Fox Control in the Countryside

A Special Report by
The Game Conservancy Trust

THE GAME CONSERVANCY TRUST

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by
Jonathan Reynolds

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Conservation through wise use

Contents

Introduction

The Game Conservancy Trust has undertaken research on foxes and fox control in relation to gamebird conservation since 1985. This research has looked variously at:

- the impact of predation by foxes on gamebird and mammal populations[1-4]
- the methods and strategies used by gamekeepers on shooting estates to control fox predation[5-8]
- the potential for non-lethal methods to control fox predation[9,10,11]
- changes in fox numbers with time and variation between regions

During 1995-97 we undertook a study specifically designed to evaluate the overall impact of culling by man on fox numbers in three large regions of Britain (see *Appendix 5. The 3-Region Study* on page 34)[12-14]. This report focuses primarily on statements that are substantiated by this body of research.

Jonathan Reynolds ear-tags a fox in summer 1986

Definitions

Man's treatment of wild foxes has become a controversial subject in Britain. Unfortunately its many aspects easily become confused by a careless use of English. In this report we adopt precise meanings for a few common English words. By fox **culling** we mean the deliberate killing of foxes by man. Foxes are also killed accidentally by man, particularly through road traffic. Although control of fox numbers ('**fox control**') is usually the chief **aim** of culling, inadequate culling or an inappropriate strategy may lead to ineffectual culling that fails to achieve control. The aim of controlling fox numbers may be common to many human **interest groups** (farmers, game managers, conservationists, public health officers, etc), each group having its own **reasons** (protection of livestock, game or wildlife; rabies control, etc) to seek control. Given that there need be little contact among individuals within or between interest groups, there may be many separate **culling efforts** within any region. The choice of **method** (snares, rifle, hounds, etc) adopted by any of these is limited by various statutes designed with animal welfare and conservation in mind. Some methods (like hunting with hounds and gun-packs - see *Chapter 4* on page 8) are **communally organised**, others (like spot-lamping and snaring) are **independent**. The culling **strategy** may involve a combination of methods used at different times or in different places to produce the fox population level desired. Other terms are defined in the text.

Chapter 1. Fox control in terms of fox biology

The fundamental aims of fox control are to reduce fox numbers or prevent their increase. For this to happen, losses of foxes (culling + other mortality + emigration) must equal or exceed gains (births + immigration). In a large geographical region (the size of a whole county) immigration and emigration will be minor relative to the births and deaths that occur within the region. Rural fox populations produce about two to three cubs per adult, every year. Thus if the population of foxes before breeding was 100, the population would increase unless 200 to 300 foxes died each year. Theoretically, culling might account for most or all such deaths. In reality, the aims of culling may be achieved by a much lower level of culling, because many deaths will also occur through accidental (eg. road traffic) or natural causes (eg. disease, starvation).

At a more local scale (eg. within the confines of a single farm or shooting estate), two further aspects of fox biology - territoriality (see *Appendix 1* on page 30) and dispersal (see *Appendix 2* on page 31) - become important. To reduce fox density on such a small area, culling must remove not only any resident territory-holding foxes and their offspring, but also any 'replacement' foxes that would normally have been excluded by the territory-holders but which now enter because the ground is undefended. These individuals will be either foxes encroaching from neighbouring territories or foxes dispersing from territories farther away. As a result, culls can be locally as high as 25 foxes per square kilometre, even though rural fox densities are typically only 0.5 to 4.0 per square kilometre in autumn, after cub production[13]. High 'bags' like this are peculiar to localised culling in autumn/winter (see *Appendix 3. The impact of local culling* on page 32). It is a mistake to assume that a high 'bag' of foxes taken on a small area indicates effective control of numbers locally (see *Appendix 9. How NOT to judge the success of localised culling* on page 38). In fact, localised culling restricted to spring and summer typically allows smaller 'bags' of foxes, because dispersal and mating behaviour are not taking place at this time of year. Either scenario may be effective or ineffective in terms of the aims (see *Comparison of different methods* on page 13).

Because it draws from a pool of potential replacement foxes in the surrounding countryside, intensive local culling does create a 'sink' effect. But it is wrong to imagine that local culling creates a vacuum that sucks foxes in from far away. Foxes on distant territories cannot be aware of the vacant space, so the local culling effort increases their risk of dying only if they are already committed to dispersal behaviour and actually arrive in the culling area. In spring/summer, when no dispersal occurs, the impact of localised culling on fox numbers does not extend more than a few kilometres outside the culling area.

How does local culling fit into the regional context? The countryside must be pictured as a mosaic of 'sinks' and 'sources'. In **sink** areas culling ensures that mortality exceeds the local fox productivity, while in **source** areas culling is insufficient to prevent an increase in fox numbers. Irrespective of whether a local culling effort meets its local aims (eg. lower predation on gamebirds), it is inescapably a component of fox mortality in the region as a whole. Indeed, because dispersal allows high 'bags' to be attained on quite small areas of land, localised fox culling may contribute substantially to the total cull of foxes in a larger region. If many local culling efforts take place within a region, the impact of these alone could amount to regional control of fox numbers (see *Chapter* 7 on page 18).

Jose Schell/BBC Natural History Unit

Territoriality, involving both scent-marking and aggression, is a fundamental feature of fox biology

Chapter 2. Reasons to cull foxes

In the UK, anyone may kill or capture a fox by a legal method, but they must have the authority to be on the land to do this, otherwise they commit a trespass (an armed trespass if carrying a firearm). Only the landowner or tenant farmer is in the position to grant this basic authority. Hence, whatever the personal motivations of those who actually carry out fox culling (eg. gamekeepers, hunts, pest controllers), the motivation of landowners or tenant farmers to cause or allow fox culling is paramount. (For simplicity we now refer to these two sets of people as **farmers**.)

In our 3-Region Study (see *Appendix 5* on page 34), we asked farmers to indicate their reasons for causing or allowing fox culling on their land[14]. Not surprisingly, these reflected variation in land-use between regions. Thus 94% of farmers in Mid-Wales cited protection of livestock, but only 28% in predominantly arable West Norfolk. Conversely, although only 29% in Mid-Wales cited protection of game, game interests motivated 75% of West Norfolk farmers (see Figure 1).

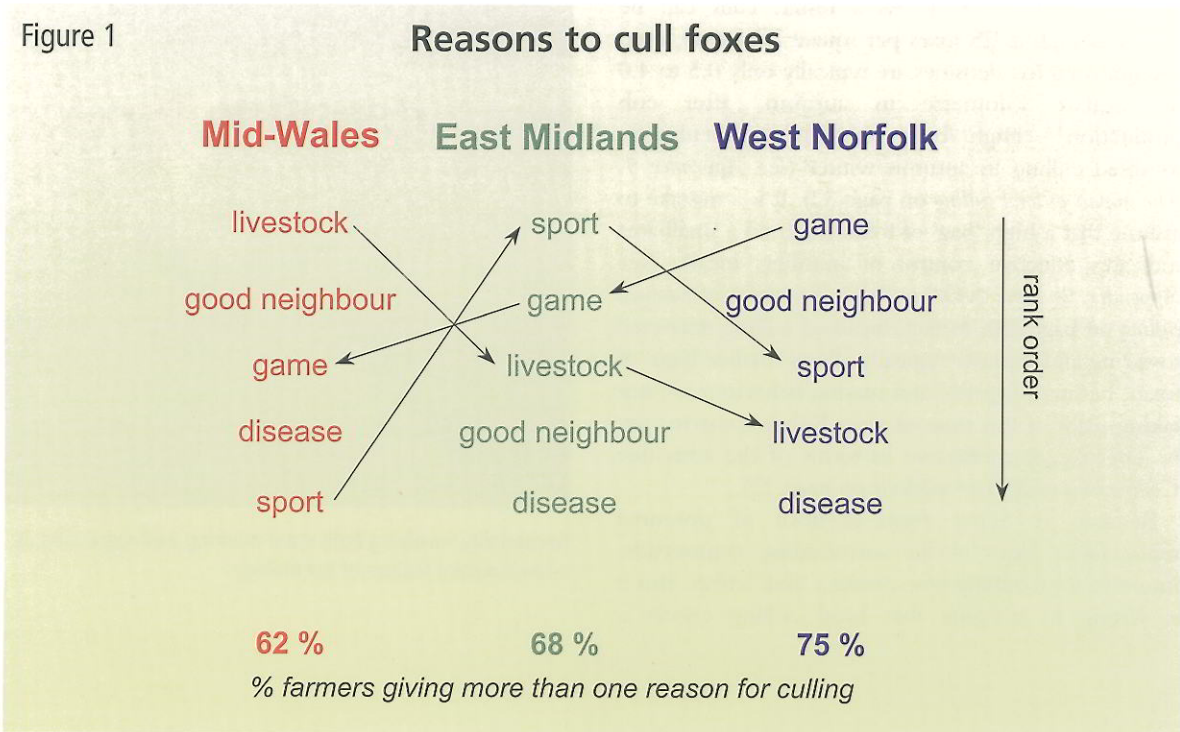
Although on small farms recent experience of livestock, poultry or game losses had often inspired independent culling effort, it did not increase or decrease the involvement of communally-organised methods like hunting with hounds. On larger farms, recent experience did not influence the decision to cull in any way. Thus fox culling decisions seem to be based on long-term personal experience, or on collective experience embodied in regional culture. Most culling is done, not in reaction to a current problem, but as a preventative measure. We re-consider the case that fox culling is actually beneficial to livestock, game and wildlife interests later (see *Chapter 9* on page 23).

Most farmers (62% to 75%, depending on region) gave two or more reasons for culling foxes. Local fox culling for the benefit of neighbours was widely cited by farmers in all regions (35-54%), but only 6.5% of this group gave 'good neighbour policy' as their sole reason for culling, so the principal motivation for virtually all farmers is self-interest.

Sport was usually cited in combination with other reasons. In Mid-Wales, not a single farmer cited sport alone. In the East Midlands 57% cited sport, but only 14% cited sport alone. No farmer claimed sale of pelts as a reason for culling.

12% of farmers did not cull foxes or allow fox culling. Among these, the commonest reason cited was lack of necessity, followed by a perceived benefit from the presence of foxes. Half of these non-culling farmers stated that they would consider culling in the future if the fox population increased. Only one fifth of non-culling farmers (2.5% of all farmers) stated that they did not approve of fox culling.

Figure 1



Reasons cited by farmers for killing foxes in our 3-Region Study. The rank order of reasons like game, livestock and sport reflected land-use in the three regions. Importantly, most culling was done for two or more reasons

Chapter 3. Aims of fox culling

What do people hope to achieve by culling foxes? In our 3-Region Study, we asked farmers to indicate from a prompt list the aims of their culling policy (or to state other reasons):

- to eliminate losses of livestock, reared or wild game, or other wildlife prey
- to reduce losses to an acceptable level
- to remove troublesome individual foxes
- to reduce the fox population locally
- to contribute to regional control of foxes

Aims proved to be related to both farm size and region. The aim of totally eliminating losses was more common on small (less than 200 hectares) farms, while on larger estates (more than 200 hectares) reducing losses to an acceptable level was more often the aim. For small farms, regional differences were also evident, with small farmers in the East Midlands more tolerant of losses due to fox predation than their counterparts in Mid-Wales and West Norfolk.

Importantly, only a quarter of farmers had purely local aims: three-quarters cited regional control of fox numbers as an aim of their culling regime.

In all cases, the expectation of culling is to achieve a temporary effect. Although the complete eradication of foxes may be a justifiable conservation aim on continents or islands where foxes have been artificially introduced (eg. Australia), very few people would wish to see their extinction from Britain. It is an accepted aspect of culling that dispersal tends to even up fox density, so that culling - like gardening or farming - is a temporary management process.

John Darling

Among gamekeepers, night-shooting using rifle and spot-lamp nowadays accounts for the greatest proportion of foxes killed

Chapter 4. Fox culling methods

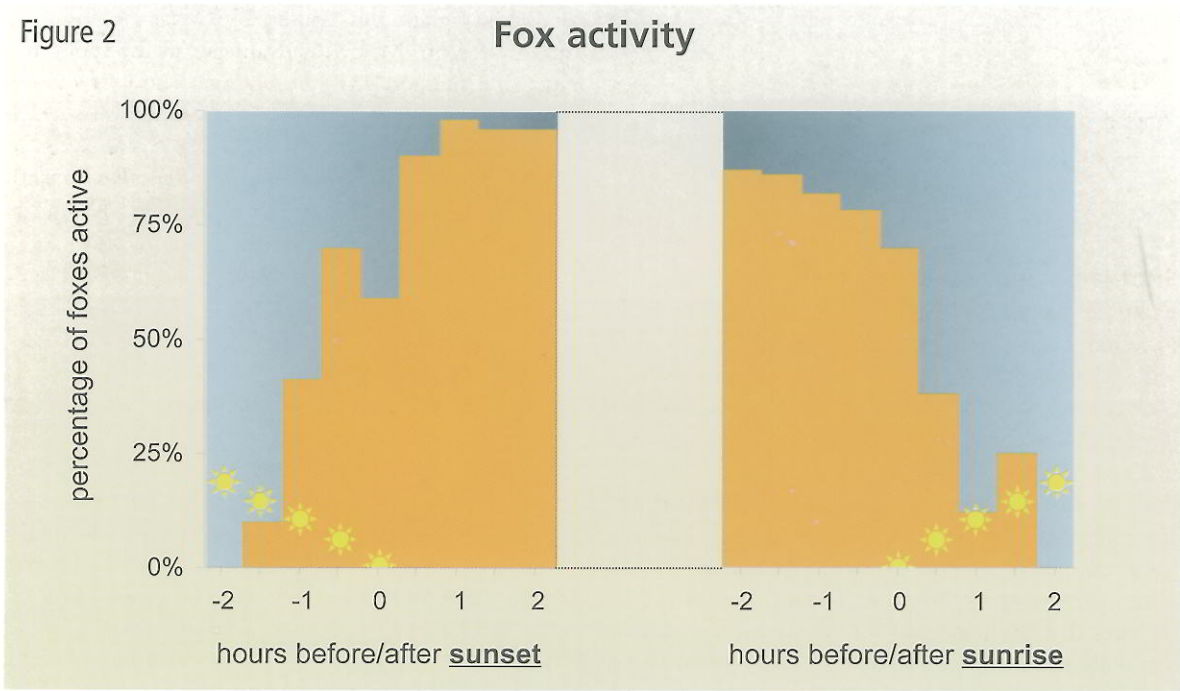
Even in the 21st century, fox culling methods are dictated by the nature of foxes. The long association of foxes with bigger predators, especially man, has selected in favour of genetic characters that contribute to a pronounced 'wariness'. (This was clearly demonstrated by Russian fur farmers who managed to breed calmer, domesticated foxes by imposing the opposite selection forces among their stock animals, favouring 'tameness' rather than wariness or aggression[53].) On top of its innate wariness, a fox, like a dog, has a considerable ability to learn during its lifetime. Foxes are of course nocturnal (see Figure 2), lying-up during the day in thick cover. Adult foxes rarely spend much time underground, except during particularly cold or wet weather or, in the case of vixens, for a few weeks around the birth of their cubs.

The methods used successfully to take adult foxes therefore fall into two categories. Night-time methods (see page 9) require either a lamp or image intensifier to make the fox visible to the operator, or else traps and snares that work in his absence. Daytime methods (see page 11) require the fox to be flushed out of cover. Additionally, the foxes' need for an underground earth to shelter cubs while they are very young creates a vulnerable period during which it is easier to locate both cubs and adults (see page 12). Because adults have to provide solid food to their cubs, their activity may also extend further into twilight hours during spring and summer, creating more opportunities for shooting without spot-light or image intensifier.

Most fox culling is done without conscious selectivity, as it is difficult at any distance to distinguish males from females, or young from old. From April to August cubs can be distinguished from adults, but this too becomes increasingly difficult as autumn approaches. Different culling methods are believed to address different sectors of the fox population, but apart from obvious generalisations (such as a preponderance of females among adults shot at cubbing earths; and predominantly young foxes caught in cage traps or shot after being attracted with a squeak) few data are available to support this. Systematic exploration of this is difficult, because biologists too must use the same capture methods to study the population.

Fox culling methods can also be categorised by how they are organised and the geographical scale on which they are practised. The decision to cull foxes or not, and the choice of strategy and methods vary from one estate to another according to the needs and preferences of farmers. For individual estates, **independent** culling efforts are most likely to involve

Figure 2



Activity in rural foxes is clearly synchronised with sunset and sunrise. This diagram is based on records of radio-tagged foxes in north-east Dorset. Because night-length varies seasonally, the middle of the night is not shown. There is often a period of inactivity around midnight during long autumn/winter nights.

night shooting, trapping and snaring, often carried out by professional gamekeepers. Other methods (mostly daytime methods involving the use of hounds and terriers) have to be organised **communally** and require the consent of several or many farmers. In upland areas especially, fox control groups exist with the aim of controlling fox numbers over quite large areas. These are often supported by subscriptions from farmers. In Scotland, there is also limited financial support from the state; similar support was abandoned in England and Wales in 1979, and Northern Ireland in 1977.

John Darling

Lamping is difficult for a single operator

Night-time methods

Spot-lamp and rifle ('lamping')

Lamping describes the use of a rifle (usually high powered centre-fire .22, .22/.250, or .243 calibre) with telescopic sight, in conjunction with a powerful spot-lamp, usually from a four-wheel-drive vehicle. This is difficult for a single operator, so even among professional gamekeepers it is usually carried out with one or two assistants. Foxes are searched for by scanning with the lamp, and detected by the reddish light reflected back off the retina. This can be seen for over a kilometre when there is no mist. Detection requires that the fox looks directly at the lamp, as it normally does. However, before a shot is taken, safety requires that the fox is close enough to see its body and thus identify it as a fox: shooting at two points of reflected light is extremely dangerous[15]. If when located the fox is too far off for a safe shot, squeaking sounds will often bring it running towards the lamp. This trick is most successful with young, naive foxes during autumn, allowing rapid culling. (In autumn 45% of foxes seen with a lamp are killed. This falls to a minimum of 28% in March.) If the fox will not approach, it is necessary to manoeuvre the vehicle closer to the fox.

A fairly common complaint among gamekeepers is 'lamp-shy' foxes that will not stop or look at the lamp for long enough to take a shot. This behaviour suggests that these individuals have previously been frightened by the lamping method. Foxes become frightened by near misses, cues associated with the lamping vehicle, and (of course) by non-fatal injuries. There are unfortunately no data on what proportion of foxes shot at are killed, though this clearly depends on operator skills.

The spot-lamp and rifle method is dependent on good vehicular access, the absence of cover, and on terrain that allows safe shots. Small fields, many gates (as in pastoral areas), absence of tracks (in arable areas), small farm size, rough terrain and steep slopes can all make it unworkable as a control method. Safety is primarily a matter of judgement and responsibility for the operator, but many police firearms officers require to inspect the ground with safety in mind before issuing a licence. The number of foxes seen varies seasonally with fox density and the height of vegetative cover, from a maximum in August (after cub production and arable harvest) to a minimum in March. Roughly 30% of all foxes killed by professional gamekeepers are taken by lamping, though this proportion varies considerably by season (50% during autumn/winter, 20% in spring/summer) and by region. Major disadvantages of the spot-lamp and rifle method are the anti-social hours required, and a low return per unit effort. Although average autumn/winter values are 0.2 to 0.6 foxes per hour (dependent on region) the return dwindles towards zero as the pool of replacement foxes dries up. Maintaining fox density at such locally low levels requires a resignation to many blank nights, or the use of other methods, such as snares.

Spot-lamp and rifle can also be used less successfully on foot or from a stationary high seat. The latter is probably the public perception of 'fox culling by an expert marksman'. Actually, night or day, the use of a stationary high-seat away from cubbing earths is extremely inefficient, because the likelihood of a fox passing in range within a reasonable space of time is very low. This is partly because rural foxes do not use their territories all that intensively. (For instance, in an area of Dorset with quite a high density of around three adult foxes per square kilometre, a fox travelling at normal speeds might circumnavigate its territory once per night, but rarely does so. As a result, when baits are placed within a territory and renewed daily, any single bait site receives on average only one visit

every three days by any fox, even though the baits are eagerly eaten when found.) A second reason for poor success from high seats is that the marksman cannot predict the fox's approach direction, so there is a risk of the fox catching wind of the marksman and avoiding him. (Similarly, it is far easier to film a fox with an unmanned camera than with a manned camera.) Lastly, the population is actually decreasing during any culling exercise. Foxes can be called towards a stationary operator by squeaking, but again this is most successful with young foxes. In fact, most foxes shot from high seats are either at a cubbing earth, or are shot opportunistically during deer culling operations.

Infra-red illuminators and scopes, and image intensifiers, are legal for fox control but expensive and uncommon. Neither method uses a visible light source capable of attracting the fox's attention. Hence detection is primarily by body shape and on a monochrome display, preventing detection at long range. These devices are therefore less valuable than visible light spot-lamps, except from a stationary high seat.

The use of a spot-lamp with a running dog (large lurcher or greyhound) rather than a rifle is popular in some areas of the UK. This tends to be practised as an unauthorised sport rather than legitimate fox control.

Traps and snares

Only live-capture traps and neck snares are allowed under UK legislation. Live-capture traps depend on the fox first entering a box or cage structure and then triggering a door release mechanism. Innate or learned wariness in the fox may prevent either of these things happening. Live-capture traps are extremely successful in an urban context, but rural foxes are typically cautious of novel man-made objects, severely limiting the efficacy of traps. Among professional gamekeepers, live-capture traps account for just 1% of all foxes taken. They are more successful when set at poultry runs or release pens than elsewhere, but it is illegal to bait a trap deliberately with a live bird.

Snares are set on any route-way likely to be used by a fox, and will catch only if undetected by the fox. This is reasonably easy to achieve, making the snare a powerful tool against wary adult foxes. In fact, this is the only culling method available where prolonged use cannot result in an untrappable population through selective removal of unwary individuals. An indication of this is that catch-per-effort for snares peaks in mid-winter when dispersal is at its height, rather than summer or autumn when the highest proportion of the population is naive.

Legislation prohibits the use of 'self-locking' snares, apparently with the intention of preventing the deaths (by strangulation) of non-target species. The use of a 'stop' to prevent closure beyond a minimum diameter

John Darling

Snares are highly effective in conditions where other methods fail

is probably more important in this respect, but is not a statutory requirement. Operator skills strongly influence capture rate and non-target captures, and whether captured animals are killed or held alive. Careful siting and frequent inspections can result in close on 100% of captured foxes being held alive. Wildlife biologists in the UK use neck snares as the only viable way to capture rural foxes alive for radio-tagging. Radio-tracking of tagged animals after release reveals no detectable deviations from normal behaviour.

About 25% of foxes killed by professional gamekeepers are taken using snares, though this proportion varies with regional circumstances. Snares are unpopular in sheep-farming country during the lambing season due to the risk of lambs being caught. In upland regions, snares are most often set around a buried carcass bait, with a surrounding fence that keeps sheep out but allows free passage by foxes - this arrangement is known as a 'midden'.

Daytime methods

Hunting with hounds

The essence of hunting with hounds is that man has taken the wolf - a natural predator of foxes - domesticated it to make it manageable, and bred it in two quite different directions. This has produced on the one hand large, fast hounds with enhanced trailing abilities that can pursue and catch a fox above ground, and on the other hand very small terriers to locate and corner the fox that has gone to ground. Combined use of the two breeds of dog provides a unique daytime method for culling a nocturnal animal.

Each registered hunt has an exclusive 'country' allotted by the Master of Fox Hounds Association, within which it negotiates permissions to hunt from individual landowners. Historically, the purpose of the country was to avoid border disputes between neighbouring hunts - it implies nothing about rights of access, which must be negotiated individually with each landowner. About one-fifth of England and Wales is not included within any registered hunt country, although there may be hunting by unregistered packs there. Within each hunt 'country' there are 'no-try' areas where no attempt is made to hunt or to seek permission, usually because the land is unsuitable for hunting. On average, no attempt is made to hunt 19% of each hunt country, usually because it is deemed unsuitable (eg. too built-up). On average, permission to hunt is sought but denied on 2% of the allotted 'country'.

Several discretionary aspects of present-day fox hunting influence the number of foxes killed. The amount of land any pack attempts to hunt, the number of meets per season, the distribution of meets in relation to fox abundance, and the length of the hunting season all determine culling intensity - as do the decision as to whether to dig out foxes that have gone to ground, and the proportion of the season run under early season rules (limited field, early morning meets). For many hunts, current choices on these aspects can only be interpreted as a policy of moderation, implying that the impact of hunting could be increased if desired. The hunt's moderation ethic also influences the fox culling strategy of others, so that for instance many shooting estates within hunting countries have a sympathy towards this ethic and refrain from intensive independent culling.

Gun-packs and standing guns

These methods involve the use of a small pack of hounds or a team of human beaters, to flush foxes out of cover towards a line of standing guns. This approach is most often used in dense woodland, especially commercial softwood plantations. The choice of hounds or human beaters varies regionally depending on availability, but hounds are clearly better in very dense cover. Some foxes may be caught and killed by the hounds before they reach the guns.

For safety, and because the opportunity to shoot an emerging fox is usually brief, shotguns are almost invariably used. At sufficiently close range the size of shot used hardly matters, but as range increases so does the risk of non-fatal wounding. (The number of shot per unit area of the 'pattern' falls with increasing distance. A cartridge can hold more small shot, giving a denser pattern, but their momentum falls below a critical threshold at a smaller distance than with larger shot. Larger shot hold their momentum better, but because there are fewer of them the 'pattern' will have gaps. Either way, wounding can result.) For this reason one code of practice recommends a maximum range of 20 metres[15]. If hounds are used, wounded foxes may be trailed and caught by the hounds.

Digging with terriers

Digging out with terriers is widely practised by fox hunts and other communal fox control groups, as well as by small groups or individuals, such as gamekeepers. As with other methods involving dogs, terrier work has an enthusiastic following for its own intrinsic interest.

Paul Quaglianna/Shooting Times

The use of terriers is the only legal method for taking a fox that is underground

For fox hunts registered with the Masters of Fox Hounds Association, 37% of foxes killed are taken by digging out (average for 145 hunts over four seasons, 1992-96; range for individual hunts 0% to 86%). Foxes are not dug out unless this has been requested by the farmer on whose land the fox has run to ground. Known earths in the area to be hunted may be lightly blocked prior to the meet. Where this is practised, it will obviously influence the proportion of the cull taken by digging. In our 3-Region Study, digging with terriers accounted for 3%, 10% and 9% (East Midlands, West Norfolk and Mid-Wales respectively) of the independent (non-hunt) cull.

Terriers can be entered speculatively into any earth, pile of straw bales, very thick cover, etc to locate and either bolt or corner the fox. More usually, terriers are entered only where hounds have marked a fox to ground, where tracking in snow has shown that a fox has entered, or where there is evidence of a cubbing earth (see below).

Fieldcraft skills are critical, as it is illegal (and undesirable) to enter a terrier or dig in any place in regular use by badgers. This may be a very limiting condition in hill areas where rock piles are commonly used as shelter or cubbing earths, as neither species leaves much surface evidence in these situations.

Foxes cornered by the terrier must be dug out. A radio-transmitter collar on the terrier aids economical and rapid digging. Once exposed by digging, the fox must be dispatched humanely, for which a .22 pistol firing a free round is recommended. In some cases the fox may be killed underground by the terrier - this is particularly likely with fox cubs. Foxes are usually prevented from bolting by lightly blocking tunnel entrances, and those that attempt to bolt can be dispatched there. In straw stacks and elsewhere, bolting foxes are either shot with a shotgun on emergence, caught using large purse nets placed over entrances, or caught by a lurcher dog.

Culling at the cubbing earth

The cubbing earth provides a focal point within the territory where adults as well as cubs may be culled. Foxes culled at the cubbing earth must be either shot (with a rifle or shotgun), dug out or caught in nets (after sending down a terrier to locate and bolt or corner the fox), or trapped using cage traps set into the tunnel entrance (effective only for cubs older than eight weeks; usually ineffective for adults). Gassing foxes in the earth is not forbidden in principle, but no substance is currently licensed for this purpose. Any such product would need to satisfy pesticide safety standards on efficacy, humaneness, human safety and non-target hazards.

Earths used for cubbing are difficult to recognise early in the spring, but become more obvious as evidence of occupation accumulates around them. Among gamekeepers, the aim will be to destroy resident breeding females as early as possible in the season. About 24% of breeding earths are located before cubs are active above ground. Correspondingly, 25% of vixens killed at the earth are killed before cubs can be culled or even counted, unless by the use of a terrier. Together, cubs and adults taken at earths constitute about 25% of the annual cull for gamekeepers, though this figure varies according to the type of shoot (primarily wild or released birds) and fox control strategy (see *Chapter 5* on page 15). Roughly 80% of adults killed at cubbing earths are females.

Non-lethal approaches to fox management

Physical barriers such as wire netting are valuable to prevent loss of poultry, gamebirds or livestock held in small areas, but are not practicable to protect them on any wider scale. Electric fencing has been used with partial success to protect wild ground-nesting birds on nature reserves, but experience has shown that it must usually be backed up by lethal control methods. It is also applicable only to colonial nesting species (eg. terns) whose nests are concentrated in small areas, or to a very few individual nests (eg. stone curlews).

Jonathan Reynolds

Physical barriers are valuable to protect birds or stock held in small areas, but are not practicable on a wider scale.

Jonathan Reynolds

In rural areas, live-capture traps of all kinds have a low catch-per-unit-effort

Two other non-lethal approaches have been widely discussed: manipulating foxes' food preferences (**conditioned taste aversion** or **CTA**) and fertility control. CTA has been the subject of recent intensive research by both The Game Conservancy Trust and Central Science Laboratory (MAFF). It is now clear that deployment difficulties and non-target hazards make it non-viable for fox management in the UK. Because reproductive biology is so similar in all mammals, the only safe approach to fertility control for wild animals is by exploiting the body's immune system (**immuno-contraception**). This too has been the subject of intensive research over several years by Australian and French government scientists. Again, despite enormous expenditure, many practical problems stand in the way of a workable methodology.

Comparison of different methods

Comparison of different culling methods can be very misleading. Part of the problem is how to measure the efficiency of a culling method. The comparison often made is of foxes killed in a given time-span. Unfortunately, this **catch-per-unit-effort** is a confused measure of both the efficiency of the method and the opportunity to cull. For instance, a high catch-per-unit-effort is possible only where there are many foxes to cull. Catch-per-unit-effort would be very low indeed when no foxes were present! Fox density varies three-fold within a year, and at least six-fold between regions of Britain. This will clearly distort comparisons of catch-per-unit-effort between methods whose use differs between seasons and regionally. The only reliable measure of **efficiency** is how much effort is required to catch a fox that is known to be present. Efficiency would then be quoted as captures per fox-day, or fox-days per capture (a fox-day being one fox present for 24 hours). To measure this would be a testing assignment for any wildlife biologist, but the point is not merely pedantic: any other measure is misleading and an unsafe basis for political decision-making.

For example, a gamekeeper in the south-east of England who went lamping for three hours, two nights a week, could shoot a fox almost every time throughout the autumn and winter (see *Appendix 9. How NOT to judge the success of localised culling* on page 38). This is possible only because dispersing foxes replace those shot. Such a rate of culling could not be sustained where the regional fox population was low, offering a small pool of dispersing foxes (see *Appendix 3. The impact of local culling* on page 32, and *Appendix 9* (Norfolk) on page 38). Nor would it be possible across a large region, because on such a scale immigration from outside will be minor compared with the size of the 'resident' population - foxes that are killed are likely to be replaced only by reproduction within the region.

Jim Meads

The Eryri huntsman watches his hounds draw rugged country in north Wales. Remote and difficult terrain can severely limit the practicality of methods effective elsewhere

Another part of the comparison problem is that time may not be the best measure of effort. Neck snares, for instance, have a low capture rate per snare and per day, yet they function in the absence of the operator. Snares also illustrate the problem of seasonal comparisons described above. They are less suited to the winter months when there is little vegetative cover in which to conceal them, but in spring/early summer when cover is higher the fox population itself is at its minimum and capture rates will inevitably be lower. Nevertheless, in spring/summer snares can contribute substantially towards a focused and effective culling strategy, not least because tall cover and short nights diminish the value of spot-lamp and rifle at this time of year.

Financial efficiency may be as important a consideration as efficiency of time or effort. Because of the number of followers, fox hunts have an apparently low capture rate per unit effort. In fact most of the followers are irrelevant to the success of the hunt, except in as much as their subscriptions pay for the upkeep of the hounds and hunt employees. The essential cost of hunting with hounds amounts to those sums, plus the time of essential volunteers like the whippers-in. However, the cost to the farmer may be zero or very small.

A further serious problem in comparison is that a culling method is rarely used exclusively. Usually any given fox is at risk of being killed by several culling methods. But a fox killed by one method is no longer available to be killed by any other method, and as a result there is a degree of interdependence between the culls obtained by each method. (If one method were banned, the culls taken by the others would certainly increase. Biologists know this as **compensation**.) Because of this interdependence, comparisons of methods may be very confused by the exact mix of methods used.

Finally, although economy of time, effort and money are important, the number of foxes killed may not be. Paramount is that the aims of culling are met (see *Chapter 3*, page 7 and *Chapter 5*, page 15). For some aims, the cost of not culling must also be considered. For instance, if regional control of fox numbers is the aim, the cost of not culling may be an increased fox population causing greater damage levels and requiring a greater effort to bring back into control.

Chapter 5. Fox culling strategies

Local culling strategy

Consciously or not, the farmer (or his 'man on the ground') adopts some strategy to achieve his aims, determining the choice of culling method(s), the amount of effort, and the timing of culling. Because different methods are best suited to particular seasons (see *Chapter 4* on page 8), these aspects are closely inter-linked.

Fox for fox, the greatest impact on population growth is achieved by culling during the period early February to late March when the fox population is largely settled into territories, the highest proportion of vixens are pregnant, and following the period of highest 'natural' (non-culling) mortality associated with dispersal. This also immediately precedes the period when fox predation is most significant for livestock, wild game (but not reared game) and conservation interests. However, this window of opportunity is generally insufficient to achieve the level of culling necessary to control fox numbers. Besides, factors other than efficacy - eg. cost, practicality, opportunity, ethics - also influence the choice of culling strategy.

Some forms of culling are free to the farmer if he allows others to enter his land. Culling by communally-organised groups is free because the participants have an enthusiasm for the control method in its own right. Associated with this enthusiasm is often a hunting ethic demanding moderation (see *Hunting with hounds* on page 11). Essentially, the bargain struck between farmer and hunt is that the hunt is given privileged opportunity to cull provided that fox numbers do not exceed acceptable levels. Because fox hunts operate primarily in autumn/winter when dispersal tends to even out fox density, the service they offer the farmer is regional in its effect. However, where required by landowners, many hunts are prepared to operate 'lambing calls' in spring to cull selectively those foxes that kill lambs. Gun-packs, also communally organised, are especially active in late winter/early spring.

A farmer employing a professional gamekeeper in the interests of game management may not share the moderation ethic (although many do). A gamekeeper costs around £30,000 a year, and this expenditure must be considered worthwhile in terms of the shooting generated. On wild bird shoots especially, fox culling effort will be particularly intense during April-July, when breeding earths are easily located and gamebirds are nesting. If reducing predation on nesting gamebirds were the sole aim, this should be a sufficient strategy. However, predation on reared game, and contribution towards regional control are often additional aims, so most gamekeepers cull when

Stephen Tapper

Sheep predation is a common motivation for fox control

they have the opportunity, accepting that culling efficacy is lower at other times because dispersal causes foxes to be replaced. Among gamekeepers in general, roughly half the foxes culled are taken during April-July. 80% of these are cubs.

Although logical and effective for a number of aims, the strategy of culling during spring and summer has a welfare cost not shared by culling in other seasons (see *Appendix 4. Culling at the breeding earth* on page 33), though this is no worse than in control of other species such as rabbits, hares, squirrels, mink and many bird species. The strategy may also not be practicable for a gamekeeper who rears gamebirds for release. Rearing neatly avoids the problem of nest predation by removing that life-history stage into predator-free conditions in captivity. However, the work of maintaining a large rearing unit will prevent the gamekeeper spending time at predator control during spring/summer. Furthermore, rearing produces young birds that have yet to learn about predators and must be protected around the time of release. Hence both the opportunity and the requirement to cull foxes shift to autumn, when the size of the fox population and dispersal substantially increase the task. These circumstances favour the method of spot-lamping with a rifle.

Regional culling strategy

Although a regional impact on fox numbers is an aim for the majority of culling efforts (see page 6), few people are in a position to organise a fox culling strategy over large geographical areas. Communally-organised hunts and fox destruction clubs are better placed to do this than anyone else, but they do not have exclusive command over fox culling. In our 3-Region Study, although organised groups operated on 88% of farms with culling, 33% to 91% of these farms (depending on region and farm size) carried out additional fox culling independently[14]. In some regions, therefore, the net impact on fox numbers is more the incidental result of local actions than the outcome of regional planning.

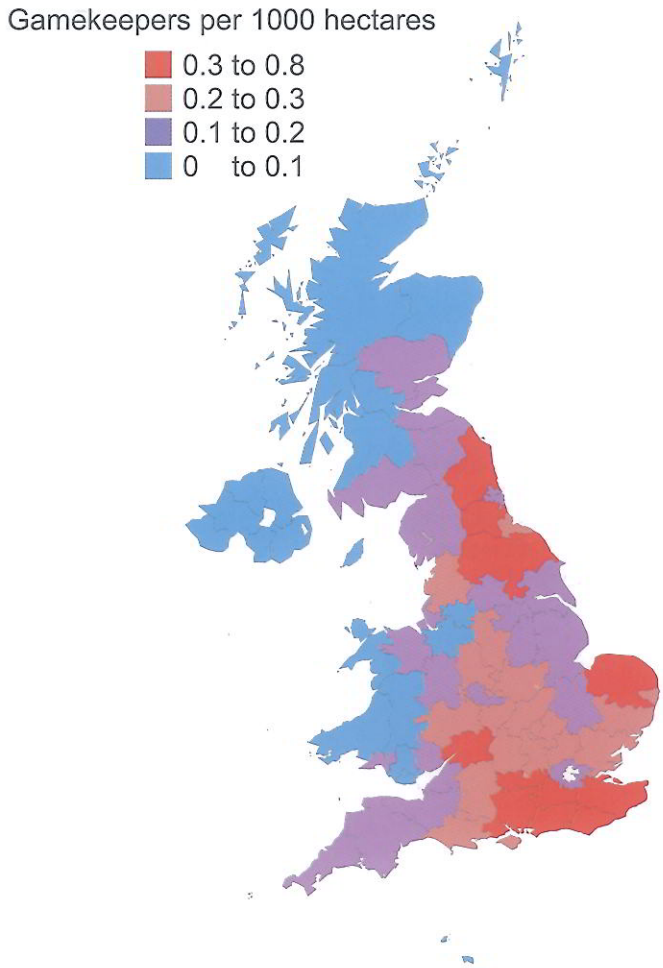
Jonathan Reynolds

The nesting season is the period when wild gamebirds are especially vulnerable to foxes

Chapter 6. Prevalence of fox culling and different methods

In our 3-Region Study, fox culling took place over 88% of land properties, but this varied between the regions. As with the reasons for culling and its aims, variation in this percentage was attributable to obvious differences in land use. In Mid-Wales, virtually all farms had sheep and/or poultry and perceived a need to cull foxes to reduce losses. In West Norfolk - a predominantly arable area - the decision to cull or not on any farm depended primarily on whether there was also a game shooting interest. The East Midlands had a mixed agriculture and showed an intermediate prevalence of culling.

The prevalence of different methods also varied with a distinctly regional character (see Figure 3). Communal methods such as hunting with hounds, gun-packs, and digging with terriers were practised on almost every farm in Mid-Wales, where fewer than 10% of land properties had a professional gamekeeper. Spring/summer culling was uniquely important here, and was reflected in high fox mortality during these two seasons. Gun-packs (involving hounds to drive foxes out of cover to standing guns) were used only in Mid-Wales. In West Norfolk, the bulk of culling was carried out independently by professional gamekeepers on large estates, hence shooting with a rifle and spot-lamp, and snaring, were the methods most commonly used.



The number of gamekeepers reflects regional game-shooting interests (data summarised by county)

Figure 3

Prevalence of culling methods

Mid-Wales	East Midlands	West Norfolk
hunting	hunting	rifle
standing guns	rifle	hunting
rifle	standing guns	snare
digging earths	snares	standing guns
lurchers	cage traps	digging earths
snares	digging earths	cage trap
other!	other!	other!
cage traps	lurchers	lurchers

rank order

Prevalence of culling methods in the 3-Region Study, ranked in order of prevalence. Choice of culling methods has a distinctive regional character

Chapter 7. Regional impact of fox culling

Our 3-Region Study (see *Appendix 5* on page 34) was designed to evaluate the regional impact on fox numbers of culling by all the various interest groups. A simple comparison of the number of foxes culled with the size of the three fox populations suggests that in all three regions the cull is very large, and is probably the major cause of fox mortality (see Figures 4 and 5).

Figure 4

Fox abundance in the 3-Region Study

Fox abundance, measured by spot-lamp survey, differed markedly between our three study regions. Characteristically, numbers are high in autumn (early September) after cub production and low in spring (late February) before breeding, but the relationship between the three regions remained constant in two successive years.

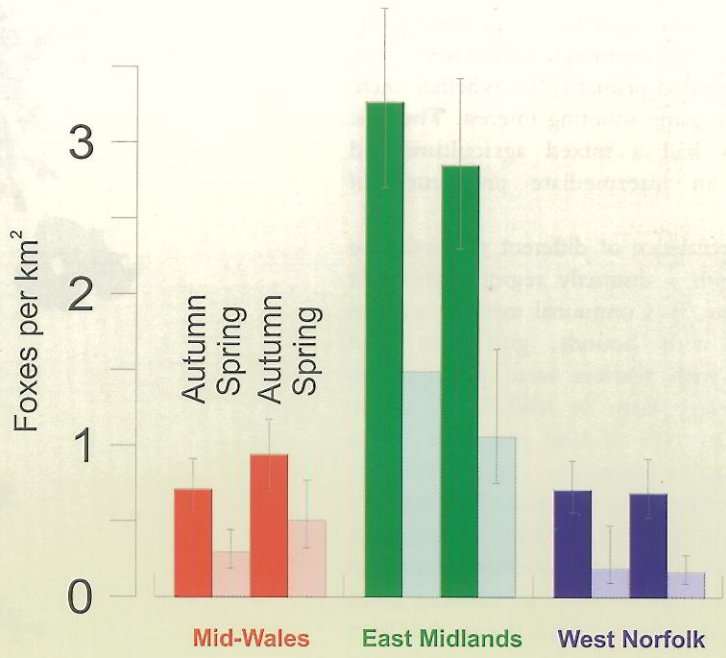
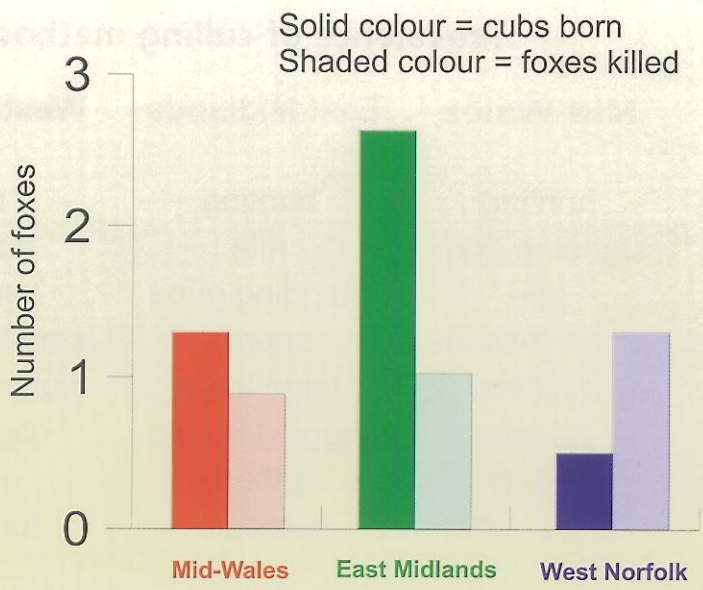


Figure 5

Cub production compared with cull

If culling is an important determinant of fox numbers across whole regions, the size of the total cull must be substantial compared with the capacity of the foxes to produce cubs. This figure compares the cub production of each regional fox population with the cull as reported to us by farmers.



Reported cull figures contain reporting or recording errors that are mostly unquantifiable, and are not in themselves a reliable basis for conclusions. Instead, our procedure was to use the comparison of cull with fox density to construct a falsifiable hypothesis about each population. We proposed that the Mid-Wales and West Norfolk populations were suppressed by the high levels of culling found there, whereas fox density in the East Midlands was likely to be closer to some 'carrying capacity' set by the resources available. Productivity was used as the criterion to distinguish a population that is crowded relative to its resources, from one that is well below such a level (see *Appendix 6. The relationship between productivity, population density and resources* on page 35).

As well as the heavy cull on them, fox populations in Mid-Wales and West Norfolk were at very low density and had high productivity. The less heavily culled fox population in the East Midlands was at high density and had low productivity. The East Midlands was in fact the only region of the three in which we found vixens that had failed to produce any cubs at all - 20% of vixens here fell into this category. Reproductive under-performance in East Midlands vixens happened at all stages of pregnancy, supporting the interpretation that this was caused by crowding effects.

We concluded that fox numbers in Mid-Wales and West Norfolk were suppressed due to heavy culling pressure (see Figure 6). In the East Midlands, culling pressure was not heavy enough to achieve this and fox density was closer to the carrying capacity of the environment. Even here, though, there was probably scope for population growth, because productivity was not as low as in some dense urban fox populations[16]. Other important implications of the 3-Region Study are listed in *Appendix 8. Conclusions and implications of the 3-Region Study* on page 37.

We caution against drawing the conclusion that hunting with hounds and mounted followers is inefficient (on the grounds that this method was most prevalent in the East Midlands region, but that culling intensity and the impact of culling were lightest there). Compared with the other two regions, the intensity of fox culling was deliberately restrained in the East Midlands. Fewer farmers had livestock or game at risk of predation, and the most vulnerable group (those with farms smaller than 200 hectares) were more tolerant of losses than in the other regions. Digging was similarly restrained: although 40% of foxes were run to ground during hunting, only 18% of the hunt cull was taken by digging out. Where culling was practised independent of the hunt - as on shooting estates - its intensity (foxes killed per square kilometre) was lower than in either Mid-Wales or West Norfolk, despite fox density being over three times greater than in Mid-Wales and over four times greater than in West Norfolk.

Figure 6

Fox productivity

REGION	embryo scars per uterus	% intra-uterine losses	litter size	% non-breeders
expected:				
saturation density	**low**	**high**	**low**	**high**
suppressed	**high**	**low**	**high**	**low**
observed:				
Mid-Wales	7.9	6	6.4	0
East Midlands	6.4	31	4.5	20
West Norfolk	7.8	18	6.2	0

Productivity is expected to be impaired in a fox population that is close to the saturation density determined by resources. Conversely, a population suppressed well below that level - for example by culling - would exhibit much higher productivity. Of our three study regions, Mid-Wales and West Norfolk conformed to the 'suppressed' model, whereas the East Midlands was closer to the 'saturation' model.

Chapter 8. Historical aspects

It is very difficult to census foxes. Before our 3-Region Study began in 1995, there was no direct measure of fox numbers in any large area of Britain. Prior to that, our sole sources of information were from very localised censuses of breeding earths and radio-tracking studies from the period 1970-95[17]. So we will probably never be able to piece together the ups and downs through history of fox numbers in Britain. However, any reconstruction of earlier centuries based on historical anecdote must run something like this[8,18].

Forest clearance and the creation of an agricultural landscape in Britain created conditions that were very favourable for the fox, significantly enhanced by the introduction of non-native prey species (brown hare, rabbit, pheasant, domestic poultry). However, conflicts with human interests in the peasant society of medieval rural Britain would also have meant that fox culling was widespread and intensive. In Tudor times culling of 'vermin' became nationally subsidised through a bounty scheme administered parish by parish. The bounty on foxes was 12 times greater than that on any other species. Until the 17th century, hunting writers regarded fox hunting as a matter of pest control with no intrinsic interest. By the early 18th century though, sporting interest in hunting had developed to the extent that it was widespread and even fashionable. Shooting estates, with their policy of intensive predator control, came to prominence during the 18th and 19th centuries. Increasing complaints by fox hunters about shortages of foxes, and the development of moderation ethics, probably reflect the fact that overall culling pressure on the fox was very high.

The industrial revolution caused a substantial movement of the rural population into towns. The invention of wire netting towards the end of the 19th century also made it easier to keep foxes and poultry separate, while the increasing centralisation of food production also decreased the importance of small-scale poultry husbandry to the rural economy. These developments probably decreased the need among the rural population to cull foxes to protect their own interests.

In the 20th century, the predominance of shooting estates was greatly upset by the two World Wars. The number of gamekeepers in employment fell to one tenth of its pre-war levels (from 23,000 to 2,500). Throughout the 20th century, legislation has progressively outlawed methods of fox culling that were unacceptable on grounds of humaneness and public or environmental safety: poison (1911), gin traps (1954), self-locking snares (1981). Gassing effectively became illegal in 1987 (see *Culling at the cubbing earth* on page 12). These measures undoubtedly made intensive local fox control more difficult than it had been. The only significant addition to legitimate control methods has been the development of spot-lamps for night shooting, which have become less cumbersome and more powerful.

Jonathan Reynolds

Gin traps were outlawed in England and Wales in 1954

Figure 7

National Game Bag Census

The National Game Bag Census is a historical collection of 'bag' records from shooting estates. For most contributing estates, predator records begin in the early 1960s. The overall trend in fox 'bags', expressed per unit area, has been a steady rise since that time. Individual regions like Norfolk have all shown a rise, but at different rates and from different starting points.

Confusingly, 'bag' records from shooting estates during the 20th century indicated a steady rise in the number of foxes culled at least since 1960, when predator records were first collected systematically[18] (see Figure 7). The majority of shooting estates in mainland Britain showed a significant rise in 'bag' size through the 1970s, '80s and '90s[18,19]. The scale of this rise varied regionally from nearly two-fold in the East Midlands to over three-fold in East Anglia, but it began from a different starting level in each region. Once again, Norfolk probably represents the extreme in this, as foxes were said to be almost absent in the early part of the 20th century, and average 'bag' size was still close to zero in the early 1960s. Anecdotal histories suggest that fox populations in other regions of Britain (eg. Hampshire, Hertfordshire, Aberdeenshire) followed similar paths a few decades earlier.

At the end of the 19th century, a famous fox catcher in Caernarvonshire and Merionethshire had killed 175 foxes in her lifetime, a total noteworthy at that time[23]. In our own time, 10% of shooting estates around Britain sustained an average cull of more than 100 foxes/year throughout the 1990s[24].

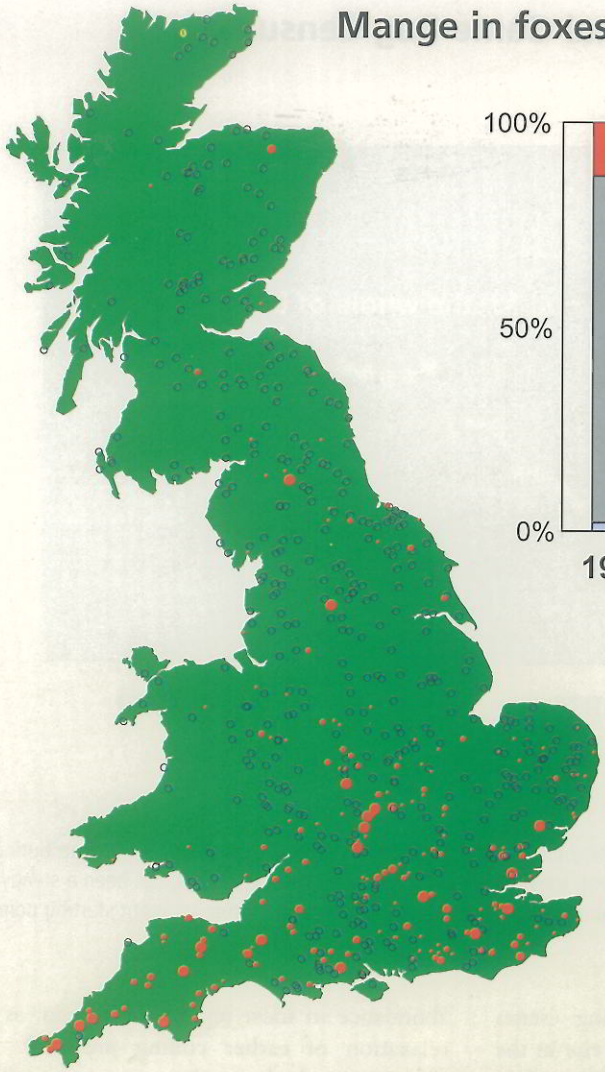
Our 'best-guess' interpretation of this confusing set of observations is that there has been an increase in fox abundance in most regions of Britain, as a result of relaxation of earlier culling pressure[6]. This view is supported by other interpreters[17,20]. The documented colonisation and settlement of urban and suburban areas with dense fox populations has also taken place in the 20th century[21].

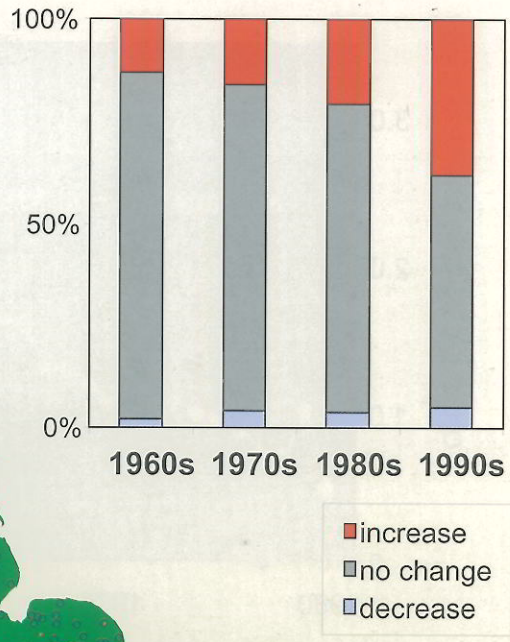
The time-scale of the suggested change in fox numbers, spanning nearly a century, may seem slow. It should be remembered that culling remains a major mortality factor, and that accidental and natural mortality is also substantial. Regions which had very low fox populations at the beginning of the 20th century, and where culling pressure has remained intense may still have fox populations that are well below the capacity of the environment. We believe Mid-Wales and West Norfolk to be two examples of this situation. Also, the rate at which (introduced) red foxes colonised California since the 1930s[22] suggests that - even in the absence of culling - foxes would take around 70 years simply to colonise a favourable area the size of our West Norfolk study area.

Denser fox populations may prove to be less stable. In the last few decades there has been a substantial increase in the prevalence and distribution of mange epidemics in rural foxes, often causing a regional slump in the fox population (see Figure 8 overleaf).

Figure 8

Mange in foxes





During the last four decades, an increasing percentage of gamekeepers have seen a rise in the incidence of mange among the foxes they cull (chart). The distribution in rural foxes in 1998 is shown in the map. Small black circles indicate no mange present, otherwise the size of the red circles indicates increasing prevalence, with the largest circles showing more than 75% of foxes affected.

Jonathan Reynolds

In recent years mange has become epidemic in many regions of Britain

Chapter 9. Reasons and aims revisited

The importance of regional considerations

The conclusions that fox numbers in some regions are suppressed by deliberate culling (see *Chapter 7* on page 18), and in most regions have shown strong changes through time (see *Chapter 8* on page 20), severely complicate any appraisal of the reasons that motivate fox culling. They mean that any investigation of the impact of foxes on human interests is specific to the fox density prevailing in that region and at that time. Where fox density is suppressed due to a history of intensive culling, it is very likely that a reduction in culling pressure would lead to an increase in conflicts between fox and man.

Predation of livestock

Wherever sheep farming takes place around the world, predation by canids (wolves, coyotes, foxes) is a perennial and controversial complaint. It is an extremely complex issue in which sheep breeds, lambing conditions, predator density and individual predator behaviour all appear to influence the outcome. Despite a number of careful studies no consistent picture has emerged. The following observations are restricted to that aspect of research where we have first-hand experience, namely the perception among farmers of lamb and poultry losses.

In our 3-Region Study, 24% to 61% of sheep farmers, depending on region (because husbandry practices, fox culling practices and fox density all varied between regions) had experienced lamb predation during the preceding 12 months that they attributed to foxes (see Figure 9). However, the losses reported amounted to only a small percentage of all lambs, in line with an earlier study in an upland area of western Scotland[25]. Maximum values for any single farmer were 5% to 15%, depending on region. Because subsidies are paid on ewes rather than lambs, these losses will translate directly in losses of profit for the farmer. We do not presume to comment on the significance of such losses against the economic background of the farming industry. The pattern of lamb losses among regions did not mirror fox abundance, but more likely reflected the vulnerability of lambs under the regionally diverse lambing practices. Thus, losses were most commonly reported in Mid-Wales, where much of the lambing happens on unenclosed hill ground with minimal shepherding. In West Norfolk and the East Midlands, most lambing takes place either indoors, or out of doors under intensive supervision. Across all regions, the effect of having a gamekeeper was to halve reported lamb losses.

Figure 9

Reported lamb losses due to foxes in the 3-Region Study

	Mid-Wales	East Midlands	West Norfolk
risk (% of flocks suffering fox predation)	61	49	24
% born indoors	41	77	57
% lambs killed by foxes			
- all lambs	0.6	0.4	0.0
- flocks where fox losses occur	1.0	1.3	1.1
(maximum)	(14.5)	(5.2)	(8.3)

NB. It should be borne in mind that these losses take place against a background of current and historical fox control, and could be higher in the absence of culling.

Figure 10

Reported poultry losses due to foxes (small flocks only, fewer than 200 birds)

	Mid-Wales	East Midlands	West Norfolk
risk (% of flocks suffering fox predation)	54	78	49
% birds killed by foxes			
- all birds	18	25	0
- flocks where fox losses occur	50	50	15
(maximum)	(100)	(100)	(100)

NB. It should be borne in mind that these losses take place against a background of current and historical fox control, and could be higher in the absence of culling.

Among farmers with free-range poultry (excluding large commercial flocks) 49% to 78% reported losses in the preceding 12 months (depending on region, see Figure 10). For poultry, the regional incidence of losses (percentage of flocks affected) did mirror fox abundance, so that West Norfolk had the fewest occurrences, the East Midlands had the most, and Mid-Wales was intermediate. Again, presence of a gamekeeper significantly reduced reported losses. It is noteworthy that, among the three regions, large-scale commercial free-range poultry units occurred only in Norfolk. Such operations may be feasible there only because of the low regional density of foxes, but each operator also put considerable independent effort into fox control.

Although we made no attempt to verify reported losses on the ground, farmers would be expected to over-estimate rather than under-estimate losses. In this respect it is encouraging to find that reported losses of lambs were similar to those found in western Scotland where attempts were made to verify the number of lambs lost and the cause of loss. In our study, though, we know that fox density was extremely low in the Mid-Wales and West Norfolk regions as a result of the heavy culling regime (see *Chapter* 7 on page 18). It seems very likely that losses would increase if culling intensity declined for any reason. This is quite clear for gamekeepered estates in all three regions.

Predation of released game

Hand-rearing of gamebirds is itself a way of avoiding predation (and other causes of mortality) at a vulnerable life-history stage. It is recognised that while hand-rearing avoids these problems it does create others. Those that relate to fox predation include:

- Concentrations of birds on the rearing field and in release pens. Both must be securely fenced against incursions by foxes, but any breach can be catastrophic[2].

The Game Conservancy Trust

Hand-reared game present an attractive and vulnerable food supply for foxes

Jonathan Reynolds

The contents of a single fox's stomach illustrate the diversity of its diet. Clockwise from left: wood mouse, brown rat, domestic chicken, chicken egg, beetle wing-cases.

- Increased vulnerability to fox predation following release as poults[26-28]. Reared birds that survive do become 'street-wise' about predators, and after their first adult year in the wild are functionally indistinguishable from wild-reared birds[29].
- Unexplained non-genetic vulnerability to fox predation in released birds during nesting in their first year after release, compared with wild-reared birds or older released birds[29,30].
- High populations of birds made possible by hand-rearing and releasing are a valuable food resource for foxes[6]. In the absence of effective fox control these may attract substantial predation, and allow higher fox density, higher cub production and improved cub survival.

Predation of wild game

The fox is implicated as a key predator in many ecosystems[8]. This is particularly true in the heavily altered man-made ecosystems of western Europe. Since our wildlife has to exist in these ecosystems, it is important to understand the relationship between predators and prey. Usually, evidence of the importance of any single predator species is circumstantial: a study of a prey species - usually investigating poor productivity or population decline - finds high predation levels. Studies of this kind identifying the fox as a major predator exist for all British gamebirds. Accumulated evidence of this kind can be very persuasive that high predation is associated with population decline. Unfortunately, it remains ambiguous: the predation could be the cause of decline, or it could be merely symptomatic of some other cause.

Unambiguous evidence about the impact of foxes on wild game populations was specifically sought through research by The Game Conservancy Trust. This evidence is of two kinds. First, an experimental study on Salisbury Plain, in which a suite of common predators, including foxes, were intensively culled on a six square kilometre 'removal' site for three years. A similar site nearby had no predator removal and acted as a 'comparison' area. After three years, 'removal' and 'comparison' treatments were switched between the two areas. Throughout the six years of the experiment, and for one year before and after, wild grey partridge numbers and productivity were monitored on both areas. The results were conclusive: under the predator control regime, autumn partridge densities increased by 75% year-on-year, finishing 3.5 times greater at the end of three years, compared with the non-removal comparison regime. These improved autumn numbers also carried over to build up spring breeding stocks, which increased 25% annually, to finish 2.6 times greater after three years.

The Salisbury Plain experiment provided decisive evidence of the importance of predators for game, but it was not helpful to indicate which predator species contributed most to the effect. After predator removal

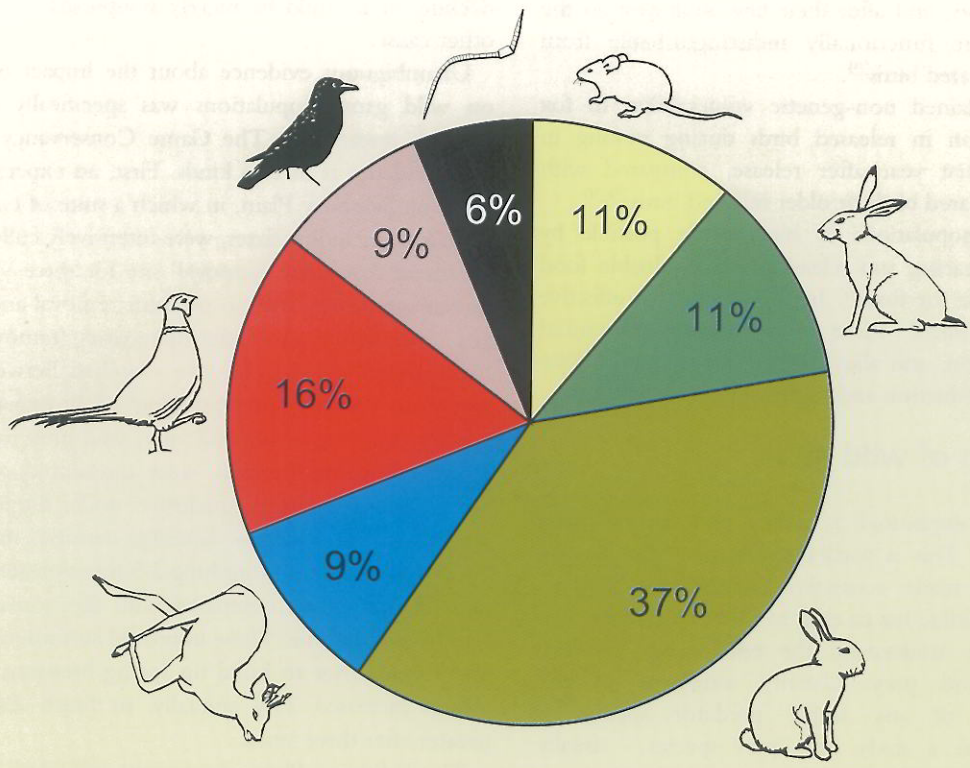
ceased, we demonstrated by radio-tagging partridges that foxes were by far the most important of the suite of predators removed. By radio-tagging foxes and analysing their diet, we were also able to show their food requirements far exceeded what the partridge population could supply. Even if foxes had eaten all the partridges present, partridges could never be more than a few percent of fox diet. Thus partridges were probably not very important to foxes, but foxes were very important for partridges. The food resources that allowed foxes to maintain such high numbers relative to partridges were rabbits and hares, which together made up 85% of fox diet.

The second type of evidence was not experimental, but was equally important. It is very rare for any field study to quantify predators, predator diet and prey numbers simultaneously. But if foxes really are important to game, it must follow that the number of game they eat makes a significant dent in the game population. We undertook this research in a mixed agriculture area in north-east Dorset with unremarkable populations of both game and foxes. We showed that the proportion of gamebirds taken by the resident foxes was indeed substantial compared with the number of birds, their productivity and the shootable surplus. For hares, which were not shot, foxes effectively wiped out the annual reproductive gains of the population. This supplemented many earlier studies of hares that had provided circumstantial evidence of the importance of foxes as hare predators. The foxes in north-east Dorset had a more diverse diet than those on Salisbury Plain, and hares comprised just 11% by weight of their food intake (see Figure 11). As with partridges on Salisbury Plain, the fox's influence on the hare population was far greater than the hare's importance to the fox.

These studies not only illustrate the importance of foxes for game populations, they also explain how foxes can be in such a commanding position. In the absence of culling, fox numbers are related to the availability of all their food resources, not just one prey species. Many of the food resources that foxes exploit are the result of human interference. For instance rabbits, brown hares and pheasants are all introduced species, and their population size depends closely on human activities. It is important to remember, too, that big predators (wolf, lynx, eagle owl) that would once have had a negative impact on fox numbers have been exterminated. The whole assemblage of animals is in fact under the influence of man[31].

Figure 11

Fox diet in north east Dorset



Predation of other wildlife

Many studies of ground-nesting birds other than gamebirds have found nest predation by foxes to be common, often alarmingly so. As with gamebirds, most of this evidence is circumstantial - no predator-removal study similar to the Salisbury Plain experiment has been carried out. It is uncertain how significant high nest losses are to bird species that are typically much longer-lived than gamebirds. Furthermore, there is an attractive argument that native predators cannot - surely? - be critical to native wildlife, because for thousands of years the two have demonstrated their ability to coexist. This presupposes that fox and prey, and the relationship between them, have remained unchanged. As described above, one conclusion of our research is that the relationship between the fox and its prey has changed considerably, through both the deliberate and the unintentional influence of man.

West Norfolk - one focus of our 3-Region Study - provides a well studied example. Predation by foxes has become an increasing problem on coastal bird reserves in Norfolk, and many reserve-owning conservation bodies have carried out or commissioned fox culling to safeguard vulnerable bird populations[32]. In most cases this has been a reluctant and controversial policy. Foxes were apparently absent in West Norfolk early in the 20th century, probably the result of the very large workforce of gamekeepers (there were 1,202 in Norfolk in 1911). Although today there is only one tenth of that number of gamekeepers, the proportion of land with professional gamekeepers remains very high compared with the rest of Britain (see Figure 12). It is easy to see that coastal reserves in North Norfolk may have been protected against foxes by a cordon of shooting estates and by the intensity of regional fox control. Furthermore, some reserves are actually on or adjacent to shooting estates. As we have seen (see *Appendix 8. Conclusions and implications of the 3-Region Study* on page 37), the present-day fox population in Norfolk is very low and well below carrying capacity, while the cull is also extremely high.

D Mason/Windrush Photos

In modern conditions, predation by foxes is a major concern for conservation of ground-nesting birds, such as these Sandwich terns

Figure 12 **Areas managed by gamekeepers in Norfolk**

A high proportion of Norfolk is managed for game by professional gamekeepers (shown in green). As a result, this area has a very low fox density which also benefits nature reserves on the north-west coastal strip.

Chapter 10. Hunting with dogs

What does hunting with dogs contribute to the regional cull?

Questionnaire returns from farmers in our 3-Region Study indicated that methods involving dogs were responsible for 73%, 18% and 11% of the regional cull for Mid-Wales, East Midlands and West Norfolk respectively, indicating clear regional variation in the importance of these methods.

What would happen if the use of hounds and terriers was banned?

Even knowing the above results, it is not possible to predict reliably what would happen to fox numbers in these three regions if hunting with hounds and terriers was banned. There are several reasons for this.

Different culling methods are almost certainly 'compensatory' to some extent: ie. in the absence of hunting with dogs there would be more foxes alive at risk of culling by other methods (see *Chapter 4* on page 8). Without any increase in effort, the culls obtained by these methods would rise to some extent, appearing to compensate partially for the lost method. A similar effect would of course occur if rifles and snares were banned, leaving increased opportunities for foxes to be killed by hunting with dogs. There is also likely to be compensation between hunting mortality and non-culling mortality such as road traffic casualties and disease.

The difficulty is that we do not know how much compensation would take place. Thus if hunting with dogs was banned and nothing else changed, anything between 0 and 812 extra foxes (the number culled using dogs) might survive the first winter of the ban in our Mid-Wales region. Given that the spring breeding population of the region was about 560 adult foxes during our study, there is the potential for breeding numbers and cub production to increase up to 2.5 times (ie. (560+812)/560) in the first year alone. By the same argument (but missing out the details), fox numbers in the East Midlands and West Norfolk might increase by a factor of 1.1 in both cases (ie. a 10% increase) in the first year of a ban.

Jim Meads

Hill pack in the Lake District

Jim Meads

Lowland fox hunting

It is likely that other things would change, although it is difficult to predict how. Most causes of mortality intensify with increasing density (are density-dependent). Thus 'natural' causes of death like epidemic disease are facilitated by higher population density. Dispersal is also more common at higher densities, and leads to increased mortality (see *Appendix 2. Dispersal* on page 31). However, the very high productivity observed in Mid-Wales and West Norfolk suggests that there is plenty of space for more foxes in those regions, and density-dependent 'natural' mortality factors may not increase much until numbers built up considerably. Thus unless checked by culling, numbers could build up rather fast.

We already know (see *Chapter 6* on page 17) that a further 5% of all farmers would begin culling if fox numbers increased. We do not know to what extent farmers who already cull would intensify their efforts, nor to what extent those increased efforts could make up for the lost cull formerly taken with dogs. It is probable that there would be an increase in shooting and snaring effort. In Mid-Wales, 95% of farms had some form of fox culling, and 69% relied exclusively on communally-organised methods that involve dogs. Given that this is intensive sheep-farming country where snaring is difficult and unpopular, 573 farmers might therefore wish to acquire firearms certificates. For the East Midlands and West Norfolk, the equivalent figures are 347 and 186 farmers. In Mid-Wales, given the nature of the landscape and farming, there is considerable doubt whether rifle and snares are efficient enough to make up for the lost cull. Any increase in snaring would also bring an increase in non-target captures.

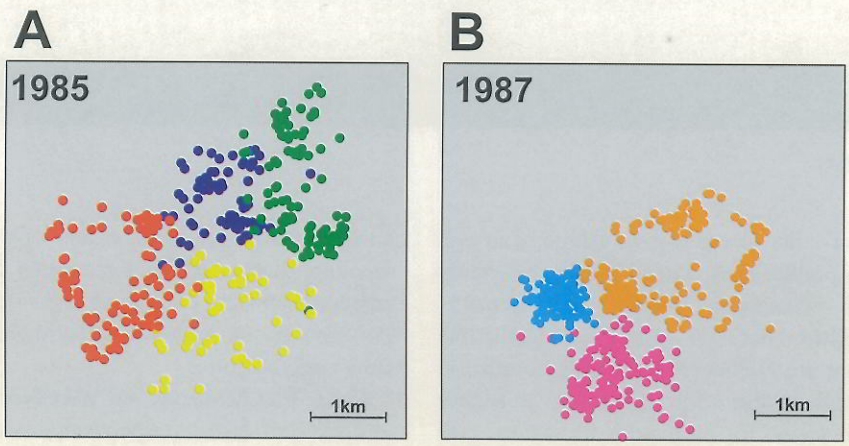
In the East Midlands and West Norfolk, where 35% and 50% of farms (respectively) have a professional gamekeeper, it seems likely that a 10% regional increase in fox numbers could be absorbed through an increased cull using rifle and snares. However, this assumes that the extra foxes would make themselves available to gamekeepers on shooting estates by dispersal. This is more likely to happen in the East Midlands where fox density is already high. In West Norfolk, a more plausible scenario is that fox density outside of shooting estates would increase somewhat. This might not affect game management interests unduly, but it would have consequences for livestock and poultry farming, and of course for wildlife outside of shooting estates.

What about the rest of England and Wales? Our three study regions were chosen for their variety of conditions, not for their representativeness. We cannot say how much of England and Wales is like any of them. What is clear is that appreciating the regional variation in land-use, fox density and fox culling practices is crucial to a proper understanding of fox control.

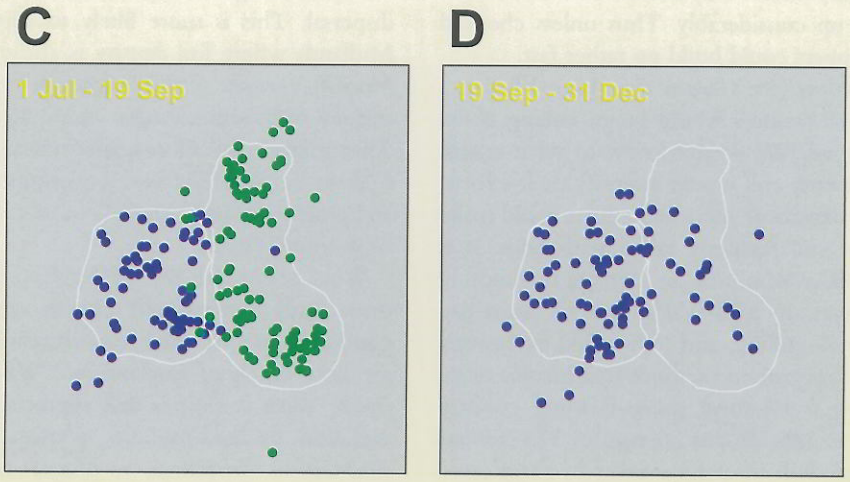
Appendix 1. Territoriality

Adult foxes establish territories, which they hold as 'social groups' - either a male/female pair, or an extended group in which a dominant male and female tolerate other subordinate individuals (especially females, often from a previous litter). 'Ownership' of the territory is advertised by scent marking, backed up by considerable aggression towards any intruding foxes. Boundaries between adjacent territories are probably determined through 'push-and-shove' by the social groups on both sides. As a result most adult foxes remain within the confines of their territory and do not make long-distance movements. If territory-holders are removed by culling, foxes occupying neighbouring territories are quick to encroach on the undefended ground, and so become exposed to the risk of culling in turn. Territories are relatively stable during spring and summer, but come under considerable pressure during autumn and winter, when foxes may travel across 'foreign' territories for two reasons: dispersal (see *Appendix 2* on page 31) and mating.

The exclusivity of fox territories revealed by radio-tracking adult foxes



Diagrams A and B show the same part of rural north-east Dorset in 1985 and 1987 respectively. Dots indicate known fox locations, accumulated during July to September, with each tagged fox shown in a different colour. Each territory is held jointly by a male with at least one female. (Blank areas of the map also had resident foxes, but none of these were radio-tagged.)



Diagrams C and D illustrate encroachment by one vixen (blue dots) after three foxes on her neighbouring territory were killed around 19 September (the radio-tagged male shown here in green). White outlines, shown for visual comparison, are computer-generated areas enclosing 90% of all locations for the first time period.

Appendix 2. Dispersal

Dispersal (movement away from the place of birth) takes place in most animals. Among mammals, it is particularly striking in foxes and related dog-like species because they are so mobile. In North America, dispersal movements as great as 394 kilometres by foxes have been recorded[33] (equivalent to London to Newcastle). Dispersal is an innate behaviour, and a feature of all fox populations, but is most likely to be expressed in certain individuals and in particular conditions. Foxes are most likely to disperse during their first winter, and males are more likely to disperse than females. Dispersal is more common in all sectors of the population where the 'producing' population is crowded. Explanations for dispersal - both in an evolutionary sense and in seeking immediate causes for individual behaviour - relate exclusively to conditions in the producing population, not elsewhere.

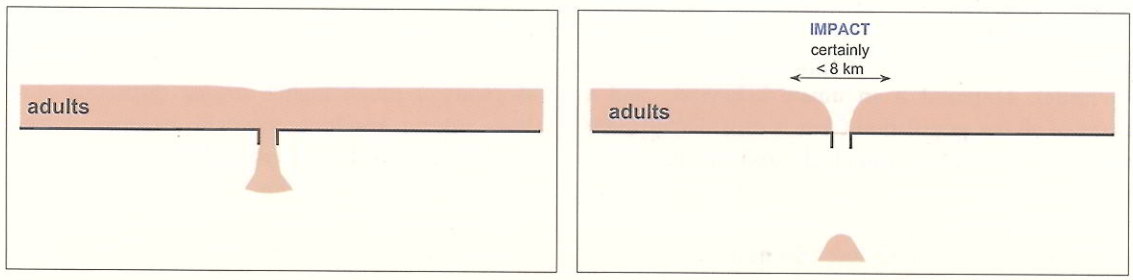
Dispersal is concentrated in the season September-January. It may involve initial exploratory forays, step-wise movements, or a single one-off movement. Mortality is much higher among dispersing animals than among resident territory-holders. Dispersal should therefore be understood as a gamble both for the individual fox and for the species, because each dispersing animal has a relatively small chance of discovering free space somewhere in which to set up a territory. Observed dispersal distances are related to mortality risks and the density of foxes in the receiving population.

Jack Scrivener

Dispersing foxes suffer higher mortality from all causes

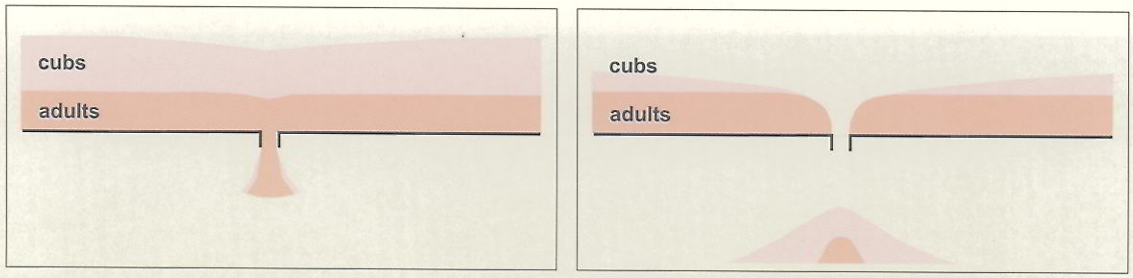
Appendix 3. The impact of local culling

Spring control



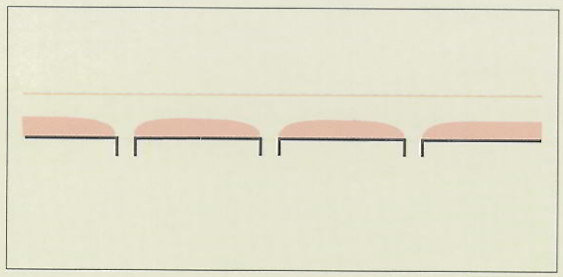
The fox population of a region can be pictured as a tray of sand. Local culling effectively pulls out a plug, creating a depression in fox numbers. In spring/summer culling, foxes from neighbouring territories may encroach and be culled in turn, so that the impact of culling extends beyond the boundaries of the estate. But the number of foxes liable to replace culled individuals is small. For a typical gamekeeper operating on a beat of six square kilometres, the effects of culling on either foxes or prey will not be detectable eight kilometres away.

Autumn / Winter control



In autumn/winter culling, juvenile foxes act like an extra layer of finer, more free-flowing sand, liable to disperse and replace culled foxes from much further away. As a result, in this season localised culling draws on a much bigger pool of potential replacement foxes, and the number of animals culled will be bigger to achieve local suppression of numbers. Because foxes are usually committed to dispersal before travelling large distances, the impact of local culling on fox numbers will again be local.

Regional impact of many local culling efforts



Finally, many local control efforts within a region may potentially amount to a regional suppression below the natural carrying capacity of the region.

Appendix 4. Culling at the breeding earth

Culling in spring/summer is especially effective because, fox for fox, it has the greatest impact on population growth at this time; also because fox predation on lambs, wild game and other wildlife is concentrated during this period. In common with many similar pest control policies (eg. rabbits, hares, squirrels, mink and many bird species), a spring/summer culling policy does carry a welfare cost associated with the failure to locate and destroy some orphaned cubs.

The following example illustrates the likely scale of this cost. Of 707 vixens killed in 1996 by a sample of 60 gamekeepers, 179 were killed during the period 10 March to 21 June in which most births occur, and roughly half of these would have given birth by the time they were killed. 39 were killed at the earth, and attempts made to destroy the cubs. 88% of cubs seen at the earth were killed. The average litter size counted was 3.74. A further 31 litters were destroyed, but no vixen associated with them was killed at the earth. From this we can calculate that 162 cubs are likely to have died through lack of maternal care due to a cull of 179 vixens.

This calculation takes no account of the existence of sub-dominant vixens who may nurse and provision the litters of dominant vixens, though it is unlikely that more than one-third of vixens killed were non-breeding helpers in this way. Arguably the loss of sub-dominant vixens - and of adult males, who also provision cubs - would also reduce cub survival.

Malcolm Brockless

Culling adults during spring and summer has the greatest impact on fox populations, but it requires good field work to ensure that dependent cubs are also killed humanely

Appendix 5. The 3-Region Study

During 1995 to 1998, The Game Conservancy Trust undertook a study to determine the impact of culling - by all the interest groups involved - on fox numbers across large regions, the size of a whole county. Previous studies of fox culling had considered individual methods only, and on either a very local scale or on a national scale that ignored regional variations.

The three large regions - in Mid-Wales, the East Midlands, and West Norfolk - were chosen to illustrate a range of landscapes, land-use and fox culling traditions, rather than to be representative of Britain as a whole. The study used three principal sources of data:

- Questionnaire survey to all farmers and landowners to determine numbers culled, reasons for culling, aims, and methods used. After posting a questionnaire to every farm property, we checked for bias by telephoning a random sample of the non-respondents. In all, we obtained data from an unbiased 51% of farm properties, giving excellent representation. (Opinion polls and other studies have typically covered less than 1% of farms in their survey areas.) We also obtained cull data directly from communally-organised culling groups, such as fox hunts and gun-packs.
- Field survey of fox density. Fox numbers had not previously been estimated on this kind of geographical scale. We developed and used a new technique for doing this, checking its reliability against other index data.
- Dead foxes. We collected and examined culled foxes from many sources to obtain measures of reproductive performance in each region.

The outcome of this research is discussed throughout this document, but see especially *Chapter 6* (page 17) and *Appendix 8. Conclusions and implications of the 3-Region Study* (page 37).

MID-WALES In the hills and valleys of Mid-Wales, sheep farming is the primary motivation for fox culling. Fox density is low and most culling involves the use of hounds and terriers.

EAST MIDLANDS This is an area of mixed agriculture and land-use. It has a mixed regime of fox culling, but hunting with hounds and mounted followers holds centre place.

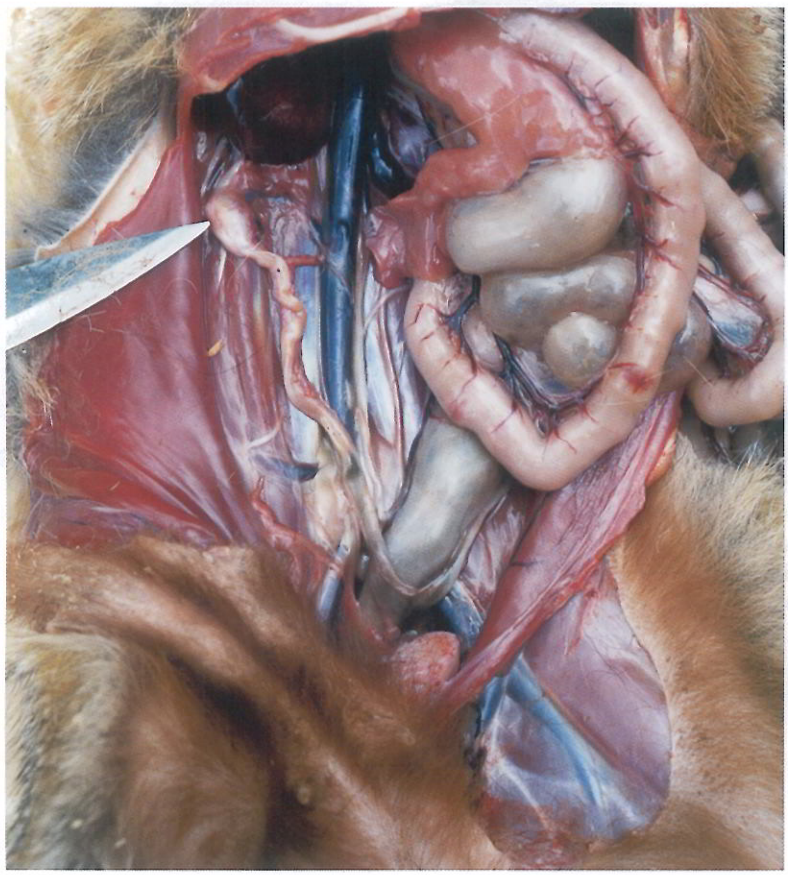
WEST NORFOLK Here, game conservation is the commonest motivation for fox culling, carried out by professional gamekeepers. The flat landscape and low fox density are well suited to culling with rifle and spot-lamp.

Appendix 6. The relationship between productivity, population density and resources

It is widely believed among fox biologists that fox populations that are dense relative to food resources are less productive than those that are less crowded. This generalisation derives from evidence of several kinds.

1. Comparing among populations, lowest average litter sizes and highest proportions of non-breeding females tend to occur where fox density is high[34,35].
2. The greatest year-to-year variation in productivity occurs where food supplies are characteristically variable - for instance in the boreal forest of Scandinavia, where the principal prey follow three to four year cycles of abundance and alternative foods are scarce[35-39].
3. In such a fox population, productivity is related to the varying food supply[40]. The mechanism is clear: vixens in good condition at the end of winter are more fecund, and lose fewer foetuses during pregnancy[39].
4. A small scale experiment suggested that the low productivity in a fox population following a poor vole year could be prevented by artificial over-winter feeding[41].
5. A 'natural experiment' in which an epidemic of Sarcoptic mange reduced a fox population to about 60% of its original level, and led to a higher proportion of juveniles in the winter population[42,43]; the same happens as a result of heavy culling effort.
6. Where productivity is low, details indicate that performance is depressed consistently at all stages of the reproductive process[12].
7. A hormonal mechanism whereby stress leads to lowered productivity has been identified[47].
8 Social stress in crowded conditions similarly reduces productivity of captive foxes in fur farms[48].
9. Rivalry between vixens within a social group expresses itself in bullying of subordinates, infanticide and cannibalism of subordinate vixens' cubs, and even infanticide of their own cubs by harassed subordinate vixens.
10. Similar evidence of reduced productivity in relation to density and resources is found in a wide variety of other mammal species (eg. arctic fox[49], racoon dog[50], badger[51], white-tailed deer[52], etc). This is significant because the hormonal processes governing reproduction and reactions to stress are basically the same in all mammals.

Jonathan Reynolds



Dissection of culled foxes in many studies has shown how reproductive performance declines when foxes are crowded

Appendix 7. Fox reproductive biology

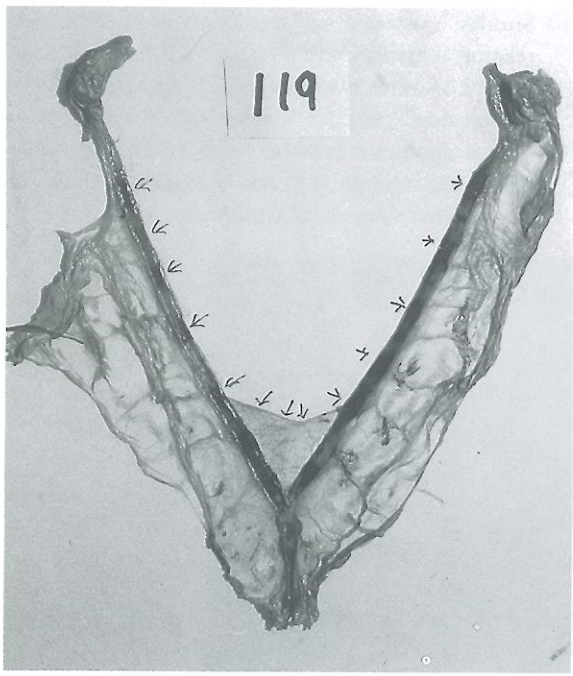
Nearly all vixens come into season from their first adult year onwards[35,36]. Virtually all are mated and conceive young. It's from here on that vixens differ in reproductive performance.

To begin with, the number of embryos conceived varies among vixens, reflecting body condition and stress, perhaps even the number of times she gets mated. Then, at any time between conception and birth (normally a period of 52 days) individual foetuses may die. Dead foetuses are re-absorbed. The depletion of a pregnancy in this way is a normal aspect of reproductive biology in foxes and many other mammals.

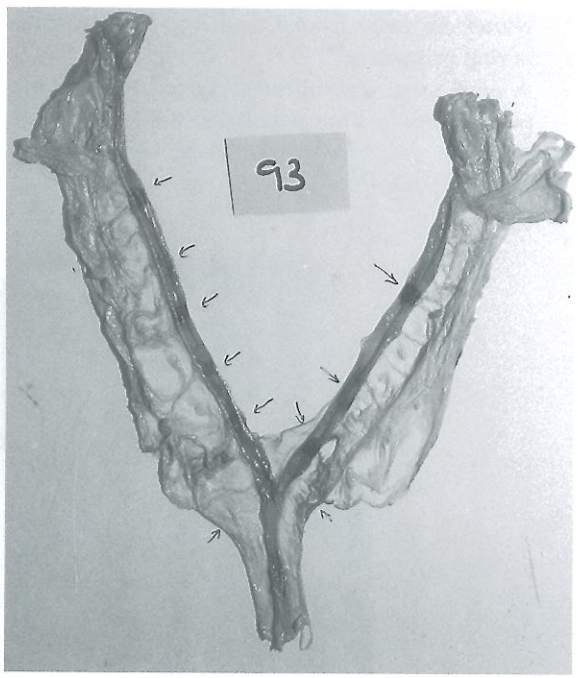
Loss of foetuses can be severe, even to the extent that the vixen loses her entire pregnancy. Although not infertile, such vixens may show no external signs of suckling cubs, and on examination may be categorised mistakenly as 'barren'. Others that have lost their entire litter may carry on to suckle the cubs of a more dominant vixen - these vixens will appear to have bred successfully, but they have not.

When a cub is born, the placenta - which takes the form of a 'life-belt' around the foetus - leaves a puckered scar around the uterus. This quickly darkens and persists for some months, allowing biologists to 'read' the number of cubs born. Where embryos have died and been reabsorbed the scar is paler, so these deaths can be recognised and counted too.

The natural attrition of cub production continues after birth, as desertion and infanticide appear to be fairly common in dense fox populations.



Within any fox population individual vixens may produce large litters. This uterus has 12 dark scars and only one light scar, implying that the vixen successfully gave birth to 12 cubs. This vixen represents the upper end of the spectrum: average litter size varied in our three study regions between 4.5 and 6.4, depending on region



This vixen had five dark scars and five light scars, implying a loss of 50% of her litter during pregnancy. We found such losses to be very rare in low density populations with heavy culling pressure

Appendix 8. Conclusions and implications of the 3-Region Study

- Fox culling takes place on the vast majority of land properties in rural areas.
- Fox culling does not merely have a local impact on fox numbers. In some regions, the impact of culling, most of it uncoordinated, can be regional suppression of fox numbers.
- Fox density and culling practices have a regional character, linked to terrain and land-use.
- In some regions, the fox density currently found is not determined by resources, but is the result of a history of intensive culling.
- Culling is mostly carried out to prevent losses, not in reaction to losses.
- Losses of livestock, poultry, game and other wildlife must be assessed in the view of the fact that in some regions fox density is suppressed. Here losses would certainly be higher if culling intensity decreased.
- Hunting with dogs accounted for 73%, 18% and 11% of the regional cull for Mid-Wales, East Midlands and West Norfolk respectively.

D Mason/Windrush Photos

Stone curlews do best where fox numbers are rigorously controlled

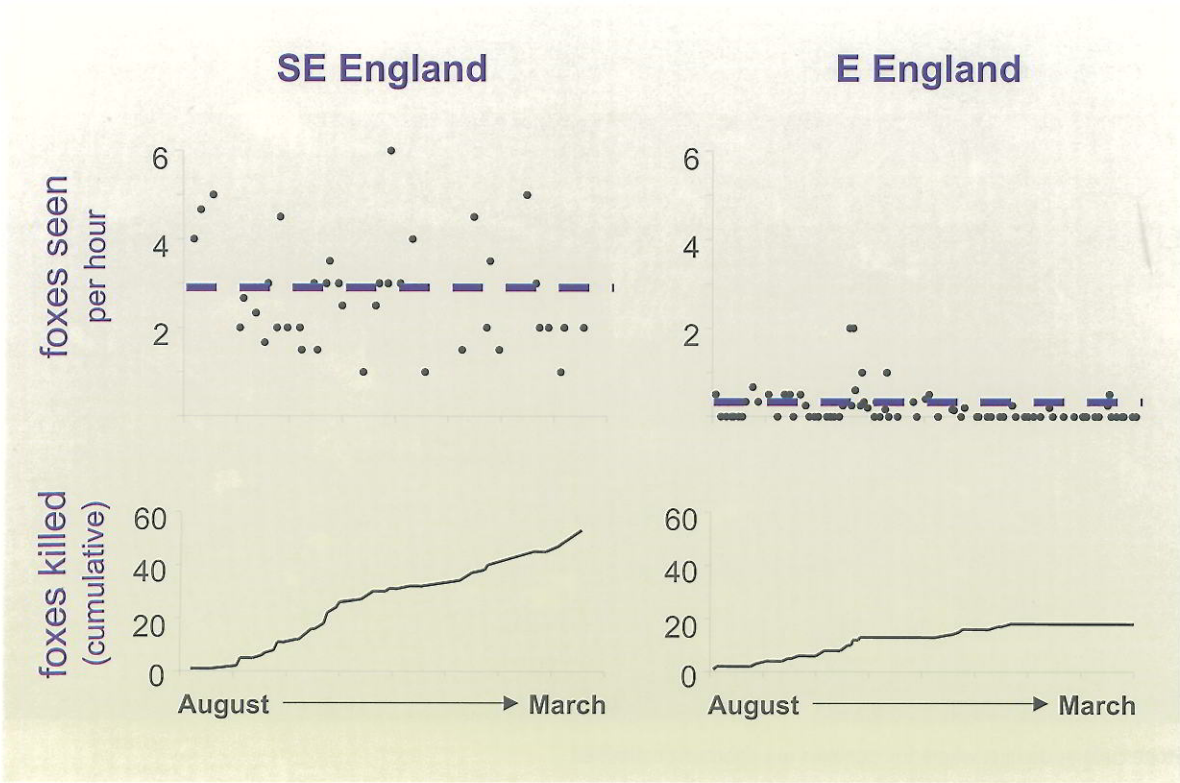
Appendix 9. How NOT to judge the success of localised culling

For any local fox control effort, success is often judged on the number killed. But the number removed often reflects the effort put in and the size of the background fox population much more than it reflects the number of foxes left.

This figure contrasts a gamekeeper in south-east England operating over 8.1 square kilometres (left-hand side) with one in West Norfolk operating over 6.1 square kilometres (right-hand side). The upper graph in each case shows a dot for each occasion the keeper went out with a spot-lamp and rifle (once or twice a week in both cases); the lower graph indicates the accumulating 'bag' of foxes (killed through this and other methods), from August to March. The keeper in south-east England saw on average about three foxes per hour (the variation between successive occasions is characteristic and is due to chance) and gradually accumulated a 'bag' of 60 foxes. But there was no indication that this cull had made any difference to the large number of foxes present. Despite flatter terrain, the keeper in Norfolk typically saw foxes at a rate of less than one per hour. As a result, despite similar effort, his 'bag' only amounted to 20 foxes, and by the latter half of the period (January-March) foxes were essentially absent. These examples probably represent extreme situations for the UK, but they illustrate how 'bag' size is a poor indicator of culling effectiveness.

Stephen Tapper

The number of foxes killed is not a good measure of effectiveness



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