals have a more even diet.

**A practical field guide to aging** should clearly demonstrate the tooth replacement pattern typical for animals up to 2.5 years of age. Thereafter, example jaws from another 3 or 4 ages spread out between age 4 and 10 will suffice. Estimating ages accurately in older animals is difficult if estimated from wear or annuli. However, the number of animals older than 10 is likely to be small so errors in these categories are not likely to bias the population estimates or the culling target based on a cohort analysis. Errors in ageing adult animals are not as important as in ageing young animals because the proportion of calves or yearlings producing calves has the most impact on population growth rates (Ratcliffe, 1987 & see below).

Concerns about assessing age on tooth eruption include:-

- Stalkers/hunters tend to produce overestimates of the age of an individual, particularly in older age classes. For example, professional hunters overestimated the age of roe deer based on tooth wear in older age classes (Szabik, 1973), this could be overcome by preparing a standard tooth wear guide based on annual ring counts in teeth from a random sample of jaws and producing a range of jaws demonstrating the typical wear for each year of age.

A guide for roe deer is available for the Forestry Commission (Ratcliffe, 1994) based on a study by Aitken (1975). A guide for red deer was produced by RDC (Mitchell & Youngson, 1969)

- The rate that teeth wear down might vary between areas so that a guide based on animals from one area is invalid for assessing age at another location. Brown & Chapman (1990) recognised that wear age estimates are really a indication of how long teeth have been functional in relation to a particular diet. The effect this might have on the applicability of wear age estimates from one area to another was not found to be a problem in a study of red deer assessed from several areas of Scotland (Mitchell & Youngson, 1969). Whilst there is evidence for this in domestic animals, wear patterns seem more consistent between populations of wild ruminants. (reviewed in Brown & Chapman, 1990). Furthermore, wear age estimates in red deer were found to be almost identical to fallow deer (Brown & Chapman, 1991). Estimating the age of older animals needs to be based on experience and training using jaws from known age animals. Purely basing age estimates from studies in the literature is not possible. Even in Brown & Chapman's study (1991) of red deer, they found that animals between 26 and 78 months of age had a worn mesial marginal ridge on the first molar.

- Tooth eruption patterns vary between species and within species sampled from different areas. Tooth eruption patterns are very similar for all 4 species (see references above). One main difference is that roe deer have usually replaced all their deciduous teeth by the end of their first year. Therefore, tooth eruption pattern is only useful in distinguishing roe deer kids from adults (Springthorpe & Myhill, 1994). Any problems would be exacerbated if animals were culled year round but most are culled in the normal open season. However, it is important to familiarise stalkers/hunters with eruption patterns because misclassifying calves and young hinds can have a big impact on calculating the reproductive rates (Ratcliffe, 1987) and this will affect the calculations that form the basis for cohort analysis and population dynamics models. Hence the cull target set from such data may be invalid.

- Tooth wear may vary between the sexes. Studies so far have failed to demonstrate differences in the wear between hinds and stags of the same age (Mitchell & Youngson,1969).

When assessing the age of a culled animal it is worth bearing in mind other general characteristics such as body shape, winter or summer coat and antler development. For example, yearling roe deer bucks are still in velvet but in summer coat in June whereas mature roe-bucks will still be in winter coat but will have hard antlers. However, the best guide is tooth eruption and tooth-wear. A brief description of the tooth eruption patterns for the 4 species concerned (Table 1) is reviewed in Springthorpe & Myhill (1994).

| Species | Age (in months) | State of incisors | Of premolars | Of molars |
|---|---|---|---|---|
| **Red** | Calf (0-12) | Milk | Milk | M1 |
| | Yearling (12-24) | Mixed | Milk | M1, M2 |
| | 24+ | Adult | Adult | M1, M2, M3 |
| | | | | |
| **Fallow** | Fawn (0-12) | Milk | Milk | M1 |
| | Yearling (12-24) | Mixed | Milk | M1, M2 |
| | 24+ | Adult | Adult | M1, M2, M3 |
| | | | | |
| **Sika** | Similar to red deer except: | | | |
| | 24-36 months | | | Lack of staining on 3rd cusp |
| | | | | |
| **Roe** | 0-12 months | All tooth eruption completed | | |

### *3.2.1 Practicalities.*

1. In the larder, the jaw should be skinned out of the head with as little flesh as possible so that the view of the incisiform teeth and the molars/premolars of one side of the jaw are not obscured. The jaw should be carefully labelled with a code that corresponds to the carcass so that age can be related to fertility and, if available, weight and condition data.
2. the teeth should then be checked to determine if any of the deciduous teeth are still present and if not, whether there is any wear or staining on the third molar. From this, the age of the animal can be judged as 0, 1+, or 2+.
3. If the teeth are all permanent and the third molar is stained and has some wear then the age has to assessed as 3 or older and the amount of wear has to be judged in order to categorise further. Training is needed for this.

Wear patterns. The main literature for the four species are as follows

| | |
|---|---|
| Red | Brown & Chapman 1991 and Mitchell & Youngson, 1969. |
| Fallow | Brown & Chapman 1991, |
| Sika | Hrabe et al., 1989 |
| Roe | Aitken 1975 and Ratcliffe & Mayle, 1992 |

## 3.3 Assessing reproduction in deer of Scotland

The fecundity of milk hinds and age at first reproduction are indictors reflecting the population growth rate. These are thought to be subject to density with the number of milk hinds that are found to be pregnant when culled lower in years when deer density is high. The main purpose here is to calculate the number of calves recruited to the population, which is important in assessing the rate at which the population can increase in the absence of culling. Fertility, or pregnancy rates in culled hinds can be determined from the presence of corpora lutea on the ovaries (Mitchell et al., 1976). Two types of data are required.

1. From culled females, pregnancy rates can be obtained by examination of the reproductive tract (ovaries and uterus). If the female is culled after the rut, she will either have conceived or remain barren. If she has conceived then the uterus will be enlarged compared to a non-pregnant hind and the ovaries will exhibit a corpus luteum which can be counted as a pregnancy in early in the season (Oct-Nov) and the enlarged uterus with an increasingly large foetus will and be diagnostic in the later part of the season (Dec onwards, Mitchell & Lincoln, 1973). It is essential to accurately age yearlings and 2 year old (and calves in roe deer) because Populations with a high proportion of yearlings present is indicative of high population growth (Ratcliffe, 1987).

2. From population censuses in the following summer. Practically, an assessment of summer calf:hind ratio which when multiplied by the number of hind present (achieved from a cohort analysis or from other population count methods) provides information on calf recruitment and will then indicate the number of hinds and calves that need to be shot in the following cull to achieve the target population density.

3. The proportion of hinds pregnant is related to body weight. Yeld hinds tend to be heavier than milk hinds and the proportion of yeld hinds pregnant is likely to be higher than milk hind illustrating the cost of having a calf (lactation) one year on the probability of being pregnant the following year (Mitchell & Brown, 1974, Albon et al., 1986).

The proportion pregnant minus the proportion found with a calf in the following summer indicates calf mortality over the first winter. Together with estimates on adult mortality and a cohort analysis to estimate population size can be used to calculate the increase (or decrease) in individuals in the population. This can be the basis for setting the level of the cull in the forthcoming year.
The use of cohort analysis is only possible after a 3-4 years of data have been collected but rapid assessments of cull targets can be calculated in the interim while the necessary data is being collected (Ratcliffe, 1987).

### *3.3.1 Practicalities.*

1. Early in the season, before 1st December, care should be taken on gutting the culled female not to remove the uterus and ovaries when removing the guts and in particular when pulling out the rectum. The uterus and ovaries can be removed back in the larder and inspected for ovulation. The appearance of the uterus will also indicate if the hind has ever had a calf before. Either the uterus and ovaries are inspected immediately and the data recorded or they can be bagged and labelled with the carcass code for inspection later.

2. The lactational status should also be recorded as this will help to corroborate the fertility from the year before.

3. Later in the season, when hinds are more heavily pregnant, care should be taken to record which carcass is pregnant if the uterus is left out with the guts.

## 3.4 Recommendations

1. Consistent and comparable data should be collected within an estate, between estates (at the Deer Management Group level) and collated across Scotland
2. Personnel involved in culling these species should be trained in estimating ages based on eruption and tooth wear patterns. The material on which training is based should be based on known aged animals or from animals where the annuli in the cementum have been measured.
3. For red deer, there is a need to calibrate tooth wear and annuli counts in deer from forests. Most guides were developed for deer from open hill. DCS should provide this?
4. Hunters/stalkers should be trained centrally in ageing and assessing reproductive rates from the reproductive tract. This should be combined with population estimate techniques and cohort analysis training so that data collection is seen as a pre-requisite in the setting of culling targets and therefore essential to the management of deer. Courses are available from BDS (and colleges of Further Education? Thurso?)

## 3.5 References


Albon S. D., Mitchell, B., Huby, B. J. & Brown, D.(1986). Fertility in female red deer (Cervus elaphus): the effects of body composition, age and reproductive status. Journal Zoology, London 209, 447-460.

Caughley, G. (1977). Analysis of vertebrate populations. John Wiley & Sons, London.

Ratcliffe, P. R. (1987). The management of red deer in upland forests. Forestry Commission, Bulletin 71.

Mayle, B. A., Gill, R. M. A. & (1999). How many deer? A guide to estimating deer population size. Forestry Commission Field Book 018.

Ratcliffe, P. R. & Mayle B. A. (1992). Roe deer biology and management. Forestry Commission Bulletin 105.

Gill, R. M. A. (1994). The population dynamics of roe deer (Capreolus capreolus L.) in relation to forest habitat selection. PhD thesis, The Open University.

Lowe, V. P. W. (1967). Teeth as indicators of age with special reference to red deer (Cervus elaphus) of known age from Rhum. Journal of Zoology, London. 152, 137-153

Springthorpe, G. D. & Myhill, N. G. (1994) Wildlife Rangers Handbook. Forestry Commission Handbook 10.

Chapman D. & Chapman, N. G. (1975). Fallow Deer. Terence Dalton Ltd, Lavenham, Surrey.

Brown, W. A. B. & Chapman, N. G. (1990). The dentition of fallow deer (Dama dama): a scoring scheme to assess age from wear of the permanent molariform teeth. Journal of Zoology 221, 659-682.

Langvatn, R. (1992). Analysis of ovaries in studies of reproduction in red deer (Cervus elaphus L.): Applications and limitation. Rangifer 12, 67-91.

Mitchell, B. (1963). Determination of age in Scottish red deer from growth layers in the dental cement. Nature 198, 350-351.

Mitchell, B. (1967). Growth layers in dental cement for determining the age red deer (Cervus elaphus L.). Journal of Animal Ecology, 36, 279-293.

Mitchell, B. & Brown, D. (1974). The effects of age and body size on fertility in female red deer (Cervus elaphus). International Congress on Game Biology 11, 89-98.

Mitchell, B., McGowan, D. & Nicholson, I. A. (1976). Annual cycles of body weight and condition in Scottish red deer (Cervus elaphus L.). Journal Zoology, 180, 107-127.

Aitken, R. J. (1975). Cementum layers and tooth wear as criteria for ageing roe deer (Capreolus capreolus. Journal of Zoology, London 175, 15-28,

Brown, W. A. B. & Chapman, N. G. (1991). The dentition of red deer (Cervus elaphus): a scoring scheme to assess age from wear of the permanent molariform teeth. Journal of Zoology 224, 519-536.

Hrabe, V., Zejda, J. & Horakova, M. (1989). Aging of Sika deer (Cervus Nippon). Folia Zoologica 38, 98-107.

Mitchell, B. & Youngson, R. W. (1969). Teeth and age in Scottish red deer: a practical guide to age assessment. Red Deer Commission, Inverness.

Szabik, E. (1973). Age estimation of roe deer from different hunting grounds of South-Eastern Poland. Acta Theriologica 18, 223-236.

Mitchell B. & Lincoln, G. A. (1973). Conception dates in relation to age and condiiton in two populations of red deer in Scotland. Journal of Zoology, London 171, 141-152.

Mitchell, B., Staines, B. W. & Welch, D. (1977). Ecology of Red Deer. A research review relevant to their management in Scotland. Institute of Terrestrial Ecology, Banchory.