Forestry Commission

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Technical Paper 23

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Front cover: Adult fox in woodland in summer. The mixed habitat offers a variety of food and cover. (John Parker)

CONTENTS

Summary

This Technical Paper describes fox biology in relation to forestry, reviews information on fox population trends, and recommends strategies for the management of fox impacts.

The red fox is an opportunist predator and scavenger with a wide distribution throughout the northern hemisphere. Foxes have catholic requirements in terms of habitat and food and consequently thrive in a wide range of urban and rural environments. In Great Britain foxes have long been accused of killing poultry, sheep and game-birds. It has been suggested that an increase in fox numbers, particularly in the uplands, has been due to an increase in forest area.

Fox population densities range from less than 0.1 km^{-2} in some upland areas to more than 5 km^{-2} in urban areas and rich farmland. Fox densities are related to prey abundance and in some areas there is evidence that cyclic fluctuations driven by changes in prey abundance occur. Generalist predators, including the fox, are capable of regulating numbers of some prey species, especially when the latter have been depressed due to other factors, such as myxomatosis in rabbits. Rare and vulnerable species that are favoured prey may occasionally need protection. In rural Britain foxes eat mainly small rodents, lagomorphs and carrion. Foxes do kill lambs, poultry and game-birds, and while the overall economic impact of the predation is small, it can be significant in localised incidents.

Efforts to reduce overall fox populations have been generally ineffective, other than in the short term and over limited areas. Based on the evidence reviewed, attempts to reduce overall fox numbers are unlikely to be successful or achieve a reduction in impact. A fox management strategy should be adopted if impacts are unacceptable, where possible targeting control effort to the time and location of unacceptable impacts and the specific foxes responsible.

Chapter 1

Aim and context

The red fox *(Vulpes vulpes)* is a generalist predator and scavenger adapted to a wide range of habitats and is present throughout mainland Britain. Characterised as wily and sly, the fox has a reputation for attacks on lambs and domestic fowl, where it is reported to kill many and eat few. Pressure to control foxes is not a recent phenomenon. In England and Wales bounties have been paid for dead foxes since the 16th century, while in Scotland a law passed in 1457 enabled payment of 6d for a fox head brought to the authorities as proof of a kill.

Forest plantations established over the last 70 years, particularly in the uplands, present an extensive habitat for foxes, which offers both food and shelter. Foxes contribute, with other mammalian and avian predators, to the functioning of animal communities and ecosystem processes.

The Forestry Commission (FC) has for many years undertaken fox control on its estate to protect neighbouring farming and sporting interests. In the lowlands, reliance was placed on local hunts, but in upland sheep-rearing areas more intensive and systematic control has traditionally been undertaken by FC rangers, often in collaboration with local fox destruction societies.

Past research provides little evidence that extensive and systematic fox killing (including that in FC forests) has had any effect on the level of lamb predation — the main reason for killing foxes. Accordingly, in 1992 when the FC's policy on fox control was being revised, there was a change of emphasis from extensive and systematic fox culling to providing a quick and effective response to lamb killing by foxes on land adjacent to FC forests. Reaction to this change in policy has been supportive from conservationists but more critical from some sheep farmers and game managers who were sceptical of the scientific basis of the policy. Information on the ecology of predation by foxes is scattered throughout the popular, technical and scientific literature and is often not easily accessible to those involved in the day to day management of land where foxes are present.

The aim of this Technical Paper is to summarise recent research on fox predation and to present an ecological background for making decisions about fox management. It is not a statement of Forestry Commission policy on fox control, but a review of literature relevant to the development of policy towards foxes in Britain, for forest managers and other land managers. Although not an exhaustive review (there is for example, a plethora of American literature, to which only limited reference has been made), a broad insight is provided into relevant aspects of the subject in Britain.

Chapter 2

Fox ecology

Distribution

The red fox occurs naturally throughout much of the northern hemisphere (Figure 2.1). The North American red fox population has been isolated from European and Asian stock for perhaps a million years, except for minor introductions from Europe in the 18th century, but is considered to be the same species that occurs in the rest of the world (Lloyd and Hewson, 1986). Foxes are found from the Sahara to the Arctic, the northern limit of their geographic range being determined by food availability, and thus ultimately by climate (Hersteinsson and Macdonald, 1992). The fox was also introduced to Australia from Europe in the mid 19th century.

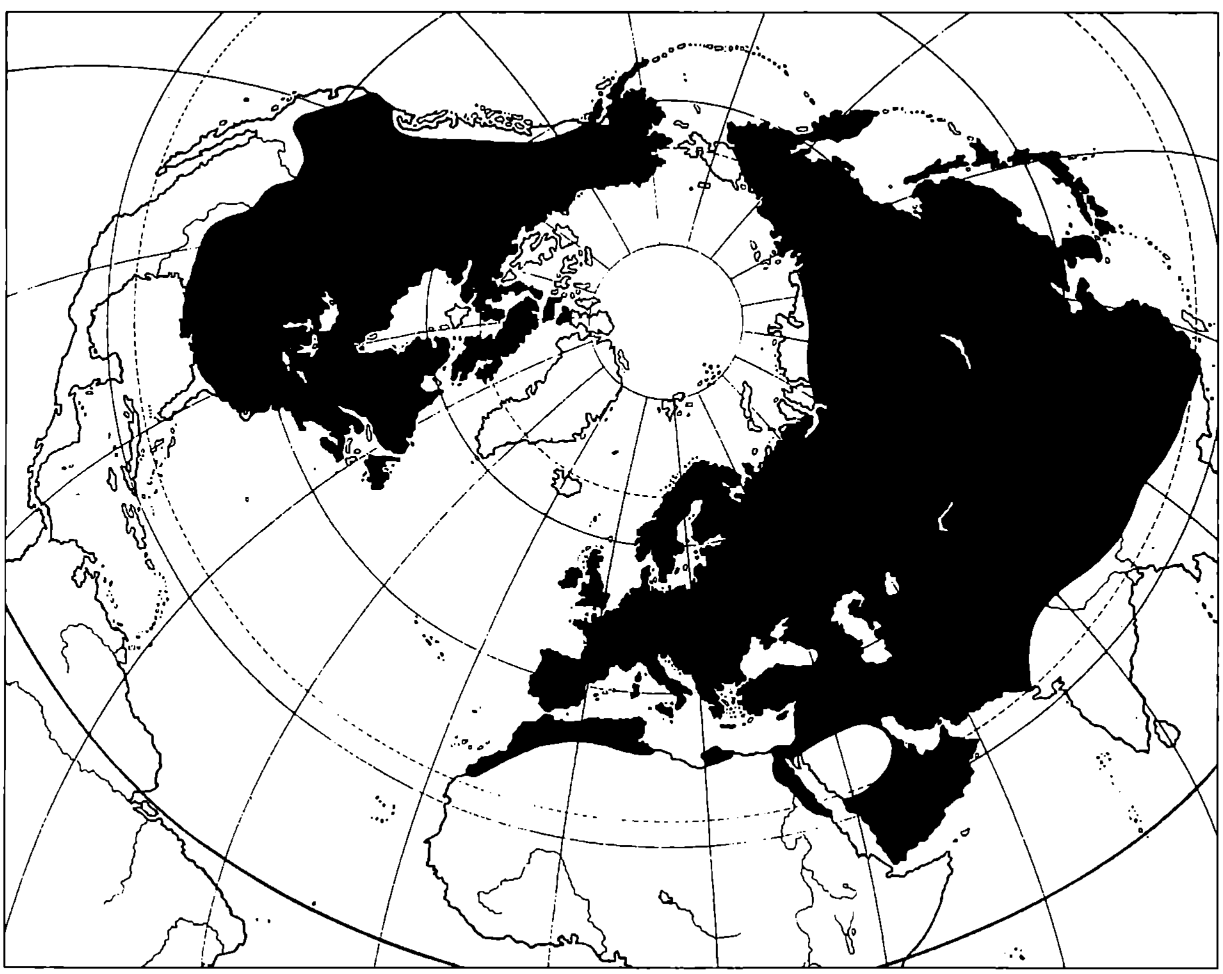

Figure 2.1 Global distribution of the red fox *(Vulpes vulpes)*. (From *The handbook of British mammals* edited by G. B. Corbet and S. Harris, with permission of Blackwell Science, Oxford)

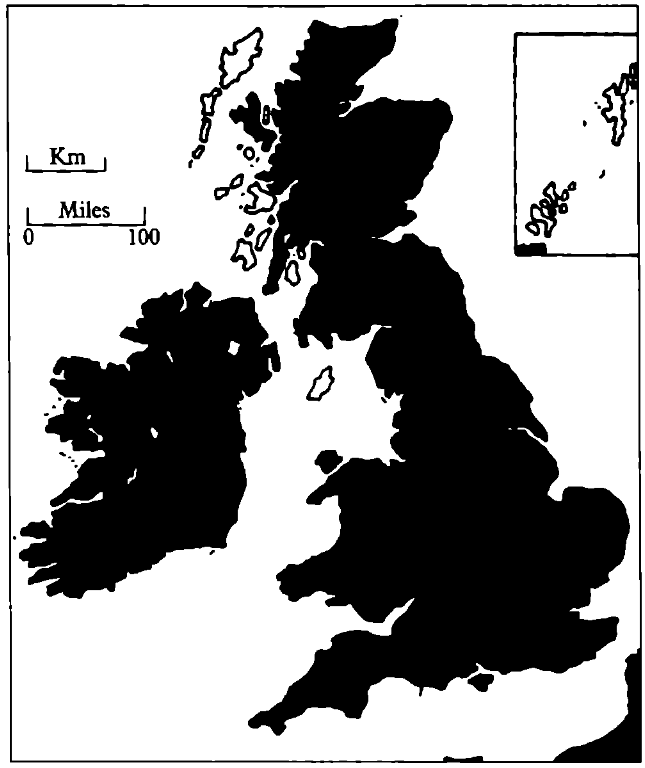

Figure 2.2 Distribution of the red fox in the British Isles. (From *The handbook of British mammals* edited by G. B. Corbet and S. Harris, with permission of Blackwell Science, Oxford)

On the British mainland and in Ireland foxes are resident in almost all regions, although until recently there were some gaps (Figure 2.2). Foxes were absent or rare in parts of Norfolk and the coastal regions of Aberdeenshire, Moray and Nairn until the 1950s (Hewson and Kolb, 1973) but are now increasingly common (Harris and Lloyd, 1991). Of the larger islands around Britain, they are present on Skye, the Isle of Wight, Anglesey (where they were absent until 1962) and the Isle of Man (where they are spreading rapidly after illegal release (Macdonald and Halliwell, 1994)). They are absent from all other Scottish islands, the Channel Islands and the Scilly Isles. The fox can be found at altitudes of over 1300 m in the Cairngorms (Harris and Lloyd, 1991) through all types of landscape to inner city areas.

Social organisation, breeding and dispersal

Social organisation

Social organisation, as with many aspects of fox biology, seems to be related to habitat and population density. Although apparently solitary or paired in the uplands, in lowland or urban areas foxes live in family groups consisting of one dog, a dominant vixen and a number of subsidiary vixens (usually related and often young of the year) in a patchwork of territories, quite rigidly delimited from neighbouring groups (Macdonald, 1987). While often together during the day, individuals in a social group generally hunt alone (Poule *et al.*, 1994). It may be that large territories in the uplands, where foxes are at low density, are less strongly defended than smaller lowland territories. In the Cumbrian hills Macdonald (1987) found territories defended by groups of at least three adults foxes. Home ranges (the area an animal occupies for feeding, courtship, breeding, lying up, etc.) and territories (that part of the home range defended from neighbours and intruders) vary in size principally due to food and habitat availability (Table 2.1). Macdonald (1984) found that there was no significant relationship between size of territory and number of family group members occupying the area.

Home range size varies from 4 ha in some urban areas (Trewhella *et al.*, 1988) to 10 to 250 ha in Oxfordshire (Voight and Macdonald, 1984) and up to 400 ha in mid Wales (Lloyd, 1980). In a study in the west of Scotland mean

Table 2.1 Reported areas of fox home ranges and territories

Location	Area (ha)	Source
Scotland (N), Eriboll		
– dog	2670-4500	Hewson, 1990
– vixen	2220-2270	Hewson, 1990
Scotland (upland)	up to 4000	Lockie, 1964
Wales, mid (upland)	200-600	Lloyd, 1980
Wales (W), rich farmland	40-100	Lloyd, 1980
England, Cumbria	1000	Macdonald, 1987
England, Oxfordshire, mixed farmland	100-250	Macdonald, 1987
England, Oxfordshire, large gardens and farmland	10-70	Macdonald, 1987
England, south	270-310	Reynolds, cit. Macdonald, 1987
GB, urban	20-100	Harris and Lloyd, 1991
North America	280	Hamilton, 1939
North America	800-1600	Schofield, 1960
Holland	400-1600	Vanhaaften, 1970

home range size was 553 ha (range 124–2649 ha) (Chadwick *et al.*, in preparation). Ranges of over 1000 ha are known on the continent (Travaini *et al.*, 1993).

Breeding

Foxes are reported as pairing for life (Lloyd, 1980; Harris, 1986). However, as mortality of adults is often high (57% in mid Wales) many single survivors remain without a mate. In Wales, combining the number of single adults with juveniles joining the breeding population, it was estimated that every year 81.5% of the breeding population comprises new pairings (Lloyd, 1980).

Vixens come into season once a year and mate in the period December to February. Dog foxes are seasonally fecund and sperm production is at a maximum during the same period. Foxes from more northerly populations breed progressively later in the year to coincide with the time of greatest food supply (Lloyd and Englund, 1973). When at high density the dominant vixen, or sometimes two vixens, in a family group will breed. Social pressures suppress breeding in subordinate vixens (Macdonald, 1979).

Pregnancy lasts 53 days and births are concentrated within a 6 to 7 week period. In Scotland cubs are born from the end of February to May, but the peak month for births in Britain is March, although there are regional and latitudinal variations. The average birth dates for north-east Scotland are 16 to 26 March and for west Scotland 28 March to 3 April, about a week later (Kolb and Hewson, 1980a). This difference probably reflects adaptation to a more intermittent food supply in the west (Kolb and Hewson, 1980b). The delay may allow foxes in the west to take advantage of the peak availability of sheep and deer carrion during April and May. Litter sizes of up to 10 cubs have been estimated from evidence of placental scars, but 4 or 5 cubs are more usual (Harris and Lloyd, 1991).

Weaning is often under way by 3 to 4 weeks of age (Englund, 1969; Sargeant, 1978; Kolb and Hewson, 1980a) and generally completed at 6 to 7 weeks (Lloyd, 1980). In north-east and west Scotland, Kolb and Hewson (1980a) found that solid food was eaten by cubs from approximately 20 days after birth and little milk was taken after day 30. Cubs first emerge above ground at about 4 weeks. They become progressively more independent during the summer, although they will hunt with the vixen until perhaps July or August (Harris and Lloyd, 1991).

Dispersal

Dispersal of juveniles occurs between September and February and is random in direction, although modified by topography in the uplands (Chadwick *et al.*, in preparation). In the USA, Sheldon (1950, 1953, cited in Lloyd, 1980) found that male cubs were more likely to disperse and dispersed earlier than female cubs. Dispersal has been investigated using two methods: tagging and recovery, and radio tracking. Distances moved varied greatly between fox populations and are related to habitat suitability and population density, not only at the place of origin but in the area to which the fox moves. For both sexes, an increase in home range size and a decrease in density lead to a greater mean and maximum dispersal distance (Trewhella *et al.*, 1988). However, this may not always be the case; for example, Allen and Sargeant (1993) found in North Dakota, USA, that dispersal distance was not related to fox density. Disturbance, particularly by hounds, may be an important stimulus to dispersal (Lloyd, 1980).

From a review, Trewhella *et al.* (1988) concluded that the majority of foxes do not move far, but that a small proportion move much greater distances. Dog-foxes tend to move considerably further than vixens, consistent with many mammals. Mean dispersal distances for dog-foxes were 4.7 km and 13.7 km in west and mid Wales respectively and 1.9 km and 2.25 km for vixens in the same areas (Lloyd, 1980). In mid Wales the greatest dispersal distance recorded for a dog-fox was 56 km in a moderately low density population, inhabiting mainly upland sheep walk or open moorland. In Northern Ireland 32 recoveries were made from 61 tagged fox cubs, 14 of which were recovered after 100 days. Two dog-foxes had moved 58 km and 37 km while the average dispersal distance was 16.5 km. One vixen moved 30.6 km while no other vixen moved more than 3.7 km (Fairley, 1969b). Hewson (1990) cited a Swedish study where more than 50% of cubs dispersed more than 20 km and a few up to 100 km. In North America most studies have recorded individual distances greater than 100 km with a maximum record of 394 km (Ables, 1965) and in Denmark three juvenile males out of 202 recovered after September had moved between 50 and 110 km (Jensen, 1973). Of 16 foxes (eight of each sex) caught on the Cowal peninsula and radio tracked between January 1993 and August 1995, six juveniles made substantial dispersal journeys which started between November and early April. Mean dispersal distances from point of capture were 7.35 km for vixens and 19.25 km for dog-foxes, the maximum being 26.7 km (Chadwick *et al.*, in preparation).

Dispersing juveniles are almost always available to occupy vacant territories, despite many juvenile foxes being killed before they have completed their dispersal movements (in Wales 91% of foxes recovered were under 15 months old). In Wales, Northern Ireland and Denmark there is little evidence to suggest significant movements among adult foxes once they have settled. Dispersal is predominantly a juvenile activity from birth place to breeding place (Lloyd, 1980; Fairley, 1969b), although food shortage or disturbance can result in further movements of adult foxes (Kolb and Hewson, 1980b).

Habitat use

Foxes are adaptable in utilising a wide range of habitats from suburban gardens to upland moors, and woodland habitats from small woods in mixed lowland landscapes to extensive upland conifer plantations. Mixed habitats which offer a variety of food and cover are favoured by foxes (Cavallini and Lovari, 1994), while movements and foraging are often related to habitat edges (Harris and Lloyd, 1991).

Little work has been directed at habitat use by foxes in large forests. However, it is clear that foxes prefer a mosaic of closed-canopy conifers to provide shelter and pre-thicket stages supporting prey (Hewson and Leitch, 1983; Petty, 1992). After canopy closure, extensive even-aged forests provide secure denning sites but lack food. Second rotation forests with a mix of age classes provide a mosaic of cover and feeding habitats. Forest stands often contain pockets of windthrown trees where root plates and horizontal stems form wooden 'cairns'. These afford security and are used by foxes for lying up and cubbing (D.I.K. Anderson, Forest Research, personal observation). A study in Wales showed that foxes use closed-canopy plantations as resting or denning places and grassy clearfell sites as feeding areas (Lloyd, 1980). In extensive Sitka spruce *(Picea sitchensis)* plantations in west Scotland, Hewson and Leitch (1983) found that foxes based in the forest usually fed within the forest rather than on the surrounding sheep walk, which was used by foxes that tended not to use the forest. However, on the Cowal peninsula in west Scotland, foxes moved freely between conifer forests and adjacent open hill and enclosed land using both habitats for feeding and lying up (Chadwick *et al.*, in preparation). During the day, forest was used more than open country by active foxes and much more by resting foxes. During the night foxes were equally and highly active both in and out of the forest; few foxes were inactive at night, particularly in open country.

Population trends

Fox abundance is notoriously difficult to estimate and indirect methods have been used. There is estimated to be a pre-breeding population of about 240 000 foxes in Great Britain; 195 000 are in England, 23 000 in Scotland and 22 000 in Wales. In addition, assuming a mean litter size of five, around 425 000 cubs are born each spring (Harris *et al.*, 1995). Harris *et al.* (1995) conclude that fox numbers may be increasing in response to increased rabbit and pheasant numbers, the exploitation of urban food resources, and relaxation of control.

Game-bag records indicate a four-fold increase in the number of foxes killed between 1961 and 1990 (Reynolds and Tapper, 1994) (Figure 2.3). This trend is supported by Lloyd (1980) for Wales, and Hudson (1992a) and Hewson (1984a) for Scotland, for a period when there was a major increase in the availability of suitable forest habitats for foxes. Between 1977 and 1989 there was no significant increase in fox numbers reported killed on a national scale, although Tapper noted some regional increases. However, subsequent game-bag records have shown increases in 1990 and in 1993 (Reynolds and Tapper, 1995a).

While the accuracy of game-bag records has been questioned (Bryant, 1994), and it is not clear how much of the increase is due to increased reporting or increased killing effort, it is believed that this trend reflects a genuine increase in fox populations. Kolb and Hewson (1980b) related the number of foxes killed to abundance of fox faeces and concluded that accurate records of foxes killed are likely to reflect fox abundance. Increases in numbers of

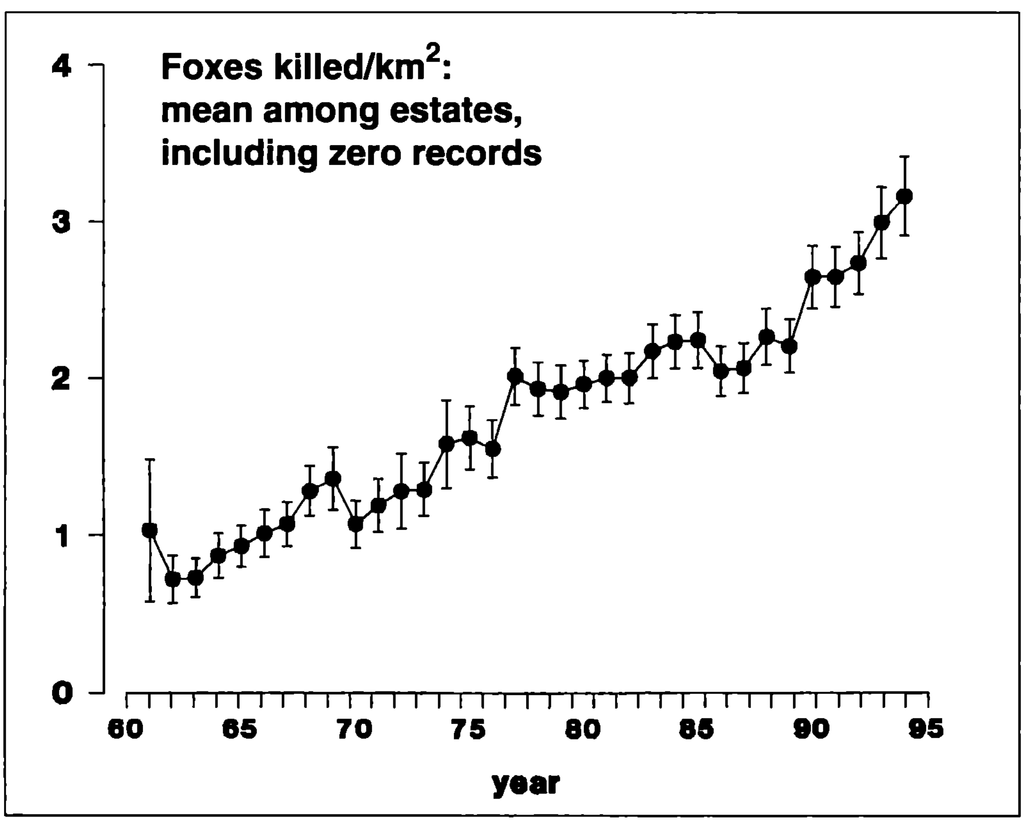

Figure 2.3 Trend in fox bags over the last 35 years. (From The Game Conservancy Trust's National Game-Bag Census)

foxes killed per unit area certainly reflected real increases in population density in East Anglia and coastal areas of eastern Scotland where foxes were absent or rare prior to 1960 (see Distribution).

Diet

Adult foxes require between 350 and 550 grams of food per day to subsist (Lloyd, 1980). They feed mainly at night but can be active during daylight, especially when not persecuted. Food items are often cached by burying, and then eaten later. A large number of studies have investigated diet, usually by looking at stomach or scat (droppings) contents. For example: Jensen and Sequeira (1978) list 34 studies of fox food from Europe; Lloyd (1980) summarises food items taken by foxes from Britain and Sweden (before and after myxomatosis), Australia, Missouri (USA), Finland and Bulgaria; and Harris and Lloyd (1991) describe some British fox food studies (Table 2.2). Some studies relate the analysis of faeces to the quantity of foods eaten (Lockie, 1959) but problems such as variability in digestibility may bias the analysis of stomach contents and scats (Cavallini and Volpi, 1995). Reynolds and Aebischer (1991) describe procedures to overcome many of the problems of faecal analysis. Even so, results may not accurately reflect dietary choice, for example, small amounts of sheep wool in a fox stomach may indicate searching for beetles in a decaying carcass as well as direct feeding on sheep flesh.

Preferences

Foxes are highly adaptable omnivores, their lack of specialised food requirements being one key to their success (Harris and Lloyd, 1991). In the UK, small mammals and rabbits tend to predominate in fox diet, with birds and carrion being locally important (Table 2.3). Foxes show marked preferences for some food items and avoidance of others, evidence coming from comparisons of ingested items and those found at cubbing dens (Jensen and Sequeira, 1978), observation of preferential recovery of cached food items and feeding trials with tame foxes (Macdonald, 1977). Among small mammals there are contrasts; field voles *(Microtus agrestis)* are strongly favoured over bank voles *(Clethrionomys glareolus)* and wood mice *(Apodemus sylvaticus)*, while insectivores such as shrews (*Sorex* spp.) are almost never eaten (Macdonald, 1977; Jensen and Sequeira, 1978). This aversion to shrews is common with other carnivores such as cats (Churchfield, 1991) and weasels (Erlinge, 1975). Some predatory species such as stoats, weasels, feral/domestic cats and chicks of ground-nesting raptors are eaten by foxes. However, Harris (1986) found that the number of domestic cats killed by foxes in Bristol was very low and mainly limited to cats less than 6 months old. Moles *(Talpa europea)* and slugs (*Arion* and *Limax* spp.) are almost never eaten. Earthworms, fruit and grass are of seasonal importance to foxes in many parts of mainland Europe (Ferrari and Weber, 1995; Jensen and Sequeira, 1978) and Britain (Table 2.2).

There is evidence that although sheep meat is eaten regularly it is not a highly favoured food. Foxes have been observed hunting rabbits in fields where lambs were ignored. Lamb carcasses often accumulate uneaten at breeding earths, along with other less-preferred foods. Often a fox will only nibble or perhaps chew off the tail of a lamb, leaving a lot of perfectly good food uneaten (Macdonald, 1987). Macdonald presented a hand-reared vixen, her family and eight wild born cubs with freshly dead lambs on five occasions. All these foxes either refused to eat the lamb or only ate it when they were extremely hungry and had no alternative food.

Fox cubs eat essentially the same diet as adults, although in Sweden (Englund, 1969) and Ireland (Fairley, 1970) there is some evidence that foxes chose hares (*Lepus* spp.) to feed to cubs in a greater proportion than in their own diet. This could be because of their large size. Lindström (1994a) and Reynolds and Tapper (1995b) both showed that foxes preferentially carried larger prey items to their cubs.

Regional variations

In the British uplands the main food of foxes is carrion (commonly sheep and deer), field voles, lagomorphs and game-birds (Kolb and Hewson, 1979; Lockie, 1964). In north-east Scotland lagomorphs and game-birds are the main prey items, while in the west, field voles are more important in autumn and winter and lambs in the spring. In north-west Scotland deer carrion is more frequent in the diet (Kolb and Hewson, 1979). In Morven, west Scotland, studies by Hewson and Leitch (1983) showed that foxes living in forests ate mostly deer carrion and field voles, compared with sheep carrion and field voles on open range. Live prey other than field voles was uncommon in both areas.

Table 2.2 Summary of some British fox food studies. The figures are percentage occurrence in either scats or stomachs and only the main food items are shown. In some studies the figures were presented in broad groupings, in others they were presented by orders, families or species; combining these into the headings used for this table may have produced a slight overestimate of percentage occurrence (adapted from Harris and Lloyd, 1991)

Location	Kent	NE Dorset	NE Dorset	S Devon	Gibralter Point, Lincolnshire	Spurn Peninsula, Yorkshire	NE Ireland	Wales	W Scotland	NE Scotland
Source	Lloyd, 1980	Reynolds and Aebischer, 1991	Reynolds and Tapper, 1995a	Richards, 1977	Howes, 1978	Howes, 1980	Fairley, 1970	Lloyd, 1980	Kolb and Hewson, 1979	Kolb and Hewson, 1979
Comment	Adult stomachs, winter	Scats away from cubbing earths	Scats away from cubbing earths[a]	Adult scats	Scats	Scats	Adult stomachs	Adult stomachs, winter	Adult stomachs	Adult stomachs
n	64	393	633	186	111	165	340	67	137	137
Lagomorphs	39	40	48	24	88	55	45	30	14	62
Small rodents	47	23	11	36	16	24	23	54	70	20
Other wild mammals	14	-	-	5	2	-	-	3	4	2
Passerines	14	5	5	6	4	16	4	9	-	-
Galliformes	19	19	16	3	-	4	16	15	-	-
Columbiformes	8	9	4	1	-	4	-	2	48	48
Other birds	5	9	-	8	9	21	22	5	-	-
Beetles	6	26	2	78	1	-	-	15	-	-
Other insects	6	-	-	37	-	5	-	3	12	6
Earthworms	-	35	2	14	-	-	-	2	-	-
Fish	-	-	-	-	1	2	-	-	-	-
Crabs	-	-	-	-	7	12	-	-	-	-
Sheep carrion	13	2	9	2	-	-	9	51	45	7
Deer carrion	-	1		-	-	-	-	-	13	4
Fruit	9	5	2	11	-	-	-	-	?	?

[a]Reconstructed % composition of total fox diet.

In lowland rural areas lagomorphs, small rodents and birds are often the most important foods, although in some locations insects, earthworms and fish are taken regularly, sometimes in large quantities. In towns and rural areas human rubbish is widely utilised by foxes (Harris, 1986; Jensen and Sequeira, 1978). In Denmark, Jensen and Sequeira (1978) found that domestic pig and poultry remains were major food items of foxes living in the Lovenholm Forest because of their availability as offal from dung heaps. The diet of urban foxes in Bristol consisted of up to 70% scavenged items such as meat, bone and fat (Harris, 1986).

Local variations in the quantity of sheep meat eaten by foxes are probably related to availability of alternative prey. Kolb and Hewson's (1979) comparison of west and north-east Scotland (see Table 2.2) suggested that in the west sheep and lamb were eaten in large quantities, but in the north-east, where alternative prey (hares, grouse and rabbits) were more abundant, sheep and lamb were only rarely eaten. Lockie (1964) suggested that sheep carrion in winter is likely to determine fox population size in upland west Scotland, because populations exist at a higher density than expected from the availability of live prey. Hewson and Kolb (1973) support this view, asserting that food availability in late winter and spring has an important influence on reproductive success or cub survival. Carrion is a particularly important component of diet at this time of year.

Over the red fox's global range rodents, particularly voles, often represent the most regular food resource (Artois and Stahl, 1989; Lloyd, 1980; Kolb and Hewson, 1979), although as generalist predators/scavengers foxes do not show specialised adaptations to hunting them. (This contrasts with some other carnivores that rely on small rodents, such as the weasel *(Mustela nivalis)* which has a small slim body, allowing it access to narrow vole runs.) Interactions between different predator species living in the same area are not well understood. Hewson (1983) compared the food of wildcat *(Felis silvestris)* and fox in west Scotland and found that foxes subsisted mainly on carrion (mainly sheep) while wildcats ate very little carrion; wildcats ate more and bigger birds (particularly gulls (*Larus* spp.)) than foxes but for both, rodents (mainly field voles) were the chief live prey. In Scotland both carnivores exploit rodents, birds and lagomorphs according to availability but it is unclear how much competition there is between them.

The ecological impact of foxes

Predator–prey theory

In early theoretical models of simple ecosystems (Lotka, 1925; Volterra, 1926), predator and prey numbers were shown to oscillate, the predator over-exploiting its prey until prey numbers decreased. This resulted in fewer prey so causing a decline in predator numbers which allowed prey numbers to recover. Thus, it was asserted that the subsequent cyclical population trends conferred long-term stability to the predator–prey relationship. More recently the role of these relationships in regulating populations of both predator and prey species has been more closely studied. For reviews of predator–prey dynamics see Crawley (1992) and for large carnivore–prey interactions see Carlo and Fitzgibbon (1992).

In some cases predators appear to have no effect on prey densities: predators utilising the 'doomed surplus' (Errington, 1946) above that required to maintain the breeding population of the prey species, including individuals most likely to succumb to disease and starvation. In other cases predators can exert a major pressure on their prey resulting in suppression of prey numbers, e.g. foxes and field voles in mid Sweden (Lindström, 1994b), foxes and rabbits in Australia (Pech *et al.*, 1995), foxes and brown hares in central southern England (Reynolds and Tapper, 1995a).

Predator impact is chiefly dependent on whether predators are specialists or generalists; and, if generalists, the availability of alternative prey. The populations of specialist predators which exploit only one or two prey species tend to be regulated by the supply of the prey. This is also the case for generalist predators faced with few prey species (such as foxes in much of the boreal zone). It is in these situations that the models referred to above are most valid.

In contrast, generalist predators, when faced with alternative prey, are able to switch to these when their favoured prey species becomes scarce. This prey switching allows generalist predators to maintain more stable populations, preventing population recovery of the favoured prey species. When prey numbers are low predation may continue to have a high impact on prey populations as the capacity for increase in the prey population is limited. However, the increased cost to the predator of exploiting a low density prey species often causes a switch to alternative prey before this point is reached. If a predator has a favoured primary prey species, periods of high abundance of the primary prey may result in a decline in abundance of secondary prey species due to increased predator populations (Reynolds and Tapper, 1996; Pech *et al.*, 1995). This effect can easily be confused with competition between prey species.

Determinants of fox population density

Natural predation does not have a significant impact on British fox populations. The larger woodland predators such as lynx *(Lynx lynx)*, wolf *(Canis lupus)* and brown bear *(Ursus arctos)*, which elsewhere prey directly on foxes, became extinct in Britain in the post-glacial period. The only avian predator to kill fox cubs in Britain regularly is the golden eagle *(Aquila chrysaetos)* (Cramp and Simmons, 1980).

Neither is a lack of cover and den sites likely to be limiting fox populations. The proportion of known breeding dens which were occupied in west Wales during 1971 was 1 in 15 where there were few available, and was as low as 1 in 80 where there were many dens (Lloyd, 1980). At high fox densities, social regulation of population occurs (Lindström, 1989), although this is unlikely to be a determinant of population density in most of rural Britain.

Food supply is the principal natural factor influencing fox density in Britain. Highest densities are found in the lowlands where food is abundant, with very high densities occurring in some urban areas (Table 2.3). In the uplands food is scarcer and fox numbers lower. Being generalist predators, fox density and productivity are not necessarily closely related to numbers of any one prey species. However, where foxes are dependent on a narrow prey base, fluctuations in prey populations can cause similar fluctuation in fox populations. In north-east and west Scotland the main cause of fluctuations in fox numbers was change in winter mortality, which in the west appeared to be related to the abundance of field voles in winter (Kolb and Hewson, 1980b). This suggests that where field voles form a major part of fox diet, fox mortality is related to cycles of abundance in field voles (Hewson, 1984a). Increased competition between foxes in high density populations, brought about by declining vole density, may cause more foxes to emigrate to areas where food is more abundant (Kolb and Hewson, 1980b). Lindström (1989) developed a model to predict how a fox population might respond to short-term fluctuations in vole numbers in south-central Sweden. This fox population was located between socially regulated stable populations to the south and food-limited populations to the north. Food supply was the primary factor limiting fox numbers, causing reduced rates of reproduction and survival during years when voles were scarce. Density-dependent regulation of the population occurred during years when vole densities were increasing or high, resulting in larger family groups within territories of fixed dimensions.

The impact of man in regulating fox population density is uncertain, continually debated, and probably regionally variable. Kolb and Hewson (1980b) suggest that starvation of foxes is relatively rare in Britain, and that human control may be replacing natural mortality as the primary regulator of fox populations. It is certainly the case that of 16 foxes (eight of each sex) caught on the Cowal peninsula and radio tracked between January 1993 and August 1995, 12 died during the study of which eight were shot or snared (Chadwick *et al.*, in preparation). Their average life expectancy after tagging was less than nine months. Reynolds and Tapper (1995a), in a study in southern England, found that killing by man was by far the most common cause of death (Table 2.4). However, this level of control, while preventing fox population increase, did not appear to result in a reduction of fox population density. It was estimated that the population immediately post-breeding would have comprised 38% adults and 62% cubs, implying that in the absence of natural mortality, 62% of the population must be removed each year to

Table 2.3 Fox population densities in Great Britain

Location or habitat	Density (km^{-2})	Unit used (dens/pairs/ families/foxes)	Source
Wester Ross, Scotland	0.025	breeding dens	Lockie, 1964
Deer forest	0.031	breeding dens	Hewson, 1986
Grouse moor/deer forest	0.043	breeding dens	Hewson, 1986
Grouse moor/agricultural	0.05	breeding dens	Hewson, 1986
Agricultural	0.1	breeding dens	Hewson, 1986
Mid Wales	1.2-4.8	breeding pairs	Lloyd, 1980
Parts of Pembroke	0.4-0.8	breeding pairs	Lloyd, 1980
New Forest	0.76	family groups	Insley, 1977
Farmland, lowland GB - very variable: typically	1	family group	Harris and Lloyd, 1991
	10	foxes	Macdonald, 1987
Urban areas			
Mean densities in 14 cities	0.19-2.24	family groups	Harris and Lloyd, 1991
Local densities	up to 5	family groups	Harris and Lloyd, 1991

maintain a stable breeding population. In a 5.6 km^2 study area on Salisbury Plain, fox control removed the entire adult breeding population each year, but the area was recolonised each winter by immigrating foxes (Reynolds *et al.*, 1993). A study of Scottish data showed that the killing of foxes over winter did not lead to fewer breeding dens in spring (Hewson, 1986). Although some evidence suggests that widespread control of foxes in the north of England probably does suppress fox breeding density on a regional scale (J. Reynolds, Game Conservancy Trust, personal communication), Fairley (1971) suggested that it was unlikely that killing of foxes by man in Northern Ireland had any long-term effect on the population size, although it may cause short-term fluctuations.

Road traffic may kill large numbers of foxes. Foxes constituted 10% of the 1566 recorded mammal road kills on an 85 km stretch of the Autobahn BAB2 in Germany between May 1992 and April 1993 (Fehlberd and Pohlmeyer, 1993). Frequency of fox kills was exceeded only by that of rabbits and mice. There are no comparable British studies available and no information is available on the possible impact of road kills on fox population density.

Table 2.4 Causes of death for 59 foxes examined in a Dorset study area between 1985 and 1987 (from Reynolds and Tapper, 1995a)

Age group	Gassed	Shot	Snared	Assumed dead (vixen killed)	Road casualty	Other (also caused by man)	Poison	Natural mortality
Adults	0	6	5	0	1	1	1	2
Weaned juveniles	0	3	0	0	1	0	0	0
Cubs	12	5	0	17	1	0	0	0
Unknown	0	2	0	1	0	0	0	1
Total	12	16	5	18	3	1	1	3

The impact of foxes on scarce species

It is unlikely that predation by foxes in Britain has caused extinctions of prey as foxes can switch to other more abundant but less favoured food when availability of a preferred prey declines (although in Australia, where the fox has been introduced, the situation may be different due to extreme prey vulnerability (Pech *et al.*, 1995)). Rare or sensitive species, while playing an unimportant role in the diet of foxes, can be severely affected by predation (Reynolds and Tapper, 1996); for example, with grey partridges *(Perdix perdix)* on Salisbury Plain (Tapper *et al.*, 1991; although the fox was not the only predator species present), golden plover *(Pluvialis apricaria)* in Scotland (Parr, 1993), pine martens *(Martes martes)* in Sweden (Lindström *et al.*, 1995) and avocets *(Recurvirostra avocetta)* at Minsmere (J. Reynolds, Game Conservancy Trust, personal communication). Fox predation on chicks of ground-nesting raptors such as merlin *(Falco columbarius)* may reduce productivity (Newton *et al.*, 1986) and predation may affect the choice of nest sites; for example kestrels *(Falco tinnunculus)* nest on the ground in Orkney where mammalian predators are absent (Newton, 1976, cited in Newton, 1979). Foxes can have a devastating effect on breeding success in individual vulnerable tern (*Sterna* spp.) colonies (Kruuk, 1972), although there has been no suggestion that the species was endangered as a result. Fox predation was found to have no significant effect on capercaillie breeding performance in eight Scottish forests while crow predation was significant (R. Moss, ITE, personal communication).

In most situations, habitat improvement, rather than fox control alone, is the key to the protection of scarce species, for example by improving the availability of ground cover for woodland grouse, or improving sight lines for ground-nesting waders. Green (1992) suggests that intervention to control predation should only be considered locally when predation is causing negative population growth on more than 1% of the national population of a threatened bird species.

Chapter 3

The economic impact of foxes

Sheep farming

Some foxes do kill lambs and the fox has therefore gained a reputation for depressing the economics of hill sheep farming. The main lambing season in upland Britain is March and April which coincides with weaning of fox cubs in the uplands when the confined vixen and cubs have a high demand for food (see Habitat use, Chapter 2). In many parts of the lowlands lambing is often over by the time foxes are producing cubs (Macdonald, 1987; Fairly, 1969a). Furthermore, lambing increasingly takes place in sheds, which protects lambs during their first few days when they are most vulnerable to predation.

A 1971 survey by The National Farmers Union in Scotland (cited in Hewson, 1990) reported that foxes killed an average of 8.3% of lambs born. Macdonald (1984) found that in England 30.2% of farmers believed foxes caused them nuisance and 54% of sheep farmers believed they had been the victims of lamb worrying at some time. Clearly foxes are perceived as a problem. However, some anecdotal reports and most research evidence is to the contrary. The number of lambs lost reported by National Sheep Association members in *The Field*'s survey of predation on lambs by foxes (Anon., 1993) was 1% of the average annual lambing, although 11% of hill farmers, who 'suffered badly', reported a loss of greater than 30 lambs (2.85% of average annual lambing).

In a west Scotland study between 1976 and 1979, foxes killed 1.3, 1.8, 0.8 and 0.6% of the lambs estimated to have been born in four consecutive years (Hewson, 1984b) and at Eriboll in north Scotland between 1987 and 1990 the figure was 'even lower' (Hewson, 1990). On the island of Mull where there are no foxes, production of lambs over a three-year period was no better than on similar ground on the mainland. This suggested that predation by foxes was part of, rather than in addition to, the normal scale of lamb losses (Hewson, 1981, cited in Hewson, 1990). Neither has surplus killing of lambs (large numbers being killed in a single event but not eaten) been consistently reported although there is some anecdotal evidence (Lloyd, 1980). However, surplus killing by foxes of large numbers of black-headed gulls and Sandwich terns at breeding colonies has been recorded (see The impact of foxes on scarce species, Chapter 2).

The national economic impact of fox predation on lambs is not known and is difficult to determine (Macdonald, 1987), but the evidence above suggests that the economic impact is generally within the normal range of expected lamb losses. However, lamb losses on individual farms can occasionally be severe, and it is at this scale that control strategies should be considered. While loss of young lambs represents a loss of potential income, an accurate cost : benefit analysis should include any savings in variable cost items such as forage, food concentrates or routine medication. Furthermore, the cost of fox control must be balanced against the cost of lamb losses.

Poultry

Studies in Northern Ireland show considerable evidence that foxes kill free-range domestic fowl, usually at night (Fairley, 1969a). Surplus killing occurs in hen-houses and may be a response to the encounter of prey confined at artificially high densities. In another study Fairley (1970) found feathers of poultry and game-birds in 14% of fox stomachs. In a Danish study poultry remains were found in 20% to 35% of fox stomachs, a high percentage compared with other European countries (10-20%), although most were scavenged as waste from farm dumps (Jensen and Sequeira, 1978). Traditional free-range poultry farms are vulnerable to predation by foxes but large-scale indoor poultry farming is unaffected. Foxes can be regarded largely as a nuisance to small flocks kept for household use but are not a hazard to economic production, although they might be a disincentive to expansion in free-range poultry production, demand for which has increased since Fairley's work.

Game

Throughout Britain wild ground-nesting game-birds are taken by foxes, while in lowland areas high concentrations of hand-reared game-birds at release pens are particularly vulnerable.

Predator removal studies show higher abundance of species such as capercaillie and willow grouse *(Lagopus lagopus)* following complete predator removal (Reynolds and Tapper, 1996). Reynolds and Tapper (1995b) showed that hares killed by foxes were a substantial loss to the population; mean breeding density of hares was 15 km^{-2} with no predator control compared to as high as 60 km^{-2} with intensive predator control. In Jutland, Denmark, intensive fox killing (by gassing and shooting), in an attempt to eradicate rabies, increased the bag of hare *(Lepus europaeus)* and pheasant *(Phasianus colchicus)* but not other game species (Jensen and Sequeira, 1978). Following the disappearance of rabies, fox control was curtailed, foxes increased and hare, pheasant and partridge decreased. As the objective was to control rabies, the killing effort was great.

It might therefore, be possible, in certain circumstances, to directly increase game-bags by reducing overall fox density (Reynolds and Tapper, 1995b), although it seems unlikely that such an effect can be realistically attainable for game management purposes in heavily forested parts of Britain in the light of the cost and logistical constraints. Reynolds *et al.* (1992) showed that keepered estates in Sussex did not have detectably better over-wintering survival of grey partridges than unkeepered estates. This suggests that untargeted killing is probably becoming increasingly ineffective, particularly where gamekeepered areas are more and more isolated in the countryside.

Traditionally, gamekeepers in both the lowlands and uplands have tried to limit predation on game-birds by reducing fox density by killing them throughout the year. However, this level of control is not necessary to achieve harvestable game numbers (Swan and Tapper, 1992). On Salisbury plain, Tapper *et al.* (1991) demonstrated that large gains in partridge (*Perdix* spp.) productivity can be achieved by killing predators from March to June. During spring and early summer predators (crows *(Corvus corone)*, magpies *(Pica pica)*, foxes, stoats *(Mustela erminea)* and rats *(Rattus norvegicus))* were killed at one site, while another site was left untouched. After three years the site treatments were switched. In the years following the control of predation the spring numbers of partridge increased by an average of 11%, while in springs following seasons without the control of predation, numbers fell by an average of 24%. The contribution of fox predation was not estimated. Hare numbers consistently increased during the six summers when there was control of predation.

In the uplands, fox predation can reduce red grouse *(Lagopus lagopus scoticus)* production on heather moors, although losses to foxes are often less than that due to parasites in high density populations and emigration. Dobson and Hudson (1994) demonstrated that small numbers of predators selectively removing heavily parasitised grouse may allow the size of the red grouse population to increase since predators effectively reduced the regulatory role of parasites. However, higher levels of predation did suppress red grouse numbers. Forests do not provide red grouse habitat and multiple regression analysis suggested that forestry adjacent to grouse moor had no significant influence on grouse bag size (Hudson, 1992b; Hudson, Game Conservancy Trust, personal communication). In Scottish arctic-alpine areas predation by foxes and golden eagles is the only important adult mortality factor for ptarmigan *(Lagopus mutus)* and this was found not to limit breeding numbers or appreciably depress production (McVean and Lockie, 1969).

Pest control by foxes

Rabbits and field voles can be pests of agriculture and forestry and are favoured fox prey species. Voles, which can be present at densities approaching 1000 ha^{-1} (Charles, 1956), eat twice their own weight in grass each day. While present at much lower density in sheep walks, they do use the same food resources as sheep (McVean and Lockie, 1969). Rabbits, since their recovery following the ravages of myxomatosis, are a major agricultural pest capable of reducing yields of both grass and other more valuable crops such as cereals. When present at high density field voles and rabbits can be a serious cause of failure of newly planted trees (Gill, 1992).

Whether foxes alone can regulate vole and rabbit numbers is open to conjecture but it is likely that generalist predators are an important contributory factor in maintaining relatively stable or non-cyclic vole populations in some areas (Erlinge *et al.*, 1983 and 1984) and limiting certain lagomorph populations (Trout and Tittensor, 1989; Lindström, 1992).

Trout and Tittensor (1989) conclude that in England and Wales predator pressure on wild rabbits may limit increases in rabbit density after rabbit populations have been reduced by some other factor, and reduce the rate of spread of rabbits into previously uncolonised areas. This assertion is supported by the research of Newsome (1990) in Australia who concludes 'carnivores can control mammalian pests for long periods, but only after pest numbers have been reduced by other means'. In Australia the cause was prolonged dry weather. The consequent low populations of rabbits can be regulated by foxes, feral cats *(Felis silvestris)* and dingos *(Canis dingo)*. Further evidence for predator impact on rabbit populations arises when natural predator pressure in an area is suddenly reduced and rabbits subsequently become more widespread and abundant. On sites where there has been continued removal of predators over a number of years, there appear to be significantly higher rabbit populations than elsewhere, although a causal link has not been proved (Trout and Tittensor, 1989). Therefore, predation may contribute to the control of mammal populations in some circumstances.

Chapter 4

Fox control practice

Management strategies

The impact of foxes in forest environments is generally neutral and may be beneficial. In some circumstances fox predation may conflict with the protection of vulnerable endangered ground-nesting birds. However, the primary concerns are generally lamb and game-bird predation on adjacent land. Where predation is unacceptable a fox control strategy based on sound understanding of fox behaviour and ecology is required to ensure that desired outcomes are both realistic and attained with the minimum of effort, killing and suffering.

Targeted control

Where predation is deemed unacceptable, the objective should be to ameliorate it rather than reduce fox populations *per se* (Tapper, 1992). For impacts on game rearing, this means targeting predator control at the most vulnerable point in the annual cycle of game production, generally the nesting period. For impact on lambs this means targeting control at lambing time. A targeted control strategy is most likely to remove the individual foxes responsible for the problem, and is more cost effective than trying to reduce overall fox populations. The latter is usually unsuccessful due to the high productivity of foxes, their dispersal capability and adaptability (see Habitat use, Chapter 2). If fox control involves a risk of animal suffering, then minimising the number of foxes killed by targeted control has an animal welfare dimension.

Targeted fox control in spring, as recommended by the Game Conservancy Trust to improve partridge production and practised by the FC in response to lamb predation incidents, are good examples of accurately directed fox control. The success of such an approach depends on the ability to react quickly and effectively to specific incidents.

Animal welfare

The issue of cruelty to animals is emotive and complicated and some traditional practices no longer have widespread public acceptance. When killing animals for control, the aim should be for a swift and painless death. The capture and killing of foxes in snares, hunting with hounds, using terriers at dens and perhaps even shooting will be considered inhumane by many (Dawkins, 1980); however shooting cleanly with a rifle is quick, selective and the most humane method available of killing foxes.

Bounty schemes

Bounty schemes or systems have been unsuccessful in achieving any long-term reduction in fox numbers. There is an overwhelming amount of data to show that they rarely work (Hamilton, 1939, cited in Fairley, 1971). In Northern Ireland a bounty system ran between 1943 and 1970 with more than 200 000 bounties paid. There was no demonstrable decrease in the abundance of foxes. It was unlikely that killing foxes had any long-term effect on population size (Fairley, 1971). In 1987/88 eight of the 29 Scottish Fox Destruction Clubs were still paying a bounty (Hewson, 1990). In some areas this has resulted in a reduction of killing of foxes at dens, so that as many full grown juveniles as possible are available to be shot over winter (usually with a lamp at night) so that bounty can be claimed. This sort of evidence confirms that most bounty schemes are in reality sustainable harvesting programmes (Caughley, 1977).

Control methods

Past and present methods of fox control that try to limit predation range from attempts to fence them out of an area to the illegal use of poisons. The sport of fox hunting is not discussed as it is not considered to be primarily directed at limiting fox impact, although a few well-controlled dogs can be an effective tool for flushing foxes from heavy cover.

Shooting with spotlight

The use of rifle and spotlight at night is usually considered to be the most acceptable method of killing foxes as it is positive, selective, quick and humane. However, it is unlikely to achieve a widespread reduction in the impact of foxes, and is only appropriate in suitable terrain. It can be very successful when dealing with specific predation incidents. Sometimes these can also be effectively dealt with by flushing foxes out of cover towards waiting guns (personal observation). While fox shooting can be more efficiently undertaken during winter due to better visibility through some vegetation types, it is unlikely to be effective in reducing late spring lamb and game-bird predation, unless undertaken in an area with inherently low fox numbers (Reynolds and Tapper, 1996).

Killing foxes at dens

Predation of lambs appears to be random and unpredictable, although it is generally believed by shepherds and some scientists to be associated with occupied breeding dens where foxes are feeding cubs (Hewson, 1990; McVean and Lockie, 1969). Where lamb-killing occurs, destruction of the offending fox or foxes at the breeding den is usually effective in stopping predation (Hewson, 1986). This suggests that just a small number, perhaps only one or a mated pair of foxes, are involved in individual incidents and that the problem can be dealt with quickly. Dens may be some distance from the site of predation and sometimes difficult to find, particularly in dense forest stands.

In the USA coyotes *(Canis latrans)* occupy a similar role as predators of sheep to that of foxes in Britain. Killing cubs at dens but leaving adults was found to ameliorate the majority of lamb predation problems (Till and Knowlton, 1983). Hewson (1990) suggests this may be applicable to foxes in Britain, when the den can be located, saving time and effort in hunting elusive adult foxes. McVean and Lockie (1969) go further and report 'it has been shown that if the cubs are destroyed lamb-killing usually stops because the parents are no longer under pressure to provide food'. Cubs can be killed after digging down to them in the den or by the use of terriers, some of which kill cubs in the den while others will bring cubs alive to the surface where they are despatched. Sometimes cubs can be enticed from their holes (shortly before dark) with panting noises (Lloyd, 1980).

Trapping and snaring

Use of leg-hold traps for foxes is illegal in this country. In the 1960s the MAFF Humane Traps Panel (Scotland) ran trials of various alternative methods of trapping foxes. In 1968 one trial compared the efficiency and cruelty of free-running and self-locking snares. Neither type of snare was significantly more efficient nor less cruel than the other (Pepper, 1969). Although external inspection of carcasses suggested that locking snares did more damage, post-mortem examination showed no significant difference in damage caused by the two snare types. Earlier, Lloyd and Jones (1962) asserted that 'the use of snares (as replacement for the illegal gin trap) from the humanitarian point of view, can hardly be less cruel in many cases than the gin', although Lloyd (1980) indicated 'it seems that careful siting of snares can reduce injury, but few people setting snares are aware of this aspect'.

It is impossible to exclude non-target species from snares. In a 1968 MAFF trial 155 foxes and 132 non-target animals were caught. Domestic pets, wildcat, badger *(Meles meles)*, pine marten *(Martes martes)*, otter *(Lutra lutra)* and hare are all at risk as they are of similar stature to foxes. Roe deer *(Capreolus capreolus)* creeping through a fence hole are very vulnerable to fox snares and birds such as capercaillie *(Tetrao urogallus)* and mallard *(Anas platyrhynchos)* have also been caught (MacNally, 1992).

However, it is possible by good practice to minimise capture and death of non-target species. Leg captures of sheep and deer can be prevented by using a 'jump bar' over the snare. 'Stopped' snares which cannot close past a minimum circumference set by the stop (about 19 cm/7.5 in) will prevent leg captures and death of some species by strangulation due to neck capture. Setting snares away from obstructions such as fences which allow entanglement or on runners which hold the animal in the open also help to minimise suffering until the snare is visited.

The most important rule, and a legal requirement, in the use of the snare is to visit them at least once every 24 hours. Common practice in many upland areas is to set a series of snares on fox runs, often at fences. In many cases these are never checked. Infrequent inspections cause prolonged suffering of trapped animals. Therefore, many argue that snares should be banned (MacNally, 1992). Others suggest that removal of snaring as a legal method of fox control might lead to an increase in illegal methods such as poisoning, which is even less species specific than snaring (Cadbury, 1991; Fletcher *et al.*, 1991).

In countries where leg-hold traps are legal, techniques have been developed to increase their selectivity and reduce injuries (Travaini *et al.*, 1996).

Cage trapping of foxes has been effectively employed in some urban areas (R. Brand-Hardy, MAFF, personal communication).

Electric fences

Electric fences can be effective for vulnerable domestic or wild animals if they are concentrated in a small area, but this control method is rarely completely effective particularly when alternative food is short.

In North America electric fences have been successfully used against mammalian predators to protect small areas. At Cape Cod, a colony of little terns *(Sterna albifrons)* was protected from red fox predation by a three-strand electric fence although at high cost and labour requirement (Minsky, 1980). In North Dakota predation on piping plover *(Charadrius melodus)* by a range of predators, including fox, was reduced by protecting nests with a net fence which had three electrified strands attached to it (Mayer and Ryan, 1991). However, other American reports are more equivocal about excluding foxes and other predators from bird breeding colonies with fences, electrified or conventional (Burkett, *et al.*, 1990; Lokemoen and Woodward, 1990). While in certain circumstances, such as across a peninsula neck, electric fencing can be effective, American wildlife biologists are pessimistic about the prospect of generally excluding predators in this way (J. Reynolds, Game Conservancy Trust, personal communication).

The British experience is similar. At Rye harbour nature reserve in southern England electric fencing is reported as inadequate to protect a colony of little terns from fox predation, although some foxes were excluded. Increased incursions, following reduced killing of predators on a neighbouring estate, prompted the fence specification to be increased to 1.5 m high with 13 wires, alternate wires being live and earthed. Some foxes were still getting through this fence (B. J. Yates, Reserve Warden, personal communication). At Scolt Head Island, Norfolk, foxes did not cross an electric fence separating a colony of Sandwich terns *(S. sandvicensis)* from the rest of the island (Musgrave, 1993). However there was obviously little pressure on the foxes to persevere with fence crossing in order to gain access to the colony as they easily found their way around the ends of the fence at low tide.

The Game Conservancy Trust recommends reinforcement of pheasant release pen fences with one to three electrified wires to protect poults from foxes, mink *(Mustela vison)* and domestic pets (McCall, 1985; Game Conservancy, 1991). Controlled experiments have not been undertaken but a reduction in predation has been noted when electrified wires are added.

Gassing

Gassing foxes in their dens with cyanide-producing powder was a practice which became widespread after the gin trap was outlawed in Great Britain (England and Wales in 1958, Scotland in 1972). Following the introduction of the Control of Pesticides Act of 1986 there are now no products approved for such use. Although gassing previously offered a potentially quick and humane method of killing animals (Lloyd, 1980) there can be practical difficulties which can reduce its effectiveness and humaneness. Problems were highlighted during licensed gassing of badgers when attempts were made to control the spread of bovine tuberculosis. Difficulties include administering lethally high concentrations of gas to animals lying in deep dead-end sets or dens, the porous nature of some soils that allows gas to escape, and the hazardous nature of the gas to operators (H. W. Pepper, Forest Research, personal communication).

Poisoning

It is illegal to lay poison baits for foxes, or any other predator, in Great Britain. The Protection of Animals Act 1911 and the Protection of Animals (Scotland) Act 1912 prohibit the placing of poisonous matter on any land or building in Great Britain. The Animals (Cruel Poisons) Act 1962 empowers the Secretary of State to restrict the use of poisons for destroying wild animals of any description stated. In Northern Ireland the situation is slightly different as the Welfare of Animals Act (Northern Ireland) 1972 permits the laying of poison baits for foxes under licence, but there are many restrictions such as the need to inform the police and erect warning notices. Although there is still no general ban on the use of poisonous substances for predator control in Northern Ireland, it became illegal to supply strychnine for killing foxes in June 1992 and further efforts are being made to stop their use altogether (J. Milburne, DANI, personal communication).

The abuse of poisons occurs in Great Britain. Foxes, corvids and raptors are the main targets of illegal poisoned baits (Johnson, 1996; Cadbury, 1991; Fletcher *et al.*, 1991). During 1979-89, 164 fox poisoning incidents were reported (Cadbury, 1991), and 55 were reported between 1990 and 1994 (Johnson, 1996). Reported incidents are likely to represent a small proportion of the total kill as detection is difficult. Cadbury (1991) indicated that poisoning occurred throughout the UK in areas where pheasants were reared and in the uplands where there are grouse moors and sheep-rearing. It occurred throughout the year but there was a marked increase in incidents during the spring immediately prior to the game-bird breeding and lambing. Thirty-five different poisons were involved, the three most common being alphachloralose, mevinphos and strychnine. To tackle the abuse of pesticides, in March 1991 agriculture departments in Britain launched a long-term Campaign Against the Illegal Poisoning of Animals. The campaign aims to change the attitudes of the small minority who abuse pesticides, to publicise the problem, to improve reporting of incidents and also publicise legal methods of predator control for those with genuine pest control problems.

In Australia, where poisoning is legal, the use of 1080 (sodium fluoroacetate) has risen significantly since the mid 1980s despite much of the literature indicating that foxes are an insignificant agricultural problem (Thompson and Fleming, 1994). Thompson and Fleming (1994) found a 66 to 73% reduction in fox density after professional use of poisoned bait. However, they questioned the effectiveness of this technique for protection of sheep flocks when used on a small scale and concluded that either continuous control over small areas throughout the lambing period or collaborative large-scale campaigns may be required to offer maximum protection.

Chapter 5

Conclusion

Foxes are effective generalist predators exploiting virtually all of mainland Britain. In rural areas fox densities tend to be highest in landscape mosaics of woodland and agricultural land, particularly where the supply of the food staples (rabbits, field voles and carrion) are abundant. Afforestation in the uplands has increased habitat diversity and contributed to increasing fox densities.

While the largest forest areas may contain entire fox ranges, most foxes range between forests and adjacent agricultural land, usually within an area of several hundred hectares. Foxes are opportunist feeders and will take lambs and game-birds. However, this tends to be a trait only of certain individuals in a population, often when feeding cubs, which can nonetheless exploit these food resources heavily. Foxes can also have a significant impact on vulnerable scarce species, particularly ground-nesting birds.

Annual recruitment to fox populations greatly exceeds the number required to replace adult mortality, and juvenile foxes readily disperse considerable distances. Efforts to reduce overall fox population density over large areas are therefore unlikely to be successful despite the considerable time and expense. A targeted fox control strategy is more effective, with foxes being killed in response to specific negative impacts at the time when, and in the locality where, the impacts are occurring. Where feasible, night shooting with a rifle and spotlight is the preferred method of killing foxes.

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The red fox *(Vulpes vulpes)* is a generalist predator and scavenger with a wide distribution throughout the northern hemisphere. It is adapted to a range of habitats, and can be found throughout most of mainland Britain and Ireland, from open mountainous regions through all types of landscape to inner city areas. Foxes contribute, with other mammalian and avian predators, to the functioning of the woodland ecosystem.

This Technical Paper

- describes fox biology in relation to forestry,
- reviews information on fox population trends,
- recommends strategies for management of the economic impact of foxes.

It provides a review of literature relevant to the development of policy towards foxes in Britain, for the information of forest managers and other land managers.

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