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Deer Population Dynamics

Brenda A . Mayle & Helen M. Armstrong
Woodland Ecology Branch, Forest Research

Summary
The recent BDS survey (Rose, in prep) of deer distribution in Scotland shows that populations of all species are increasing in range, such that deer of at least one species are present in every 10km square. With increasing range and numbers we can expect to see increasing impacts to agriculture, forestry and conservation interests, examples of which are described in later papers.

Proactive management based on a sound understanding of the levels of and factors influencing the dynamics of a population, and its impact on the habitat, will enable us to maintain healthy populations of deer whilst at the same time limiting their impact on the habitat. To inform decisions about culls we need to know about rates of deer population change and current impact levels, and relate this to habitat quality. Current research is focusing on the interaction of deer populations with their habitats, to allow us to predict impact levels and habitat changes under different browsing and grazing levels.

To predict population change we need to know the current status of the population; *population range, numbers, birth-rate, and mortality.* Research over the past 25 years or so has provided an insight into the population dynamics of red, roe, sika and more recently fallow deer. This paper provides an overview of the information available on woodland deer population dynamics, and how this can be used to predict rates of population increase as a basis for cull determination.

Numbers
Effective methods of estimating deer densities within different woodland habitats and across the whole forest have been developed. Research has shown variation in the densities of deer species monitored in different woodland habitats, as below.

Table. 1. Deer density monitored in different forest growth stages (after Chadwick et al, 1996; Fairweather, Unpub.1992; Kibi Otim, unpub,1989; Ratcliffe, 1987; Latham, 1993).

Structure	**Deer density km^{-2}**		
	Roe	**Red**	**Sika**
Establishment	8-30	2	2-4
Prethicket	13-30	5-8	4-14
Thicket	1-7	10-40	10-35
Prefell	3	2	4-11

Birth-rate
Birth-rate can be estimated by counting embryos carried by females shot during the cull season. In roe deer as embryos are not present until after

Christmas an estimate of fertility can be obtained by counting corpora lutea in the ovaries before Christmas.
Wide variation in fertility has been observed for woodland deer populations. In some red and sika populations almost all adults (2 years +) and yearlings (12-23 months) carry a calf, whilst in others few yearlings are pregnant. Up to 30% calves (<12 months) are pregnant in some sika populations, and twinning is a regular occurrence for adults and yearlings in many roe deer populations, but rare in others.

Mortality
For unshot populations natural mortality may be high, particularly during bad winters, but unless carcasses are found it is difficult to evaluate natural mortality levels in adults. However, many woodland populations are 'managed ' and so old and infirm animals will be removed before 'natural death' and hence 'natural mortality levels will tend to be low. Mortality levels in the first year of life have a major influence on recruitment and rates of population change and wide variation in survival of kids/calves between years and populations has been observed. Calf : hind counts after winter or doe : kid counts over winter allow estimates of juvenile natural mortality.

By evaluating all of these factors for your own population it is then possible to model population changes in the presence of different culls, and this will be demonstrated later.

However, predicting how the population will change is only a part of the equation.
To be most effective we need to try and evaluate how the density of deer that can be supported without causing unacceptable damage is going to change in the future. This is perhaps the most complex issue and we are some way from being able to provide models to predict this. However if we look at things simplistically and assume that we can expect similar habitat specific densities of deer to occur in the future, and that current impact levels at these densities are acceptable, then we can predict the potentially acceptable 'management carrying capacity' for deer in the future. This can then be compared with predicted population changes based on population dynamics, and the cull set to ensure that the predicted population levels do not exceed the predicted ' management carrying capacity'. However if current impact levels are unacceptable then the 'management carrying capacity' can be adjusted downwards accordingly.

Modelling population changes
Computer models can be useful tools to help with the prediction of future deer numbers and the estimation of current numbers. Predicting the impact of a given culling regime on deer populations is an integral part of any cost-benefit analysis of deer control and tree protection. Fig. 1 demonstrates the range of information that is needed to carry out a cost-benefit analysis. Our eventual aim is to provide computer-based tools that can help managers assess the cost effectiveness of deer management and tree protection for any site whether it is to achieve an economic or a biodiversity output. To achieve this we need information in three areas:

1. the effects of browsing damage on the final value of the woodland. This obviously varies with the objectives of management. Currently we have some information with which to build models but we need more.
2. the impact deer have on both trees and on ground vegetation. This requires an understanding of both landscape level behaviour of deer and of their dietary preferences at the stand scale. Currently there is limited information available with which to predict deer impacts. This needs to be a priority area for further data collection.
3. Deer population dynamics. This is the area where we probably have most information and this is where we have been, and will be, concentrating our efforts in the short term.

Currently we are using a very simple spreadsheet model to predict the impact of culling on deer populations. It does not include density dependence i.e. there is no increase in mortality at high densities. Obviously, in an unculled population, mortality rates must increase at some point as populations increase otherwise the population would increase forever. However we had little information with which to add density dependence to our model and even less to enable users to make the density dependence relationship site-specific. Since most populations we deal with are heavily culled, hence are well below the density at which survival rates would be affected by density, we decided that a model without density dependence would be a useful management tool. The model requires information on recruitment, survival and culling rates for each age class of deer as well as the size, and age and sex distribution, of the initial population. Since the predictions the model makes are only as good as the data going into it, it is important to use the best available information for any site.

Sources for model inputs 1. Calf recruitment
In the model, the probability of calving is the probability of a hind having a calf at foot at the time the cull starts i.e. after pre- and post-natal mortality. This value is needed for each age class of hind. There are several potential sources of this information:

- Pregnancy rates of culled females are one indicator of the productivity of the population. Information on pre-natal and post-natal mortality will also be needed if pregnancy information is used as a measure of recruitment. These can be high and can vary between years. In roe and sika deer, juveniles can become pregnant and in all deer species yearlings can have a lower pregnancy rate than hinds of 2 years old or more. Aging of females to at least juvenile, yearling and 2+ years old therefore makes predictions much more reliable if the age structure of the population changes over time.
- Lactation rates should only be used as an indicator of recruitment rate if all, or a random sample of hinds are recorded and if only data are used which have been collected up until the time when the females start to dry up. Alternatively, the mammary gland can be cut open to reveal if the hind has been lactating that year or not. If a female has a juvenile at foot when shot it should always be recorded as lactating. Lactation only reveals if a female has had young, not how many, so this is less useful measure of recruitment rate for roe deer, which can produce twins. As with pregnancy

rates, the information is more useful if young, culled females have been aged. Since 2-year-old females can have lower birth rates than older females in some populations, 2-year-olds need to be distinguished from older females where this is the case.

- Culled juvenile:adult female ratios can be a very useful measure of recruitment if culling has been random and if young females have been aged. This allows yearling females to be excluded from the analysis for those species, or populations, where juveniles do not become pregnant. Where they do become pregnant, the juveniles need to be apportioned between yearling, and older, females. Lactation information could be used to do this if it is assumed that there is an equal number of twins amongst yearlings as amongst older females (probably not true). Alternatively the pregnancy information could be used to apportion juveniles between yearling and older females if the assumption is made that the offspring of yearlings and older females are equally likely to survive (also probably not true).
- Calf:hind observations can be used to back up other information if they are carried out rigorously i.e. doing them in passing is probably not good enough.

For all of these measures, sample size must be large (at least 100 animals for pregnancy and lactation rates and preferably at least 300 for juvenile:adult female ratios) to have a high degree of confidence in them. Information from several years can be combined for red or sika deer if habitat conditions have not changed over the time during which data have been collected. Weather is thought to have a larger effect on the survival of juvenile roe deer so juvenile:adult female ratios are likely to vary more from one year than the next in this species then in red or sika.

In the absence of site-specific information the default is to decide whether the site is a ‘good’ one or a ‘bad’ one and use the information given in Ratcliffe (1987) and Ratcliffe & Mayle (1992). We hope to improve on the ability to recommend ‘default’ recruitment rates through gaining a better understanding of the effects of habitat type and weather on recruitment rates.

Sources for model inputs 2. Survival rates
The model needs survival rates for each age class of deer from the end of one summer to the end of the next summer. Survival data are time consuming to obtain however previous research work suggests that survival rates in culled populations are generally high i.e. 98% survival between years for adults but perhaps a survival rate of 90% or less for juveniles. Estimates can be obtained from Ratcliffe (1987) and Ratcliffe & Mayle (1992).

Sources for model inputs 3. Initial population size
This can be assessed by dung counting, vantage point or infra-red imager counts or cohort analysis. If it is from a dung count then ideally the number of animals culled should be taken account of in the final estimate then the likely number of juveniles added to give the total number at the start of the next cull. Visual counts can usually only be done where there is a good network of paths or tracks. Cohort analysis can only be done when several years’ worth of data have been accumulated on the age of culled deer. It requires

estimates of recruitment rate, hind:stag ratio and, ideally, mortality rate as well. Total numbers of deer, including yearlings and calves, should be used as initial population estimates for model runs.

Sources for model inputs 4. Sex and age structure
Sex ratio can be assessed from observations or from the cull. If from the cull then this assumes that stags and hinds are equally likely to have been culled, which is unlikely, so observations may be better if sample sizes are large enough and observations are unbiased. If there is no information then assume a 1:1 sex ratio. The age structure can be assessed from the aged cull. If no aging has been done then use a 'typical' age structure for a culled (or unculled) population (Ratcliffe 1987; Ratcliffe & Mayle 1992).

Sources for model inputs 5. Age and sex-specific culling rates
The cull can be entered as a proportion or as an absolute figure. It needs to be entered for stags and hinds separately. If there is no age-class information, then simply
allocate the cull equally amongst age classes (assumes random culling). The model can be run retrospectively with actual numbers of culled deer or can be run into the future with proposed culls.

Examples of model output

The model was run for an initial population of 100 upland red deer (50 stags, 50 hinds) and an age structure typical of a culled population. The results illustrate the effect of increased culling rates and of increasing the hind cull relative to that of the stag cull (Fig 2). In general, even with very high culling rates, several years are needed to significantly reduce deer numbers.

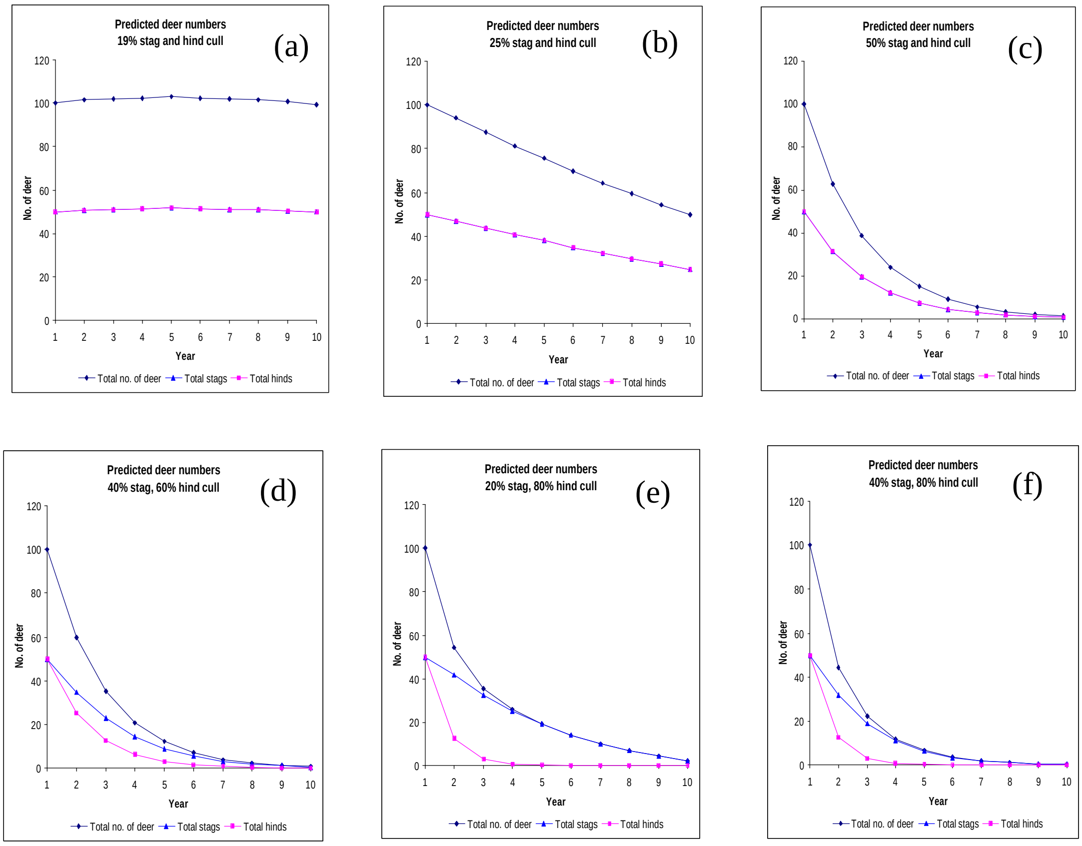

Figure 2. Predicted deer population sizes under different culling regimes. a) 19% stag and hind cull, b) 25% stag and hind cull, c) 50% stag and hind cull, d) 40% stag, 60% hind cull, e) 20% stag, 80% hind cull and f) 40%stag, 80% hind cull.

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Figure 1. Schematic representation of the issues involved in making decisions about deer management in woodlands. Gray boxes represent human inputs and outputs, which need to be quantified for cost-benefit analysis.