MINISTRY OF AGRICULTURE, FISHERIES AND FOOD **CSG 15**

Research and Development

Final Project Report

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Research Policy and International Division, Final Reports Unit
MAFF, Area 6/01
1A Page Street, London SW1P 4PQ
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Project title	Habituation of badgers to electric fencing
MAFF project code	**VC0324**
Contractor organisation and location	Central Science Laboratory Sand Hutton York YO41 1LZ
Total MAFF project costs	£ 88,800
Project start date	01/04/98
Project end date	31/03/01

Executive summary (maximum 2 sides A4)

1. The effects of increasing voltage and the use of different conducting materials (steel wire and polywire) on the effectiveness of an electric fence for use to exclude badgers (*Meles meles*) were assessed in a field trial conducted in the south-west of England.
2. Fences were erected to prevent badgers feeding at bait points to which they had previously had unrestricted access. Effectiveness was measured by comparing bait consumption before and after fence erection.
3. The effectiveness of both steel wire and polywire fences maintained at 6 kV was compared with that of fences in which the voltage was increased, in 2 kV steps, from 0-6 kV.
4. Behavioural observations were conducted to determine how badgers reacted to the different fence types.
5. Both the steel wire and polywire fences, maintained at 6 kV throughout, proved effective at excluding badgers (steel wire 90% reduction in activity; polywire 89% reduction in activity). In contrast, fences erected without being electrified (0 kV) afforded no protection at all.
6. As the voltage was stepped up there was a corresponding increase in the level of effectiveness. At every voltage stage, the steel wire fence appeared to be more effective than its polywire counterpart (0 kV: steel wire 4%, polywire 3%; 2 kV: steel wire 68%, polywire34%; 4 kV: steel wire 83%, polywire 59%;

6 kV: steel wire 95%, polywire 63% reductions in activity).

7. The stepped voltage steel wire fences at the 6 kV stage were as effective as those maintained at 6 kV throughout. In contrast, increasing the voltage in steps reduced the ability of polywire to deter badgers at the highest voltage.

8. The proportion of badgers observed to cross the staged voltage fences fell with increasing voltage. A smaller proportion was observed to cross the steel wire design. Most badgers crossed by means of pushing between the upper wires.

9. The results demonstrate that landowners and occupiers considering the use of electric fencing to exclude badgers should, whenever possible, use steel wire in preference to polywire. Fence voltages should not be allowed to fall below 4 kV, particularly during the first few weeks after erection, if effective management is to be achieved.

Scientific report (maximum 20 sides A4)

Introduction

The European badger (*Meles meles*) is widely distributed throughout mainland Britain which now supports one of the largest populations in Europe (Griffiths & Thomas, 1993). Adult numbers are currently estimated to be in excess of 300,000 and appear to be rising (Wilson, Harris & McLaren, 1997). Unfortunately, some aspects of badger behaviour can cause problems for agriculture (Macdonald, 1984; Symes, 1989; Wilson, 1993; Moore *et al.*, 1999). Under certain circumstances, the level of damage may be considered unacceptable (Neal, 1986) and some form of humane and cost-effective management may be necessary.

In Britain, badgers and their setts are protected by law. Damage prevention must therefore rely on behavioural manipulation rather than population reduction. The most common form of management is to deny badgers access to vulnerable areas. Electric fencing is being used increasingly to manage wildlife in Britain (McKillop & Sibly, 1988) but its use to manage badgers has proved only partially successful (Benham, 1985; Roper, Lups & Lycett, 1989; Wilson, 1993; Brown & Cheeseman, 1996). Recently, however, a strained-wire design was developed which reduced badger damage to forage maize (*Zea mais*) by an average of 95% (Poole & McKillop, unpublished Ministry of Agriculture, Fisheries and Food report). This design is now recommended by MAFF advisers as a means of excluding badgers from areas prone to damage.

On occasion, MAFF has received complaints regarding the effectiveness of this electric strained-wire design. In most cases, the unsatisfactory performance can be attributed to poorly erected fences. This can result in situations where the voltage is insufficient to deter badgers. Even after these fences have been modified, however, badgers are often reported to cross the improved designs. This has also been shown for rabbits in research conducted by McKillop & Sibly (1988) and McKillop *et al.* (1993) who identified a reduction in the effectiveness of electric fences, which are initially erected without power, compared to those electrified from the outset. The reason may be that animals become accustomed to the low shock levels produced by the initial design and are consequently more tolerant to the higher shock levels generated once the problem has been rectified.

Another factor, which may influence electric fence effectiveness, is the type of conducting material used. There are two types of conducting material in common use: steel wire and polywire. Many farmers use polywire in preference to steel wire because it is cheaper to purchase. However, steel wire offers a number of advantages over polywire in that: it is a better conductor; it is more robust and it can be tensioned over a greater distance. Consequently, it may be that continued crossings are a problem when polywire is used rather than steel wire. This could further explain some of the difficulties experienced by farmers using electric fencing to manage badgers.

The aims of this study were to investigate the extent to which fence voltage and the type of conducting material used to construct fences influences their effectiveness. The results will be used to provide recommendations on the best design and maintenance of electric fencing to exclude badgers.

Methods and materials

The study area

The study was conducted within and around Woodchester Park in the Cotswold escarpment region of Gloucestershire. The area supports a high density of badgers (Neal & Cheeseman, 1996) the biology, behaviour and ecology of which have been studied extensively by the Central Science Laboratory (CSL). Habitat details are described broadly in Cheeseman *et al.*, (1981).

Experimental design

The study was conducted between May and December of 1998 and between May and August of 1999 and of 2000. Twenty-four social groups of badgers were initially selected from the study area and an area of pasture, used regularly by badgers, identified for each. Within each area, a pair of 4 x 4 m plots were established, equidistant from the main sett and separated by no more than 20 m. Within each plot, four feeding points, baited with dehydrated dog food, were installed. The bait was housed in small plastic bowls, dug into the ground, and covered initially with 0.5 kg quarry tiles to prevent bait consumption by small mammals and birds. When badgers began to feed regularly at the bait points the quarry tiles were replaced by 10 kg paving slabs as an additional precaution to prevent bait consumption by other species.

Consumption at each bait point was recorded daily for two weeks and scored as follows: none 0; partial 1; and complete 2 (the maximum score for each plot was therefore 8). After the two week pre-fencing period, during which badgers became accustomed to feeding at the bait points, one of the paired plots was randomly assigned to one of four treatments. The other plot remained unfenced throughout the trial and acted as a control. Consumption was monitored at this plot to confirm that any changes in consumption from the fenced plots was due to the presence of the fence and not because badgers had moved from the area. The treatments were:

(1) A wire fence in which the power was increased from 0 kV to 6 kV in three, 2 kV, steps (six replicates).

(2) A wire fence in which the power was maintained at 6 kV throughout (six replicates).

(3) A polywire fence in which the power was increased from 0 kV to 6 kV in three, 2 kV, steps (six replicates).

(4) A polywire fence in which the power was maintained at 6 kV throughout (five replicates – badgers could not be encouraged to feed at one of the sites assigned to this treatment).

Each voltage stage was maintained for two weeks and each replicate therefore lasted eight weeks. Bait consumption was recorded as before. Fence effectiveness was assessed by comparing bait consumption from within each of the test plots.

Results were analysed by comparing the difference in consumption between each paired control and fenced plot. Thus, in an ideal situation, where all the bait was consumed from within the control plot but none from the fenced plot, the difference would have a value of eight. By contrast, if the fence were totally ineffective, the difference would be zero. For each treatment, at each voltage stage, the mean difference in consumption was therefore calculated and an analysis of variance conducted in which the treatment variability was broken down into three single degree of freedom contrasts. The first tested for a difference between the steel wire and polywire fences, the second contrasted the staged fences with those maintained at 6 kV throughout and the third tested for an interaction between the previous two contrasts.

The fences

The fences were erected around the small 4 x 4 m plots to enclose fully the four bait points. The fence design was the same as that used successfully by Poole & McKillop (unpublished MAFF report) to protect forage maize crops in the south-west of England. It consisted of four parallel conducting wires at heights of 10, 15, 20, and 30 cm above the ground. All four wires carried current. The wires were tensioned by hand and the corner posts staked down to ensure the fence remained taut.

Each fence was powered by a 70 Ah battery-operated energiser that produced a pulsed energy output of 1.5 J into a resistance of 500 ohms. This specification generated a maximum voltage of around 6 kV when earthed using 50 cm copper rods. The system therefore complied with British Standards which require energy output to be less than 5.0 J and voltage to be less than 10 kV. On fences where the voltage was to be increased in 2 kV steps, a voltage stager was fitted between the energiser and the fence. This device controlled the resistance of the fence system and enabled the voltage output to be varied between low, medium and high levels (2, 4, and 6 kV respectively). Fence voltage checks and maintenance visits were conducted on a daily basis.

Two types of conducting material were used: steel wire and polywire. The steel wire was 2 mm in diameter and constructed from seven twisted strands of galvanised steel. The polywire was 2 mm in diameter and composed of three, 0.2 mm, steel conducting wires interwoven with plastic strands. Steel wire costs around twice as much as polywire to purchase (on average £30/400 m compared to £15/400 m).

Shorting of the fence by vegetation growth was prevented by clearing the fence line using a strimmer. Fence maintenance and voltage checks were conducted daily and batteries replaced as necessary. Where livestock were present, a stock fence was erected around each of the test plots to prevent bait consumption by domestic animals. This fence consisted of a single strand of polywire at a height of 100 cm for cattle and 70 cm for sheep.

Behavioural observations.

Badger behaviour was observed at eight sites (four steel wire and four polywire) where the fence voltages were stepped up every two weeks (Treatments 1 and 3). Observations were conducted on the first two nights and the final night (night 14) of each voltage stage. In total, 48 observations were therefore conducted at each of the two fence types, 12 at each voltage stage for each fence type. The observations were conducted to compare how badgers behaved at each of the fence types and to determine how voltage affected behaviour. Each session began about half an hour before dusk and lasted two hours. Binoculars were used to view badger behaviour before dark and an image intensifier after dark.

During each observation session a record was made of the total number of badgers seen, the number of badgers entering the fenced and control plots to feed and the number of badgers which approached to within a few metres of each of the plots but did not enter. For comparison, these figures have been expressed in the results, as a proportion of the total number of badgers observed at each treatment during each voltage stage of the trial. It was not possible to analyse statistically the behavioural data because the number of replicates was small and the variation between individual sites large. General descriptive comparisons have been used instead.

Results

Bait consumption

Pre-fencing stage

Badgers appeared to have little difficulty finding the baited plots at the start of each replicate and by the end of the two-week pre-fencing stage they were feeding at all of the baited plots. Mean bait consumption during this stage was high (mean: 6.2 $\pm$ 1.26) and, as would be expected, there was no difference between consumption from within the control plots and those plots to be fenced later (the mean difference in consumption was close to zero; Figure 1). Consumption at the control plots continued to remain high throughout the trial (mean: 7.8 $\pm$ 0.38).

0 kV stage

When the fences were erected without power, both the steel wire and polywire designs were found to be almost totally ineffective (4% and 3% reductions in activity respectively) with a mean difference in consumption between the fenced and control plots close to zero (Figure 1). The small difference in effectiveness was not significant ($F_{1,19}$ = 3.07, P>0.05). As would be expected, consumption from within the fences maintained at 6kV during this stage was significantly lower ($F_{1,19}$ = 950.5, P<0.001).

2 kV stage

Increasing the voltage to 2 kV resulted in a corresponding increase in the effectiveness of both the steel wire (68%) and polywire fences (34%). The wire fences appeared more effective (Figure 1) but the difference was found to be non-significant ($F_{1,19}$ = 3.07, P>0.05). Although the staged voltage fences were now showing some degree of effectiveness they were still performing significantly less effectively than those maintained at 6 kV ($F_{1,19} = 3.07$, $P<0.001$).

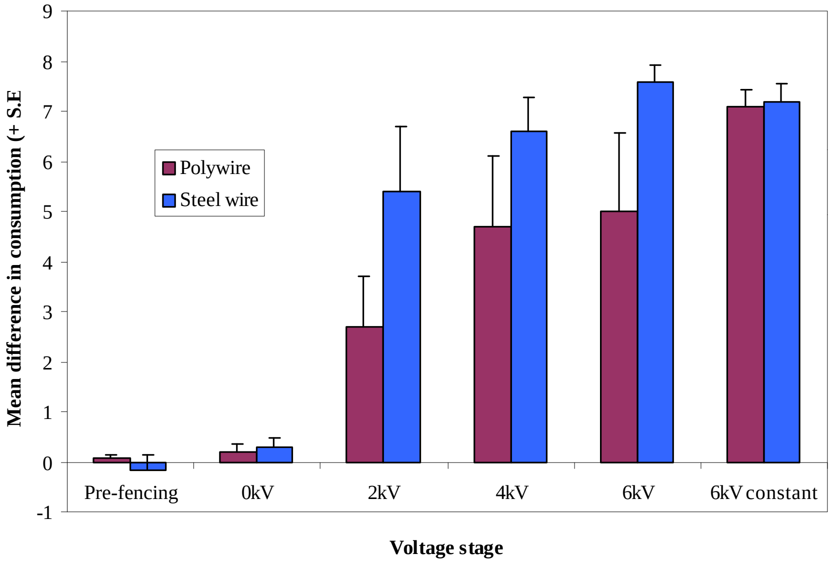

Figure 1. The mean difference in consumption between the fenced and control plots at each stage of the trial (Totally effective 8, totally ineffective 0)

4 kV stage

At the 4 kV stage there was a further increase in the effectiveness of the steel wire (83%) and polywire fences (59%) as indicated by the higher mean difference in consumption (Figure 1). Again steel wire appeared to be more effective than polywire but the difference was not significant ($F_{1,19} = 1.73$, $P>0.05$). At this voltage level there was no significant difference between the effectiveness of the staged voltage fences and those maintained at 6 kV ($F_{1,19} = 2.04$, $P>0.05$). The 6 kV fences did, however, appear to provide slightly more protection (mean difference : 6 kV 7.1 $\pm$ 1.64; staged 5.7 $\pm$ 2.76).

6 kV stage

When the staged fence voltages were increased to 6 kV their effectiveness once again increased (steel wire 95%; polywire 63%). As in all the previous stages, the steel wire fences appeared to be more effective than their polywire counterparts (Figure 1). However, this difference was once again non-significant ($F_{1,19} = 0.64$, $P>0.05$). Interestingly, the staged voltage steel wire fences reduced bait consumption by a greater amount than those maintained at 6 kV (mean difference: staged 7.6 $\pm$ 0.81; 6 kV 6.0 $\pm$ 3.02). By contrast the staged voltage polywire fences were not as effective as the corresponding fences maintained at 6 kV (mean difference: staged 5.0 $\pm$ 3.86; 6 kV 6.9 $\pm$ 2.18). These differences were not significant ($F_{1,19} = 0.03$, $P>0.05$).

6 kV constant

Both the steel wire and polywire fences maintained at 6kV afforded good protection (steel wire 90%; polywire 89%) and the mean differences in consumption between the fenced and control plots were both close to eight (Figure 1). The small amount of bait consumption was attributed to badgers at two of the six steel wire sites learning to regularly cross the fence and similarly at one of the five polywire sites. On only a very small number of occasions was bait taken from the remaining eight sites.

Behavioural observations

When the two fence types were initially erected without power (0 kV stage) badgers, without exception, approached them cautiously and only after a period of investigation. Typically they would circle the fenced areas moving nearer and nearer until close enough to touch the components of the fences, usually with their noses. During the approach badgers would regularly stop and raise their heads to sniff in the direction of the fenced plots. If unsure of the novel object they would often retreat a few metres from the fence before initiating their approach again. A few were observed to retreat to the harbourage without appearing to touch the fence.

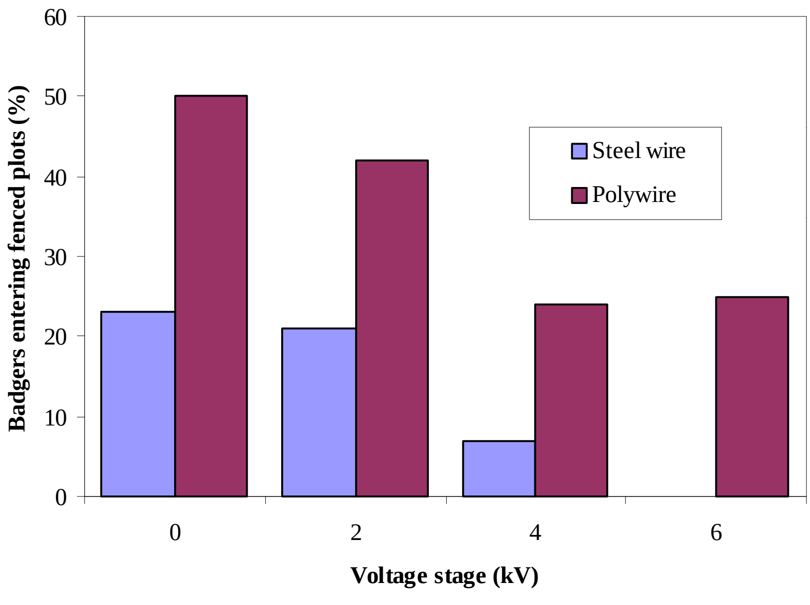

Figure 2. The mean proportion of the total number of badgers observed which cross the fenced plots to feed during each voltage stage of the trial.

Badgers which crossed the fence to feed did so by stepping slowly between the upper wires of the fence. Both the steel wire and polywire fences were crossed in exactly the same way. During the first two nights on which observations were conducted (nights 1 and 2 at 0 kV), badgers tended to cross the fences slowly and cautiously and only after a measured approach. By the time the next observation was conducted (night 14 at 0 kV), and for the remainder of the trial, badgers which crossed the fences approached them directly and crossed without hesitation by pushing their heads between the third and fourth wires from the ground and stepping through. None was observed to jump over or push under the wires. Badgers which successfully crossed the electrified designs showed no obvious behaviour to suggest that they had received a shock.

As would be expected, the proportion of the total number of number of badgers observed each night entering the fenced plots to feed fell with increasing voltage (Figure 2). At each of the voltage stages the steel wire fences appeared to be more effective than their polywire counterparts and by the time the fence voltages had been increased to 6 kV no badgers were observed to enter the plots protected with the steel wire design. By contrast, 25% of the badgers observed at the polywire sites were seen to cross the fences to feed at this voltage stage (Figure 2). At the corresponding controls, there appeared to be little difference between the proportions of badgers feeding at the steel wire and polywire sites (Figure 3).

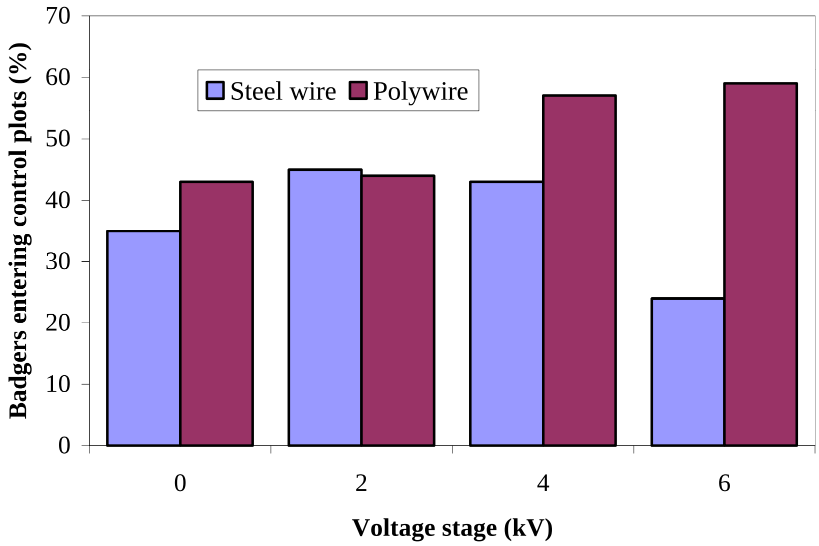

Figure 3. The mean proportion of the total number of badgers observed to cross the control plots to feed during each voltage stage of the trial.

It was not always possible to determine whether badgers that approached the fence but, did not cross, actually touched the electrified wires. However, the proportion of animals that approached to within a few metres of the fence and then retreated was generally low regardless of the voltage (Figure 4). The only exception occurred during the 4 kV stage when over 30% of the badgers observed at the steel wire sites approached to within a few metres of the fence before retreating without crossing. Badgers that were definitely seen to touch the electrified wires generally responded by retreating immediately to the nearest harbourage.

This response was most marked when the badgers concerned touched the electrified wires with their noses. Badgers did not appear overly stressed by the receipt of an electric shock and their response appeared the same regardless of the fence voltage.

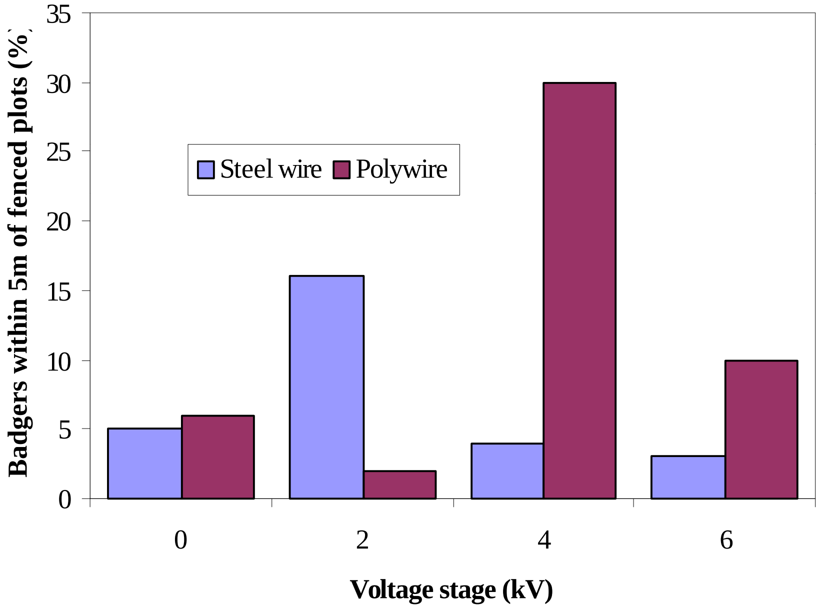

Figure 4. The mean proportion of the total number of badgers observed within 5m of the fenced plots (without crossing) during each voltage stage of the trial.

Discussion and conclusions

Both steel wire and polywire were effective at excluding badgers when the fence voltages were maintained at around 6 kV (steel wire 90% effective; polywire 89% effective). The level of effectiveness was similar to that attained in an earlier field scale trial where erection of the steel wire fence reduced the overall damage caused by badgers, to forage maize, by 95% (Poole & McKillop, unpublished MAFF report). However, only the steel wire staged voltage fences reached this level of effectiveness. The staged polywire fence was never more than 63% effective. At every voltage stage, steel wire provided better protection than polywire and should therefore be regarded as the most suitable conducting material of the two. The unelectrified fences afforded only minimal protection and it can thus be inferred that it is electrification rather than the physical presence of the fence itself that is acting as the deterrent.

Observations at the staged voltage sites further highlighted differences between the efficacy of the two conducting materials. At each voltage stage, the proportion of badgers entering the steel wire fenced plots to feed was always less than half that of the polywire fences and at the 6 kV stage no badgers were seen to cross the steel wire fences. At the same stage, a quarter of the badgers observed at the polywire sites crossed the fences to feed. Even at the unelectrified stage steel wire fences excluded a greater proportion of badgers. These observations provide further evidence to support the use of steel wire in preference to polywire.

It was not possible to determine precisely why steel wire was more effective than polywire but results from the unelectrified stage suggest that the former may provide more of a physical barrier to the movement of badgers, perhaps because it can be tensioned to a greater extent. Thus, badgers would find it easier to push through slacker polywire fences (their preferred method of crossing). The problem of tensioning (particularly polywire) increases with fence length and is therefore likely to be exacerbated in ‘real life’ situations where many hundreds of metres of fencing may be erected to protect large areas vulnerable to badger damage.

Electric fences are not designed to be robust impenetrable barriers but instead rely upon animals changing their behaviour as a result of receiving a shock. It is unlikely, therefore, that this barrier effect is the only reason for the difference in effectiveness between the two fence types. The difference in the thickness of the two conducting wires may also influence effectiveness. Steel wire is constructed from a number of individual strands of galvanised wire and is much thicker (2 mm) than the three (0.2 mm) conducting wires that are interwoven into the polywire design. When an animal attempts to cross each of these fence types a better contact between the conducting wire and the individual may, therefore, be achieved using the thicker steel wire. Given that the level of contact determines, to some extent, the severity of the shock and the subsequent reaction (McKillop & Sibly, 1988) the use of a thicker conducting wire is likely to produce a more pronounced adverse response, leading to greater effectiveness. This factor may be particularly important in situations where contact with the wires is made by less sensitive areas such as the neck, back and chest.

When badgers encountered the fences for the first time their initial response was the same as would be expected for any unfamiliar object (Storer, Vansell & Moses, 1938; Spencer, 1948; Staines, Ozment & Lippoldt, 1961; Prior, 1983). In most instances, badgers approached the fences cautiously before investigating, usually with their noses, which are poorly insulated and highly innervated. Any individual touching an electrified fence with their nose will, therefore, receive a severe shock. Similar investigative behaviour by badgers was observed in an earlier study (Poole & McKillop, 1999) and serves to enhance the effectiveness of electric fencing by ensuring that badgers, investigating the fence for the first time, receive a relatively severe shock and subsequently learn to avoid the area. Investigatory behaviour of this nature should therefore be encouraged and a number of approaches have been used previously to achieve this. These include attaching either unfamiliar objects (Patterson, 1977; McCutchan, 1980; Prior, 1983) or food items (McAtee, 1939; Goolsby, 1969; Porter, 1983; McMurchy, 1984) to the fence.

On receipt of a shock, many mammal species will learn to avoid electric fences (e.g. Bartay, Friend & Litterst, 1979; Schumake *et al.*, 1979; Niven & Jordan, 1980; Hone & Atkinson, 1983). This conditioned avoidance will often result in a decrease in the number of animals approaching a fence. If the experience is unpleasant enough the effect can be immediate and long lasting (McKillop & Sibly, 1988). Conditioned avoidance has been recorded in badgers which were observed to avoid electric fences for periods of up to six weeks after receiving a shock (Poole & McKillop, 1999). However, badgers at the staged voltage fences, particularly at the lower voltage polywire sites, did not follow this pattern of behaviour and were observed regularly to approach and cross the electrified fences to feed. The extent to which this occurred did, however, fall as the fence voltage increased. The results suggest that conditioned avoidance is dependent upon the severity of the shock and that its effect is limited at lower voltages.

During the unelectrified stage, badgers became accustomed to the fences and subsequently learnt to cross them, usually by means of pushing between the upper wires. Domestic stock, familiar with strained-wire fences, have also been observed to push through the large gaps between fence wires (Pharoah, 1976; McCutchan, 1980). As a consequence of crossing the fence in this way, contact with the conducting wires occurs only to the less sensitive parts of the body such as the neck chest and back which are insulated, to some extent, by thick fur. Thus, regardless of fence voltage badgers will receive only a mild shock and may continue to cross the fences to feed. This type of behaviour could further explain the absence of conditioned avoidance early into the staged voltage replicates. In practical terms, these observations highlight the need to ensure that power is maintained to the fences during the first few days of electrification. This will prevent badgers learning how to cross the fence by increasing the likelihood of them avoiding the area following the receipt of a relatively severe shock, during the investigatory period, when fences are first erected.

The small number of individuals that were observed to touch the electrified fences with their noses typically reacted by retreating away from the fence, usually to the nearest harbourage. This is the most usual reaction shown by mammals in response to an electric shock (McKillop & Sibly, 1988) and has been reported previously for badgers (Poole & McKillop. 1999). This pronounced flight behaviour will serve to contribute to the effectiveness of electric fencing as a management tool for badgers. By contrast, badgers observed to push between electrified wires almost always completed the crossing and showed no sign of having received a shock. This observation provides further evidence to support the claim that badgers receive only a mild shock when crossing in this way.

Interestingly, a small proportion of badgers was observed to approach to within a few metres of the staged voltage fences before retreating, without ever touching them. During the unelectrified phase, this behaviour suggests a neophobic response to the presence of an unfamiliar object. Following electrification, the behaviour may be explained differently. Firstly, as suggested above, the badgers could be exhibiting a form of conditioned avoidance having received an earlier shock. Secondly, some form of socially learned avoidance may have been in operation. In the case of the latter, it would suggest that badgers may copy others retreating from the fence or witness their reaction (on receiving a shock) and thus learn to avoid the fence. Conversely, social behaviour may be involved in initiating crossings. Thus, badgers which learn to cross the fences to feed may be observed by other individuals which consequently cross the fence to join them. Badgers may also observe how and where others cross the fence and subsequently copy them.

This type of social facilitation and learning has been recorded previously in both domestic stock (Bartay *et al*., 1979, McCutchan, 1980) and wild mammals (Patterson, 1977, Shelton, 1978; McKillop, Phillips & Ginella, 1992). It was not possible to determine the extent to which each of these behavioural processes was in operation because observations were conducted on too few nights and because individuals were not marked. It may, though, explain how late into the study badgers at a small number of sites began regularly to cross the fences to feed. However, results from this and an earlier study by Poole & McKillop (1999) indicate that social learning probably has a deterrent effect and contributes to fence effectiveness, provided fence voltages are maintained, especially during the first few days after erection when badgers initially encounter the fences.

Overall, results from the study indicate that both steel wire and polywire fences have the ability to exclude badgers from vulnerable areas provided fence voltages are maintained at a suitable level. Steel wire appears to be the most effective conducting material and may deter badgers at a lower voltage (4 kV) than polywire (6 kV). Steel wire is also more durable than polywire, tensions over greater distances and can carry a higher voltage. Whenever possible, therefore, landowners and occupiers should select steel wire in preference to polywire. A key finding to emerge from the study is the importance of ensuring the electrification of fences during the first few weeks after erection. During this period, badgers first encounter the fences and establish their future patterns of behaviour. If their initial experience with the fence is a bad one, brought about by the receipt of a relatively severe shock, they are likely to avoid the area and thus the effectiveness of the technique is enhanced. Conversely, if they learn to cross the fence at this stage, subsequent crossings are far more likely. In practical terms, fence inspections should, therefore, be conducted at one to two day intervals during the first two weeks after erection and subsequently, when behavioural patterns have been established, these intervals between visits can be increased to one to two weeks. If these recommendations are followed and a suitable energiser and power supply are used the four strand, electrified steel wire, fence should provide an effective means by which to reduce the damage caused by badgers.

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