Forest Mammals – Management and Control

Seán Rooney, Thomas J. Hayden

COFORD, National Council for Forest Research and Development
Agriculture Building
Belfield, Dublin 4
Ireland
Tel: + 353 1 7167700
Fax: + 353 1 7161180

First published in 2002 by COFORD, National Council for Forest Research and Development, Belfield, Dublin 4, Ireland.

ISBN 1 902696 21 2

Title: Forest Mammals - Management and Control
Authors: Seán Rooney and Thomas J. Hayden

Citation: Rooney, S. and Hayden, T. 2002. Forest Mammals - Management and Control. COFORD, Dublin.

Design and production: Magner Communications

Forest Mammals – Management and Control

Seán Rooney, Thomas J. Hayden

Mammal Research Group, Dept. of Zoology, UCD

TABLE OF CONTENTS

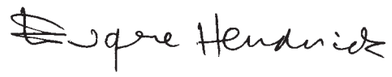
FOREWORD

Ireland's broadleaved and coniferous forests provide habitats for a range of mammals, many of which, such as sika deer and grey squirrel, were introduced in the past century. Some of these introduced species cause economic damage to trees by browsing or bark stripping. While the full economic impact of the damage has not been quantified, it is an increasing problem in forest management in Ireland. Furthermore, damage to trees by browsing and overgrazing can lead to a reduction in the amenity and habitat values of woodland areas, in addition to losses in wood production.

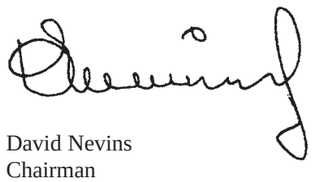
Sustainable forest management involves the protection, management and development of forests, such that their social, economic, environmental and ecological functions are fulfilled. The management of mammals present in forest habitats is therefore an important component of its implementation. There is a need to balance habitat diversity and biodiversity enhancement with control of the main pest species. For example, the fragmented nature of Ireland's forest estate has facilitated the growth of deer populations to such an extent that they are now limiting the range of tree species that can be used in afforestation.

This publication is aimed at educating forest owners and foresters about the management and control of the principal mammal species living in our forests. It provides information about the forms of damage caused by mammals, and identifies the species responsible. Methods for managing mammal populations and controlling the damage they cause are presented.

Much of the report builds on research funded by COFORD and other national research bodies over the past decade. Such research plays a vital role in ensuring the protection of the forest estate and the pursuit of economic forestry.



Dr Eugene Hendrick
Director
COFORD



David Nevins
Chairman
COFORD

COFORD
October 2002

ACKNOWLEDGEMENTS

The authors wish to thank the following for their input and assistance during the course of this research:

- Professor Eamonn Duke and Dr Mark Rogers, Dept. of Zoology, UCD, for the use of their facilities.
- COFORD for their input, advice and funding.
- Mr Barry Coad, Dr Pat Neville and Mr John Casey, Coillte (Newtownmountkennedy).
- The ranger staff in Killarney National Park.
- Members of the Mammal Research Group, Dept. of Zoology, UCD, especially Dr David O' Brien, Dr Fiona Saunders, Mr John Meehan and Ms Ruth Carden.
- Dr John Rochford and Dr Colm Lawton, Wildlife Ecology Group, TCD.

We are grateful to Mr Barry Coad, Ms Ruth Carden and Mr William Clarke for providing additional photos and slides.

GLOSSARY

Afforestation: Planting of trees on land not previously used for forestry.

Bioaccumulation: The build-up of toxic substances in the bodies of animals.

Biocontrol: The natural use of native or introduced species to control a pest species.

Biodiversity: A recently-coined word which describes all aspects of biological diversity including species richness, complexity of ecosystems and genetic variation.

Brash: Side branches of trees, usually bordering roads and lanes, which are cut off and often discarded or used to form 'mats' to aid the passage of machinery within the forest.

Broadleaves: In Ireland this refers to the majority of deciduous trees, i.e. tree species with relatively wide leaves that are shed in autumn and grown anew in spring.

Conifers: In Ireland this refers to evergreen trees with needle-like leaves which are not shed during autumn. Larches, however, are the exception. Conifers also bear cones.

Ecology: The lifestyle and adaptions of an organism or groups of organisms and their relationship with their environment and other organisms.

Ecosystem: Communities of organisms and the environment in which they live.

Felling: The final stage of a silvicultural rotation when trees are harvested. This may occur in small patches or in large swathes known as 'clear-felling'.

Habitat: The place or environment in which organisms live.

Herbivore: An animal feeding largely or entirely on plant material.

Lop and top: Debris from thinning and felling which is often discarded.

Native: Refers to species that colonised regions naturally without the intervention of man.

Pre-fell: The penultimate stage of a silvicultural rotation.

Plantation: An area of forest where trees have been planted and are growing. Also includes planted forests where natural regeneration is occurring and semi-natural woodlands which have been restocked by planting.

Pole stage: A latter stage in forest rotation following thicket when lower branches are shaded-out and die. The trunk of the tree is straight and pole-like.

Reforestation: Replanting of an area on which the previous crop of trees has been clearfelled. Also known as 'restocking'

Regeneration: Renewal of a forest through planting or natural regeneration.

Rotation: The period of years required to establish and grow timber crops to a specified level of maturity, at which stage the crop is clearfelled.

Scrub: Non-commercial unmanaged forest area.

Semi-natural woodland: In Ireland, woodland composed in the main of native and semi-native trees and shrubs that derive from natural seedfall with the probability of some infill planting at one stage or another.

Special areas of conservation (SACs): Areas of significance as designated under the EC Habitats Directive (92/43/EEC) for the conservation of special habitats.

Sustainable forest management: Defined in Helsinki 1993 as "the maintenance of biodiversity, productivity, regenerative capacity, vitality and the potential to fulfill now and in the future, relevant ecological, economic and social functions".

Thicket: The stage in a rotation when trees are between 3 and 10 metres in height and the canopy closes. This phase offers security to deer species.

Thinning: A temporary reduction in standing volume made after canopy closure to promote growth and greater value in the remaining trees.

Ungulate: A mammal with hooves.

1. INTRODUCTION

1.1 IRELAND'S WOODLANDS

Ireland's woodland cover currently stands at 660,000 ha, representing 9% of its land area. Roughly 100,000 ha of the total cover consists of broadleaved forest, of which 20,000 ha is semi-natural woodland. Sitka spruce is the principal tree species, representing over 60% of Coillte's forests and 65% of annual afforestation. Broadleaves constitute 16% of Coillte woodland and 20% of current annual afforestation. Despite having one of the smallest areas of woodland in Europe, Ireland's current rate of afforestation is the highest in the European Union (EU). The government's strategic plan for the development of the forest industry, *Growing for the Future*, outlines a trebling in timber production between the present and the year 2035, and an increase in the amount of land under cover at least 17%, roughly 1.2 million ha of woodland. The biodiversity of these forests, i.e. the variety of ecosystems and living organisms that they can support, is of paramount importance and is dependent upon the health, vitality and management of these habitats. In addition to the socio-economic advantages, forestry has numerous other benefits such as landscape enhancement, amenity and recreation opportunities, wildlife conservation, sequestration of atmospheric carbon, and the control of soil erosion.

Sustainable forest management (SFM) involves the protection, management and sustainable development of forests. The Irish National Forest Standard defined a number of criteria to ensure that Irish forests are managed in a way that enhances their social, economic, environmental and ecological functions. A balance is achieved between maintaining forest ecosystem health and vitality and the appropriate enhancement of biological diversity in forest ecosystems. Forest certification promotes and upholds the principles of sustainable forest management. To gain accreditation, wood producers must develop a set of forest management standards - a suite of management plans and operating procedures that outline their forestry practices. The management of mammals present in forest habitats is an important component of SFM. In May 2001, Coillte Teoranta was awarded certification for its forest management operations in Ireland.

1.2 MAMMALS AND IRISH FORESTS

Ireland's broadleaved and coniferous forests provide habitats for a range of mammal species, from large and medium sized herbivores such as red, fallow and sika deer, to smaller mammals such as pine martens, red and grey squirrels, bank voles, wood mice and shrews. In addition, hares and rabbits are frequently found at the edges of such habitats.

1.3 DAMAGE TO TREES AND VEGETATION

Many of the mammal species mentioned have the potential to cause damage to trees and vegetation by browsing, overgrazing and stripping of bark (Table 1.1). Large herbivores can cause additional physical damage such as the abrasion of tree-trunks and the fraying and thrashing of smaller saplings with their antlers. Although the full economic impact of damage caused by mammals has not been quantified, it is a growing problem in Ireland. A comprehensive survey of mammal damage and habitat use within Irish commercial woodlands found that potential pest species were widespread, with deer, squirrels and rabbits reported from 53%, 83% and 93% respectively of the 173 forests from which a questionnaire was returned (Hannan 1986). The survey indicated differences between the various species in terms of the form and level of damage and habitat selection.

Mammals will remove bark for food and to gain access to softer tissues and sap underneath, whilst buds, shoots and leaves will be browsed as food. Browsing and bark stripping can lead to stunted tree growth, deformities and structural weaknesses, increased susceptibility to disease, fungal attack and further mammal damage (Welch *et al*. 1992). Although trees can tolerate and recover from relatively small amounts of damage, the quality and economic value of the timber is often reduced. Bark stripping can result in the permanent discoloration of the underlying wood as a consequence of fungal infections and other diseases gaining entry (Plate 1.1). Severe and frequent bark damage may cause the eventual death of the tree (Gill

1992c). An example of severe damage would be when large areas of bark are removed, often from around the entire trunk, a process known as ‘girdling’ or ‘ring-barking’ which leads to breakage during high wind (‘windsnap’) and premature tree death.

Excessive knots (Plate 1.2) and multi-leaders (Plate 1.3) are caused by browsing of leader shoots (Plate 1.4). Removal of the leader shoot results in the formation of multi-leaders and the tree takes on a bushy appearance instead of the normal conical shape. As the tree grows, the multi-leaders leave marks and knots in the wood that may reduce the value of the timber. Browsing of side shoots can lead to stunted tree growth and a closely cropped appearance (Plates 1.5 and 1.6).

Significant damage to trees can therefore lead to economic loss and a reduction in the amenity and habitat values of a woodland area. In many situations, it may be uneconomical to plant certain species due to the threat of mammal damage. While the main culprits in Ireland include red, fallow and sika deer, grey squirrels, rabbits, hares and bank voles, damage can also be caused by domesticated mammals such as cattle, sheep, horses and feral goats (Plates 1.7 and 1.8). Preventative measures that may be employed to protect trees and crops include the use of repellents, habitat management, protective tree guards, fencing, trapping and other population control regimes (Plate 1.9).

Mammal damage to forests in Ireland is not a recent phenomenon (Mooney 1952). Levels of damage will undoubtedly escalate in both extant and newly planted woodlands unless preventative measures are taken. Similar to the scenario in Scotland (Ratcliffe 1986, Anon. 1997), sika and sika-like deer are expanding their ranges (Hurley 1996, Hayden 1997) and are existing at ultra-high densities and causing unacceptable levels of damage to trees. Grey squirrels and bank voles are also expanding their geographic ranges, thus bringing them into contact with previously uncolonised woodlands. Biodiversity within woodlands tends to be compromised by high densities of deer, as plant diversity can suffer through browsing activity (Gill *et al*. 1995). Reduction or complete removal of the shrub layer and understorey habitat will affect animal biodiversity, with marked effects on small mammal, bird and invertebrate species richness.

Grazing by large herbivores, such as deer, on seedlings and young trees, can have adverse effects on natural regeneration and canopy structure (Putman and Moore 1998) which is especially pronounced when animal populations reach high densities. This may result in a loss of diversity, as less-preferred or more-resilient species become dominant. In general, the amount of grasses and unpalatable species increase at the expense of broadleaved trees, shrubs and understorey (Gill *et al.* 1995).

PLATE 1.1: DISCOLORATION RESULTING FROM BARK STRIPPING VISIBLE IN CROSS-SECTION.

PLATE 1.2: KNOTS INDUCED BY MULTI-LEADERS.

PLATE 1.3: MULTI-LEADERED, BUSHY CONIFERS RESULTING FROM BROWSING OF LEADER SHOOT.

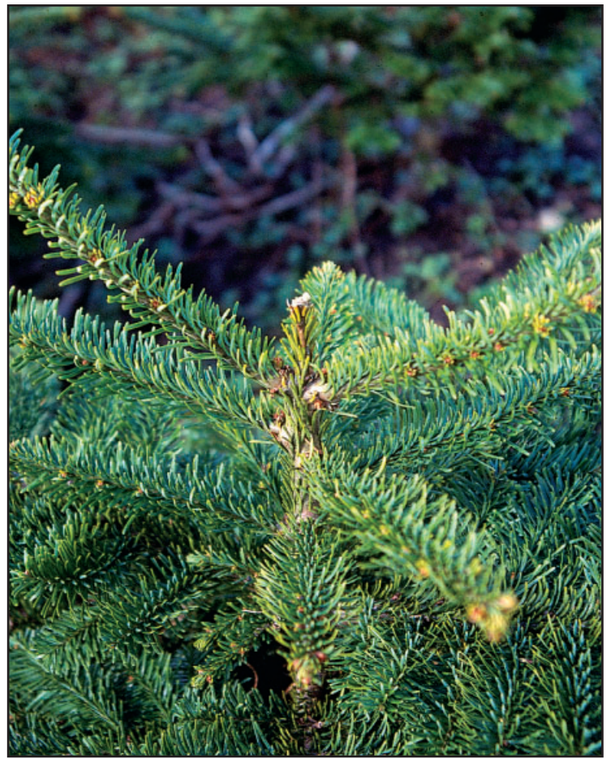


PLATE 1.4: LEADER SHOOT BROWSING.

PLATE 1.5: WELL-BROWSED CONIFERS.

PLATE 1.6: SEVERELY BROWSED YOUNG CONIFERS.

PLATE 1.7: BARK DAMAGE CAUSED BY SHEEP.

PLATE 1.8: TRUNK OF A CONIFER DAMAGED AS A RESULT OF INTENSE RUBBING BY CATTLE.

PLATE 1.9: STAKE AND WIRE FENCING IS THE MOST EFFECTIVE METHOD OF EXCLUDING LIVESTOCK FROM WOODLAND, ALLOWING THE UNDERSTOREY TO DEVELOP.

1.4 FOREST BIODIVERSITY AND THE NEED TO MANAGE MAMMALS

Grants and premiums for afforestation allow forestry to compete favourably with other agricultural enterprises. A new support package recently launched by the Department of the Marine and Natural Resources should result in an increase in the annual afforestation rate. Broadleaf species will account for at least 20% of this afforestation programme. The recently issued Forest Biodiversity Guidelines also specify that 5 to 10% of each forest area should be left as open space. These guidelines will help to enhance the biodiversity and habitat richness of each plantation. However, leaving open spaces and planting more broadleaves are two factors that favour deer populations. A specific plan to manage mammal species must therefore be a component of any overall forest management plan.

1.5 IRISH FOREST MAMMALS AND THE LAW

The majority of Irish mammals, including many forest-dwelling species, are protected under national and international statutes. The main national legislation that protects and conserves mammals is the Wildlife Act, 1976, and the Wildlife (Amendment) Act, 2000. It is upheld and administered by the Department of the Environment and Local Government. Under this Act, a number of species are protected at all times from persecution, hunting and deliberate injury. Their habitats are also protected from damage or destruction. Forest mammals protected under this Act include all species of deer, both species of hare, red squirrel and pine marten. The Act defines a selection of species as ‘quarry’ or ‘game’, i.e. species that may be hunted for periods of the year designated as official open seasons. Mammals that qualify as game include all deer species and both hare species. Under Section 42 of the Wildlife Act, permission may be sought from the Department to control protected species which are causing a nuisance or damaging crops and property. In Northern Ireland, protection is afforded to mammals and other wildlife by the Wildlife (Northern Ireland) Order, 1985. A list of mammals (as well as other vertebrates) which are regarded as threatened in Ireland may be found in ‘The Irish Red Data Book No. 2’ (Whilde 1993). Amongst the list of threatened or vulnerable mammals are the Irish mountain hare and pine marten, both of which are considered category 2 or ‘internationally important’ species.

A number of Irish forest mammals are protected under European legislation. The 1979 Convention on the Conservation of European Wildlife and Natural Habitats, also known as the ‘Bern Convention’, protects all deer species, both species of hare, red squirrels and pine martens amongst others. EU Directive 92/43 on the Conservation of Natural Habitats and of Wild Fauna and Flora, also known as ‘The Habitats Directive’, aims to preserve biodiversity through the protection of habitats and species by designating them as special areas of conservation (SACs). Under Article 15 of this Directive the pine marten and mountain hare are listed as vulnerable and protected species.

1.6 AIMS OF THIS PUBLICATION

This book seeks to outline the various forms of mammal damage to forests as well as facilitate the identification of the species responsible. Information regarding the ecology of each potential pest species is provided. Reference is made to findings from a number of COFORD funded research projects. Finally, specific methods to manage mammal populations and control the damage caused by them are described.

TABLE 1.1: IDENTIFICATION OF DAMAGE THAT MAMMALS CAN INFLICT UPON TREES.

Type and location of damage	*Season*	*Age and species of tree*	*Features*	*Height of damage (above ground)*	*Mammal responsible*	*Other features/ notes*
Bark stripped at base of tree/low branches	Winter	All ages – willows, rowan, Norway spruce, Scots pine.	Teeth marks, 3 - 4 mm wide.	Up to 55 cm. May be higher with snow.	Rabbit, occasionally hare	Round droppings often in immediate vicinity
Bark stripped at base of tree/low branches	Late spring and early summer	Young trees, 10 to 40 years old – beech and sycamore most at risk (Table 4.1).	Teeth marks sometimes visible. Fragments of bark on ground	Beginning from base and extending often high up the trunk	Grey squirrel	
Bark stripped on trunk/low branches and boughs	All year	All ages – various species (Table 2.2).	Teeth marks, 8 - 9.5 mm wide	1.8 m	Red deer	Droppings and foot prints (‘slots’) in the immediate vicinity
			Teeth marks, 6.4 mm wide	1.2 m	Sika deer, fallow deer, feral goat	
Bark gnawed at base. Often completely ringed	Winter and early spring	Very young, i.e. 2 to 5 years old – Sitka spruce extremely susceptible.		Usually close to base and under vegetation. Sometimes higher	Bank vole	
Trunk lacerated with long deep vertical and diagonal grooves	Autumn (September)	Mature – Norway and Sitka spruce, yew, ash.		1 m	Sika deer	Using antlers to mark territory and spread scent
Fraying and thrashing of stem, branches and foliage. Bark often removed in patches	Autumn and early winter	Saplings – various species.		1 to 2 m	All deer species	Territorial scrapes often on nearby ground. Fragments of antler tissue (‘velvet’) attached to foliage
Browsing on tips of stems and twigs	Winter and early spring	Young – various conifers and broadleaves.	Clean angled cut end on stem or twig	0.55 m	Rabbit	Round droppings often in immediate vicinity
Browsing on tips of stems and twigs. Cut tips often lying underneath	Winter and early spring	Young – various conifers and broadleaves.	Clean angled cut end on stem or twig	0.70 m	Hare	Round droppings often in immediate vicinity
Browsing of leading shoots, side shoots and foliage	Late winter to early summer, sometimes all year	All ages – various species (Table 2.1).	Ragged instead of cleanly nipped tips. Trees may develop multi-leaders and appear sculpted	Up to 1.8 m	All deer, goats, sheep, goats and other domestic ruminants	Wool may be attached to foliage in the case of sheep browsing
Trees uprooted	All year	Recently planted – various conifers and broadleaves.			Fallow deer, sheep, goats, cattle, horses, rabbit.	

2. DEER

Populations of deer are increasing across Ireland, Great Britain and much of the Northern Hemisphere (Mayle 1996). This is due mainly to the availability of suitable habitat offered by woodlands and the lack of predator species. Furthermore, the increase in numbers over time is exacerbated by the introduction of non-native deer species.

The presence of deer in woodlands may be indicated by a number of signs. Firstly there may be a 'browse-line' where the foliage of trees will be neatly cropped as high as the deer can reach (Plates 2.1 and 2.2). They will also leave droppings, which tend to be cylindrically shaped pellets ranging in colour from black to light brown. Sometimes the pellets will be clustered together (Plate 2.3), while at other times they may be dispersed (Plate 2.4). Deer also leave tracks or 'slots' in soft ground. Discarded or 'cast' antlers may be found on the ground in various areas and their distinctive shapes and sizes can be used to identify the species of deer present. Male antlers are not permanent structures but are grown over the summer in time for the autumn breeding season or 'rut', and then they are shed or 'dropped' late during the following spring and regrown yet again. (While the new antlers are growing they are covered in a soft tissue known as 'velvet', which is shed when the antlers are fully-grown and hard).

PLATE 2.1: OBVIOUS BROWSE LINE ALONG THIS WOODLAND EDGE INDICATES PRESENCE OF BROWSING ANIMALS, IN THIS CASE FALLOW DEER.

PLATE 2.2: BROWSE LINE WITH FALLOW DOES IN THE BACKGROUND.

PLATE 2.3: GROUP OR CLUSTER OF DEER PELLETS (50P COIN USED FOR SCALE).

PLATE 2.4: DEER PELLETS (NOTE THE CYLINDRICAL SHAPE).

2.1 COMMON TYPES OF DEER DAMAGE

Deer can be responsible for much damage in and around woodlands (Table 1.1), consisting of some or all of the following:

2.1.1 Bark stripping

Bark stripping is caused by red, fallow and sika deer and sika-hybrid animals, and most commonly occurs during the winter and spring. Deer shave the bark upwards using the incisors on their lower jaw, often leaving visible teeth-marks. The width of tooth-marks ranges from 6.4 mm for sika and fallow to 9.5 mm for red deer (Springthorpe and Myhill 1994). Sika and fallow deer strip bark to a height of about 1 m while red deer can reach up to 1.7 m (Plates 2.5 - 2.8).

PLATE: 2.5

PLATE: 2.6

PLATE: 2.7

PLATE: 2.8

PLATES 2.5-2.8: BARK STRIPPING DAMAGE CAUSED BY DEER.

2.1.2 Browsing

This is the removal of buds and growing shoots of young trees and is caused by all deer species (Plates 1.3-1.6, 2.9). Foliage that is consumed in this manner is often referred to as ‘browse’. Such damage can occur at all times of the year, but especially in springtime when buds and growing tips are tender. Browsing may result in a tree developing several leading shoots or ‘multi-leaders’ (Plate 1.3) instead of a single leader. One or more side shoots grow upwards to replace the leader in a process known as ‘side-shoot flagging’, thus affecting the future growth and economic value of the tree. Although browsing of side shoots is less damaging, it may become pronounced and unsightly (Plates 1.5 and 1.6), especially when deer populations reach high densities. Browsing can stunt or check tree growth substantially and may be more important in reducing overall growth rates rather than causing direct tree mortality (Putman and Moore 1998).

PLATE 2.9: SIKA HIND BROWSING.

2.1.3 Fraying and thrashing

Young trees are used by deer to clean the velvet tissue from growing antlers (Plate 2.10), and to deposit scent by males of all species during the build-up to the rut in autumn. Branches and foliage are often broken and young trees may suffer severe damage (Plates 2.11 and 2.12). Tree shelters and other stationary objects may also be utilised for fraying and thrashing.

PLATE 2.10: BLACK-COATED FALLOW BUCK WITH VELVET PEELING FROM THE FULLY FORMED ANTLERS.

PLATE 2.11: FRAYED CONIFERS.

PLATE 2.12: FRAYED AND THRASHED CONIFER.

2.1.4 Bole scoring

Antler damage known as ‘bole scoring’ is attributed to sika and sika-like animals and is the vertical laceration of the tree trunk by the antlers as a territorial display (Plate 2.13) (Carter 1984). The amount of damage that deer can cause depends mainly on three factors: population density, use of habitat and the choice of available foodstuffs (Gill et al. 1995). Sites offering an attractive combination of food and cover often attract damage, for instance, woodland edges, clearings and thoroughfares (Thirgood and Staines 1989). Tree species differ in their vulnerabilities to damage. Smooth or thin-barked species are generally preferred over those with thick or rough bark, e.g. ash versus oak.

PLATE 2.13: BOLE SCORING BY SIKA STAGS.

2.2 FACTORS THAT INFLUENCE DEER DAMAGE

Factors such as plantation or woodland size, species composition and amount of available cover will also be important in determining levels of damage (Moore *et al.* 1999). In lowland Britain, conifers that suffered bark stripping were generally older than those browsed, whilst for broadleaved species it was young trees that were bark stripped, especially beech and sycamore (Putman and Moore 1998). Bark stripping may be more common in monocultures.

Future numbers and range expansion of all deer species in Ireland will be directly dependent on patterns of land use and population management strategies. An increase in afforested area has often been accompanied by a rise in deer numbers, e.g. red and fallow (Gill *et al.* 1995). Deer will also utilise agricultural habitats, preferring to occupy and operate from edge-habitats at the interface of mature and older-stage woodland and the adjoining farmland. Red deer have been noted to make more use of stands less than 15 years of age rather than older stands (Welch *et al.* 1990, Staines and Welch 1984).

Deer browsing can have mixed impacts on plant species important in areas of high biodiversity such as native and semi-natural woodland. Species that are thus affected by deer browsing include bramble (*Rubus* spp.), holly (*Ulex* spp.), heather (*Calluna vulgaris*), willow (*Salix* spp.) and ash (*Fraxinus excelsior*). Species which are more resilient and which may increase include bracken (*Pteridium aquilinum*), grasses, toxic species such as ragwort (*Senecio jacobea*) and ground ivy (*Glechoma hederacea*).

A study of mammal damage in Irish woodlands found that deer preferred recently planted areas in which there was plenty of cover, especially when there were neighbouring areas of open land (Hannan 1986). Bordering areas between woodland and open upland and farmland, also known as ‘edge habitats’ or ‘ecotones’, were favoured feeding habitats for deer. Damage was caused to a high proportion (35 to 51%) of trees in very young plantations. Thicket stage, the stage before initial thinning of trees, was less affected. Browsing was the chief form of deer damage recorded.

2.3 RED DEER (*Cervus elaphus*)

2.3.1 Biology and range

Red deer are large, hoofed herbivores and are possibly Ireland’s only native deer species. Their geographic range covers much of Western Europe. In Ireland, red deer are found mainly in and around three major National Parks, *viz.* Killarney, Wicklow and Glenveagh (Figure 2.1). Populations also occur in Counties Galway, Clare, Meath and on one of the Blasket Islands in Co Kerry.

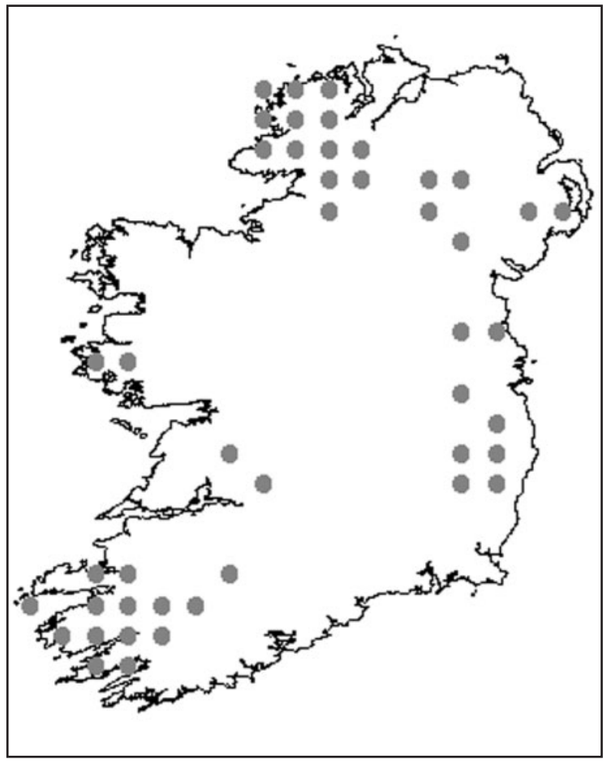


FIGURE 2.1: THE CURRENT DISTRIBUTION OF RED DEER (*Cervus elaphus*) IN IRELAND (DOTS ARE CENTRED WITHIN 20 X 20 KM² SQUARES WHERE RED DEER CAN OCCUR IN SUITABLE HABITAT).

2.3.2 Identification and field signs

Red deer are large and unspotted (except for the young) with a reddish-brown coat, a yellowish rump and a short brown tail (Plates 2.14 and 2.15). Males have a mane around their neck that appears especially shaggy during the breeding season. Only males bear antlers that are branching in nature (Plate 2.14). The antlers of a mature male or ‘stag’ may be quite impressive. Stags may measure up to 1.5 m at the shoulder and weigh up to 225 kg, with the females or ‘hinds’ being smaller, measuring up to 1 m at the shoulder and weighing up to 130 kg.

PLATE 2.14: RED DEER STAGS (NOTE THE BRANCHING ANTLERS AND YELLOWISH-BROWN RUMP).

PLATE 2.15: HERD OF RED DEER RESTING.

2.3.3 Diet and habitat

Originally a woodland species, red deer are now commonly associated with upland, open mountainside and rugged wilderness areas, due mostly to loss of their former habitat (Mitchell *et al.* 1977). Radio-tracking studies have revealed that while hinds do not range very far in dense forests, stags are much more variable in their movements (Catt and Staines 1987), a trait shared with sika and sika-like animals (Casey 1999). Hunting pressure can affect the activity and habitat selection of red deer. In areas where culling occurs, red deer spend more time in cover, emerging into more open areas at dawn and dusk to feed (Staines *et al.* 1985). In areas where there is little or no hunting, red deer may be readily seen in open habitat during daylight hours (Mitchell *et al.* 1977). Because they are larger and able to eat much more than other smaller species, they often retreat into cover for longer periods to digest (Thirgood and Staines 1989). Grasses comprise the most important component of the diet from spring to autumn (Staines *et al.* 1985). Coniferous foliage, or 'browse', is heavily consumed during spring and early summer while heather is an important foodstuff during the winter.

2.3.4 Populations and reproduction

Densities of red deer can vary with habitat. In Britain, densities of 5 to 40 animals per km^2 have been recorded in plantation forests, while 12 to 15 animals per km^2 may be typical of upland hillside (Harris *et al.* 1995). In common with other deer species, red deer display sexual segregation for much of the year with the stags living separately from groups containing hinds and their young. Male and female groups come together only to mate. As with other Irish deer species, breeding is seasonal and single calves are born. The rut begins in September and may last until early November. Stags are fertile from the time that antlers are fully developed until they are cast in April. Hinds can breed from the age of 2 to 3 years and, after a gestation period of eight months, give birth from late May through June. Hinds make a distinctive barking call while stags are quite vocal and roar during the rut.

2.3.5 Impact on forestry

Red deer may cause damage in plantation forests by uprooting newly planted trees, browsing leader and side shoots of young trees, and stripping bark from the trunk and branches of older trees (Ratcliffe 1987). Damage may often go unnoticed, especially when it occurs in the interior of 'thicket' stage forest. Red deer in woodlands will browse from trees wherever it is favourable to do so (Mitchell *et al.* 1977). Tree species differ greatly as regards their attractiveness as a food source for red deer. Table 2.1 contains the pooled results from a number of independent studies of browsing on certain tree species ranked in decreasing order of susceptibility.

The size, age and species composition of the woodland can greatly influence the browsing habits of red deer (Mitchell *et al.* 1977). Tree species that are considered unpalatable may themselves be selected in situations where more preferred food types are scarce or when deer density is high. Browsing by red deer has a greater impact on smaller trees since relatively more biomass is taken with each bite. Browsing of leader shoots, for instance, can seriously depress the height of young Sitka spruce while also affecting the girth of the tree (Welch *et al.* 1992). Browsed material from conifers, while representing a small proportion of the diet, is most important during spring and early summer, coinciding with fresh growth (Staines *et al.* 1985). Any alteration in red deer feeding habits, however, could increase their potential threat to upland Sitka spruce plantations (Welch *et al.* 1983). At night, red deer can move from the cover of older woodland into younger stands where they cause damage (Thirgood and Staines 1989).

TABLE 2.1: RELATIVE SUSCEPTIBILITY OF TREE SPECIES TO BROWSING BY RED DEER, RANKED IN ORDER OF DECREASING SUSCEPTIBILITY

Species	*Susceptibility to red deer browsing damage*
Willow (*Salix* spp.)	
Oak (*Quercus* spp.)	
Scots pine (*Pinus sylvestris*)	**HIGH**
Rowan (*Sorbus aucuparia*)	
Ash (*Fraxinus excelsior*)	Decreasing susceptibility
Birch (*Betula* spp.)	↓
Aspen (*Populus tremula*)	
Juniper (*Juniperus* spp.)	
Norway spruce (*Picea abies*)	**MEDIUM**
Silver fir (*Abies alba*)	
Maple (*Acer* spp.)	
Sycamore (*Acer pseudoplatanus*)	
Hazel (*Corylus avellana*)	
Buckthorn *(Frangulus alnus*)	
Sitka spruce (*Picea sitchensis*) *	Decreasing susceptibility
Larch (*Larix* spp.)	
Lodgepole pine (*Pinus contorta*)	↓
Alder (*Alnus* spp.)	
Beech (*Fagus sylvatica*)	
Douglas fir (*Pseudotsuga menziesii*) **	
Hornbeam (*Carpinus betulus*)	
Cherry (*Prunus avium*)	
Elder (*Sambucus* spp.)	**LOW**
Lime (*Tilia cordata*)	

**Sitka spruce only suffered damage in Scottish studies.*
***Douglas Fir mentioned in one study only.*
Note: Table modified from Gill 1992a (Table 1).

Red deer strip bark in summer when the sap is rising and the bark is easy to peel, and also in winter in response to food shortage. During winter, the bark is tougher and is gnawed from the trunk. Age and girth of trees are important factors in determining the severity of damage. For instance, most damage to the bark of Sitka spruce is inflicted upon trees aged between eight and 35 years. Relatively little stripping of trees occurs to older trees, as their bark is often too thick and rough (Welch *et al.* 1987). Bark may also be eaten during spring as a source of roughage. Damage to bark is often quite patchily distributed, with many instances of repeated damage to individual trees. It is possible that the sight of a fresh wound is a cue for red deer to strip more bark, and this may also be the case for other deer species. As with browsing, various tree species differ greatly as regards their susceptibility to bark stripping by red deer. A number of European studies (Gill 1992a) have again produced conflicting results, for example Scots pine (*Pinus sylvestris*) suffered high levels of damage in some studies and relatively little or none in others. Table 2.2 contains the pooled results from these studies ranked in order of decreasing susceptibility of trees to bark stripping.

TABLE 2.2: RELATIVE SUSCEPTIBILITY OF TREE SPECIES TO BARK STRIPPING BY RED DEER, RANKED IN ORDER OF DECREASING SUSCEPTIBILITY.

Species	*Susceptibility to bark damage by red deer*
Willow (*Salix* spp.)	
Norway spruce (*Picea abies*)	**HIGH**
Scots pine (*Pinus sylvestris*)	
Ash (*Fraxinus* spp.)	Decreasing susceptibility
Lodgepole pine (*Pinus contorta*)	↓
Rowan (*Sorbus aucuparia*)	
Aspen (*Populus tremula*)	
Larch (*Larix* spp.)	
Other pines (*Pinus nigra, P. mugo*, etc)	**MEDIUM**
Firs (*Abies* spp.)	
Douglas fir (*Pseudotsuga menziesii*)	
Sycamore (*Acer pseudoplatanus*)	
Alder (*Alnus* spp.)	Decreasing susceptibility
Hazel (*Corylus avellana*)	↓
Birch (*Betula* spp.)	
Oak (*Quercus* spp.)	
Beech (*Fagus* spp.)	
Sitka spruce (*Picea sitchensis*)	
Lime (*Tilia cordata*)	**LOW**
Hornbeam (*Carpinus betulus*)	

Note: Table modified from Gill 1992a (Table 2).

2.4 FALLOW DEER (*Dama dama*)

2.4.1 Biology and range

The Normans first introduced fallow deer to Ireland in the 1200s. Subsequent escapes from enclosed populations led to the establishment of herds in the wild as early as the fifteenth century. Many park herds escaped or were released to the wild at the beginning of the 20th century. These supplemented the already wild fallow populations such that fallow are now Ireland's most widespread deer species and may be found in most counties (Figure 2.2).

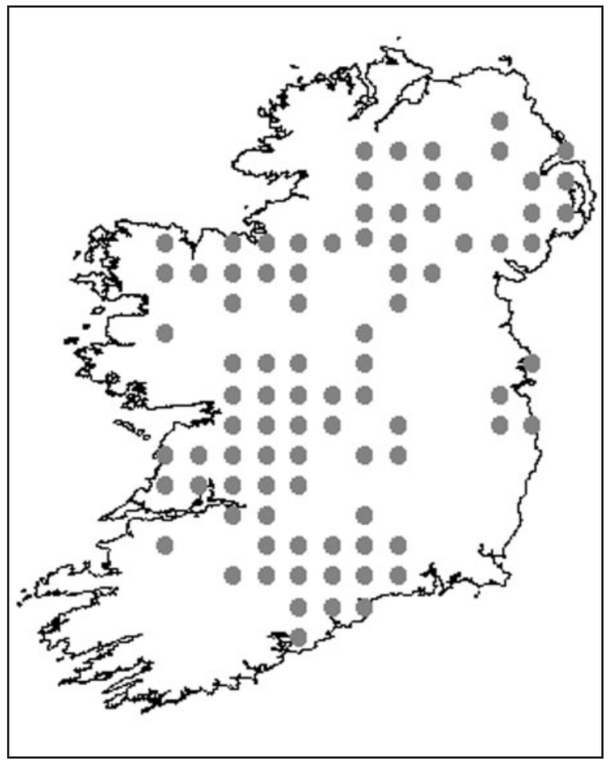


FIGURE 2.2: THE CURRENT DISTRIBUTION OF FALLOW DEER (*Dama dama*) IN IRELAND (DOTS ARE CENTRED WITHIN 20 X 20 KM² SQUARES WHERE FALLOW DEER CAN OCCUR IN SUITABLE HABITAT).

2.4.2 Identification and field signs

Adult males or 'bucks' stand about 1 m at the shoulder and weigh about 100 kg in autumn. Females or 'does' are smaller than bucks, measuring between 80 and 85 cm in height at the shoulder and weighing from 40 to 45 kg. The coat colour can vary from blackish-brown to a yellowish-white (Plate 2.16). The main colour varieties in Ireland are black, brown, menil (brightly spotted) or white. The main beam of each fully-grown antler is flattened or 'palmate' (Plate 2.17), a feature which is unique amongst Irish deer species. Antlers are cast from April to May. Fraying and thrashing of saplings occurs from August to November as bucks clean the velvet from their fully-grown antlers and display rutting behaviour (Plates 2.10, 2.16 and 2.17).

PLATE 2.16: FALLOW BUCK AND DOES DURING THE RUT (NOTE THE RANGE OF COAT COLOURS AND THE DARK TAIL STRIPE).

PLATE 2.17: FALLOW BUCK DURING THE RUT (NOTE THE FLATTENED PALMATE ANTLERS).

2.4.3 Diet and habitat

The preferred habitat of fallow deer consists of deciduous or mixed woodlands with a good understorey and interspersed grassy openings. Bramble (*Rubus* spp.) is an important constituent of their diet. During autumn, fallow deer inhabit mature broadleaved woodlands where they can obtain acorns and other seeds. Pre-thicket forest is also important throughout the year as a source of food and cover. In addition, fallow deer will utilise pasture when it is in close proximity to woodland.

2.4.4 Populations and reproduction

The rut begins in late September or early October and lasts for roughly one month during which older males join the herds of females and younger animals. Bucks become very vocal during this period, emitting a belch-like groan. Aggressive behaviour such as fighting and sparring is commonplace between rival males as they vie to establish a hierarchy and gain access to fertile does. Fawns (usually one per doe) are born in late May and June.

2.4.5 Impact on forestry

Because of their feeding habits, fallow deer can pose a threat to woodlands. Tree type is an important factor influencing browsing damage, with broadleaved and deciduous conifers sustaining more extensive and heavier damage than evergreen conifers. Damage by fallow deer can be seasonal in nature with broadleaves and conifers targeted in summer and winter respectively. The peak period of browsing damage to broadleaved trees occurs in July with a decrease thereafter attributed to an increase in the levels of tannins and other secondary metabolites, a decrease in sap flow and a general decline in nutritional value (Key *et al.* 1998). Browsing in reforestation sites, for instance, can affect the future performance of newly planted trees. Studies in Co Down on browsing by fallow deer in mixed reforestation sites showed clear preferences for broadleaves (beech, oak and ash) and larch over Douglas fir (Calvert 1997). Where conifers were browsed, species such as Douglas fir and Norway spruce were preferred over Scots pine and Noble fir. Within three years of planting almost all (95%) European larch suffered browsing damage in comparison with 36% of Douglas fir, while 100% of ash and oak were browsed within two years of planting. Beech was also browsed heavily (95%) within the first year by fallow deer and hares. Browsing also affected survival, causing the death of roughly 40% of ash and oak within the first year of planting. Uprooting of newly planted trees is also a problem, highlighting the need for protective tree-guards. Heavy browsing by fallow was responsible for prevention of succession in scrubland (Ward *et al*. 1994) where woody species important for promoting and maintaining biodiversity, such as blackthorn (*Prunus spinosa*), were severely browsed. Amongst broadleaves, the species most affected by browsing are ash, cherry, rowan, lime, maple and oak, with sycamore, birch, alder and poplar less affected (Moore *et al*. 1999).

A number of factors have been investigated to explain the incidence of browsing by fallow deer in young broadleaved plantations. These include characteristics such as plantation area, length of perimeter, tree species composition, proximity to existing woodland and the amounts of cover and alternative foodstuffs available for deer both internally and along the periphery (Moore *et al*. 1999). In general, smaller rather than larger woodlands suffer higher levels of damage. Woodlands with appreciable amounts of shrub and ground layer cover, which conceals fallow deer and allows them to feed, can also suffer heavy damage.

In Britain, fallow deer are the species most widely implicated in damage to crops and forestry in lowland areas. In one study for instance, fallow accounted for over 50% of damage reports and requests for advice concerning deer received by MAFF, the British Ministry of Agriculture, Fisheries and Food (Putman and Moore 1998). While numbers in Britain are on the increase, the expansion of their geographic range is relatively slow. Farming practises such as ‘set aside’, the planting of farm woodlands, sowing of cereals and vegetables such as turnips, and new crops such as oil-seed rape, have been identified as factors which may encourage the future spread of fallow deer. This will also apply to populations of fallow deer in Ireland.

2.5 SIKA DEER (*Cervus nippon*)

2.5.1 Biology and range

Sika deer are a small to medium sized species indigenous to Japan and north eastern Asia. They were introduced into Ireland in 1860 by Lord Powerscourt to his estate in Wicklow and began to hybridise with red deer already present on the grounds. The hybrid offspring were fertile and were thus capable of further breeding and crossing. Sika hybrids subsequently escaped from the estate and dispersed into the surrounding countryside. The expansion of their range was facilitated by wide-scale afforestation from the 1940s onwards. Sika and hybrid deer from Powerscourt Park were used to stock other parks around the country. Through escape and deliberate release, they have formed populations in other parts of Ireland. The geographic range of sika, aided by afforestation, is expanding across the entire British Isles at a rate of 3 to 5 km per year (Harris *et al.* 1995). Their spread and potential to cause damage is of great concern, especially in Scotland where consideration was previously focussed on red and roe deer (Anon. 1997). Sika and sika-like animals are found in three principal areas in Ireland from where they are spreading outwards (Figures 2.3 and 2.4). These areas are the eastern region centred on Co Wicklow, south west Munster centred on Killarney and the north western region centred on Donegal, Fermanagh and Tyrone.

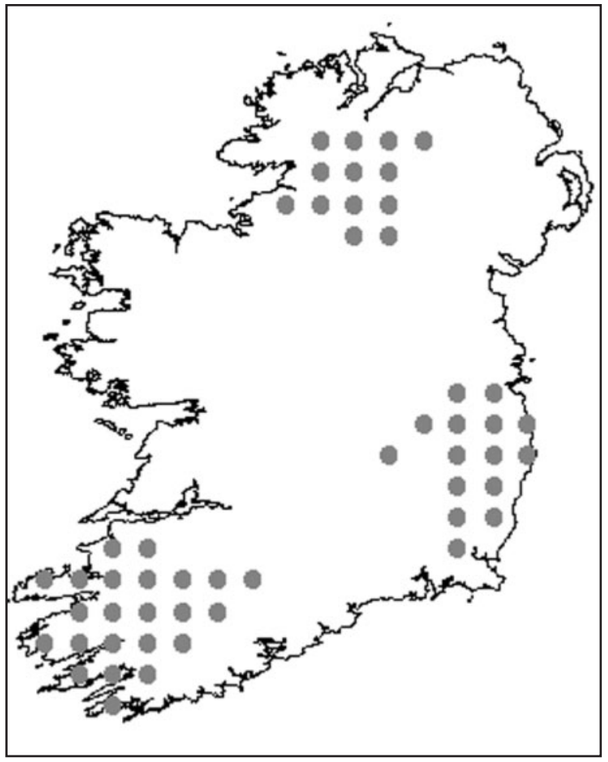


FIGURE 2.3: THE CURRENT DISTRIBUTION OF SIKA DEER (*Cervus nippon*) IN IRELAND (DOTS ARE CENTRED WITHIN 20 X 20 KM^2 SQUARES WHERE SIKA DEER CAN OCCUR IN SUITABLE HABITAT).

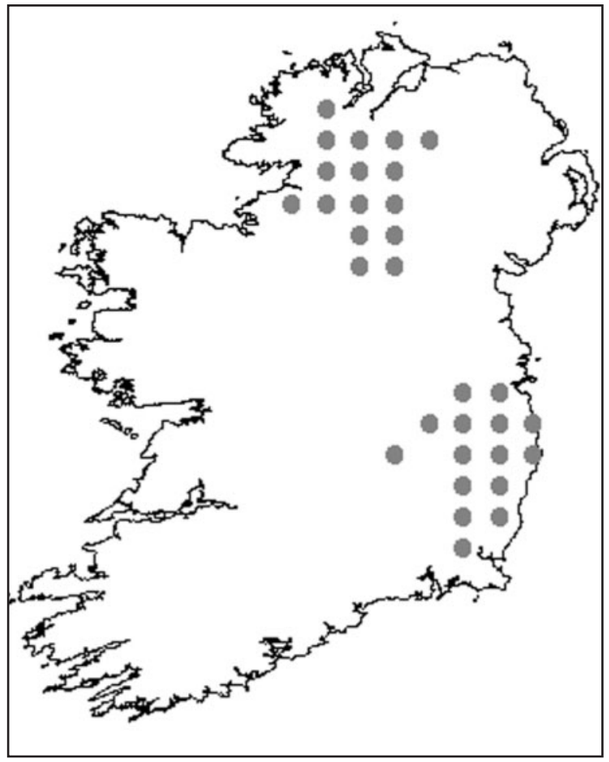


FIGURE 2.4: THE CURRENT DISTRIBUTION OF SIKA-LIKE / RED X SIKA HYBRIDS IN IRELAND (DOTS ARE CENTRED WITHIN 20 X 20 KM² SQUARES WHERE HYBRID DEER CAN OCCUR IN SUITABLE HABITAT).

2.5.2 Identification and field signs

Sika is the smallest species of deer present in Ireland. Adult stags stand about 75-80 cm at the shoulder and weigh about 50-60 kg in autumn. Hinds are smaller than stags, 65-70 cm tall at the shoulder and weigh from 30-35 kg. Sika may appear faintly spotted in the summer (Plate 2.18), while during the winter their coat becomes darker and unspotted (Plate 2.19). They have white rumps with a black outline (Plate 2.20, 2.21 and 2.22). Their tail is white and relatively short. Also conspicuous are white glandular regions on the outside of each hind leg used for scent marking. Only the males bear antlers and these are similar to the branching antlers of a young red stag, rarely having more than four points. The antlers have a distinctive V-shape when viewed from the front (Plate 2.22). Dark facial markings towards the end of the snout, giving the appearance of a frown, are also distinctive.

PLATE 2.18: SIKA HIND IN SUMMER COAT.

PLATE 2.19: SIKA HIND IN WINTER COAT.

PLATE 2.20: HERD OF SIKA DEER (NOTE THE WHITE RUMP WITH BLACK BORDER).

PLATE 2.21: SIKA HIND AND CALF.

PLATE 2.22: SIKA STAG (NOTE THE BRANCHING V-SHAPED ANTLERS).

2.5.3 Diet and habitat

Sika deer are primarily grazers but their diet may be influenced by season and availability. A study from Killarney showed that the sika diet was composed of 40 to 60% grasses with the remainder consisting of material browsed from trees (O'Donoghue 1991). Food items of sika deer within their natural range can consist mostly of sedges and bamboo and to a lesser extent tree foliage, ferns and grasses (Takatsuki 1986).

In Asia, their natural habitat is broadleaved woodland. In Britain and Ireland, they have moved into a number of woodland types, particularly plantation forestry, as well as onto heath and moors. Sika are potentially more difficult to control than other deer species due to their elusiveness and use of cover (Ratcliffe 1986).

2.5.4 Populations and reproduction

Sika deer often travel in small herds (Plate 2.20). The rut begins in late September and ends in November, during which the stags whistle or shriek. Calves, usually one per hind, are born in late May or June and remain with the hind for most of their first year (Plate 2.21). Antlers are cast from late March onwards.

Since sika can interbreed with red deer to produce fertile hybrid offspring, they pose a threat to the genetic integrity of native reds (Hayden 1997). Hybridisation has occurred in many parts of the world, including Ireland (Figure 2.4). The majority of deer in the Wicklow area are sika x red hybrids. Hybridisation has not yet occurred in Killarney National Park. The genetic integrity of both Killarney reds and sika will be threatened at some stage in the near future when they encounter the spreading sika-like animals from the eastern region. The genetic integrity of both the Killarney red and sika deer is important and measures to prevent hybridisation should be considered.

2.5.5 Impact on forestry

Sika can cause high levels of damage not only by browsing and bark stripping but also by the bole scoring behaviour of stags with full hard antlers (Plate 2.13). Species affected include Norway and Sitka spruce

(*Picea* spp.), yew (*Taxus bacata*) and ash (*Fraxinus excelsior*). The stags may prefer species with smooth bark as they afford less resistance to the antlers, especially when the trees are young (Larner 1977). This will have implications for the species selection in areas where sika populations have the potential to cause damage. Density of deer populations and the number of mature stags present during the rut may also affect the incidence of bole scoring. Damage only occurs during periods of 'hard antler' when antlers are fully-grown and will therefore be highest in November and December.

2.6 CURRENT RESEARCH IN IRELAND

Since 1995 COFORD have funded two independent research projects that examined the status and ecology of sika/sika-like deer. Prior to 1995, little or no research had been carried out regarding the biology of this species in Ireland. Both studies were based in Co Wicklow where roughly 20% of the county area, over twice the national average, is under forest cover. In this area, there is also an extremely large and widespread population of deer, mainly sika-like animals, which is increasing in both number and range. These deer are, for the most part, inadequately managed and are causing unacceptable levels of damage.

The first project involved a study of the habitat use and ranging behaviour of sika/sika-like deer in Co Wicklow (Casey 1999). Twenty individual deer were radio-tracked over a two-year period in three areas of Wicklow, namely Glendalough, Glencree-Luggala and Blessington forests. Both sexes differed in their home range sizes and internal use of space. Males had much larger ranges than females - the average male range size was 843 ha while that of the females was 53 ha. The range location was static over time for both sexes. They also displayed core activity areas within their range where most of their time was spent. Three of the stags showed similar behaviour in that they spent time in a core summer area, moved to new areas to coincide with the rut and afterwards returned to their previous summer range. Despite crossing large tracts of open hill they limited amounts of time spent away from cover.

Females spent the majority of their time in their core areas, the average size of these areas being 22 ha. The ranges of the hinds increased in size during the period from March to June, coinciding with low forage availability at the beginning of the growing season and the impending birth of their calves. Conversely, their ranges were smallest from December to February. Many hinds made uncharacteristic long-range movements during the rut, and this was attributed to pressure from the stags. Not all females conformed to the above - during the course of the radio-tracking one hind completely shifted her range a distance of over 6 km while another made a large exploratory movement, returning to its original range some time later.

There were also differences between the sexes as regards habitat selection. Stags preferred to spend much of their daytime hours in mature and thicket stage forest where there was a high amount of cover. Other forest classes that had available cover were also utilised, for instance certain areas of pre-thicket stage forest.

Females preferred thicket and first thinned forests. Cover was again an important factor - the only mature forest habitat that was utilised were areas with a good understorey layer. Mature forest, however, was important at night for refuge purposes. Open hills were largely avoided, as was establishment, pre-thicket and undeveloped forest stages except at dawn and dusk when animals might have felt less threatened.

Both sexes demonstrated a preference for transitional 'edge' habitats or 'ecotones', as noted in other studies (Welch *et al.* 1992, 1990). Males frequently occupied the periphery of various stages with access to the open hill where they grazed at dawn and dusk. Females spent much of the day at the edges of thicket and young broadleaved stages where food and cover was available.

For the second project, the deer cull in Co Wicklow over a number of years was used as a source of management information (O'Brien 1999). Methods of assessing age, body quality and fertility of individual deer were applied to samples provided through the participation of hunters, forest owners and park rangers in the Wicklow area. The majority of the deer culled during the study period were sika-like. Analyses of the age structure revealed that 1-2 year olds are most frequently shot. Many of the hinds shot were quite old, a feature which does not occur in a well-hunted and managed population. Their molars showed no signs of severe wear so presumably these animals were capable of living much longer. Stags, however, did not reach the ages that hinds attained, suggesting that there is more hunting pressure on them.

Pregnancy can be assessed in a carcass from December onwards. The pregnancy rates in Co Wicklow were extremely high with 87% of females found pregnant. Pregnancy rates among yearling females were equally high, which suggests that they occupy good quality habitat in the absence of limiting factors such as poor forage and population levels which are close to or exceeding the carrying capacity of the region. Sika hybrid hinds in Co Wicklow become pregnant each year and can easily regain condition to become pregnant once more after rearing a calf in the same year. The high survival rate of calves was attributed to a favourable climate and a general lack of predation.

Body condition of culled animals, as determined by amounts of fat on the rump and in the body cavity, was assessed and noted in the field by hunters. Over 90% of the carcasses were described as being in good or excellent condition, with less than 5% considered in poor condition or having no fat. In addition, two further indices of condition based on marrow fat in both the jaw and lower leg bones were used. None of the samples examined had depleted reserves, again indicating good habitat and conditions. Sika are able to survive on lower quality foodstuffs and thus have the potential to attain extremely high densities where good quality forage is available.

Habitat quality, population density and size of herd can influence body weight in many deer species, including sika, with lighter deer found in low quality forage habitats and/or high densities and *vice versa*. Hybrid sika deer in Co Wicklow are heavier than their pure bred counterparts in Co Kerry, yet they remain roughly half the weight of sika in their native habitat in Asia. Importantly, Co Wicklow sika generally maintain their weight during the year, the only decrease attributed to rutting males. This again implies no shortage of quality forage and conditions across this area.

The populations of sika and sika hybrids in Wicklow have a long life expectancy, high reproductive and survival rates, access to abundant forage and shelter, and relative freedom from predators, disease and heavy hunting. Under prevailing management conditions, the long-term forecast is that sika and sika hybrids will continue to proliferate and spread inexorably outwards from the Wicklow area. Preliminary census results from three areas in Co Wicklow indicate that sika and hybrid animals are present at densities of between 13 and 25 animals per km^2.

Damage to broadleaves and susceptible conifers occurs when population densities exceed 5 animals per km^2, while species such as Sitka spruce and other less palatable conifers suffer damage at densities of 8 to 10 animals per km^2 (Ratcliffe 2000). These figures represent maximum desired deer densities from a forest management perspective.

2.7 MANAGEMENT OF DEER POPULATIONS AND DAMAGE

Deer and their habitats have to be managed so that damage may be reduced or prevented, and forward planning is vital. The spread of species, such as sika/sika-like deer, threatens much woodland and their arrival in new areas should be anticipated. The ability to predict future changes in forest structure and the extent of damage is also a priority (Ratcliffe *et al*. 1986). This can depend very much on the species planted. The threat of bark stripping to Sitka spruce increases steadily during the rotation while the hazard of browsing damage disappears after about 10 years. The incidence of bark stripping to Norway spruce and lodgepole pine peaks between 15 and 20 years into the rotation and decreases thereafter. The threat of browsing to these species decreases steadily throughout the early years of the rotation.

2.8 MANAGEMENT OF DEER IN WOODLAND

Effective management of deer in woodland areas involves three approaches (Mayle 1999):
(1) Design, manipulation and management of the habitat;
(2) Physical protection of vulnerable areas or individual trees;
(3) Humane culling to reduce and maintain deer numbers.

These approaches can be combined in varying degrees to form an integrated pest management plan. The strategy will be specific to each locality, taking into account the unique set of problems and influencing factors that will occur there.

2.9 DESIGN, MANIPULATION AND MANAGEMENT OF THE HABITAT

Creation of open space is of prime importance in forest design, not only for the enhancement of local biodiversity but also to facilitate hunting and culling. Open glades and lawns where deer can graze and rest should be incorporated into the forest structure. Hunting high seats and hides should be situated around these

areas where visibility is good. Networks of rides and winding lanes should link the open spaces. Trees should be cut back at least 5 m from the boundary of the woodland. This allows hunters to stalk along the periphery and shoot deer without trespassing as, by law, they can only shoot when both they and their quarry animal are within the bounds of the property. Trees should also be cut back along forest roads. Large-scale clearfelling often forces deer onto farmlands or into young plantations where they can cause damage. Such practices should be undertaken with as little disturbance as possible to deer.

Human activity may often serve to force deer into forest stands with thick cover during daylight where they feed on bark. Limiting recreational activities, for instance hill walking, orienteering, rallying, scrambling and mountain biking will reduce this threat.

2.10 PHYSICAL PROTECTION OF VULNERABLE AREAS OR INDIVIDUAL TREES

Fencing for the exclusion of deer must be sufficiently high to prevent it being jumped over. It should have a mesh size small enough to prevent animals pushing through it and it should be secure, taut and flush with the ground surface so that deer cannot get underneath it. Optimal heights and mesh sizes for the various deer species are shown in Table 2.3 (Pepper 1999).

Line wire fences are useless since deer can push between strands. Barbed wire should be avoided as animals can easily snag a leg when trying to jump over it, particularly pregnant hinds being heavier than usual. Fencing is important in excluding stock such as cattle, sheep, horses and goats that can cause damage to trees. The area to be fenced should obviously be free of deer, as any enclosed animals will cause high levels of damage. Permanent fencing is often essential where trees need protection over 10 to 15 years. However, fencing is expensive to erect and maintain.

Where fencing is not an option, individual trees may be protected by tree shelters. These are translucent plastic tubes that play a dual role - firstly, in the protection of the young tree from mammal damage, and secondly, by acting as a mini-greenhouse in altering the immediate microclimate which in turn promotes growth and survival (Potter 1991). The structure also allows herbicide application close to the base and the clearance of encroaching undergrowth without risk to the growing tree. A tree guard is a wire or plastic collar that protects against animal and mechanical damage. Tree shelters are designed to degrade and become brittle within a few years. In this brittle state, however, deer and farm animals can easily break them. The size and robustness of tree shelters should depend on the mammal threat, i.e. 0.6 m for rabbits, and up to 1.8 to 2.0 m for deer, accompanied by a supporting stake. Extra height should be incorporated to counteract uneven or sloping ground and snowfall.

TABLE 2.3: OPTIMUM HEIGHTS AND MESH SIZES FOR DEER FENCING.

Species	*Minimum height*	*Maximum mesh size*
	m	*mm*
Red/sika/hybrid	1.8	220 x 300
Fallow	1.5	220 x 200

2.11 HUMANE CULLING TO REDUCE AND MAINTAIN NUMBERS

Culling is possibly the best method of reducing and maintaining deer numbers rapidly and effectively. A culling rate of 20 to 25% of adults (mature females especially) is necessary to prevent local populations from increasing. Accurate estimates of deer density are an important prerequisite to establish cull targets. The importance of incorporating open space and deer lawns interlinked by a network of rides and lanes into the forest design becomes apparent when the need to cull arises.

2.12 DEER MANAGEMENT PLANS

An ideal forest management plan should aim to reduce the risk of damage to trees by addressing methods of pest control and the exclusion of livestock. Populations of deer (as well as other problem mammals) may be managed to a level that ensures they are not causing damage, thereby allowing the forest's potential for economic return and sustainability to be achieved. This may often be part or fully realised through co-operation with neighbouring landowners and forest managers. If populations cannot be adequately controlled, the emphasis may have to be placed upon physical protection of trees. A possible solution, as mentioned in a previous section, is an approach that integrates both population control and physical protection together with habitat design and manipulation.

Different populations of deer across a number of areas will require varying management approaches depending on numerous prevailing factors. Foremost among these factors will be the species of deer present. Other important factors that require consideration are aspects of their ecology such as population dynamics, breeding potential, longevity, ranging and dispersal behaviour and use of habitat. Finally, habitat and landscape characteristics, measured across several scales from basic woodland structure up to regional geography and topography, must be considered. There cannot be a universal, all-encompassing deer management plan as each area will possess a unique set of prevailing factors which themselves are subject to change over time. The concept of a biological management unit becomes important. A localised and rapid reduction in deer numbers through culling may not have any long-term effects on the overall population which may occupy a much larger area and which will simply recolonise over time. Effective, independent biological units should be identified so that deer populations can be managed *en bloc*. These management units should recognise and incorporate landscape features such as rivers, mountainous areas and forest compartments that may act as natural borders between neighbouring units, or that concentrate or attract deer into centres of activity or population 'hotspots'.

Estimation of deer numbers is another necessary aspect of management. It is important to obtain estimates of abundance, not only to decide on the most appropriate course of action but also to monitor the efficacy of the chosen control measures over time. A number of estimation techniques exist (Mayle *et al.* 1999). Deer may be directly counted during daylight using open hill counts, drive counts and vantage point counts. They may be counted at night using spotlights. Thermal imaging to locate and count deer is a recent innovation that is gaining popularity in the United Kingdom. Other methods such as dung counting, track counts and impact/damage assessments are indirect census techniques that produce indices of deer abundance. Finally, the cull can be used as a source of information on the demographics of a population (O'Brien 1999).

A deer management plan is an important document that specifies how information will be gathered and how decisions will be implemented. Deer management plans must be prepared for all forest management units where deer are present. The document should address the following areas:

1) Land use: An outline of the geology and geography of the area as well as a habitat and vegetation description across the range of the deer. Also required is an outline of the land use in the area, i.e. forestry, farming, recreation, residential, etc. This will help to identify locations where damage is already occurring and where it may be likely to occur in the future. This section should also address potential problems such as land ownership and conflicts of interest that may hamper deer management operations. It should also discuss the level of co-operation between land-owners and interested parties and the establishment of local deer management groups.

2) Deer: The number of species that occur in the area, their status and distribution, and pertinent legal considerations, i.e. protection, hunting seasons, requirement of hunting licenses, etc. Information regarding their ecology, i.e. population dynamics, reproductive potential, mortality rates, recruitment, immigration and emigration, should be included in this section. Data from previous culls may be used to supply much of this information. The impact that deer have within the area must also be quantified and the methods used to assess damage should be outlined. Finally, there should be an outline of the immediate and long-term objectives for the deer population and their management.

3) Deer management strategy: This section deals in greater detail with the objectives for the deer population and their management and describes the requirements needed to reach these goals. Included in this section will be the required deer densities that must be attained, as well as population modelling to assess future trends in population size and impacts. Table 2.4 contains a classification of deer densities that will be important for management plans and for decision-making. Cull targets must be addressed, i.e. can the cull easily achieve the target or will extra effort be required? Forest design and layout should help to reduce damage and facilitate deer control. In areas where culling and habitat design are not effective there may be a need for fencing..

4) Monitoring: This section addresses the efficacy of the cull and of the methods used to estimate population density across the range. Information obtained from the cull, such as body weight, condition, and incidence of pregnancy, can be used as indicators of status of the population. The results of ongoing monitoring of tree health and grazing impacts are discussed and compared with results from previous years.

TABLE 2.4: CLASSIFICATION OF DEER DENSITIES.

Classification	*Density animals per km²*
Absent	0
Very Low	1 – 3
Low	4 – 5
Moderate	6 – 10
High	11 – 15
Very High	> 16

2.13 LEGAL PROTECTION OF DEER

All species of deer are protected under Annex III of the Bern Convention (1979) on the conservation of European wildlife and natural habitats. In Ireland, deer are protected under the Wildlife Act, 1976 and the Wildlife (Amendment) Act, 2000. Deer are designated game or quarry species, i.e. species that may be hunted under licence for periods during the year specified as open seasons. Hunting can only be carried out by persons qualified to hunt using admissible weapons and adhering to specified means of pursuit and hunting. Under Section 42 of the Wildlife Act, deer may be shot outside the open season with permission from the Minister in order to protect forestry and other crops that are being damaged.

3. FERAL GOAT (*Capra hircus*)

3.1 BIOLOGY AND RANGE

Goats are small, hoofed herbivores related to cattle, sheep and antelopes. Feral goats are descendants of domesticated animals that have reverted to the wild. By definition, feral animals have gone through a prolonged period of domestication in the past and now exist in a wild and free-roaming state with self-sustaining populations. Goats originate from the highlands of the Middle East where they were domesticated from the wild bezoar goat native to that region, possibly as far back as 9000 years ago. The first records of goats in Britain and Ireland date back 4,500 years and come from Wiltshire in England. Feral goats have a worldwide distribution and have become serious pests in many parts of the world. In Ireland, they are commonly associated with upland and relatively isolated areas (Figure 3.1).

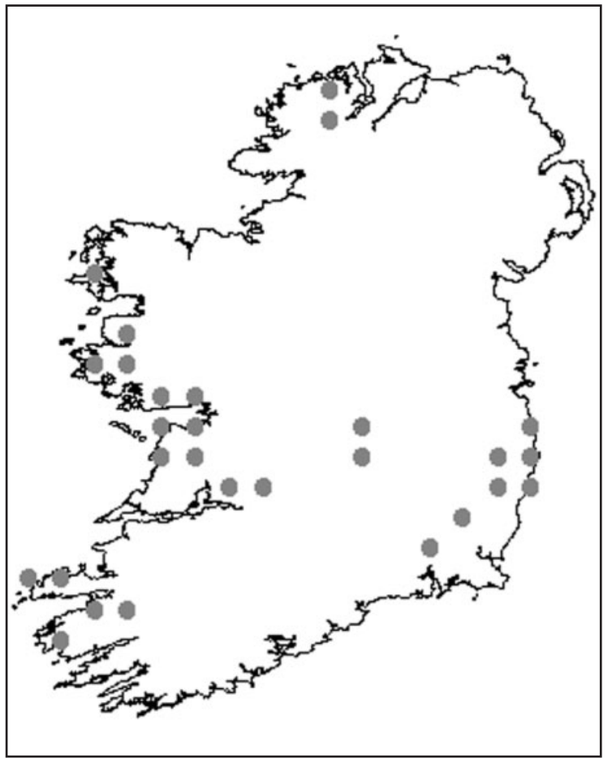


FIGURE 3.1: THE CURRENT DISTRIBUTION OF FERAL GOATS (*Capra hircus*) IN IRELAND (DOTS ARE CENTRED IN 20 X 20 KM² SQUARES WHERE FERAL GOATS ARE KNOWN TO OCCUR IN SUITABLE HABITAT).

3.2 IDENTIFICATION AND FIELD SIGNS

Feral goats are long-haired with extremely variable coat colour, ranging from white, grey, brown, black or mixtures of various colours (Plates 3.1 and 3.2). Males or 'billies' often have a mane, but this is absent from the females or 'nannies'. Both sexes have a distinctive beard and have horns that grow continuously and, unlike the antlers of deer, are not shed. The bases of the horns are quite close together on the top of the head and curve back and outwards, sometimes having a spiral twist (Plates 3.1 and 3.2). Each horn has a series of visible growth rings that may be used to age the animal. Billies are larger than nannies, weighing from 50 to 75 kg and 35 to 60 kg respectively and may be 1.6 m in length. The tail may be up to 20 cm long. Their cloven hooves leave footprints or 'slots' on soft ground and their droppings are cylindrical pellets, sometimes deposited in a group similar to those of sheep.

PLATE 3.1: MALE FERAL GOATS OR BILLIES (NOTE THE SHAGGY COAT WITH A VARIETY OF COLOURS AND THE CURVING HORNS).

PLATE 3.2: FEMALE FERAL GOATS OR NANNIES (NOTE THE DIFFERING COAT COLOURS AND THE SPIRAL IN THE HORNS OF THE LOWER ANIMAL).

3.3 DIET AND HABITAT

Feral goats are normally associated with rocky hillsides and upland areas but they will also live happily in lowland habitats. They show a preference for well-drained ground as waterlogged conditions can lead to hoof ailments. Upland goats will move to lower, less exposed ground in winter where they spend much time in woodland to obtain shelter from the weather. Goats prefer to browse woody plants and coarse vegetation rather than graze (Smith and Bullock 1993). Diet, however, will depend on availability of food. There is also evidence for habitat and dietary differences between billies and nannies due to the difference in body size and the seasonal segregation that occurs between the sexes (O'Brien 1988). In upland areas, male and female diets are similar, consisting mainly of grasses, sedges, gorse and heather. Goats in lowland areas mainly browse woody shrubs and trees, tending to graze less. Interestingly, nannies in such habitats feed more on grass and less on browse material than billies which in turn are most likely to damage the bark of trees. Browse material from trees is especially important in the diet of goats during the summer, while sedges comprise a large proportion in spring and early summer. Goats, whilst able to feed selectively, also demonstrate an ability to exploit food types and habitats avoided by other medium and large herbivores. In general, goats eat more fibrous materials and graze less than cattle and sheep (Bullock and Kinnear 1988).

3.4 POPULATIONS AND REPRODUCTION

Herds of feral goats may exceed one hundred animals and are comprised of smaller groups of varying sizes known as 'hefts'. Each heft will have a definite home range within the main herd and neighbouring hefts often show much overlap. Home ranges of billy hefts are larger than those of nannies. In Glendalough, for instance, the average size of billy hefts was 284 ha in comparison to 186 ha for nannies (Saunders 2000). Billies and nannies usually remain segregated in unisex hefts for most of the year. Groups of males tend to be smaller than groups of females. The breeding season or 'rut' begins in autumn. During this period, billies join female groups and fight amongst themselves to establish a mating hierarchy. Although nannies usually mature in their second year, some may mature earlier. Single kids, and sometimes twins, are born throughout the spring after a gestation period of about one hundred and fifty days and are weaned within six months. There is a high mortality rate among kids, due mainly to poor weather conditions. In other parts of the world they must also contend with predators such as eagles and wolves. Young females usually remain in their mother's heft while young billies disperse and join male hefts (O'Brien 1988, Riney and Caughley 1959). Goats may often become concentrated in certain areas, resulting in high population densities. Population levels of 14 animals per km^2 have been recorded in the Burren, Co Clare. In Wales, population densities exceeding 10 goats per km^2 are perceived as a potential damage threat to woodland and other sensitive habitats.

3.5 IMPACT ON FORESTRY

Feral goats will browse extensively upon buds, leaves and twigs (Hellawell 1991) (Table 1.1). Saplings are often bent over and foliage completely removed. This may be a common occurrence with broadleaf species such as oak and rowan, resulting in their eventual death. These species are also commonly subject to bark stripping, especially when they have a small girth. Other broadleaves, such as holly and ash, may suffer bark stripping throughout their life (Plates 3.3, 3.4 and 3.5). Conifers may also have their bark gnawed (Plates 3.6 and 3.7). Billies are more responsible than nannies for bark stripping damage, especially on mature trees.

Goats may be exploited for their ability to control the invasion of 'scrub' species such as willow in certain environmentally sensitive and important areas (Bullock and Kinnear 1988), such as the Burren. Feral goats are more effective in this respect than their domestic counterparts, and they are also less likely to wander and break out when kept in groups of three or more. In such a capacity, feral goats may be a valuable asset to land managers. Unfortunately, goats show little or no interest in rhododendron, a problem species in many parts of Ireland. There is, however, a fine line between management of scrub and invading species and the potential to overgraze and damage sensitive areas. Herds of goats, if not managed, can rapidly expand in size. The herd in Mullach Mór, Co Clare, for instance, grew in size from 75 animals to over 200 in the ten years between 1984 and 1994 (Moles 1994).

PLATE 3.3: MATURE ASH THAT HAS BEEN FRESHLY BARK STRIPPED BY WILD GOATS.

PLATE 3.4: MATURE ASH THAT HAS BEEN FRESHLY BARK STRIPPED BY WILD GOATS (THE RHODODENDRON IN THE FOREGROUND IS UNTOUCHED).

PLATE 3.5: SEVERE BARK STRIPPING BY GOATS (THE BARK HAS BEEN PEELED UPWARDS IN STRIPS, SOME OF WHICH ARE DISCARDED AROUND THE BASE).

PLATE 3.6: CONIFER WITH GNAWED BARK, NOTE THE TEETH MARKS.

PLATE 3.7: FRESH BARK STRIPPING BY GOATS.

3.6 CONTROL

Goat numbers are best estimated by direct counting, especially during winter when they move down from higher ground and become more visible. Entire groups may be rounded-up in a pen, and the animals may then be translocated. Fencing may serve to exclude goats from a susceptible area (Hellawell 1991). This may be constructed from regular stock-proof fencing as used for pigs and sheep. It should be at least 1.2 to 1.4 m high. Wire fencing can be used instead of netting. Individual strands must be no more than 10 cm apart and kept taut. Culling by shooting is often the most effective method of reducing and maintaining low numbers of feral goats. Billies should be preferentially removed over nannies since they cause the most damage to bark and range over larger areas. There is a high level of bonding and structure within nanny hefts that can be disrupted if individuals are removed. Control measures for these female groups should therefore focus upon removing young animals or those that appear unwell.

3.7 LEGAL PROTECTION

Feral goats are not protected in Ireland under the Wildlife Act, 1976 and Wildlife (Amendment) Act, 2000.

4. SQUIRRELS

4.1 GREY SQUIRREL (*Sciurus carolinensis*)

4.1.1 Biology and range

Squirrels are agile tree-dwelling rodents. The two species found in Ireland are the native red squirrel (*Sciurus vulgaris*) and the introduced grey squirrel (*Sciurus carolinensis*). Grey squirrels are native to the forests of the eastern United States and were introduced into parks and demesnes in Britain from 1879 until 1930. In Ireland, the introduction took place in Castle Forbes, Co Longford in 1911. They are currently found throughout much of Ireland (Figure 4.1) and are expanding their range. The spread of grey squirrels or 'greys' is associated with a corresponding decline in numbers of native red squirrels ('reds'). Greys are capable of causing much damage, mainly through bark stripping, to growing broadleaved trees (Table 1.1).

Greys are active during the daytime. Most activity occurs in the early hours of the morning and before dusk, with a minor peak at midday. Grey squirrels reduce their activity in the winter but do not hibernate. Males and females are for the main part solitary, associating only to breed. They maintain an exclusive core area within their home range while the remaining peripheral areas may overlap extensively with those of neighbouring animals. Family groups consisting of a female and her young may sometimes be seen.

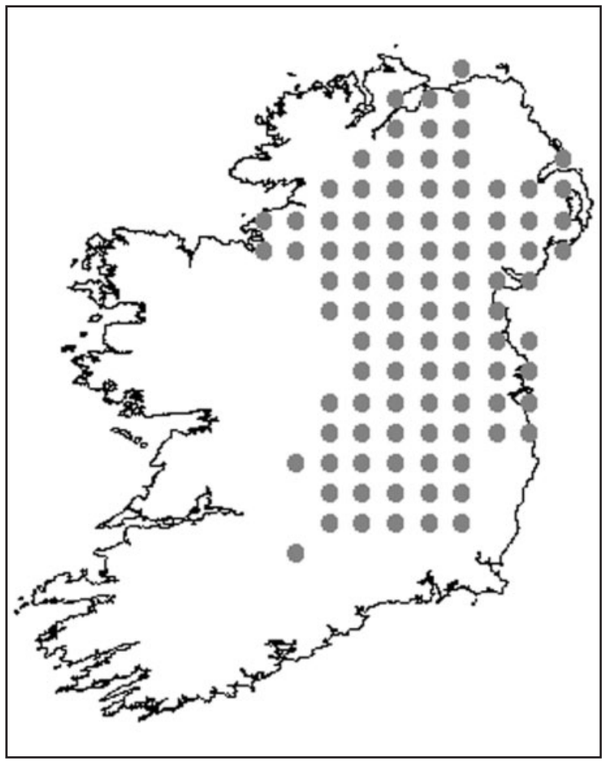


FIGURE 4.1: THE CURRENT DISTRIBUTION OF GREY SQUIRRELS (*Sciurus carolinensis*) IN IRELAND (DOTS ARE CENTRED IN 20X20 KM^2 SQUARES WHERE GREY SQUIRRELS ARE KNOWN TO OCCUR IN SUITABLE HABITAT).

4.1.2 Identification and field signs

Grey squirrels are, as their name suggests, mainly grey in colour (Plate 4.1). The tail is slightly whiter than the main body which itself may take on a reddish tinge during the summer, allowing greys to be occasionally confused for reds (Plate 4.2). Grey squirrels are, in general, larger than reds with a head and body length of 23 to 30 cm, a tail length of 14 to 24 cm (proportionately smaller than for reds) and a body weight of 400 to 800 g.

Signs of feeding activity often indicate the presence of squirrels. Grey squirrels will strip pine cones, hollow out acorns and crack hazel nuts cleanly in half, often leaving the remains scattered on the stumps of trees (Plate 4.3). They will also gnaw through the tips of horse chestnut shoots and stems, leaving rosette-like bunches of leaves scattered on the ground underneath (Plate 4.4).

PLATE 4.1: GREY SQUIRREL.

PLATE 4.2: RED SQUIRREL.

PLATE 4.3: STRIPPED CONES ARE TYPICAL SQUIRREL FEEDING SIGNS.

PLATE 4.4: FRESHLY GNAWED BUNCHES OF HORSE CHESTNUT LEAVES AND SMALL BRANCHES.

4.1.3 Diet and habitat

Grey squirrels will eat a range of foodstuffs but they remain primarily seed-eaters (Moller 1983). The seed and fruit of deciduous trees is by far the most favoured food type. Their favourite woodland habitat will contain many of those broadleaved tree species that can produce large quantities of nutritious seeds, e.g. oak (*Quercus* spp.), beech (*Fagus sylvatica*), sweet chestnut (*Castanea sativa*) and hazel (*Corylus avellana*). Other miscellaneous food items that occur in the diets of both reds and greys include shoots, buds, flowers, lichens, mosses, adult insects and larvae and occasionally birds eggs and nestlings. Squirrel diets display immense variability in relation to season, location and individual behaviour, and greys especially can be regarded as opportunistic feeders.

4.1.4 Population dynamics and reproduction

Grey squirrels in Britain may reach densities as high as seven or more animals per ha in a good habitat, e.g. oak and hazel woodland (Gurnell 1983, Kenward *et al.* 1998). However, densities of one to four animals per hectare during summer, generally higher than reds, are the norm (Harris *et al.* 1995). Suburban and urban areas such as parks and gardens can often support higher densities of greys due to their scavenging behaviour and through feeding by the public. In Ireland, greys have been recorded at densities of 2.5 per ha in deciduous woodland and 1.64 per ha in coniferous habitats where their average home range size was 3.65 per ha.

Grey squirrels can live for eight to nine years, roughly twice as long as reds (Gurnell 1983). Variation in the size of the annual seed crop can have direct effects on squirrel demographics (Gurnell 1983, 1996). Greys are capable of breeding twice a year. Availability of seed supplies will affect such parameters as the length of breeding season (usually from winter to late summer), number of females producing two litters, the numbers of adults and yearlings which can breed, and the number of young per litter (usually three but sometimes as many as nine). A good seed crop will also enhance ability to overwinter, survival rates and resistance to disease. Young are born and weaned in dreys, which are balls of twigs, leaves and bark strips situated in branches high off the ground and close to the

trunk. Hollows in trees and disused nests will also be used. Greys have also been known to den in roof-spaces. Numbers peak in autumn but may vary between years. Such inter-annual fluctuations are commonplace features of rodent population dynamics.

4.1.5 Impact on forestry

Grey squirrels will feed upon buds, flowers and seeds but can turn their attention to the main body of the tree, biting or stripping the bark on the trunk and branches to expose underlying softer tissues and sap (Plates 4.5 to 4.8). This is especially common from April to July when the sap is rising. Younger trees are more susceptible to attack, i.e. 10 to 40 years old, and will be increasingly susceptible during periods of vigorous growth when there is much sap available immediately below the bark in soft tissue (phloem) (Gill *et al.* 1995, Gill 1992b). Thinning out of stands may lead to increased sap flow in the remaining trees as their crowns fill out and the canopy closes, thus increasing the threat of bark stripping. A larger area of canopy will also enhance future seed production, thereby supporting greater squirrel numbers (Gurnell 1987). Damage may also be higher amongst well-spaced plantation trees in comparison to areas of self-seeded trees as the former are less crowded and will grow faster (Kenward *et al.* 1992). The threat of damage may act as a disincentive to the planting of many broadleaved species. Curiously, grey squirrels in their native United States rarely, if ever, damage trees to the same extent and are not considered a pest in forests (Kenward 1983).

Shortage of food is not believed to be the main reason behind bark stripping, but is due instead to behaviour initiated by juveniles, particularly in high density populations (Kenward *et al.* 1998, Kenward and Parish 1986). The animals are believed to develop a taste for sap and retain their bark-stripping behaviour as adults. Beech, sycamore and oak are the most frequently attacked species with up to 20% of these trees in a stand sustaining damage (Rowe 1984, Rowe and Gill 1985). These species are so vulnerable to damage that they often require protection where grey squirrels occur. Other species that may suffer damage include maple, sweet chestnut, ash, birch and hornbeam.

Grey squirrels may aid regeneration by dispersing and burying seeds, however there is evidence that many of these seeds may be damaged and may never germinate. Overall, grey squirrels are not believed to affect the structure and diversity of woodland vegetation (Anon 1997).

PLATE 4.5: BARK-STRIPPING DAMAGE ON A YOUNG ASH CAUSED BY GREY SQUIRRELS.

PLATE 4.6: WOUNDING TO A SYCAMORE CAUSED BY GREY SQUIRRELS.

PLATE 4.7: WOUNDING TO A SYCAMORE CAUSED BY GREY SQUIRRELS.

PLATE 4.8: FRESH DAMAGE TO THE BARK OF A SYCAMORE, STRIPS OF BARK ARE STILL ATTACHED.

4.1.6 Current research in Ireland

A preliminary study of mammal damage in Irish forests (Hannan 1986) demonstrated that, in comparison to deer, squirrels damaged fewer numbers of trees in forests where they were found. However, the amount of damage they caused to individual trees was greater than that caused by deer and was often considered severe. Squirrel damage occurred most often in spring and summer and was recorded mainly in older stands. More recently, a COFORD funded research project examined aspects of the ecology of the grey squirrel in relation to broadleaved woodland in Ireland (Lawton and Rochford 1999). The study had particular reference to the control of damage and addressed a number of questions pertaining to grey squirrel biology and behaviour in an Irish context. It examined distribution, colonising behaviour and habitat preferences in Ireland, the factors influencing the bark stripping damage caused and the appropriate control measures that can be taken. A 50 x 50 km study area was selected in the north east of Ireland, centred on Navan, Co Meath. A number of broadleaved woodlands were selected from within this area and questionnaires sent to the owners to ascertain woodland size and species composition, presence of squirrel species, resulting damage levels and control methods (if any) in use.

The majority of the woodlands were between 10 and 20 ha in size. The principal species found throughout were beech, oak, ash, sycamore and horse chestnut. Conifers such as larch, Scots pine, Sitka spruce and Norway spruce were present in much lower proportions. Woodland owners also indicated when grey squirrels first arrived in their areas, thus allowing the estimation of a crude dispersal rate. This was estimated at between 4 and 5 km per year, slightly faster than the 2.5 km per year spread estimated for Northern Ireland (O'Teangana 1999). Most damage apparently occurred from March to May. Owners also indicated the levels of bark stripping damage occurring in their woodlands. Subsequent groundtruthing by the researchers showed that many owners underestimated the extent and severity of damage. Species such as sycamore, beech and ash were most affected, followed by birch and oak. Less-commonly found species such as willow, elm and hazel were often severely damaged where they occurred. Across the study area, however, sycamore and beech were by far the most susceptible to bark stripping. Sycamore received the largest bark wounds, implying that grey squirrels favour this tree species. Sycamore was followed by beech, elm and oak as regards size of wounds. Sycamore was also the species most often ringbarked or girdled. Most trees damaged measured up to 40 cm diameter at breast height (dbh), with the most frequently wounded being between 10 and 20 cm dbh and therefore relatively young. Sycamore was more frequently damaged than beech when young. Ash suffered most damage across a wider diameter class (10 - 80 cm dbh) than either sycamore or beech. Wounds were distributed evenly along the length of trees studied. The presence of ivy appeared to offer some protection to the tree against damage by squirrels. A feature also noted was that the callus forming over wounds was frequently targeted itself, hinting that sap flow was more pronounced in these areas. Broadleaved species were categorised, based on their susceptibility to bark stripping, into the groups presented in Table 4.1.

Two areas of woodland from the study area were chosen for population studies. Research was undertaken to obtain demographic data such as population density, sex ratio, weight and size, breeding condition, age and the effectiveness of culling on control of grey squirrel numbers. In one of the sites, Ardmulchan in Co Meath, control measures were already in place with on average fifty squirrels removed from 12 ha of woodland each year. This apparently high level of control still had no overall effect in maintaining low numbers. The sex ratio was often biased towards males and was attributed to the trapping of dispersing males who were captured more frequently than the less-further dispersing females. Males were in breeding condition from February/March until June/July. The majority of the culled squirrels were aged between one and two years. Following the culls, squirrel populations in both sites recovered to pre-cull levels, generally within ten weeks. It became apparent that squirrels were able to use even the most insubstantial of corridors such as hedgerows to recolonise from surrounding woodlands, thus highlighting the need to control squirrels in these neighbouring 'donor' areas. This action will have the added effect of creating a larger area for recolonisation and thus slowing the rate of re-establishment.

A study of home range sizes of six radio-collared animals (two males, four females) before and after the cull demonstrated much variation in their behavioural response to population control. There was no unanimous response, as some ranges remained static, some shrank in size while other increased.

TABLE 4.1: SUSCEPTIBILITY OF BROADLEAVED SPECIES TO DAMAGE BY GREY SQUIRRELS.

Group	*Species*	*Comments*
1	Sycamore and beech	The main species common in broadleaved woodland and the ones most at risk. It is recommended that there should be no commercial planting of these species in areas where grey squirrel densities are moderate to high (two or more animals per ha) as the resulting damage will severely impact economic viability.
2	Willow, alder, elm and hazel	Species not planted as often but which are potentially at high risk.
3	Ash, birch and oak	Species which are occasionally attacked, but which suffer fairly low amounts of damage overall.
4	Lime and horse chestnut	These species are not widely planted and little damage has been recorded where they occur. This could, however, be due to the fact that these species had grown past the age of susceptibility before the grey squirrel had spread into the area. Young and newly planted trees belonging to this group could also be at risk.

4.1.7 Impact of greys on native red squirrels

Native reds have been replaced in much of their former range across Britain and Ireland by greys (Gurnell 1987). Deciduous and mixed woodlands across England and Wales are now occupied almost exclusively by greys, with reds confined to extensive coniferous forests to the North (Scotland now holds roughly 75% of the British red squirrel population) and on islands such as the Isle of Wight. A similar scenario of replacement is occurring in Ireland (O'Teangana 1999, McGhie 1996, Reilly 1999). A patchwork of habitats exists across the countryside in the form of various sized woodlands connected by hedgerows. This landscape mosaic supports and facilitates the ease of movement and spread of grey squirrels, the average rate of which has been calculated at 1.94 km a year (O'Teangana 1999). Much research has focused on the factors facilitating the replacement of reds and the conservation of their populations. Grey squirrels have a competitive advantage by way of a physiological and metabolic superiority over reds in many existing habitats. Aggressive behaviour of greys towards reds may also be an important factor (Wauters and Gurnell 1999). The presence of grey squirrels, however, does not appear to adversely affect the spatial organisation of reds (O'Teangana 1999). Grey squirrels can forage for longer and put on more weight during late autumn and winter than reds (Kenward 1983). Because they are larger and more powerful, greys can retrieve buried seeds with more ease, particularly important when the ground is frozen or under snow. Reds have problems digesting acorns, a problem not shared by greys that can utilise unripened acorns (Kenward and Holm 1993). There is also a theory that greys are a vector for a parapox virus disease that debilitates reds. The large tracts of mature coniferous woodland favoured by red squirrels are now largely fragmented or non-existent, leaving only small deciduous woodland, mixed woodland and plantation forest which may not provide sufficient forage. Reds devote over 70% of their activity to foraging in trees and therefore need an extensive continuous canopy to thrive. The amount of beech and especially oak within a wood is also an important factor in allowing competitive exclusion by greys - a statistical model predicts that if the amount of oak exceeds 14% then reds are disadvantaged Kenward and Holm 1993). Greys can also utilise certain coniferous species such as Norway spruce (Reilly 1999).

4.1.8 Control of damage and management of populations of greys

COFORD-funded research has identified two management and control strategies that may be pursued, i.e. population control and damage control.

1. Population control: Attempting to control the number of squirrels is frustrating and often futile where densities of two or more per hectare exist. Control measures may not be required when squirrels exist at low densities and need only be applied during late spring and summer, the main period of squirrel damage. The need to practice control in surrounding donor sources of squirrels is also of paramount importance. Trapping is best employed in spring when squirrels are most easily trapped. Poisoning using warfarin should be avoided if possible and used only where non-target species such as pine martens and red squirrels are not present (Pepper and Currie 1998). Since populations of greys are influenced by the size of the preceding autumn's seed crop, so this knowledge may be used to forecast damage, i.e. a heavy seed crop will support high spring numbers of animals resulting in an increased possibility of damage (Ratcliffe and Pepper 1987). A census of winter and spring numbers will also indicate the levels of damage that may be expected. Supplemental food such as pheasant feed may attract grey squirrels into woodland where they will then cause damage.

2. Damage control: Woodland management and tree planting offers a means of avoiding/reducing damage. In areas where damage is likely, the emphasis should be on planting less susceptible tree species. Foresters and growers should be aware that thinning and the application of fertilizer will stimulate growth and flow of sap and may encourage squirrel attack. The proximity of high squirrel density areas also needs consideration as they may invade and attack trees during periods of food shortage. The degree of isolation of the woodland is therefore important. Presence of ground cover can also serve as a deterrent as grey squirrels spend a certain amount of time on the ground and heavy cover can hide predators (Kenward *et al.* 1992). Heavy cover can, however, encourage other potentially damaging mammals such as deer. Ultimately, the maintenance and future planting of broadleaves should be undertaken with grey squirrel impacts in mind.

4.1.9 Legal protection

Grey squirrels are not protected in Ireland under the Wildlife Act, 1976 or the Wildlife (Amendment) Act, 2000.

4.2 RED SQUIRREL (*Sciurus vulgaris*)

4.2.1 Biology and range

The geographic range of the red squirrel extends across most of Europe and Northern Asia as far as Japan. In Europe, reds are found from Scandinavia to the Mediterranean but are largely absent from the Iberian Peninsula. Although referred to as native, Irish red squirrels ('reds') became extremely scarce, if not extinct, during the late 17th and early 18th century due to extensive tree felling and hunting for fur. Reintroduction occurred at a number of sites, mostly in Leinster, from 1815 to 1876. The range of the red squirrel in Ireland (Figure 4.2) is steadily being encroached upon by that of the non-native grey squirrels, which are now becoming the dominant species. Reds are now absent from many parts of Ireland and have been completely replaced by grey squirrels across large areas of their former range.

Reds spend over 70% of their time, much more than greys, foraging in the canopies of trees. Their activity patterns are similar to that of greys. They are active in the daytime with most activity just after dawn and before dusk with a minor peak around midday. Reds do not hibernate during the winter, choosing instead to reduce their activity to a single bout during the day. Like greys, they are mainly solitary animals, associating mostly during the breeding season. Their social organisation is also similar. Both males and females maintain an exclusive core area within their home range while the remaining peripheries may overlap extensively with those of neighbouring animals.

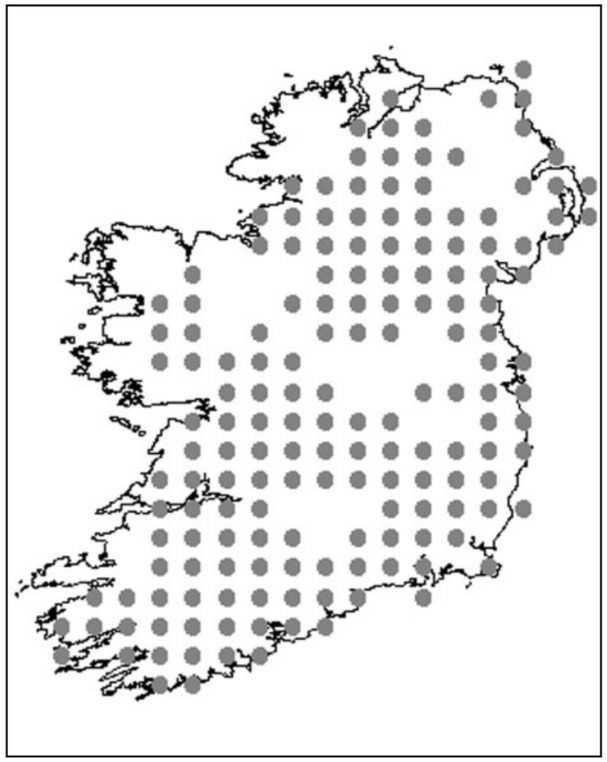


FIGURE 4.2: THE CURRENT DISTRIBUTION OF RED SQUIRRELS (*Sciurus vulgaris*) IN IRELAND (DOTS ARE CENTRED IN 20X20 KM^2 SQUARES WHERE RED SQUIRRELS ARE KNOWN TO OCCUR IN SUITABLE HABITAT).

4.2.2 Identification and field signs

Red squirrels have a reddish coat in summer with whitish-cream underparts (Plate 4.2). Onset of winter brings about a darkening of the coat to brown as well as a lengthening of the distinctive tufts on the ear-tips. Reds are generally smaller and lighter than greys. The length of the head and body is 18 to 27 cm, the tail is 14 to 20 cm long and body weight varies between 200 and 480 g.

Signs of feeding activity indicate the presence of red squirrels. Their feeding signs are difficult to distinguish from the feeding signs of greys (Plate 4.3) and consist of stripped cones, discarded cone scales and neatly cracked hazelnut shells.

4.2.3 Diet and habitat

Conifer seeds, when available, are the most important component of red squirrel diet (Moller 1983). Research shows that spruce and pine seed comprises between 50 and 85% of stomach contents. Cones will even be eaten while still green and unripened. Reds prefer spruce to pine cones since they are easier to open and strip. Other components of the diet include conifer buds, which are eaten in winter and spring, fungi, fruits, berries and seeds from deciduous trees such as beech, hazel and oak. Red squirrels thrive and reach their highest densities in mature coniferous forest but will also inhabit deciduous woodland.

4.2.4 Population dynamics and reproduction

In Britain, population densities of 0.5 to 1.5 animals per hectare are the average across most habitat types (Gurnell 1987). However, in extremely rich habitat, numbers may reach peak levels of 7.5 per ha, e.g. Scots pine forest ((Harris *et al.* 1995). In Ireland, reds were noted as living at densities of 1.2 per ha in coniferous forest with an average home range size of 6.15 ha as determined by radio-tracking (O'Teangana 1999).

Population dynamics and reproductive biology of reds is largely similar to that of greys. Numbers peak in autumn but may vary between years. The size of the annual seed crop can have direct effects on red squirrel demographics (Gurnell 1983, 1996). Females are capable of breeding twice per year. Availability of seed supplies will affect such parameters as the length of breeding season (usually from winter to late summer); number of females producing two litters; the number of adults and yearlings which can breed; and the number of young per litter (usually three but sometimes as many as seven). A good seed mast will also enhance the ability to overwinter, survival rates and resistance to disease. Young are born and weaned in dreys, i.e. balls of twigs, leaves and bark strips situated in branches high off the ground and close to the trunk. Hollows in trees and disused nests will also be used. The average lifespan of a red squirrel is between four and five years, much less than that of a grey (Gurnell 1983).

4.2.5 Impact on forestry

Red squirrels, besides consuming cones and buds, may occasionally strip the bark from upper parts of conifers such as Scots pine, European larch, Norway spruce and lodgepole pine (Springthorpe and Myhill 1994). Damage levels are usually quite low. Red squirrels rarely reach population densities where serious harm will occur.

4.2.6 Legal protection

Red squirrels are listed as a protected species under Annex III of the Bern Convention, 1979. In Ireland, they are protected at all times under the Wildlife Act, 1976 and the Wildlife (Amendment) Act, 2000.

4.2.7 Conservation of red squirrels

The red squirrel is a distinctive and endearing member of our mammal fauna. Forest design and management can aid the conservation of reds and measures that encourage them should be an integral part of any forest management plan. Reds survive better in their optimum habitat, namely mature expansive coniferous forest where they have an advantage over grey squirrels (Kenward *et al.* 1998). Preservation and maintenance of such habitat will therefore aid their conservation. Supplementary feeding using grey-proof hoppers may help in giving reds an advantage. Red squirrels do not prosper in monocultures of Sitka spruce and require the presence of other species such as Scots pine and Norway spruce (Reilly 1999). Greys, however, avoid areas dominated by Sitka spruce, thus providing possible refuges for reds with a suitable mix of conifers. The planting of broadleaves or mixed woodland may provide suitable habitat for greys and jeopardise the status of any red squirrels in the locality. The minimum area of conifer woodland that will support a viable population of reds has been estimated at between 2,000 and 5,000 ha (Pepper and Patterson 1998). Another alternative is to create a terrestrial island, i.e. maintain a core area of 200 to 300 ha surrounded by a significant buffer zone that is maintained grey-free. The buffer zone should be 1 to 3 km wide and should contain unsuitable habitat for greys such as monoculture coniferous forest or small-seeded broadleaves, marginal land, moorland or arable land lacking substantial hedgerows or other corridors. The core area, meanwhile, should contain sufficient forage and cover and should ideally comprise a mosaic of stands of differing ages, shapes and species composition. A small amount of broadleaves may be included but should not contain oak, hazel or chestnut, as these will sustain grey squirrels. Reds may be further encouraged within these control zones through manipulations which maximise seed production, e.g. south-facing aspects and non-felling of large crowned trees.

5. RABBIT (*Oryctolagus cuniculus*), IRISH MOUNTAIN HARE (*Lepus timidus hibernicus*) AND BROWN HARE (*Lepus europaeus*)

5.1 BIOLOGY AND RANGE

Rabbits and hares are small herbivores belonging to the order of mammals known as 'Lagomorphs'. They differ from rodents in that they have an extra smaller pair of gnawing incisors behind the main incisors on the upper jaw. In Ireland there are three lagomorph species, namely the rabbit, the Irish mountain hare and the brown hare (Plates 5.1, 5.2 and 5.3). Rabbits in particular can impact heavily upon woodland through browsing and bark-stripping activities (Table 1.1).

PLATES 5.1 AND 5.2: RABBIT (*Oryctolagus cuniculus*).

PLATE 5.3: IRISH MOUNTAIN HARE (*Lepus timidus*).

Rabbits are one of our best-known mammals with their characteristic hopping gait. They are social and territorial, typically found living communally in excavated burrows. Rabbits originated from Mediterranean regions and were introduced throughout much of Western Europe and the 'New World' by humans who valued them for food, fur and sport. They are widespread throughout Ireland, having being introduced as domesticated animals by the Normans during the 13th century and held in warrens from where they escaped. Their spread in Ireland and Britain was aided over the past few centuries by a number of factors, namely the persecution of predators such as foxes, stoats and birds of prey for the enhancement of game species, a warming of the climate and increases in the amount of grassland and pasture (Sumption and Flowerdew 1985).

The Irish mountain hare is one of Ireland's few truly native mammals, and it is found throughout the country. Due to a number of differences to British and mainland European populations, the Irish mountain hare in Ireland enjoys the status of a unique sub-species. Mountain hares and rabbits are unique in Ireland in that they are sympatric, i.e. they live alongside each other in similar habitats. In other parts of their geographic range there is a degree of separation, with the mountain hare occurring chiefly in upland areas whilst rabbits are found in lowland areas and in the foothills of mountains.

The brown hare is one of Ireland's rarest and least-known land mammals. It occurs in lowland areas of Britain, Europe and parts of Asia, generally at lower latitudes than the mountain hare. During the last century it was introduced into Ireland at a number of locations, mainly in Ulster. It failed, however, to become well established and information regarding its current distribution and status is lacking. Figure 5.1 shows the current distribution of the brown hare based on available records. It is almost certainly present in Northern Ireland, particularly to the west of Lough Neagh. Its current status in the Irish Republic, however, is not known. To date, there has been no detailed research carried out concerning the ecology of the brown hare in Ireland. There is evidence also that the brown hare is in decline across Europe (Harris and Harris 1997). This decline is believed to be due to changes in farmland management practices affecting overall crop and landscape diversity, which in turn affects brown hare nutrition and reproductive potential (Edwards *et al*. 2000). In Ireland, the mountain hare occupies lowland regions and is the ecological equivalent of the brown hare.

The brown hare is similar in size to the Irish mountain hare. Its main distinguishing features are its longer black-tipped ears, sandy-brown coat and the tail, which is dark on top and white underneath. Although cereals and grasses are the main food, they often damage root crops and gnaw bark from trees. The life cycle of the brown hare is similar in many regards to that of the mountain hare.

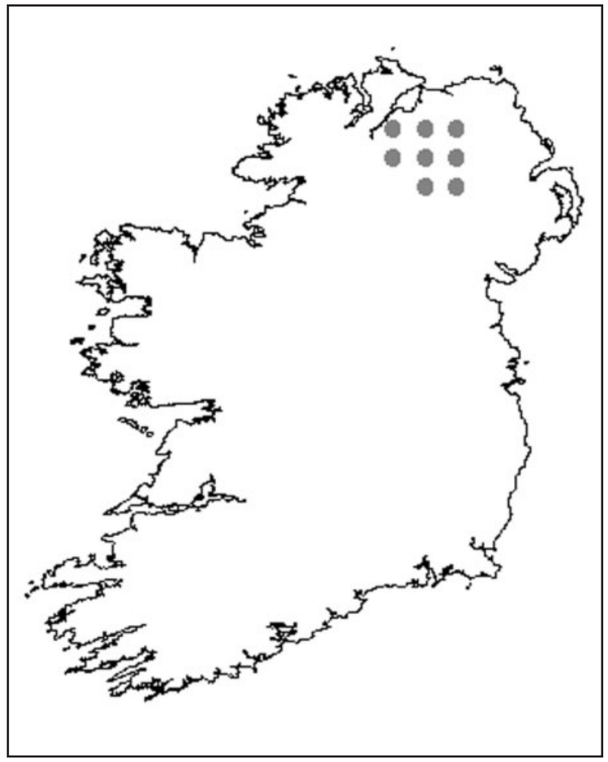


FIGURE 5.1: THE CURRENT DISTRIBUTION OF THE BROWN HARE (*Lepus europaeus*) IN IRELAND (DOTS ARE CENTRED IN 20 X 20 KM^2 SQUARES WHERE BROWN HARES WILL BE FOUND IN SUITABLE HABITAT).

5.2 IDENTIFICATION AND FIELD SIGNS

Rabbits can have a body length of 50 cm and can weigh 2.5 kg. Males or 'bucks' are slightly larger than females or 'does'. Their coat is a greyish-brown colour, although some lighter and darker varieties may occur. They have a short tail or 'bob' which is white underneath and flashes distinctively as they run away. Their burrows are quite conspicuous along headlands and on sand dunes. Their droppings are small and spherical and range in colour from black to greenish-brown.

The Irish mountain hare is much larger than the rabbit with a body length of 65 cm or more and weighing up to 5 kg. Females are often slightly larger than males. Their coat is a similar greyish brown to that of the rabbit, although adults may take on a reddish tinge in the summer. Mountain hares in more northerly parts of their range turn white in winter. This does not happen in Ireland. The ears have distinctive black tips and the fully white tail does not 'bob' in the same way as a rabbit's tail while running. Their round fibrous droppings are, for the main part, indistinguishable from those of rabbits.

Mountain hares are more solitary than rabbits, but they may often be seen feeding or associating in groups of up to five individuals. Hares are noted for their speed and manoeuvrability. Their home ranges can be quite large, with males travelling further than females. Male and female hares on Dublin's Bull Island, for instance, have ranges of between 50 and 20 ha respectively (Wolfe and Hayden 1996). This, however, is smaller than that recorded in Scotland where mountain hares range over as much as 100 ha of upland (Hewson and Hinge 1990). Hares will range further in poor habitats in order to acquire sufficient food. A range will contain daytime resting areas and night-time feeding areas.

5.3 DIET AND HABITAT

The most suitable habitats for rabbits are areas with short grass, which typically comprises 75% of their diet (Duffy *et al.* 1996). However, a wide range of other plants will also be eaten. Habitat types such as dune systems, machair, heathland and agricultural pastureland will support rabbits. Two basic requirements are necessary to support large numbers of rabbits - suitable topography to excavate and maintain a burrow system and access to adjacent feeding areas. Woodland edges and field boundaries, therefore, make ideal habitats for them. Rabbits may often choose not to excavate burrows in areas where substantial cover is available in the form of bramble, gorse and brash. Most activity is concentrated within the immediate vicinity of cover with adults rarely venturing far (Cowan *et al.* 1989). Home ranges therefore tend to be quite small, varying between 0.3 and 3 ha in size (Cowan 1991).

Mountain hares in their natural habitat alternate between grazing in the summer, feeding chiefly on grasses and vetches, and browsing in the winter, when they feed upon heather, twigs and bark. Despite their reputation as animals of the open hill, mountain hares will make use of many habitats, especially newly planted and young plantations with favourable amounts of undergrowth (Hulbert *et al.* 1996). Rabbits, in comparison, are less variable and often rely on habitat edges, for example, woodland edge and hedgerows.

Analysis of the diets of Irish mountain hares and rabbits living in the same area demonstrated an extremely high dietary overlap between the species throughout the year (Wolfe *et al.* 1996). Direct competition, however, is reduced due to the different ranging behaviours of the species, thus allowing them to cohabit.

5.4 POPULATIONS AND REPRODUCTION

Rabbits are prolific breeders, with females capable of having five litters per year, each consisting of between three and eight 'kittens', and being able to mate again almost immediately after giving birth. They have a gestation period of thirty days and young are weaned within 3 to 4 weeks. The breeding season typically runs from January to August but may be extended given favourable weather and food conditions. Early-born juveniles are capable of breeding towards the end of the season and overall numbers peak in late summer. Mortality is quite high, especially among juveniles, with as many as 90% of young rabbits failing to survive past their first year. Adult mortality is lower but may still reach 50% per year. While predators such as foxes, stoats and buzzards take many rabbits, disease remains a major contributory factor to the low survivability. Average countrywide estimates of rabbit density in Britain, for instance, are believed to consist of five animals per ha of scrubland, bracken, sand dune and coastal cliffs, two animals per ha in all woodland types (semi-natural and plantation) and 0.5 animals in upland grassland (Harris *et al.* 1995).

The breeding season of the mountain hare is from January to September. Females may have two or three litters each year. Each litter will usually comprise two to three young or 'leverets', which are weaned after 21 days. Mortality amongst young hares may be extremely high in their first year, the principal predator in Ireland being the fox. In other parts of its range, e.g. Scotland, mountain hares must also contend with large birds of prey such as golden eagles. Population densities can range from 3 to 46 animals per km^2 in poor quality areas, to as many as 300 per km^2 in richer foraging areas (Harris *et al.* 1995). Numbers can increase on blanket bog and upland following afforestation, thus having implications for future damage.

5.5 RABBIT DISEASES

In the United Kingdom, rabbit numbers dropped dramatically by 99% with the introduction in 1953 of myxomatosis, a highly virulent South American virus spread by mosquitoes and fleas (Sumption and Flowerdew 1985). Since then rabbit abundance has being increasing steadily. It is believed that rabbit numbers currently stand at 80% of pre-myxomatosis levels (Trout 2000). Myxomatosis was first reported from Ireland in 1954. While there are no records, it may be safe to assume that the virus had the same effect on rabbits in Ireland as in other parts of Europe and that their subsequent recovery was also similar. This disease is endemic in rabbit populations across Britain and Ireland and accounts for 20 to 25% of rabbit deaths annually. Infected animals may be recognised by their grossly swollen eyes and lower ears accompanied by discharge. Animals also lack co-ordination and may be seen in the open behaving erratically. Many are killed by traffic around this time and an increase in the number of roadkills often indicates local prevalence of the disease. The myxomatosis virus mutates between four different strains. Mutation normally occurs when the population is breeding and increasing in numbers, affecting up to 75% of individuals, mainly juveniles but also some adults who are immune to the previous strain. The small number of rabbits that will survive will all be immune to the current strain. When numbers begin to rise again following breeding, the virus mutates into another strain, thus beginning the cycle again. As well as the regular yearly cycles, there is an additional five yearly cycle of virulence.

A more recently introduced virus, rabbit haemorrhagic disease or 'RHD', has yet to establish itself fully in Ireland. Its impact in the United Kingdom can vary greatly from causing little or no casualties to severe and pronounced reduction in rabbit numbers over time (Trout *et al.* 1997). This disease, originally from Asia, was introduced into Australia to control wild rabbits where it has had profound effects (Finkel 1999). It spread into Europe via domestic rabbit trading, reaching Britain in 1992 and Ireland in 1996. The virus kills more adults than juveniles but exists in a single strain only. Therefore, proportionally more survivors are rendered immune to RHD than to myxomatosis. The effects of RHD will gradually become less obvious with time, as fewer rabbits are killed and more survivors become immune. The virus causes massive internal haemorrhaging and autopsy will reveal leaked blood in and around the major organs and body cavity. In contrast to myxomatosis, rabbits infected with RHD show few outward signs and fresh carcasses will appear to be in good condition (Anon. 1998). Most animals will die in the burrow and under cover and as such may go undetected. The disease is spread amongst rabbits by vectors such as fleas, mosquitoes and flies but also through close contact with infected animals and their excreta. Rabbits in this part of the world are exposed to non-pathogenic RHD-like viruses that may help to confer a certain amount of immunity to RHD and help to lower its virulence (Trout *et al.* 1997). Therefore, the disease may not have the same effects here as seen in Australia.

5.6 IMPACT ON FORESTRY

Much planting of new woodland is occurring on agricultural and marginal land where rabbits are already present (Plate 5.4). Browsing is the most common form of damage caused by rabbits and hares to young trees (Plates 5.5 and 5.6) (Hannan 1986, Springthorpe and Myhill 1994). It is usually most severe in winter and early spring but may occur all year round (Hannan 1986). Rabbits will also browse and bite-off low side-shoots and sometimes completely through thin stems. The cut ends have a characteristic clean angle (Plate 5.7) as distinct from the ragged ends left by deer browsing (Springthorpe and Myhill 1994, Pepper 1998). Hares will often leave the cut tips lying by the side of the tree. The height of the browse often serves as a clue to the species which caused it, i.e. browsing damage caused by rabbits will be lower than that of hares who have a higher reach. Fresh rabbit signs such as droppings, scrapes, active burrows and the proximity of cover will also give an indication. Hares will systematically move along a line of trees, browsing each one in turn (Springthorpe and Myhill 1994). Species such as willow and rowan are particularly susceptible, but coniferous species common in plantations such as spruces, pines, and larches are also targeted (Hewson 1977).

PLATE 5.4: AREA SEVERELY DAMAGED BY RABBITS.

PLATE 5.5: RESULTS OF RABBIT BROWSING - NOTE THE CLEANLY CUT TIP.

PLATE 5.6: YOUNG CONIFER HEAVILY BROWSED BY RABBITS.

PLATE 5.7: TIP CLEANLY BROWSED AT AN ANGLE, DISTINCTIVE OF RABBITS AND HARES.

Bark stripping by hares and rabbits occurs in winter and early spring. This damage may be distinguished from that of other mammals by its size and position low down on the stem or trunk. Teeth marks are often visible and measure 23 mm wide or less. Trees with smooth bark are generally preferred. Damage usually occurs to young trees, however mature trees can also suffer bark stripping (Anon. 1997). The extent of this damage is limited to within the reach of the animal and is usually no higher than 60 cm, although snowfall can allow rabbits to reach and damage beyond this height. Bark is stripped from the boles of large trees in late winter, much earlier than when caused by squirrels. Damage to trees can also be significant even at low rabbit densities. Bark can be stripped where protective tree-guards are poorly fitting.

Damage to crops can occur all year round, but it tends to be most severe in winter and spring. Rabbits graze crops such as winter wheat heavily, and are responsible for £120 m (€ 190 m) worth of damage per year in the United Kingdom alone (Crawley 1989). Grazing on early crops can also encourage early breeding, giving rise to higher numbers of rabbits in the late summer. Six to ten adult rabbits can eat as much as a single sheep during a single day.

Infestations of rabbits can often be heavier than perceived. A general rule of thumb is that there may be two to five times the number seen at twilight in summer and winter respectively (Trout 2000). Census methods, such as night-time spotlight counting (Fletcher *et al.* 1999) or daytime transect counting do not provide accurate estimates unless repeated often over a short period of time, with the findings pooled and averaged. The number of active burrows may also be used as a rough index of rabbit abundance. Rabbits can have profound effects along woodland edges and in openings and glades. The effect of rabbits on woodland and grassland structure became apparent following the introduction of myxomatosis when, in the absence of grazing, rapid regeneration and profuse growth was noted in many plant and tree species (Sumption and Flowerdew 1985, Pepper 1998).

5.7 CONTROL OF DAMAGE AND MANAGEMENT OF POPULATIONS

Rabbit populations can be extremely resilient and persistent, being able to withstand huge mortality rates. The potential to cause damage to new and existing woodlands is high, especially when many of these plantations occur on or near agricultural sites where rabbits already exist. While rabbits will be almost impossible to eradicate, the emphasis may be better placed on minimising damage through measures such as fencing and removal of cover and brash.

Fencing must be carried out systematically. Ideally, the area should be fenced prior to planting, with all rabbits completely removed from within the fenced area. Mesh size should not be larger than 31 mm and should be at least 18-19 gauge in thickness, as rabbits can bite through thinner wire. The base of the fence should be turned outwards along the ground for at least 15 cm to prevent rabbits burrowing underneath. This flange should be turfed over or covered with a layer of soil. Alternatively, the base may be completely buried to a depth of 15 cm. Overground, the fence should be 1 m high. Rabbits may learn to climb, in which case an outwardly turned mesh flange should be incorporated onto the top of the fence. If the area cannot be completely fenced off, lengths of fencing can be used instead to act as barriers in areas where rabbit activity is high. These should extend for at least 150 m in both directions beyond the infested area. Such fencing will not deter hares that are easily able to jump obstacles of 1 m in height.

Tree-guards and shelters can prevent bark-stripping damage by both rabbits and hares. Care should be taken with spirally wound tree-guards as bark can still be gnawed through gaps and spaces as small as 5 mm.

Chemical repellents may be applied to entire young trees, or to vulnerable areas around the base as an alternative to fencing. ‘Aprotect’ is highly recommended (Ratcliffe and Pepper 1987, Pepper 1998), however it can only be applied in winter as it is toxic to foliage and will not protect spring growth from being browsed.

Predators such as foxes and stoats will prey heavily upon rabbits. Buzzards, whose principal prey is rabbit, are steadily increasing their range throughout Ireland. Attempts to eradicate rabbits by gassing or shooting are best carried out when numbers are at their lowest, i.e. from November to March, or directly after a myxomatosis wipeout. Gassing, using hydrogen cyanide or phosphine, should only be undertaken by fully trained and competent people, as these gases are activated by dampness in the air and permeate through the burrows.

5.8 LEGAL PROTECTION

The Wildlife Act, 1976 does not protect rabbits. Both brown and mountain hares are listed protected species in Annex III of the Bern Convention, 1979. Mountain hares are also protected under Article 15 of the European Habitats Directive (92/43). Both species of hare are protected under the Wildlife Act, 1976 and the Wildlife (Amendment) Act, 2000. Hares are a designated game species and may be captured and coursed under licence during the specified season.

6. BANK VOLE (*Clethrionomys glareolus*)

6.1 BIOLOGY AND RANGE

The bank vole is a small, mouse-like rodent capable of damaging young trees by gnawing at the base of their stems (Table 1.1). The bank vole is found across most of Europe, from tundra zones of Scandinavia in the north to Mediterranean regions in the south and from roughly the Ural mountains in the east to Ireland in the west (Alibhai and Gipps 1991). It is the most widespread of the so-called 'red-backed voles' (*Clethrionomys* spp.) in this region, these voles having larger eyes and ears and longer tails (Plate 6.1) than other vole species, e.g. grass voles (*Microtus* spp.). Although they exhibit 24-hour activity, they are mainly diurnal with peaks at dawn and dusk.

PLATE 6.1: BANK VOLE. NOTE THE SHORT EARS, SHORT SNOUT AND CHESTNUT COLOURED COAT.

In general, bank voles and other small mammals tend to be short-lived, prolific breeding animals with a high population turnover. They occupy a position low in the food chain and are an important prey item for larger predators. Adult females are territorial and maintain exclusive home ranges that vary in size from 200 to 1,200 m^2 depending on the habitat. Males have larger ranges, between 400 and 2,000 m^2, which overlap with the ranges of several females.

Bank voles were considered absent from Ireland until they were discovered by chance near Listowel, Co Kerry in 1964 (Claassens and O'Gorman 1965). Subsequent trapping showed them to be also present in west Limerick. Trapping carried out in more central locations of the southwest revealed their presence in mid-Cork (Fairley 1969, Fairley and O'Donnell 1970). Subsequent localised trapping to the north and east in counties Clare and Tipperary also located voles (Fairley 1971a). In the latter site the edge of the range was believed to have been located as trapping a few miles further east failed to catch voles. Assuming almost equal dispersal in all directions, a possible introduction point was suggested near Glin, Co Limerick (Fairley 1971b). By 1987 bank voles had reached areas of southwest Cork and south east Kerry where they had been absent in 1967 (Leirs *et al.* 1987). Recently the bank vole was recorded in Co Galway (Fairley 1985) and in Co Waterford (Fairley 1992). It was suggested that bank voles were spreading at an annual rate of 4.5 km, especially through valleys (Smal and Fairley 1978). Their rate of spread and current distribution implies a

recent introduction, possibly as recently as the 1950's. Their dispersal is assisted by natural corridors such as railway embankments, roadside verges and valleys and is in turn obstructed by features such as upland areas, rivers, lakes, motorways and built-up urban areas. The bulk of habitat available for small mammals on rural land will be in the form of hedgerow and headland, farm woodland, road-verge and unmanaged farmland. They currently occupy most of the south west of Ireland (Figure 6.1) and their range is constantly expanding outwards.

The ecology of the bank vole is especially interesting in Ireland since, owing to the general lack of other small mammal species as possible competitors, the opportunity to broaden its niche and alter its behaviour exists. A recent study concluded that bank vole ecology in Ireland appears similar and unchanged to that in other parts of Europe (Rooney 1999).

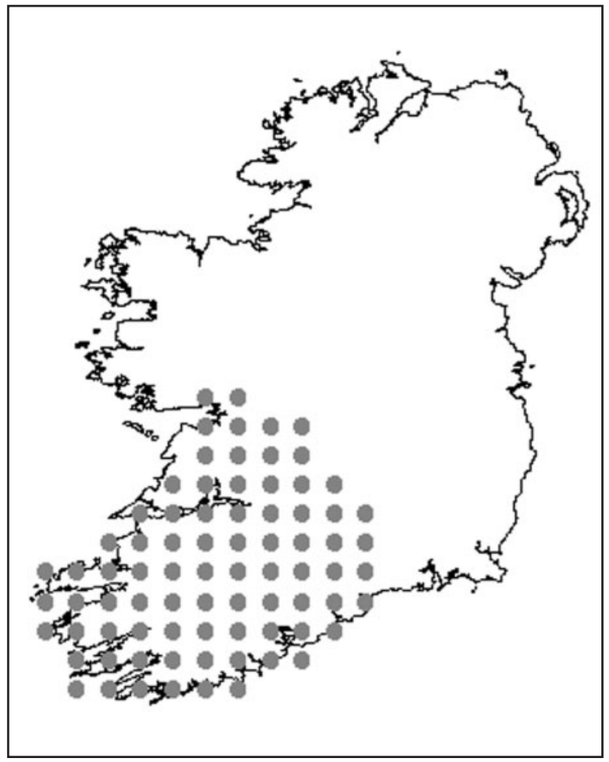


FIGURE 6.1: THE CURRENT DISTRIBUTION OF THE BANK VOLE (*Clethrionomys glareolus*) IN IRELAND (DOTS ARE CENTRED IN 20 X 20 KM^2 SQUARES WHERE BANK VOLES WILL BE FOUND IN SUITABLE HABITAT).

6.2 IDENTIFICATION AND FIELD SIGNS

Adults generally measure 115 mm in length, including the tail. While pregnant females may weigh as much as 33 g, the average adult weight is more in the region of 20 to 24 g. They have a chestnut brown coat with creamy-beige underparts (Plates 6.1 and 6.2). Young animals tend to have a slightly darker coat that brightens after a number of moults. Older animals may have small amounts of grey along their flanks. Droppings are small and cylindrical, about 3 to 5 mm in length and range in colour from black/dark brown to greenish yellow. Droppings are usually deposited under cover and are rarely seen.

PLATE 6.2: AN ADULT BANK VOLE IS ROUGHLY THE SAME SIZE AS A MOUSE.

6.3 DIET AND HABITAT

Bank voles typically prefer mixed and deciduous woodland with close dense cover in the form of shrubs and undergrowth where they mainly forage undercover, moving around using a network of concealed 'runs' (Alibhai and Gipps 1991). They may also be found in scrub, young deciduous and coniferous plantations and hedgerows (Plate 6.3). Afforestation schemes, farm woodlands, hedgerow planting, and other Rural Environmental Protection Scheme (REPS) initiatives (Plate 6.4) will provide suitable habitats for bank voles.

Bank voles are almost totally herbivorous and rely on fleshy fruits, soft seeds, leaves, fungi, roots, flowers, grasses and mosses in roughly this order (Hansson 1985, Watts 1968). They may also eat insects and worms. They can also adapt to local food supplies, e.g. ash seed in an ash woodland (Flowerdew and Gardner 1978) and diet will often be determined by availability at that time. Experiments carried out in Killarney on the diet of voles in oak and yew woodland yielded similar results to those obtained in England in that bank voles showed a preference for fruit flesh over seed (Watts 1968, Smal and Fairley 1980). Consumption of fungi, or 'mycophagy', has been noted in small mammals, especially in bank voles (Watts 1968).

PLATE 6.3: POORLY MANAGED YOUNG FARM WOODLAND IS PRIME HABITAT FOR THE BANK VOLE.

PLATE 6.4: SETASIDE HEADLAND IS PRIME HABITAT FOR THE BANK VOLE.

6.4 POPULATION DYNAMICS AND REPREDUCTION

In late summer, population densities along Irish hedgerows may be 150 voles per km while on long-term setaside their peak numbers may be 70 to 80 animals per ha (Rooney 1999). The breeding season runs from March/April to October/November, however the length of this season can vary depending on factors such as severity of winter weather and availability of food. Gestation takes about 20 days with an average litter size of four young or 'pups'.

The population dynamics of the bank vole typically consists of a late autumn/early winter peak in numbers followed by a late spring/early summer low (Smal and Fairley 1982). This trough is brought about by factors such as predation, dispersal and the cessation of breeding that ensures individuals are not replaced as easily during this period. With the resumption of breeding, usually around April, numbers begin to rise. Food and cover are also increasing at this time, thereby allowing habitats to support higher numbers of voles. Predation is heavy in late summer but has less effect on overall numbers due to the intensity of breeding, which is also contributed to by the now sexually mature early-born young of the year. Numbers peak in late autumn/early winter when breeding finishes. Bank vole population dynamics generally fluctuate in this manner, but the scale of the seasonal fluctuations may differ from year to year and between habitats. Numbers are often high following good seed or 'mast' years (Mallorie and Flowerdew 1994). Bank voles in Britain and Ireland are 'non-cyclic', i.e. they do not display the 3 to 4 year population cycles common in Scandinavia which consist of an extremely high peak in densities followed by a pronounced crash in numbers, recovering slowly to peak numbers towards the end of the cycle. Despite much research, scientists do not yet understand the exact causes of these mysterious cycles.

Many forms of predators either rely on or will readily incorporate this small mammal into their diet. Because of its location and island status, Ireland has fewer species in general when compared with other European countries. As a result, many bank vole predators common throughout Britain and the rest of Europe are absent here, for example snakes, weasels and tawny owls. In Ireland, bank vole predators include animals such as foxes, stoats, pine martens, barn owls, long eared owls, buzzards, kestrels and feral cats.

6.5 IMPACT ON FORESTRY AND CURRENT RESEARCH IN IRELAND

Bank voles have the capacity to damage newly planted and young trees by stripping bark and gnawing at the stem (Plates 6.5 and 6.6), sometimes ringbarking the entire base and killing the tree. In Ireland, bank vole damage was first noted in 1973 and reports of damage have increased as the voles both increase their range to colonise new areas and move into recently planted woodlands already within the range. Bank vole damage is usually quite localised within plantations aged two to five years (Keane 1998). Studies in Co Limerick have shown that while overall levels of damage across an area can be quite low (occurring to less than 1% of trees planted), localised 'hotspots' can have high levels of damage with 15% to 40% of trees affected. Sitka spruce is the most frequently damaged species. Bark is removed to a height of 25 cm from the ground and the underlying soft tissue attacked. However, as trees age their bark becomes more difficult to strip and they are less palatable. As a result, the incidence of damage drops off markedly in trees aged four to five years and older.

PLATE 6.5: GNAWING DAMAGE CAUSED BY A BANK VOLE TO THE BASE OF A YOUNG CONIFER

PLATE 6.6: GNAWING DAMAGE CAUSED BY A BANK VOLE TO THE BASE OF A YOUNG BROADLEAVED TREE.

In 1990, an experiment was initiated in Mullaghareirk forest, Co Cork, to investigate the possible benefits of vegetation management in lessening bank vole damage in two year-old Sitka spruce plantation forest (Ward 1993). Damage to between 22% and 32% of trees planted was recorded from plots where no attempt was made to control vegetation, the accumulation of brash and the encroachment of scrub. Plots in which vegetation was suppressed and debris removed had lower levels of damage with only 11% of trees attacked. This study highlighted the importance of cover to voles and the role of surrounding scrubland, ditches and other routes by which voles can move into plantations. Another interesting point that emerged was that very often bank voles did not move into newly planted areas for two to three years, presumably due to the lack of essential cover.

Voles also have a beneficial role in woodlands and forests. In North America, the Californian red-backed vole (*Clethrionomys californicus*) is an important disperser of the non-wind blown spores of underground fungi or 'mycorrhiza' (Ure and Maser 1982, Tallmon and Mills 1994). A network of mycorrhizal fungi is required by tree roots to aid nutrient and water exchange. The fungi, through association with the tree, gain nutrients in return. In the United States, habitat fragmentation due to logging and poor management results in localised extinction of voles and may have long-term negative repercussions for the natural regeneration and welfare of forests.

6.6 CONTROL OF DAMAGE AND MANAGEMENT OF POPULATIONS

Application of rodenticides can directly poison non-target species and can bio-accumulate in predators (Murua and Rodriguez 1989). Habitat manipulation and management offers the best solution. Vegetation can be cleared, thus creating a barrier and helping to isolate areas with young trees. This may be complemented by applying herbicide to the cleared strips, creating an open 'buffer zone' that may discourage voles from entering. Removal of brash, lop-and-top and other debris will also serve to reduce available cover for bank voles. In small stands, e.g. orchards, small plantations and farm woodlands, damage by voles can be reduced by raking the grass and vegetation from between trees to expose their runways. This is especially effective in late summer and substantially reduces the numbers of voles that overwinter and breed during the following year. This can be used in conjunction with vegetation control measures such as mowing and/or herbicide spraying. Protective collars or sturdy tree shelters may also be used to guard against damage. These should be pushed into the ground or buried a distance to prevent voles gaining access. In Britain, this is effective in reducing damage from field voles (*M. agrestis*) but not from bank voles which are lighter and may be able to climb, especially with the aid of neighbouring vegetation. Around each young tree a surrounding vegetation-free zone will directly discourage voles from approaching the base. A good solution is to use a sturdy wrap-around 'vole guard'. Herbicide may be applied around each guard if desired. Many of the above measures are practical in small stands only and may be unfeasible in larger plantations.

6.7 BIOCONTROL

Natural predators of bank voles can be encouraged as a form of biocontrol. Predatory birds such as barn owls, long-eared owls, kestrels and buzzards may be attracted to an area by installing perches. Potential nest sites for these species can be provided by preserving old and dead trees and farm buildings. These will also provide denning sites for pine martens, if present. Foxes will also prey heavily upon voles and other small rodents such as rats and rabbits.

6.8 LEGAL PROTECTION

Bank voles are not protected in Ireland under the Wildlife Act, 1976 and the Wildlife (Amendment) Act, 2000.

7. REFERENCES

Alibhai, S. and Gipps, J. H. W. 1991. The bank vole (*Clethrionomys glareolus*). In: *The Handbook of British Mammals*. 3rd Edition. Corbet, G. B. and Harris, S. (Eds). p 192-203. Blackwell Science, Oxford.

Anonymous. 1997. A policy for sika deer in Scotland. Deer Commission for Scotland.

Anonymous. 1998. *Rabbit control and rabbit calcivirus disease: a field handbook for land managers in Australia*. The Anti-Rabbit Research Foundation of Australia, Adelaide.

Bullock, D. J. and Kinnear, P. K. 1988. The use of goats to control birch in dune systems: An experimental study. *Aspects of Applied Biology 16*: 163-168.

Calvert, R. F. 1997. Impact of fallow deer (*Dama dama*) feeding at reforestation sites within a mixed woodland. Unpublished Ph.D. thesis, University of Ulster.

Carter, N. A. 1984. Bole scoring by sika deer (*Cervus nippon*) in England. *Deer* 6: 77-78.

Casey, J. 1999. A study of the dispersion and habitat usage of forest deer as determined by radio tracking. Final report of COFORD project no. 2-2-95. Mammal Research Group, Dept. of Zoology, U.C.D. and Coillte.

Catt, D. C. and 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.

Claassens, A. J. M. and O'Gorman, F. 1965. The bank vole (*Clethrionomys glareolus*, Schreber): a mammal new to Ireland. *Nature* 205: 923-924.

Cowan, D. P. 1991. Rabbits. In: *The Handbook of British mammals*. 3rd Edition. Corbet, G. B. and Harris, S. (Eds). Blackwell Science, Oxford.

Cowan, D. P., Hardy, A. R., Vaughan, J. A. and Christie, W. G. 1989. Rabbit ranging behaviour and its implications for the management of rabbit populations. In: *Mammals as Pests*. Putman, R. J. (Ed). Chapman and Hall, London. p 178-185.

Crawley, M. J. 1989. Rabbits as pests of winter wheat. In: *Mammals as Pests*. Putman, R. J. (Ed). Chapman and Hall, London. p 168-177.

Duffy, S. G., Fairley, J. S. and O'Donnell. 1996. Food of rabbits (*Oryctolagus cuniculus*) on upland grasslands in Connemara. *Biology and Environment: Proceedings of the Royal Irish Academy* 96b(2): 69-75.

Edwards, P. J., Fletcher, M. R. and Berney, P. 2000. Review of the factors affecting the decline of the European brown hare, *Lepus europaeus* (Pallas, 1778), and the use of wildlife incident data to evaluate the significance of paraquat. *Agriculture, Ecosystems and Environment* 79: 95-103.

Fairley, J. S. 1969. Bank voles (*Clethrionomys glareolus*, Schr.) in Co Cork. *Irish Naturalists'Journal* 16: 209.

Fairley, J. S. 1971a. Bank voles (*Clethrionomys glareolus*, Schreber) in Co's. Clare and Tipperary. *Irish Naturalists' Journal* 17: 23-24.

Fairley, J. S. 1971b. The present distribution of the bank vole (*Clethrionomys glareolus*, Schreber) in Ireland. *Proceedings of the Royal Irish Academy* 71B: 183-189.

Fairley, J. S. 1985. Bank vole in County Galway. *Irish Naturalists' Journal* 21: 372.

Fairley, J. S. 1992. *Bank voles in County Waterford. Irish Naturalists' Journal* 24: 174.

Fairley, J. S. and O'Donnell, T. 1970. The distribution of the bank vole (*Clethrionomys glareolus*) in south-west Ireland. *Journal of Zoology*, London 161: 273-276.

Finkel, E. 1999. Australian biocontrol beats rabbits, but not rules. *Science* 285: 1842

Fletcher, D. J., Moller, H. and Clapperton, B. K. 1999. Spotlight counts for assessing abundance of rabbits (*Oryctolagus cuniculus* L.). *Wildlife Research* 26: 609-620.

Flowerdew, J. R. and Gardner, G. 1978. Small rodent populations and food supply in a Derbyshire ashwood. *Journal of Animal Ecology* 47: 725-740.

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

Gill, R. M. A. 1992b. A review of damage by mammals in north temperate forests. 2. Small mammals. *Forestry* 65: 281-308.

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

Gill, R. M. A., Gurnell, J. and Trout, R. C. 1995. Do woodland mammals threaten the development of new woods? In: *The Ecology of Woodland Creation*. Ferris-Kaan, R., Wiley, J. and Chichester (Eds). p 201-224.

Gurnell, J. 1983. Squirrels numbers and the abundance of tree seeds. *Mammal Review* 13: 133-148.

Gurnell, J. 1987. Squirrels. In: *The Handbook of British mammals*. 3rd Edition. Corbet, G. B. and. Harris, S (Eds). p 176-191. Blackwell Science, Oxford.

Gurnell, J. 1987. *The Natural History of Squirrels*. Christopher Helm, Beckenham, U.K.

Gurnell, J. 1996. The effects of food availability and winter weather on the dynamics of a grey squirrels population in southern England. *Journal of Applied Ecology* 33: 325-338.

Hannan, M. J. 1986. *The influence of forests and forestry practises on the behaviour of mammals.* M. Agr. Sc. thesis, University College, Dublin.

Hansson, L. 1985. The food of bank voles, wood mice and yellow-necked mice. In: *The ecology of woodland rodents,bank voles and wood mice*. Symposia of the Zoological Society of London 55: 141-168.

Harris, E. and Harris, J. 1997. *Wildlife Conservation in Managed Woodlands and Forests*. 2nd Edition, Research Studies Press Ltd, Taunton, Somerset, U.K.

Harris, S., Morris, P., Wray, S. and Yalden, D. 1995. A review of British mammals: population estimates and conservation status of British mammals other than cetaceans. *Joint Nature Conservancy Committee*, Peterborough.

Hayden, T. J. 1997. Invasion of the sika. *Irish Timber Grower. Newsletter of the ITGA.*

Hellawell, T. C. 1991. Aspects of the ecology and management of the feral goat (*Capra hircus* L.): Populations of the Rhinogau and Maentwrog areas, North Wales. Unpublished Ph.D. thesis, University of Wales, Cardiff.

Hewson, R. 1977. Browsing by mountain hares on trees and shrubs in N.E. Scotland. *Journal of Zoology* 182: 168-171.

Hewson, R. and Hinge, M. D. C. 1990. Characteristics of the home range of mountain hares (*Lepus timidus*). *Journal of Applied Ecology* 27: 651-666.

Hulbert, I. A. R., Iason, G. R. and Racey, P. A. 1996. Habitat utilization in a stratified upland landscape by two lagomorphs with different feeding strategies. *Journal of Applied Ecology* 33: 315-324.

Hurley, E. 1996. *Range expansion of sika deer (*Cervus nippon*) in Leinster*. Unpublished M. Appl. Sc. thesis, National University of Ireland, Dublin.

Keane, E. 1998. Bank vole spreads. *Irish Timber and Forestry* 7: p32.

Kenward, R. E. 1983. The causes of damage by red and grey squirrels. *Mammal Review* 13 (2/3/4): 159-166.

Kenward, R. E. and Holm, J. L. 1993. On the replacement of the red squirrel in Britain: a phytotoxic explanation. *Proceedings of the Royal Society, London* (B) 251: 187-194.

Kenward, R. E. and Parish, T. 1986. Bark-stripping by grey squirrels (*Sciurus carolinensis*). *Journal of Zoology* 210: 473-481.

Kenward, R. E., Hodder, K. H., Rose, R. J., Walls, C. A., Parish, T., Holm, J. L., Morris, P. A., Walls, S. S. and Doyle, F. I. 1998. Comparative demography of red squirrels (*Sciurus vulgaris*) and grey squirrels (*Sciurus carolinensis*) in deciduous and coniferous woodland. *Journal of Zoology* 244: 7-21.

Kenward, R. E., Parish, T. and Robertson, P. A. 1992. Are tree species mixtures too good for grey squirrels? In: *Ecology of mixed species stands of trees*. Cannell, M. G. R., Robertson, P. A. and Malcolm, D. C. (Eds). p 243-253. Blackwell Scientific Publications, Oxford.

Key, G., Moore, N. P. and Hart, J. 1998. Impact and management of deer in farm woodlands. In: *Population Ecology, Management and Welfare of Deer*. Goldspink, C. R., King, S. and Putman R. J. (Eds). p 44-47, Manchester Metropolitan University, Manchester, UK.

Larner, J. B. 1977. Sika deer damage to mature woodlands of south western Ireland. *13th Congress of Game Biologists*.

Lawton, C. and Rochford, J. 1999. The ecology of the grey squirrel in relation to broadleaved woodland in Ireland. *COFORD Report* 2-5-95. Wildlife Ecology Group, T.C.D.

Leirs, H., Antonissen, A., Boehts, H., Vranken, A. and Vrinssen, A. 1987. Additional data on the distribution of the bank vole, *Clethrionomys glareolus* (Schreber, 1780), on the Beara peninsula, Counties Cork and Kerry. *Irish Naturalists' Journal* 22: 321-322.

Mallorie, H. C. and Flowerdew, J. R. 1994. Woodland small mammal population ecology in Britain: a preliminary review of the Mammal Society survey of wood mice (*Apodemus sylvaticus*) and bank voles (*Clethrionomys glareolus*), 1982-87. *Mammal Review* 24: 1-15.

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

Mayle, B. 1999. Managing deer in the countryside. *Forestry Commission Practice Note No. 6*, Forestry Commission, Edinburgh.

Mayle, B. A., Peace, A. J. and Gill, R. M. A. 1999. How many deer? A field guide to estimating deer population size. *Forestry Commission Fieldbook No. 18*, Forestry Commission, Edinburgh.

McGhie, J. 1996. Northern Ireland's squirrels: Better red than dead? *Irish Timber and Forestry* 5: 18-19.

Mitchell, B., Staines, B. W. and Welch, D. 1977. Ecology of red deer: a research review relevant to their management in Scotland. Natural Environmental Research Council, Institute of Terrestrial Ecology.

Moles, R. 1994. Eating the Burren. *Elements of Engineering, Mathematics and Science*, Issue 2: 23-24, University of Limerick.

Moller, H. 1983. Foods and foraging behaviour of red (*Sciurus vulgaris*) and grey (*Sciurus carolinensis*) squirrels. *Mammal Review* 13 (2/3/4): 81-98.

Mooney, O. V. 1952. Irish deer and forest relations. *Irish Forestry* 9: 11-27.

Moore, N. P., Hart, J. D. and Langton, S. D. 1999. Factors influencing browsing by fallow deer (*Dama dama*) in young broadleaved plantations. *Biological Conservation* 87: 255-260.

Murua, R. and Rodriguez, J. 1989. An integrated control system for rodents in pine plantations in central Chile. *Journal of Applied Ecology* 26: 81-88.

O'Brien, D. 1999. Interrogating the resource base: the deer cull as a source of management information. Report prepared for COFORD. Mammal Research Group, Dept. of Zoology U.C.D.

O'Brien, P. H. 1988. Feral goat social organization: a review and comparative analysis. *Applied Animal Behaviour Science* 21: 209-221.

O'Donoghue, Y. A. 1991. Growth, reproduction and survival in a feral population of Japanese sika deer (*Cervus nippon* Temminck, 1836). Unpublished Ph.D. thesis, National University of Ireland, Dublin.

O'Teangana, D. E. 1999. The distribution and ecology of the red squirrel (*Sciurus vulgaris*) and the grey squirrel (*Sciurus carolinensis*) in Northern Ireland. Unpublished Ph.D. thesis, The Queen's University of Belfast.

Pepper, H. 1998. The prevention of rabbit damage to trees in woodland. *Forestry Commission Practice Note No. 2*, Forestry Commission, Edinburgh.

Pepper, H. 1999. Recommendations for fallow, roe, and muntjac fencing: New proposals for temporary and reusable fencing. *Forestry Commission Practise Note No. 9*, Forestry Commission, Edinburgh.

Pepper, H. and Currie, F. 1998. Controlling grey squirrel damage to woodlands. *Forestry Commission Practise Note No. 4*, Forestry Commission, Edinburgh.

Pepper, H. and Patterson, G. 1998. Red squirrel conservation. *Forestry Commission Practice Note No. 5*, Forestry Commission, Edinburgh.

Potter, M. J. 1991. Treeshelters. *Forestry Commission Handbook 7*. HMSO, London. 48pp.

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

Ratcliffe, P. R. 1986. Forestry, conservation and the Japanese sika deer. *Deer* 7: 15-17.

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

Ratcliffe, P. R. 2000. Deer Commission for Scotland. Personal Communication.

Ratcliffe, P. R. and Pepper, H. 1987. The impact of roe deer, rabbits and grey squirrels on the management of broadleaved woodlands. In: National Hardwoods Programme; Report of the seventh meeting. Saville, P. S. (Ed). *Oxford Forestry Institute occasional papers no. 34*, p 39-50, Oxford.

Ratcliffe, P. R., Hall, J. and Allen, A. 1986. Computer predictions of sequential growth changes in commercial forests as an aid to wildlife management, with reference to red deer. *Scottish Forestry* 40(2): 79-83.

Reilly, S. S. 1999. The implications of forestry management for the red squirrel. *Irish Timber and Forestry* 8: 16-17.

Riney, T. and Caughley, G. 1959. A study of home range in a feral goat herd. *New Zealand Journal of Science 2*: 157-170.

Rooney, S. M. 1999. Spatial organisation and ecology of sympatric small mammals: wood mice (*Apodemus sylvaticus*) and bank voles (*Clethrionomys glareolus*). Unpublished Ph.D. thesis, National University of Ireland, Dublin.

Rowe, J. J. 1984. Grey squirrel (*Sciurus carolinensis*) bark-stripping damage to broadleaved trees in southern Britain up to 1983. *Quarterly Journal of Forestry* 78: 231-236.

Rowe, J. J. and Gill, R. M. A. 1985. The susceptibility of tree species to bark-stripping damage by grey squirrels (*Sciurus carolinensis*) in England and Wales. *Quarterly Journal of Forestry* 79: 183-190.

Saunders, F. C. 2000. Mating system, seasonal breeding and survival of feral goats (*Capra hircus*) in the Wicklow Mountains, Ireland. Unpublished Ph.D. thesis, National University of Ireland, Dublin.

Smal, C. M. and Fairley, J. S. 1978. The spread of the bank vole since 1970. *Irish Naturalists' Journal* 19: 237-239.

Smal, C. M. and Fairley, J. S. 1980. Food of wood mice (*Apodemus sylvaticus*) and bank voles (*Clethrionomys glareolus*) in oak and yew woodlands at Killarney, Ireland. *Journal of Zoology*, London 40: 413-418.

Smal, C. M. and Fairley, J. S. 1982. The dynamics and population regulation of small rodent populations in the woodland ecosystems of Killarney, Ireland. *Journal of Zoology*, London 196: 1-30.

Smith, J. E. and Bullock, D. J. 1993. A note on the summer feeding behaviour and habitat use of free-ranging goats (*Capra*) in the Cheddar Gorge SSSI. *Journal of Zoology*, London 231: 683-688.

Springthorpe, G. D. and Myhill, N. G. 1994. The wildlife rangers handbook. *Forestry Commission Handbook* 10, HMSO.

Staines, B. W. and Welch, D. 1984. Habitat selection and impact of red and roe deer in a Sitka spruce plantation. Proceedings of the Royal Society Edinburgh 82b: 303-319.

Staines, B. W., Welch, D., Catt, D. C., Scott, D. and Hinge, M. D. C. 1985. Habitat use and feeding by deer in Sitka spruce plantations. *Institute of Terrestrial Ecology Annual Report 1984*, p 12-16, NERC, Swindon, U.K.

Sumption, K. J. and Flowerdew, J. R. 1985. The ecological effects of the decline in rabbits (*Oryctolagus cuniculus* L.) due to myxomatosis. *Mammal Review* 15: 151-186.

Takatsuki, S. 1986. Food habits of sika deer on Mt. Goyo, Northern Honshu. *Ecological Researches* 1: 119-128.

Tallmon, D. and Mills, L. S. 1994. Use of logs within home ranges of California red-backed voles on a remnant of forest. *Journal of Mammalogy* 75: 97-101.

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

Trout, R. C. 2000. *Fencing to prevent damage to crops and trees by rabbits*. Tinsley Wire Ltd., Sheffield.

Trout, R. C., Chasey, D. and Sharp, G. 1997. Seroepidemiology of rabbit haemorrhagic disease (RHD) in wild rabbits (*Oryctolagus cuniculus*) in the United Kingdom. *Journal of Zoology* 243: 846-853.

Ure, D. C. and Maser, C. 1982. Mycophagy of red-backed voles in Oregon and Washington. *Canadian Journal of Zoology* 60: 3307-3315.

Ward, D. 1993. Protective measures against the bank vole. *Irish Timber and Forestry* 2: p22.

Ward, L. K., Clarke, R. T. and Cooke, A. S. 1994. Long term scrub succession deflected by fallow deer at Castor Hanglands National Nature Reserve. *Annual Report of the Institute of Terrestrial Ecology* (1993-4), p 78-81, NERC, Swindon, U.K.

Watts, C. H. S. 1968. The foods eaten by wood mice (*Apodemus sylvaticus*) and bank voles (*Clethrionomys glareolus*) in Wytham woods, Berkshire. *Journal of Animal Ecology* 37: 25-41.

Wauters, L. A. and Gurnell, J. 1999. The mechanism of replacement of red squirrels by grey squirrels: A test of the Interference Competition Hypothesis. *Ethology* 105: 1053-1071.

Welch, D., Staines, B. W., Catt, D. C. and Scott, D. 1990. Habitat usage by red (*Cervus elaphus*) and roe (*Capreolus capreolus*) deer in a Scottish Sitka spruce plantation. *Journal of Zoology* 211: 453-476.

Welch, D., Staines, B. W., Scott, D. and Catt, D. C. 1983. Browsing damage done by red deer to young stands of Sitka spruce. *Annual Report of the Institute of Terrestrial Ecology 1982*, p 10-12, NERC, Swindon, U.K.

Welch, D., Staines, B. W., Scott, D. and Catt, D. C. 1987. Bark stripping damage by red deer in a Sitka spruce forest in Western Scotland. I. Incidence. *Forestry* 60(2): 249-262.

Welch, D., Staines, B. W., Scott, D. and French, D. D. 1992. Leader browsing by red and roe deer on young Sitka spruce trees in Western Scotland. II. Effects on growth and tree form. *Forestry* 65 (3): 309-330.

Whilde, A. 1993. Irish Red Data Book 2: Vertebrates - threatened mammals, birds, amphibians and fish in Ireland. HMSO, Belfast.

Wolfe, A. and Hayden, T. J. 1996. Home range sizes of Irish mountain hares on coastal grassland. *Biology and Environment: Proceedings of the Royal Irish Academy* 96b(3): 141-146.

Wolfe, A., Whelan, J. and Hayden, T. J. 1996. Dietary overlap between the Irish mountain hare (*Lepus timidus hibernicus*) and the rabbit (*Oryctolagus cuniculus*) on coastal grassland. *Biology and Environment: Proceedings of the Royal Irish Academy* 96b(2): 89-95.

RECOMMENDED FURTHER READING

Coillte. 1999. *Coillte's forests: A Vital Resource*. Coillte, Dublin.

DAFF. 1996. *Growing for the Future: A Strategic Plan for the Development of the Forestry Sector in Ireland*. Department of Agriculture, Food and Forestry, Dublin.

DAHGI. 2002. *National Biodiversity Plan.* Department of Arts, Heritage, Gaeltacht and the Islands, Dublin

Environmental Protection Agency. 2000. *Ireland's Environment: A Millennium Report*. Eds. Stapleton, L., Lehane, M. and Toner, P. EPA, Wexford, Ireland.

Forest Service. 2000. *Forestry and the Landscape Guidelines*. Department of the Marine and Natural Resources, Dublin.

Forest Service. 2000. *Forest Biodiversity Guidelines*. Department of the Marine and Natural Resources, Dublin.

Forest Service. 2000. *Forest Harvesting and the Environment Guidelines*. Department of the Marine and Natural Resources, Dublin.

Forest Service. 2000. *Irish National Forest Standard*. Department of the Marine and Natural Resources, Dublin.

Hayden, T. J. and Harrington, R. 2000. *Exploring Ireland's Mammals*. Townhouse and Countryhouse, Dublin.

Hodge, S. and Pepper, H. 1998. *The Prevention of Mammal Damage to Trees in Woodland*. Forestry Commission Practice Note No. 3, Forestry Commission, Edinburgh.

Putman, R. J. 1989. *Mammals as Pests*. Chapman and Hall, London.