ELSEVIER

Forest Ecology and Management 79 (1995) 91–97

Forest Ecology and Management

# Diet selection by roe deer *Capreolus capreolus* in Kielder Forest in relation to plant cover

C.B. de Jong [a,*], R.M.A. Gill [b], S.E. van Wieren [a], F.W.E. Burlton [c]

[a] *Department of Terrestrial Ecology and Nature Conservation, Agricultural University, Bornsesteeg 69, 6708 PD Wageningen, Netherlands*
[b] *Forestry Authority Research Division, Alice Holt Lodge, Wrecclesham GU10 4LH, UK*
[c] *Forest Enterprise, Kielder Forest District, Eals Burn, Bellingham, Hexham NE48 2AJ, UK*

Accepted 20 June 1995

**Abstract**

The diet of roe deer *Capreolus capreolus* in relation to the cover and abundance of ground vegetation was investigated at two sites in Kielder Forest, Northumberland. Positive selection was found for heather *Calluna vulgaris*, other dicotyledons and evergreen ferns, which together formed a large part of the diet. Coarse monocotyledons were avoided. Sitka spruce *Picea sitchensis* formed a significant part of the diet in spring. Differences in the diet were apparent between the two sites, with more Sitka spruce eaten and more browsing damage occurring on the site with the poorer soil type. The management implications of these results are discussed.

*Keywords:* Roe deer; Diet selection; Faecal analysis; Food quality; Plant cover

## 1. Introduction

Forests of non-native conifers were planted extensively in the border regions of Scotland and northern England during the 19th and early 20th centuries. Although initially scarce throughout the region, roe deer *Capreolus capreolus* appeared to increase their range and numbers in parallel with this afforestation (Ritchie, 1920), probably aided by the cover and food that young plantations provide (Prior, 1968; Rowe, 1982; Gill, 1994). It is now necessary to cull roe deer in this region in order to limit their numbers. Both carcase weights and female fertility rates appear to be typical for British populations of this species (Ratcliffe and Mayle, 1992; McIntosh et al., 1995). The most abundant plants available as food for herbivores in these forests are Sitka spruce *Picea sitchensis* and Norway spruce *Picea abies*. Tissues of these trees contain high (although variable) levels of terpenes, which are known to limit browsing and interfere with rumen microbial activity in other deer species (Oh et al., 1967; Duncan et al., 1994). Consequently these spruce species are thought to be relatively unpalatable to roe deer (Borg, 1970; Szmidt, 1975; Hosey, 1981). Because of their small size, roe deer have a shorter gut retention time than larger ruminants and therefore appear to be less able to digest grasses (Hofmann, 1985). Taken together, these facts suggest that roe deer in Kielder Forest may be forced to select less common plant species as food, and that food quality may limit the population.

* Corresponding author.


*SSDI* 0378-1127(95)03622-9

Browsing by roe deer causes considerable economic damage in spruce plantations, principally because it results in an increase in the proportion of trees with multiple leaders (Eiberle, 1975; Staines and Welch, 1984). Comparisons between sites in Kielder Forest indicate that this form of damage is variable, although it tends to be more severe in areas where the soil is poorest, rather than where deer density is greatest. This suggests, as some other studies of browsing have done (reviewed in Gill, 1992), that the availability of alternative plant foods can affect the amount of damage sustained by young conifers.

We therefore examined the diet of roe deer at two sites, with the objective of describing variations in relation to season, site type and nutrient composition, whilst also investigating associations between diet and browsing damage.

## 2. Materials and methods

### 2.1. Study areas

Investigations were carried out on two recently re-stocked sites in Kielder Forest, differing markedly in soil and ground vegetation composition. The richer site in terms of soil quality and tree growth at Pundershaw was at 220–230 m above sea level (a.s.l.) with predominantly surface water gleyed soils. This 82 ha restocked area was planted with Sitka spruce seedlings in late 1988. The poorer site (Highfield) was at 290–310 m a.s.l. on deep peat soils, with a restocked area of 102 ha that was planted with Sitka spruce in early 1989. Tree growth was initially more rapid at Pundershaw, but at both sites the average tree height was within browsing reach (1.2 m) until the summer of 1992.

### 2.2. Faecal analysis

Fresh dung pellets were collected bimonthly from each site (except in July 1992 when pellets were collected only from Highfield) and preserved by either drying or freezing. Both sites were searched extensively for pellets, resulting in samples of 9–30 pellet groups for each site and season, except during May 1993 when only three groups were recovered from Highfield and one from Pundershaw. Samples consisted of five pellets from every pellet group found at different sites and seasons. All the pellets from each collection and site were gently boiled in water for about 1 h and left to soak overnight. In order to separate inner tissue from epidermis and cuticle, a 5 g subsample was mixed with more water for 1 min in a household blender and then washed over a 0.05 mm screen (modified from methods by Rogerson et al., 1976; Fitzgerald and Waddington, 1979; Davitt and Nelson, 1980; Pulliam and Nelson, 1980; Sanders et al., 1980). Household bleach was added to these samples after straining, to clear the plant fragments. The residue was then washed again with tap water, transferred into a Petri dish and allowed to settle. Using a Pasteur pipette, ten random grab samples of the residue were then taken. Each droplet was put on a glass slide, spread out evenly and covered with a 2.4 cm cover slip. On each slide, ten fragments of epidermis were identified in at least two transects.

Photomicrographs of epidermal material on a set of reference slides were used to identify the fragments. At least 100 cuticle or epidermis fragments were identified in each sample with the aim of identifying the plant species making up 5% or more of the faecal contents (Stewart, 1967). To quantify the composition of the faecal material, the area of epidermal fragments was measured at a magnification of $\times 100$ using a grid of small squares (each representing 0.01 $mm^2$) in the microscope eyepiece. The abundance of each species was represented as a percentage of the total measured fragment area (Putman, 1984).

### 2.3. Vegetation cover assessment

The species composition of the ground vegetation was assessed to give an approximate measure of available biomass. At each site, the percentage cover of all plant species (excluding the spruce trees) was estimated visually in each of 72 quadrats, each 1 m $\times$ 1 m. Twelve quadrats were placed along each of six parallel transect lines. Both the starting position of the transect and the position of all quadrats along each transect were random. The cover of spruce trees was omitted because at the time of assessment many were tall enough to be out of browsing reach, making any estimate of their ground cover percentages a biased measure of available biomass.

### 2.4. Damage to trees

Damage to trees was assessed at each site in 80 clusters, each consisting of five neighbouring trees (Melville et al., 1982). The first cluster was positioned randomly near the compartment edge and thereafter clusters were spaced uniformly, at approximately 100 m intervals across the compartment. Each tree was recorded as having a either a recently damaged or undamaged leading shoot. The total proportion damaged was then taken as an estimate of the level of damage in the compartment. Assessments were carried out each spring and autumn between 1989 and 1993.

### 2.5. Relative deer density

The relative density of deer on each site in 1990 was assessed using pellet group counts. Ten quadrats, 7m × 7m in size, were spaced uniformly along transects across each site. The average rates of deposition and decay were assumed to be the same at both sites (Ratcliffe and Mayle, 1992; McIntosh et al., 1995).

## 3. Results

### 3.1. Diet composition and vegetation cover

Roe deer diet, as revealed by faecal analysis, was found to vary between sites and seasons (Fig. 1). Sitka spruce remains were always present in the faeces, but generally occurred in greater proportions in those from Highfield than Pundershaw. At both sites this was highest in spring when the tips of new shoots, distinguishable in faecal samples by their thinner cell walls, constituted a considerable part of the Sitka spruce eaten.

Although Sitka spruce trees were planted during the same winter (1988–1989) at both sites, their growth was more rapid at Pundershaw and resulted in the trees being large enough to dominate the vegetation by the time this study took place. In spite of this, spruce needle fragments were only a minor

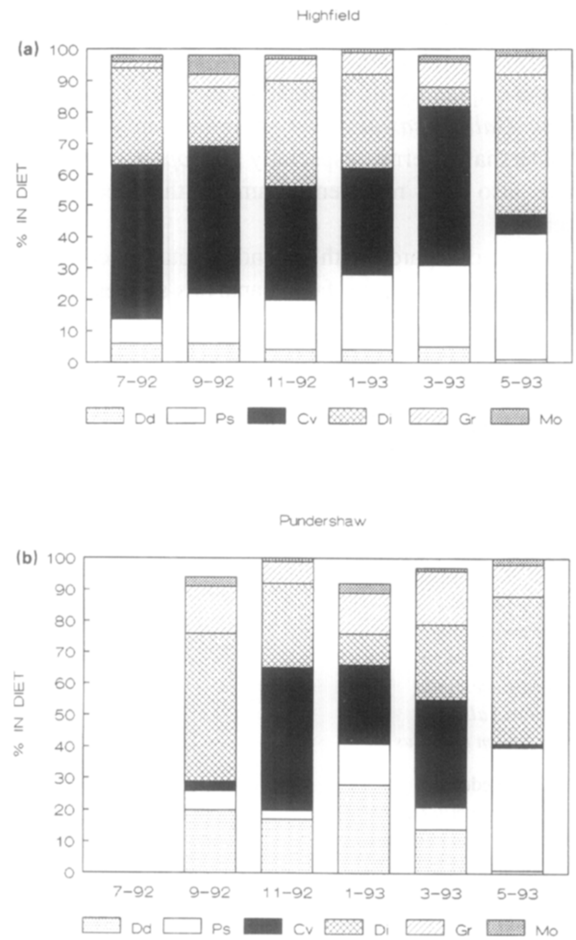


Fig. 1. Contents of roe deer faeces at Highfield and Pundershaw. Numbers under bars refer to the month and year of sampling. Dd, *Dryopteris dilatata*; Ps, *Picea sitchensis*; Cv, *Calluna vulgaris*; Di, other dicotyledons; Gr, grasses; Mo, other monocotyledons. Where the bar does not reach 100%, mosses, ferns other than *Dryopteris*, and unidentified seeds remains made up the remainder of the faecal contents.

component in the faecal samples collected at most times of the year at Pundershaw. These results suggest that the amount of Sitka spruce ingested varies considerably between sites as well as with the time of year.

Throughout the year the greater part of the faecal material consisted of fragments of dicotyledons, with heather *Calluna vulgaris* as the main species in all periods except in May. Bilberry *Vaccinium myrtillus* was present in smaller quantities. Among herbs, rosebay willowherb *Chamaenerion angustifolium* was dominant, but tormentil *Potentilla erecta* and common sorrel *Rumex acetosella* were also present in some quantity in summer (Table 1). Heath bedstraw *Galium saxatile* was prominent in winter. At Pundershaw, ferns, especially *Dryopteris dilatata*, were also well represented among the faecal fragments.

When compared with ground vegetation composition, the results of the faecal analysis suggest a high degree of selectivity in the diet (Fig. 2). Grasses and other monocotyledons accounted for most of the ground vegetation cover at both sites but made up only a small proportion of the faecal material. The most important ground cover species, *Deschampsia cespitosa*, *Juncus conglomeratus* and *Eriophorum vaginatum*, hardly appeared at all in the faeces (Table 1). In contrast, *Holcus lanatus* and *Carex nigra*, although not significant in terms of cover (2–3% and

Table 1
Species composition of the herbs and grasses identified in roe deer faecal samples from Kielder Forest in 1992–1993. Values represent the percentage of total epidermis surface area sampled (see text for method)

| | Jul | Sep | Nov | Jan | Mar | May |
|---|---|---|---|---|---|---|
| Highfield | | | | | | |
| Dicotyledons | | | | | | |
| *Chamaenerion angustifolium* | 16 | 16 | 5 | 2 | | 11 |
| *Erica tetralix* | | | | < 1 | | |
| *Galium saxatile* | | | 21 | 15 | 4 | 5 |
| *Potentilla erecta* | < 1 | | < 1 | | | 9 |
| *Rumex acetosella* | | | | | | 1 |
| *Stellaria alsine* | 1 | | < 1 | | | |
| *Vaccinium myrtillus* | 13 | | 3 | 7 | 2 | 4 |
| Monocotyledons | | | | | | |
| *Agrostis capillaris* | < 1 | | 1 | 1 | | |
| *Deschampsia cespitosa* | < 1 | | | 2 | | |
| *Deschampsia flexuosa* | 1 | | 1 | 2 | 4 | |
| *Holcus lanatus* | < 1 | 2 | 1 | 2 | 4 | 4 |
| *Molinia caerulea* | < 1 | | | | | |
| *Carex nigra* | 2 | 6 | 1 | < 1 | 2 | |
| *Eriophorum vaginatum* | | | | | | 2 |
| *Juncus* spp. | < 1 | | | | | < 1 |
| Pundershaw | | | | | | |
| Dicotyledons | | | | | | |
| *Betula* spp. | | < 1 | | | | < 1 |
| *Chamaenerion angustifolium* | | 19 | 4 | < 1 | | 11 |
| *Erica tetralix* | | | | < 1 | 4 | |
| *Galium saxatile* | | | 10 | 9 | 15 | 11 |
| *Potentilla erecta* | | 2 | < 1 | | | 1 |
| *Rumex acetosella* | | | | | | 8 |
| *Salix* spp. | | | | | | 4 |
| *Stellaria alsine* | | | | | | < 1 |
| *Vaccinium myrtillus* | | 5 | 7 | < 1 | 5 | |
| Monocotyledons | | | | | | |
| *Agrostis capillaris* | | | 3 | 2 | | |
| *Deschampsia cespitosa* | | | | 6 | < 1 | 6 |
| *Deschampsia flexuosa* | | | 1 | | 1 | |
| *Holcus lanatus* | | 4 | 3 | 4 | 15 | 4 |
| *Molinia caerulea* | | | | | | |
| *Carex nigra* | | 3 | | 3 | | |
| *Juncus* spp. | | < 1 | < 1 | | < 1 | |

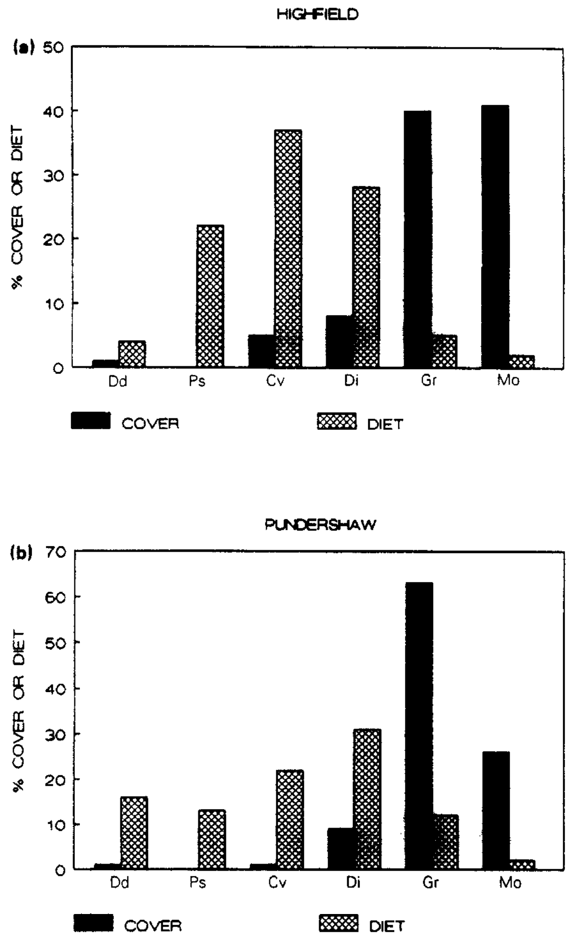


Fig. 2. Percentage vegetation cover at Highfield and Pundershaw, compared with percentage occurrence in faecal samples. Key as for Fig. 1. No percentage cover estimates were made for *Picea sitchensis* (see text).

1–2% respectively), were the best represented monocotyledons in the faeces. Heather, evergreen ferns and herbaceous dicotyledons were also much better represented in the faecal samples than they were in the vegetation on the ground.

### 3.2. Damage and deer density

With the exception of the first year, a greater proportion of leaders were damaged at the Highfield site than at Pundershaw (Table 2). A general reduction in damage occurred as the trees grew taller on both sites. The mean numbers of dung pellet groups per plot were 3.4 at Pundershaw and 1.0 at Highfield, suggesting that more damage was sustained where there were fewer deer and vice versa.

## 4. Discussion

### 4.1. The diet, vegetation cover and quality

The quantification of herbivore diets from faecal analyses rests on the assumption that the species composition of epidermal fragments identified in the faeces corresponds closely with the proportion of each species ingested. Although faecal analysis has been reported to underestimate the proportion of some species in the diet (e.g. herbs), recent studies suggest that is in part due to poor methodology, and good correspondence can be obtained if appropriate attention is given to the preparation and identification of the epidermal material (Alipayo et al., 1992).

The results of this investigation suggest that roe deer frequenting our two study areas in Kielder forest had a selective diet, favouring shrubs and certain herbs in preference to most grasses. Where grasses were eaten, the species taken most was *Holcus lanatus*, which has thin cell walls and few silica bodies (Metcalfe, 1960; Watson and Dallwitz, 1988).

Table 2
Assessments of browsing damage to Sitka spruce trees at Pundershaw and Highfield during 1989–1993. Values represent the estimated percentage of trees with damaged leading shoots (with 95% confidence intervals)

| Year | Spring | | Autumn | |
|---|---|---|---|---|
| | Pundershaw | Highfield | Pundershaw | Highfield |
| 1989 | 84.9 (6.9) | no data | 4.7 (2.4) | 19.5 (5.1) |
| 1990 | 22.8 (5.1) | 52.5 (6.7) | 1.7 (1.6) | 4.7 (2.6) |
| 1991 | 5.5 (2.6) | 30.9 (6.5) | 1.0 (1.2) | 6.0 (3.5) |
| 1992 | 2.0 | 8.7 | 0.0 | 0.6 |
| 1993 | 0.0 | 0.2 | no data | no data |

Coarse grasses like *Molinia caerulea* and *Deschampsia cespitosa*, which have thicker cell walls and a large number of silica bodies, were avoided.

In spite of a lower relative deer density, more leader damage occurred and more Sitka spruce was found in the diet at Highfield than at Pundershaw. Ferns, soft grasses and dicotyledons also appeared relatively more frequently in the faecal samples from Pundershaw than from Highfield. These comparisons suggest that the availability of other plants may affect the amount of winter browsing on Sitka spruce. However, the trees at Pundershaw suffered exceptionally severe leader damage during their first winter, which may have been because the trees had a higher nutrient content (Wray, 1992) or because of the lack of ground vegetation after clearing. Further research on the value of both ground and coniferous vegetation as food for roe deer needs to be carried out before firm predictions about the likely extent of browsing damage at different sites can be made.

### 4.2. Management implications

In this study, roe deer were found to be avoiding coarse grasses and Sitka spruce trees, the dominant species present. This suggests that they may contribute to the persistence of coarse grass communities, therefore reducing overall vegetation diversity (Crawley, 1983). In view of the new policy to enhance the biodiversity of production conifer forests (Ratcliffe and Peterken, 1995) some deer control may be justified for this reason alone.

The difference in levels of damage between the two sites suggests that soil or other site factors influence the development of the vegetation community, which in turn can affect the level of browsing on spruce. This implies that management action to protect trees, such as fencing or deer control, will be more effective if adapted to site differences. Culling, for example, could be applied more intensively on the poorer re-stock sites than on more productive sites which suffer less damage.

Alternatively, attempts to improve the abundance of dicotyledonous plants, for instance establishing forest clearings or re-establishing riparian strips of deciduous trees, may reduce damage while at the same time permitting an actual increase in deer density (Putman, 1988). The costs of these and other control measures need to be carefully weighed against any likely benefit.

## Acknowledgements

We would like to thank Paul Gough, John Raggers and the rangers of Kielder Forest District for their help in the vegetation assessments and for collecting vegetation and dung pellet samples.

## References

Alipayo, D., Valdez, R., Holecheck, J.L. and Cardenas, M., 1992. Evaluation of microhistological analysis for determining ruminant diet botanical composition. J. Range Manage., 45: 148–152.

Borg, K., 1970. On mortality and reproduction of roe deer in Sweden during the period 1948–1969. Viltrevy, 7: 121–149.

Crawley, M.J., 1983. Herbivory: the Dynamics of Animal–Plant Interactions. Blackwell, Oxford, 437 pp.

Davitt, B.B. and Nelson, J.R., 1980. A Method of Preparing Plant Epidermal Tissue for Use in Fecal Analysis. Circ. 0628, College of Agriculture Research Center, Washington State University, 4 pp.

Duncan, A.J., Hartley, S.E. and Iason, G.R., 1994. The effect of monoterpene concentrations in Sitka spruce *Picea sitchensis* on the browsing behaviour of red deer *Cervus elaphus*. Can. J. Zool., 72: 1715–1720.

Eiberle, K., 1975. Results of a simulation of game damage by cutting the shoots. Schweiz Z. Forstwes., 126: 821–839.

Fitzgerald, A.E. and Waddington, D.C., 1979. Comparison of two methods of fecal analysis of herbivore diet. J. Wildl. Manage., 43: 468–473.

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. Ph.D. Thesis, The Open University, Milton Keynes, 191 pp.

Hofmann, R.R., 1985. Digestive physiology of the deer—their morphophysiological specialisation and adaptation. In: P.F. Fennessy and K.R. Drew (Editors), Biology of Deer Production. The Royal Society of New Zealand, Wellington, pp. 393–407.

Hosey, G.R., 1981. Annual foods of the roe deer *Capreolus capreolus* in the south of England. J. Zool., London, 42: 276–278.

McIntosh, R., Burlton, F.W.E. and McReddie, G., 1995. Monitoring the density of a roe deer *Capreolus capreolus* population subjected to heavy hunting pressure. For. Ecol. Manage., 79: 99–106.

Melville, R.C., Tee, L.A. and Renolds, K., 1982. Assessment of

Wildlife Damage in Forests. Forestry Commission Leaflet 82, HMSO, London.

Metcalfe, C.R., 1960. Anatomy of the Monocotyledons. I Gramineae. Clarendon Press, Oxford, 731 pp.

Oh, H.K., Sakai, T., Jones, M.B. and Longhurst, W.M., 1967. Effect of various essential oils isolated from Douglas fir needles upon sheep and rumen microbial activity. Appl. Microbiol., 15: 777-784.

Prior, R., 1968. The Roe Deer of Cranbourne Chase. Oxford University Press, London, 222 pp.

Pulliam, D.E., Jr. and Nelson, J.R., 1980. Determination of digestibility coefficients for a quantification of fecal analysis with elk. In: M.S. Boyce and L.D. Hayden-Wing (Editors), North American Elk: Ecology, Behavior and Management. University of Wyoming, Laramie, pp. 240-246.

Putman, R.J., 1984. Facts from faeces. Mammal Rev., 14: 79-97.

Putman, R.J., 1988. The Natural History of Deer. Christopher Helm, London, 191 pp.

Ratcliffe, P.R. and Mayle, B.A., 1992. Roe deer biology and management. Forestry Commission Bulletin 105, Forestry Commission, Edinburgh, 28 pp.

Ratcliffe, P.R. and Peterken, G.A., 1995. The potential for biodiversity in British upland spruce forests. For. Ecol. Manage., 79: 153-160.

Ritchie, J., 1920. The Influence of Man on Animal Life in Scotland. Cambridge University Press, Cambridge, 200 pp.

Rogerson, S.J., Stevens, E.J. and Hughes, J.G., 1976. An improved preparation technique for identification of plant cuticle in animal faeces. N.Z. J. Bot., 14: 117-119.

Rowe, J., 1982. Roe research in relation to management in British woodlands. In: Roe and Red Deer in British Forestry. The British Deer Society, Warminster, pp. 25-41.

Sanders, K.D., Dahl, B.E. and Scott, G., 1980. Bite count vs. faecal analysis for range animal diets. J. Range Manage., 33: 146-149.

Staines, B.W. and Welch, D., 1984. Habitat selection and impact of red deer and roe deer in a Sitka spruce plantation. Proc. R. Soc. Edinburgh, 82: 303-319.

Stewart, D.R.M., 1967. Analysis of plant epidermis in faeces: a technique for studying the food preferences of grazing herbivores. J. Appl. Ecol., 4: 83-111.

Szmidt, E., 1975. Food preference of roe deer in relation to principle species of forest trees and shrubs. Acta Theriol., 20: 255-266.

Watson, L. and Dallwitz, M.J., 1988. Grass genera of the World. Research School of Biological Sciences, Australian National University, Canberra, 46 pp. (with microfiches and floppy disks for MS-DOS microcomputers).

Wray, S., 1992. The ecology and management of European hares *Lepus europaeus* in commercial coniferous forests. Ph.D. Thesis, University of Bristol, 238 pp.