Protecting ground-nesting birds from predation using fencing and floating rope barriers

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A Fox scaling the mesh of a 1.8 m high barrier fence before deciding it cannot get over its angled mesh top and jumping back down to the ground

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1. Introduction

This manual updates guidance produced by Hirons & White (2017) on the use of predator-exclusion fences to protect ground-nesting birds from nest and chick predation by Red Foxes *Vulpes vulpes* (hereafter referred to as Foxes) and nest predation by European Badgers *Meles meles* (hereafter referred to as Badgers).

While the 2017 guidance included descriptions of a wide range of variations in fence design, subsequent experience has enabled us to hone down what we consider to be the best designs for the four main types of predator-exclusion fence used on RSPB reserves, and which we describe here. This updated guidance also describes the use of an additional method, floating rope barriers, to prevent Foxes and Badgers from swimming to islands, together with additional information on the effectiveness and longevity of different fence types.

We also describe the use of temporary electric fencing. Separate guidance on the use of temporary fencing, and of nest cages, for protecting *beach-nesting* birds is being produced by the LIFE on the Edge project and will be available in 2026 https://www.rspb.org.uk/helping-nature/what-we-do/protecting-species-and-habitats/projects/life-on-the-edge.

The rest of this manual is structured as follows.

Section 2 describes the conservation rationale for using predator-exclusion fencing, including why predation has become an increasingly important issue for many ground-nesting birds in the UK and elsewhere in western Europe in recent decades.

Section 3 provides information to help decide which type of predator-exclusion fence or other form of nest protection to use, by considering their effectiveness, cost, advantages, and disadvantages. It also provides information on the numbers of predator fences in use on RSPB wet grassland reserves. An assessment of the effectiveness of breaching rates of combination fences, the most commonly used type of predator fence on RSPB reserves, and their effects on Northern Lapwing *Vanellus vanellus* (hereafter referred to as Lapwing) productivity, is given in Appendix 1.

Section 4 describes important information and considerations relevant to all, or most, types of predator-exclusion fencing.

Section 5 provides information on choosing different electric fence components and on electrical Health and Safety.

Section 6 provides detailed information on the specification, installation, maintenance and longevity of different types of predator-exclusion fences and floating rope barriers.

2. Rationale for the use of predator-exclusion fencing

Ground-nesting birds have experienced large declines across Europe in recent decades, particularly in Britain and Ireland where waders have declined more in range than any other group of birds between the 1968-72 and 2007-11 Breeding Bird Atlases (Balmer *et al*. 2013; McMahon *et al*. 2020).

In the case of wet grassland-breeding waders/meadow birds, recent declines have been largely driven by low breeding productivity (e.g. Peach *et al*. 1994; Chamberlain & Crick 2003). There is now abundant evidence that in western Europe this is principally due to high levels of predation by Foxes, a wide range of avian predators, and at some sites in the UK also by Badgers (Ottvall 2005; Teunissen *et al*. 2008; Bellebaum & Bock 2009; Barton *et al*. 2025).

Meanwhile, along many sections of the coast, breeding Common Ringed Plovers *Charadrius hiaticula*, Eurasian Oystercatchers *Haematopus ostralegus*, Sandwich Terns *Thalasseus sandvicensis* and Little Terns *Sternula albifrons* are largely absent from areas with high levels of recreational disturbance, or else suffer very low breeding success in them (e.g. Liley & Sutherland 2007; Tratalos *et al*. 2021). In most areas where these species still breed along the coast, they are largely or completely dependent on measures to protect their nests and chicks from both recreational disturbance and predation.

Therefore, protecting the nests and chicks of threatened ground-nesting birds from Foxes and Badgers, together with providing suitable nesting habitat free from recreational disturbance, are key measures for these ground-nesting bird species' conservation. Likely reasons for the increase in levels of predation on ground-nesting birds in the UK are summarised in Box 1. Studies have demonstrated the benefits of predator-exclusion fences at increasing breeding productivity of wet grassland-breeding waders (Malpas *et al*. 2013; Verhoeven *et al*. 2021).

Fencing areas of nature reserves to prevent access by Foxes and Badgers may nevertheless seem anathema to people who think that nature reserves should be wild and natural places free, or largely free, from human intervention. The reality is that countries such as the UK, and particularly lowland areas of them, have long been heavily modified by people. Therefore, the use of predator-exclusion fencing can be seen as just another form of human intervention, in this case one that seeks to mitigate the impacts of high levels of predation that is itself the result of human activities.

It is often asked how breeding waders managed to persist on wet grassland before numbers of predators were reduced through persecution. The most likely answer is that high numbers of breeding waders only ever occurred on wet grassland in the UK during a relatively short period in history, during which there were both large areas of suitable habitat present *and* low densities of generalist predators due to persecution, as explained in Box 2.

Box 1. Changes in densities of predators, and of levels of predation, on ground-nesting birds in the UK

In the UK, recent high and increasing densities of predators are thought to be due to a combination of:

1) Increased and high levels of easily accessible live prey and carrion for many meso-predator (medium-sized) species resulting from the annual release of increasingly large numbers of non-native gamebirds (Pringle *et al*. 2019; Robertson *et al*. 2017; Aebischer 2019; https://www.gwct.org.uk/research/long-term-monitoring/national-gamebag-census/bird-bags-summary-trends), and apparently increasing other sources of carrion from roadkill (e.g. Harris 2022).

At the peak of their numbers in August, released, non-native gamebirds are estimated to comprise about half the biomass of all wild birds in Britain (Blackburn & Gaston 2021). Fewer than half of these released gamebirds are shot, and many of the remainder are predated by Foxes (Madden *et al*. 2018; Sage *et al*. 2018).

2) Changes in land-use, particularly the expansion of non-native, commercial forestry in the uplands, which may increase densities of predators in surrounding open habitat (e.g. Valkama *et al*. 1999; Douglas *et al*. 2013).

3) The recovery of many predator species from historical persecution (e.g. Lovegrove 2007). Some species in this last category have also benefitted from the above two changes.

Meanwhile, the quality of habitat for many ground-nesting birds in the wider landscape has in recent decades become less favourable. For waders, intensification of grassland management, for example through drainage, loss of diverse hay meadows to monocultures of rye grass silage, use of inorganic fertilisers and higher grazing livestock densities, particularly of sheep, have resulted in great declines in their populations and range.

Beach-nesting birds are under additional pressure from increasing recreational use of the coast, particularly involving dogs, while steepening of some beach profiles through increased climate change-driven coastal erosion and coastal squeeze further reduces available nesting habitat. Both have resulted in suitable nesting habitat often becoming increasingly confined to the same, predictable, limited areas each year, which may in some cases increase nesting birds' vulnerability to predation.

Overall, the UK has very high densities of Foxes and Carrion/Hooded Crows *Corvus corone*/*cornix*, both of which are known to be important nest predators of ground-nesting birds, compared to most other western European countries (Roos *et al*. 2018). The UK also suffers from the absence (Wolf *Canis lupus* and Eurasian Lynx *Lynx lynx*) or low numbers (Eurasian Goshawk *Astur gentilis*) of some apex predators that reduce densities of meso-predators elsewhere, such as Foxes and Carrion/Hooded Crows (Ellenberg *et al*. 1984; Elmhagen & Rushton 2007; Elmhagen *et al*. 2010; Pasanen-Mortensen *et al*. 2013).

In some situations where predation by Foxes and Badgers is reduced to very low levels through the use of predator-exclusion fencing, the target bird species may nevertheless still suffer low productivity due to high and possibly increased levels of nest and/or chick predation by other species. This can include nest predation by Carrion/Hooded Crows; possibly significant nest predation by Brown Rats *Rattus norvegicus* at some sites where they may benefit from the absence of Foxes within fenced areas and occur in high densities following runs of mild winters; chick predation by Stoats, again possibly benefitting from the absence of Foxes; and chick predation by a wide range of other avian predators, particularly birds of prey and gulls. Despite this, as shown in Appendix 1, the evidence is that excluding Foxes and Badgers still increases Lapwing productivity.

The use of the methods described in this manual aim to deliver win-wins, in both benefitting bird species of high conservation priority, while also minimising the numbers of predators killed in order to achieve this. The aim of the measures described is to increase breeding productivity of the target species to at, or above, the level believed to be required to maintain a stable population. It is important to note that the use of predator-exclusion fencing does not necessarily negate killing Foxes. This is because, as shown in Appendix 1, fences are unlikely to ever be 100 % effective at excluding them and, if a Fox breaches a fence during the breeding season, then usually the only way to prevent it from predating large numbers of birds' nests within the fence is to shoot it. Nevertheless, as also shown in Appendix 1, the number of Foxes shot within fenced areas is very low. It is, though, also clear that the risk of predator-exclusion fences being breached by Foxes can be reduced by also shooting Foxes in the surrounding area (Jellesmark *et al*. 2023), and this may be important at sites with very high densities of Foxes. Recent improvements in the effectiveness of predator fences should hopefully reduce the need to kill Foxes that have breached fences, while also reducing the added benefits of shooting Foxes outside of fences.

Box 2. Changes in the nature of wet grassland in Britain and its implications for breeding wader populations

There is no information about wet grassland waders, or of many other smaller birds, in Britain during Medieval times. Most of the limited information on birds during this period is from archaeological finds of bones of larger birds that were eaten by people (e.g. Yalden & Albarella 2009).

However, given their high sensitivity to human disturbance (e.g. Holm & Laursen 2009), and the likelihood that any wader eggs found by people working in fields would have been taken for food, waders are unlikely to have prospered on grazed grassland or hay meadows during Medieval times. Instead, it seems likely that most waders and other wetland birds in Britain would have bred in remaining areas of more natural wetland, commonly referred to as the 'waste', which was managed through a system of commons rights.

Subsequent historical evidence indicates that, following the enclosure and drainage of much of this common land by Victorian times, wet grassland breeding waders had become rare. For example, More (1865), when describing the current status of birds in Great Britain during the nesting season, stated for Common Redshank *Tringa totanus* (hereafter referred to as Redshank) that ‘A few pairs still breed in Kent and Essex, but the bird is rapidly decreasing in the south, and has almost deserted the fens of the eastern counties, being driven out as its haunts become more and more circumscribed by drainage and cultivation.’ Lapwings were described as being far more widespread at the time in a variety of open habitats but were considered under pressure from both land drainage and commercial harvesting of their eggs for food, these being considered a particular delicacy (Holloway & Gibbons 1996). These pressures on wetland birds during Victorian times resulted in the extinction as breeding species in Britain of Eurasian Bittern *Botaurus stellaris*, Western Marsh Harrier *Circus aeruginosus*, Pied Avocet *Recurvirostra avosetta*, Black-tailed Godwit *Limosa limosa*, Ruff *Calidris pugnax*, Black Tern *Chlidonias niger* and Savi’s Warbler *Locustella luscinioides*, with Western Marsh Harrier also suffering persecution due to being a raptor. This was certainly not a halcyon period for wetland birds in Britain.

The onset of agricultural recession, which began in the 1880s, is assumed to have improved habitat conditions for breeding waders. It resulted in the abandonment of arable and other more marginal land, and an increase in the area of rough grazing, with these changes being more pronounced in southeast England than further north and west (Newton 2017). Accounts are that wet grassland waders then became more widespread, with breeding Redshank steadily increasing in numbers and range in England, Wales and southern Scotland during the last decades of the nineteenth century (Thomas 1942). Conditions then eventually became less suitable for waders again, in this case due to re-intensification of farming, although the earlier stages of agricultural intensification may have benefitted at least some wader species (Beintema 1986). This period of re-intensification began in Britain with government-incentivised drainage from the 1920s onwards, followed by further drainage and increasing use of inorganic fertilisers after the Second World War in the drive for agricultural self-sufficiency.

Crucially, the period between the onset of agricultural recession in the 1880s and the post-war re-intensification of agriculture, also coincided with a period when predator numbers were low. This followed the extermination of Common Buzzards *Buteo buteo*, Western Marsh Harriers, and Red Kites *Milvus milvus* from the lowlands in Victorian times, and the continued widespread persecution of Badgers and Foxes. It is during this relatively short period of history, when there was low intensity agriculture *and* low densities of predators, that wet grassland-breeding waders fared well.

3. Choosing the most suitable type of predator-exclusion fence or other method of nest protection

3.1. Permanently fencing areas of wet grassland, scrapes & other lagoons

There are three types of permanent predator-exclusion fence recommended to protect waders breeding on wet grassland, and a variety of waterbirds nesting on scrapes/shallow lagoons. These are called '**combination**', '**barrier**' and '**underwater/in-ditch**' fences. **Floating rope barriers** have also been used in *wide* ditches at a small number of wet grassland sites to prevent/reduce access by Foxes and Badgers.

Combination fences (Fig. 1) are so-called because they use a combination of both a *ca* 1.3 m high mesh barrier *and* electric wires to prevent access by Foxes and Badgers. The electric wires provide a psychological barrier, since once an animal has received a shock it will then associate the fence with an unpleasant experience and avoid it. The use of electric wires above the mesh, as well as usually half-way up the fence, means that the mesh need not be so high and visually obtrusive than in a barrier fence. Combination fences also have a mesh apron, ideally extending below the fence or else outwards and pegged to the surface of the ground, to prevent Foxes and particularly Badgers from digging beneath the fence.

Barrier Fences are so-called because they work simply by creating a physical barrier to access by Foxes and Badgers (Fig. 2) and do not have electric wires. Barrier fences require taller vertical mesh (typically extending to at least 1.6 m above ground level) than combination fences, plus a cranked (i.e. angled), floppy mesh top that extends outwards and upwards to about 1.9 m above ground level. Trials have found that most Foxes are contained by a 1.8 m high wire netting fence that contains a curved 'floppy' mesh overhang (Moseby & Read 2006). Barrier fences also have a similar underground or surface metal mesh 'apron' to that used in combination fences.

Underwater / in-ditch fences consist of a non-electrified, metal mesh fence installed in a ditch or other water body and that has its top 30 cm or so of mesh protruding above the water's surface (Fig. 3). When installing these fences in ditches, they need to be located > 4 m from the outer bank of the ditch, 4 m being the maximum horizontal distance that a Fox can jump. Hence, they are only suitable for use on fairly wide ditches.

Underwater fences work because neither Foxes nor Badgers are able to jump or climb over even a low fence from a 'swimming position', while the underwater section of the fence prevents them from swimming beneath it, should they attempt to (but see below). The water therefore needs to be > 50 cm deep on the outside of the fence (the maximum height of a Foxes' shoulder), so that a Fox or Badger is swimming, rather than touching the bottom of the ditch, when approaching the fence.

Floating rope barriers consist of a rope with small floats attached to it at frequent intervals, which rests on the surface of the water (Fig. 4). Floating rope barriers work because neither Foxes nor Badgers, being terrestrial mammals, are willing to put their heads underwater and swim beneath the rope.

Fig. 1. A typical combination fence with wooden fence posts at Campfield Marsh. This has two live wires above the mesh with an earth wire between them, and one live wire offset lower down on the outer side of the mesh. The outside of the fenced area is to the left. *Photo by Gavin Thomas.*

Fig. 2. A typical barrier fence with metal posts and a 'cranked' floppy mesh top at Shorne Marshes East. The outside of the fenced area is to the right. *Photo by Malcolm Ausden.*

Fig. 3. A typical underwater/in-ditch fence, in this case with recycled plastic fence posts at Road's Farm, Frampton Marsh. This is part of a mixed fence that also includes a section of barrier fence that protects 52 ha of freshwater and brackish scrapes and other wetland habitat. The outside of the fenced area is to the left. *Photo by Malcolm Ausden.*

Fig. 4. A section of floating rope barrier (swimming rope as it is known in Germany) in the perimeter ditch at Rikelsbuller Koog in the German Wadden Sea. The rope is anchored to the ditch bed every 10 metres by lengths of rope tied to breeze blocks.

The use of larger/more closely-spaced floats, as shown in this picture, may help prevent Foxes and Badgers from pushing over the top of the rope, despite it needing to be held more taught than a floating rope barrier in a larger body of water as described in Section 6.5. *Photo by Gavin Thomas*.

The three types of permanent predator fence differ from one another not only in the way they prevent access by Foxes and Badgers, but also in their cost, level of ongoing maintenance, visual impact and overall suitability for use in different situations. These differences are summarised in Table 1 and discussed in more detail below.

As shown in Table 1, predator-exclusion fences are expensive, and cost far more than current payments for them through agri-environment schemes. For example, the Countryside Stewardship capital payment rate for 'anti-predator fencing' at the beginning of 2025 was just £13.76 per m.

The numbers of different types of predator fence in use on RSPB wet grassland reserves are shown in Fig. 5. A fourth type of fence, **permanent electric strand** (described in Hirons & White 2017), is no longer used on RSPB reserves and is not described in this guidance. This is because permanent electric strand fences rely solely on electric wires to prevent access, and thereby require large amounts of ongoing maintenance to maintain their effectiveness and are more prone to failure than the other types of permanent fence described.

As can be seen from Fig. 5, by far the most commonly used type of permanent fence on RSPB wet grassland reserves are **combination fences**. These have proved popular because they are more effective than the previously described permanent electric strand fences, and cost less and have far lower visual impact than barrier fences. Combination fences do, however, have two major disadvantages.

The first is that **combination fences** require large amounts of ongoing checking and maintenance to ensure they maintain a sufficiently high voltage to deter Foxes and Badgers, as well as needing their battery changing if the fence is not connected to mains electricity, as is most often the case. Time spent checking and repairing combination fences can increase markedly as the fence ages, and one fault can require painstaking and time-consuming checking of the entire fence line.

The second disadvantage is that, although successful at increasing wader productivity and breeding populations on RSPB wet grassland reserves, individual **combination fences** are knowingly breached by Foxes and/or Badgers during the wader breeding season in, on average, 24 % of years (see Appendix 1). These average figures conceal the considerable variation in breach rates between fences though, with some having only very rarely been knowingly breached. For example, as of the start of 2025 the combination fence at Beckingham Marshes has been in place for ten breeding seasons and has, so far, never knowingly been breached by Foxes or Badgers during the breeding season. Meanwhile, a combination fence at Otmoor has been in place for fifteen years and is only known to have been breached during the wader breeding season once by a Badger, and never by a Fox.

We have only limited information on the effectiveness of **barrier** and **underwater/in-ditch fences**, since very few have been in place for very long. However, we have no reason to suspect that either Foxes or Badgers are able to jump or climb over the floppy mesh top of **barrier fences**, and indeed have trail camera evidence of Foxes climbing up the fence but then being unable to climb over the floppy mesh top (see image on the front page of this manual). Furthermore, various designs of barrier fence have been widely used elsewhere in the world over a long period of time and shown to be very effective, for example in preventing incursion by non-native mammals into nature reserves in New Zealand, while the inability of Foxes to climb or jump over them has been demonstrated in previously mentioned trials. The effectiveness of the small number of **underwater/in-ditch** fences installed for more than five years is given in Box 3. Overall, the indications are that if properly installed, both **barrier** and **underwater/in-ditch fencing** should be far more effective than **combination fences**, because both provide considerable physical barriers to Foxes and Badgers, and do not rely on fallible electric wires.

We also only have limited information on the effectiveness of **floating rope barriers.** The Rikelsbuller Koog polder in the German Wadden Sea has been protected using a floating rope barrier for several years and despite the narrow perimeter ditch in which it sits, has apparently been successful at keeping Foxes out but not Common Racoon Dogs *Nyctereutes procyonoides* that swim under it. Meanwhile, floating rope barriers have also been used to protect nesting islands as described in Section 3.3, and evidence so far suggests a high level of effectiveness in those situations. However, we assume that, because we know that at least some individual Badgers have learnt to put their heads underwater (and presumably some Foxes will do as well), floating rope barriers will undoubtedly prove less effective than permanent fences.

Because of the assumed high effectiveness of both **barrier** and **underwater/in-ditch** fences compared to **combination fences**, together with their far lower maintenance requirements, both may provide valuable alternatives where appropriate and feasible. The disadvantages of barrier fences, though, are their high cost and high visual obtrusiveness. Meanwhile, underwater/in-ditch fences are cheaper, assuming their installation does not require expensive widening, excavation and/or reprofiling of ditches, and they are by far the least visually obtrusive type of predator-exclusion fence. However, a current concern with underwater/in-ditch fences, and indeed with sections of combination and barrier fences that lie in water, is the rate of corrosion of their mesh, although this has been very variable, as described in Section 6.3. More expensive, PVC-coated mesh is being installed at several sites, which it is hoped will last much longer. An underwater/in-ditch fence at Hodbarrow, comprised of PVC-coated V Mesh panels, has been in place since 2016 and has so far not suffered from corrosion.

Barrier fences are likely to be a good alternative to combination fences where both higher levels of funding are available, and their installation will not unduly impact on the landscape and/or viewing. In some situations, the high visual impact of barrier fences may be mitigated by locating them amongst Common Reeds (Fig. 6). Locating them amongst tall, emergent vegetation is not thought to reduce their effectiveness, but may increase the rate of corrosion of mesh (see later).

If suitably wide and deep ditches are present, then **in-ditch/underwater fences** may be the most suitable of the three types of permanent fence described, due to their apparently high level of effectiveness, requirement for virtually no ongoing maintenance (but with the big caveat of probably needing to replace sections of corroding mesh as discussed elsewhere, or else needing to use more expensive mesh), and very low visual impact. Underwater/in-ditch fences can also be located in areas that deeply flood in winter, such as washlands, other regularly flooding floodplains and many intertidal areas, where higher barrier and combination fences would be at greater risk of severe damage from larger flood debris (Fig. 7).

Floating rope barriers may also be an option in suitably wide and deep ditches. As with their use in larger water bodies, although they will undoubtedly be less effective than a fence, their advantages are their low cost and low visual impact.

Additional considerations:

As described in Section 6, additional measures used to make fences more effective or to increase their longevity will inevitably increase their cost. Examples of increasing effectiveness include installing deeper buried mesh beneath the fence or fitting a floppy mesh to underwater/in-ditch fencing. Examples of increasing fence longevity include using plastic instead of wooden posts for underwater fencing and using PVC-coated mesh for both buried mesh aprons and underwater fencing. The cost-benefits of using more effective/long-lasting fence designs need to be made at a site level, and it is worth remembering than no predator fencing is ever likely to be 100 % effective at excluding Foxes and Badgers. The key consideration is whether the fence will be *effective enough* to increase the productivity of the target species to a *sufficiently* high level over a long enough period of time to either maintain, or increase, their breeding population. This having been said, it is worth pointing out that if a Fox or Badger breaches a fence protecting high densities of nesting birds, such as on scrapes or seabird nesting islands, it can have very rapid and severe consequences.

As will also become apparent in Section 6, if Badgers are a persistent issue, then greater investment may be required to prevent them from burrowing beneath a fence, while if Foxes are the main issue, than efforts are likely best spent in measures to prevent them from climbing/jumping over it. It is particularly important to prevent Badgers from gaining access to within predator-fenced areas, since once they have got inside them, they can often be very difficult to tempt back out again (Section 4.9).

When considering the specification of a fence, it is also worth remembering that the costs of installation can comprise a large proportion of the total costs of the fencing, while replacing an existing fence may also require quite costly removal and disposal of the old fence. Therefore, spending more on fencing materials that last longer may prove cheaper in the long term.

An issue when replacing fences is that their buried mesh can corrode, leaving sharp pieces of broken mesh that could be hazardous to livestock. One option would be to place soil on top of these areas to bury these pieces which will eventually corrode altogether.

Finally, it is also worth pointing out that an individual predator-exclusion fence can consist of different types of fence joined together. For example, the fence enclosing Roads Farm at Frampton Marsh mainly comprises underwater/in-ditch fencing, but with a section of tall, barrier fence where there is no ditch or other open water, and its presence does not obstruct viewing. However, as also referred to later on, joins between different types of fence (known as transitions) can provide weak points for entry of Foxes and Badgers, so it is also desirable to minimise the number of transitions as far as possible.

Box 3. The effectiveness of underwater/in-ditch predator-exclusion fences that have been in place for more than five years

We are only aware of underwater/in-ditch predator-exclusion fences having been in place for more than five years at the following four sites in the UK: at Rye Harbour Sussex Wildlife Trust Reserve, where the use of underwater fences was pioneered by Barry Yates, and where underwater fences have been used since the 2003 breeding season to protect nesting terns and gulls on islands; at Elmley NNR where an in-ditch fence was installed in 2012; at Hodbarrow where a tall in-ditch fence has been in place since 2016 to isolate a lagoon island tern colony from the 'mainland' (Fig. 28); and at Wallasea Island where an in-ditch fence was installed in a specially created ditch prior to the 2017 breeding season.

At Rye Harbour, installation of the first predator fence around a seabird nesting island resulted in no known breaches by Foxes or Badgers during the ten years of operation of the fence, following a period where nesting seabirds on these islands had been regularly predated by ground predators.

At Hodbarrow, a tall V Mesh barrier fence installed in 2016 has, as far as we know, prevented any Fox incursions onto the island during the eight breeding seasons it has been in place.

On Wallasea Island, the in-ditch fence encloses 103 ha of land. During the eight breeding seasons that it has so far been in place, the fence has been breached by a Fox twice during the breeding season twice. The first was when a Fox was seen jumping through a small gap in the mesh next to a gate soon after the fence was installed. The second was when a Fox was seen once inside the fence when the ditch froze making the fence easy to jump/step over. Other than this, there has been only one additional sighting of a Fox in the fenced area, this having been outside of the bird breeding season, and no evidence of Badgers ever having breached it. It is not known how the last Fox breached the fence. This success is despite there being Badger setts on the reserve outside the fenced area, as well as reasonable numbers of Foxes in the wider area.

At Elmley, the fence does not completely enclose the *ca* 300 ha area of coastal grazing marsh that it helps protect, and instead aims to reduce incursions by Foxes along sections of the reserve boundary that are not otherwise bounded by wide (> 30 m) water bodies or intertidal habitat. Following the installation of the fence, sightings of Foxes on the wet grassland reduced from about 90 to 20 per year (Gareth Fulton, pers comm).

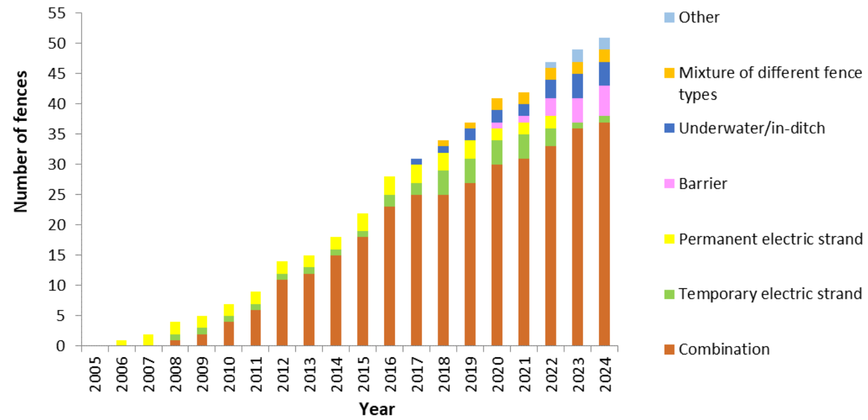
Table 1. Summary of the advantages and disadvantages of different type of permanent predator-exclusion fence and floating rope barriers for protecting areas of wet grassland, scrapes & lagoons.

*Figures for cost per m are *approximate* figures for 2024 and have been calculated by dividing the total costs of fencing materials and gates, and their installation, by the length of the fence. Costs can vary enormously due to site-specific factors and the contractor involved. New fences may require additional costly levelling of areas of ground before the fence can be installed. Replacement of existing fences may involve significant additional costs of removing and disposing of the old fencing. ** costs for underwater/in-ditch fences do not include any costs of deepening/reprofiling ditches or, when used in other water bodies, any deepening required along the fence line.

Fence type	**Effective-ness**	**Approx cost (£ per m) ***	**Longevity**	**Visual impact**	**Level of checking & ongoing maintenance**	**Situations where most suitable for use**
Combination	Medium to high	30-40	Medium	Medium	Very high	Wet grassland and scrapes where barrier fences would be too visually intrusive and there are no suitable ditches in which to install an in-ditch/underwater fence, but where the fence can also be regularly checked to maintain a sufficient voltage. Unsuitable for areas subject to deep and extensive flooding (such as washlands and floodplains) as likely to be damaged by large flood debris.
Barrier	Probably very high	45-55	Probably high, providing its mesh apron does not remain wet	High	Low	Wet grassland and scrapes where they will not unduly visually impact on the landscape or impede viewing of wildlife. As with combination fences, unsuitable for areas subject to deep and extensive flooding.

Fence type	Effective-ness	Approx cost (£ per m) *	Longevity	Visual impact	Level of checking & ongoing maintenance	Situations where most suitable for use
In-ditch /underwater	Probably very high	30-35**	Possibly low due to corrosion of its mesh in water	Very low	Virtually none initially, but may need regular checking to patch up corroded mesh as they age	Wet grassland that has sufficiently wide and deep ditches in which to install them, including areas subject to deep and extensive flooding (flood debris will pass over the top of them), and to protect islands in fairly shallow water bodies (but with areas > 0.5 m deep in which to install the fence).
Floating rope barrier	Probably medium	5	Probably high	Extremely low	Virtually none	To protect islands in fairly large and deep (> 0.5 m) water bodies, such as gravel pits, and possibly an option for protecting wet grassland that has sufficiently wide and deep perimeter ditches.

(a) Number and type of fences installed



(b) Areas of wet grassland enclosed by different types of fence

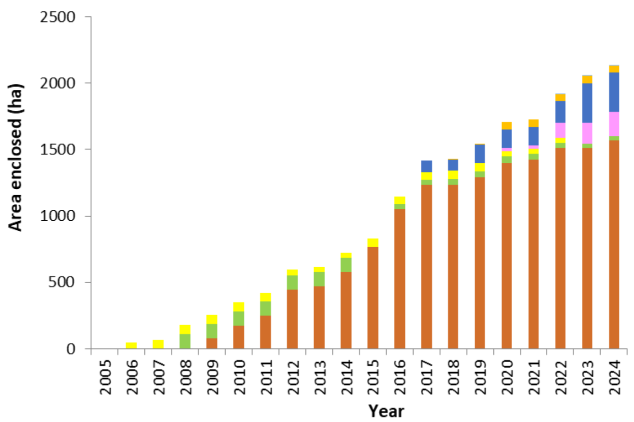


Fig. 5. Numbers and types of predator-exclusion fence on RSPB wet grassland reserves, and the areas of grassland enclosed by them.

As of the end of 2024, there were 51 predator-exclusion fences installed on 41 of the RSPB's 65 nature reserves that contain lowland wet grassland. As can be seen from the graphs above, the vast majority of these are combination fences, with permanent electric strand fences having been phased out (see main text), while the proportion of both barrier and underwater/in-ditch fences has increased in recent years.

The mean size of predator-exclusion fences installed on RSPB wet grassland reserves is 37.4 ha, with the smallest being 2.5 ha and the largest 134 ha (at March Farmers on the Nene Washes). At sites where they have been installed, predator-exclusion fences enclose a mean of 44.4 % of the total area of wet grassland present (range 2.2 % to 100 %).

(a)

(b)

Fig. 6. Barrier fences are tall and can be visually intrusive, but in some situations can be hidden amongst vegetation or mitigated for by elevated viewing points. **(a)** A section of *ca* 1.9 m high barrier fence shortly after installation at Frampton Marsh, which is obscured by Common Reed from the side away from where the photo was taken. **(b)** A similarly high barrier fence largely obscured by Common Reed at Bower's Marsh. The top cranks of the fence can just be seen on the left and right hand sides of the photo. *Photos by Toby Collett (top) & Malcolm Ausden (bottom).*

Fig. 7. A section of combination fence flattened by flood debris at Middleton Lakes in 2020. *Photo by Kate Thorpe.*

3.2. Protecting individual nests using temporary fencing

Temporary electric fences can be used to protect individual wader nests, such as those of Eurasian Curlews *Numenius arquata* (hereafter referred to as Curlews), Black-winged Stilts *Himantopus himantopus* and Eurasian Stone-curlews *Burhinus oedicnemus* (hereafter referred to as Stone-curlews) as well as tern colonies. Temporary electric fences consist of *ca* 1.1 m high multiple electric strand fences (Fig. 8), or electric mesh fences. Guidance on the use of temporary fencing for Little Terns and other beach-nesting birds is being produced by the LIFE on the Edge project and will be available in 2026 https://www.rspb.org.uk/helping-nature/what-we-do/protecting-species-and-habitats/projects/life-on-the-edge.

The obvious advantages of temporary electric fencing are the ability to protect birds that do not nest in the same area every year, and their use in areas where it is not practical or desirable to install permanent predator fencing. The disadvantages of temporary electric fences are that they rely solely on electric wires, or electrified netting, to prevent access by Foxes and Badgers, and so require regular checking and maintenance to ensure they maintain a sufficiently high voltage. They also require replacement of their battery where they are not connected to mains electricity, which is usually the case, although solar powered set-ups are now increasingly efficient.

Temporary electric strand fencing is undoubtedly less effective at preventing access by Foxes and probably Badgers compared to combination, barrier or underwater fences. However, set against this, is that where temporary electric fences are used to protect individual nests, they only need to exclude ground predators for the relatively short period of time between the fence being installed, and the individual nest hatching, rather than for the whole breeding season as is the case with permanent fencing that protects large areas of habitat with multiple nests. Temporary electric fencing is unlikely to survive long in areas where cattle are present.

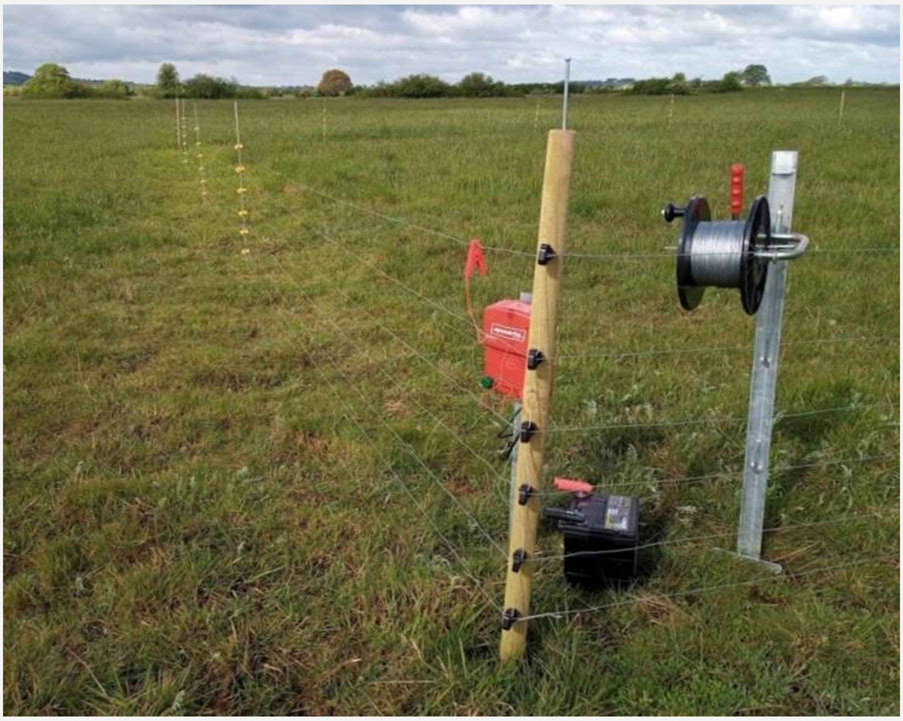


Fig. 8. The corner of a temporary, *ca* 15 m x 15 m square six-strand electric fence installed to protect a Curlew nest at Otmoor. *Photo by David Wilding.*

Alternatively, individual nests of Common Ringed and Little Ringed Plovers *Charadrius dubius* can be protected using **nest cages**. These consist of a wire mesh structure that encloses the nest and is firmly attached to the ground to prevent Foxes or Badgers from dislodging it. The mesh has large enough holes to allow access to and from the nest by incubating birds, but that are not large enough to allow access by Foxes, Badgers, cats, crows, gulls and other larger predators. If installed on beaches, it is worth also cordoning off a small area around the nest cage and including signage to prevent people and their dogs from inadvertently, or intentionally, approaching too closely and disturbing the incubating bird. It is worthwhile also installing cages on areas without nests, to help reduce the likelihood of predators associating the presence of cages with nests.

It is important to note that the use of nest cages to protect small plovers can require large amounts of time, due to the need to monitor progress and quickly locate and protect nests, including re-lays, before they are predated. It is also important to carefully consider whether their use is appropriate to an individual site with its particular predator guild, particularly in the case of urban-fringe locations where adult birds are particularly vulnerable to being predated at the cage by domestic cats. Best practice guidance on the use of nest cages for Common Ringed Plovers is being prepared through the LIFE on the Edge project and will be available later in 2025 https://www.rspb.org.uk/helping-nature/what-we-do/protecting-species-and-habitats/projects/life-on-the-edge.

Nest cages can only be used to protect the nests of smaller wader species, since the width of the mesh needed to allow access by, for example Eurasian Oystercatchers, would be wide enough to also allow access by crows and smaller gull species. Nest cages have also been successfully used to increase the breeding productivity of Lapwings (e.g. Isaksson *et al*. 2007), but again with the risks of increasing adult mortality and nest abandonment. In general, nests of wet grassland waders are best protected by enclosing larger areas of habitat using permanent fencing as described earlier.

Nest cages are not to be confused with nest protectors, which are used to prevent trampling of wader nests by livestock e.g. see Guldemond *et al*. (1993).

3.3. Protecting islands in scrapes & larger water bodies

There are two types of structure that can be used in lagoons to prevent Foxes and Badgers from swimming to islands, or groups of islands – **underwater fences** and **floating rope barriers** (Fig. 9).

Floating rope barriers are used to encircle an island or group of islands. The rope is loosely anchored in place using weights and, in large, exposed water bodies with strong wave action, also prevented from being dragged too far out of position by installing small numbers of wooden posts in the water. As with underwater fencing, floating rope barriers need to be installed in water that is > 50 cm deep, so that Foxes and Badgers approach them while swimming.

Floating rope barriers are assumed to be most effective if the rope is slack, meaning that a swimming Fox or Badger keeps on pushing against it, rather than being able to push over the top of a more taught rope. Therefore, floating rope barriers are assumed to be more effective if located in large water bodies and relatively wide ditches so that the animal swims and pushes against the slack rope for a reasonable distance. It is also assumed that a floating rope barrier is likely to be more effective if located far from shore, so that the swimming animal becomes tired more quickly after swimming up against the rope and gives up and returns to land.

Underwater fences used in lagoons are of the same design, and work in the same way, as those used in ditches, as described in Section 3.1. They similarly require the water to be > 50 cm deep on their outer side. They are, though, impractical to install in very deep water and are easiest to install by drying out the water body to facilitate access.

Fig. 9. A section of a floating rope barrier used to protect islands with nesting Common Terns *Sterna hirundo* and Black-headed Gulls on the Main Lake at Saltholme. *Photo by Gavin Thomas.*

Standard **barrier** and **combination fences** can also be installed around the perimeter of lagoons to prevent access by Foxes or Badgers to islands within them. Barrier fences can also be extended out into open water, with the 'wet' end of the fence angled back towards land, to guide any swimming animal back towards the shore rather than towards the island(s), as animals are believed to focus their efforts on breaching the fence at the angle, rather than swimming around it. The end of such a combination fence at Seaforth Lancashire Wildlife Trust reserve, which protects a causeway, has been extended out into the lagoon and continued into deep water as a floating rope anchored to a single float at its end. This fence has successfully excluded Foxes from the causeway and its islands, where Common Terns and several species of wader nest, during the three years that it has been in operation since 2022.

Combination fences are unsuitable for use on islands themselves, because their high level of ongoing maintenance would cause too much disturbance to nesting birds. Barrier fences, although used on some islands, are also not ideal, because of the risk of birds, particularly young gulls, getting caught in the fence and dying.

Standard barrier and combination fences with 5 cm maximum gaps between their vertical wires should prevent access by Eurasian Otters *Lutra lutra* (hereafter referred to as Otters). Underwater fences are only likely to prevent access by Otters if they also have similarly narrow mesh that extends to the bottom of the ditch, so that Otters cannot swim beneath it, together with a floppy mesh top to prevent them from climbing over. Otters may cause high levels of predation in tern and small gull colonies, but while they also take wader chicks and for example ducklings, they do not appear to really target them. Hybrid Polecat Ferrets *Mustela putorius x Mustela furo* may become an increasing issue at tern and gull colonies as they increase in numbers and range, and preventing access by them would require a smaller mesh size than the 5 cm recommended in this guidance. Floating ropes will obviously not provide a barrier against Otters or, in continental Europe, Common Racoon Dogs.

We only have limited evidence of the effectiveness of floating rope barriers, as they have only been installed at a small number of sites and in most cases only for a short period. Nevertheless, they have been successfully used to protect islands at two nature reserves in Denmark, Margrethe Kog and Harboøre Tange for, as of the start of 2025, respectively, four and six or seven years, with no known breaches by Foxes (information from Henning Fjord Aaser at the Ministry of Environment and Food of Denmark). Floating rope barriers have also been used to protect islands in the Main Lake at Saltholme (for three years so far), and to protect groups of islands in two gravel pits at Dungeness (for two years so far) and neither are so far known to have been breached by either Foxes or Badgers.

Floating rope barriers will, though, undoubtedly prove less effective at preventing access by Foxes and Badgers than underwater fencing, as they do not provide such a physical barrier. The big advantages of floating rope barriers over underwater fences are that they are both cheap and very unobtrusive and can also be used to protect islands in larger, deeper water bodies, for example gravel pits, in which it will usually be impractical to install underwater fences.

4. General considerations

Before we describe best practice design and maintenance of different type of predator-exclusion fence, we will first describe some over-arching considerations that apply to more than one, and in some cases all, fence types.

4.1. Legal and planning requirements

Installing predator-exclusion fences on SSSIs and ASSIs will require consent from the relevant country statutory conservation organisation. They may be concerned about digging a trench in which to bury a mesh apron of a permanent predator fence that cross valuable habitat, such as unimproved grassland. They may also require reassurance that permanent fences installed on SSSI/ASSI saltmarsh are likely to have little or no adverse effects on waterbirds through collisions, or that fenceposts installed on saltmarsh are unlikely to result in significant erosion around their base. Where Badgers are present, representatives of statutory agencies may also need convincing that the installation of permanent fences does not unduly reduce the area of land over which they can forage.

A disturbance licence will be needed if working near to nesting Schedule 1 bird species, for example when installing temporary electric fencing around nesting Stone-curlews, Black-winged Stilts, Little Terns and in the case of Northern Ireland also Curlews. This is less likely to be required when installing permanent predator-fencing, since their installation does not take place during the breeding season. However, checking and maintaining permanent fences may nevertheless cause disturbance to Schedule 1 breeding birds. Legal considerations regarding Eurasian Beavers *Castor fiber* (hereafter referred to as Beavers) are described in Section 4.10.

Fences less than 2 m high are very unlikely to require planning consent. Flood Risk Activity Permits (FRAPS) are required if installing a fence within 8 m of a main river or 16 m from a flood defence (i.e. a sea wall). It has so far proved straightforward obtaining these permits.

Legal requirements regarding electric fencing are described in Section 5.

4.2. Size & location of fences & minimising the number of weak points

Permanent fencing

It should go without saying, that the primary consideration is ensuring that the area within the fence is in prime condition for the target species. This includes not enclosing areas of vegetation within the fence in which any Fox breaching the fence can hide and so avoid detection, and avoiding where possible areas of high, dry ground into which any Foxes and Badgers that breach the fence can burrow.

Protecting a larger area of habitat with predator fencing will be more cost-effective than protecting a smaller area, in terms of the area of habitat protected per cost of fencing. Fencing a larger area will make it easier to include sufficient chick foraging habitat within the fenced area, thereby increasing the likelihood of chicks remaining within the fenced area, safe from Foxes, until they fledge.

Permanently fencing a larger area can, though, make it more difficult to shoot or otherwise remove any Foxes that do get inside the fence. The sizes of areas enclosed by permanent predator-exclusion fences on RSPB wet grassland reserves are given in Fig. 5.

It is also important to consider the visual impact of permanent predator fences on the landscape, particularly in the case of more visually intrusive barrier fences, together with the impact the fence may have on viewing wildlife and photography. Fences should not be installed on Scheduled Monuments/Scheduled Ancient Monuments/Scheduled Historic Monuments and other archaeological sites without specialist approval, and they should not block access on Public Rights of Way or on CRoW land. An archaeological survey may be required before digging deep trenches in which to bury a fence's mesh apron. Always consult your RSPB archaeologist beforehand. Any new fencing on registered common land requires the permission of the Secretary of State.

A predator-exclusion fence is only as good as its weakest points, and usually these are their gateways. The recommended gates for barrier fences are usually very substantial structures and are unlikely to be breached, although the surroundings of gates of both combination and barrier fences still have a variety of potential gaps that Foxes and Badgers can be quick to exploit, including beneath the closed gates in both types of fence. The widest part of a Fox or Badger is its head, with the skull of an adult Fox skull typically being 7 cm wide, that of a Badger being 8 cm wide, while the width of the skull of younger, fairly independent Foxes is just 5 cm. Gaps wider than these dimensions can allow these animals to pass through. In addition, another seemingly frequent way that Foxes get inside fenced areas is by people, most often graziers, leaving predator fence gates open. Because of all of these risks, it is best to minimise the number of gates within a predator fence as far as possible, while balancing this against not having too few access points that this unduly impinges on day-to-day management.

Other potential weak points are 'transitions', where different types of fence join to each other, for example where a section of underwater fence joins a section of barrier fence. Culverts beneath fences may also provide weak points through which Foxes or Badgers may pass when water levels are low.

It can be tempting and often sensible to locate fences close to field boundaries to reduce their visual impact, and so as to include as much habitat as possible within the fenced area. However, introducing more changes in direction of a fence and generally making it more complex, will reduce the strength of the fence and thereby make it more vulnerable to being breached. This is particularly the case with combination fences since their high tensile live wires require firm strainer posts at every change in direction of the fence. Leaning strainer posts, and loose and sagging wires, together with the need for more complex wire arrangements around strainer posts, increase the likelihood of live wires touching other parts of the fence and shorting out. Because of the extra cost of strainer posts, more complicated fence shapes with more changes in direction are also more expensive.

Set against all of this, having a simpler fence route risks cutting off isolated areas of land on the outside of the fence, for example between a fence and a ditch, on which vegetation is difficult to manage, and which may make the fence more difficult to check and repair. Again, this is likely to be a bigger issue with combination fences due to their greater need for regular vegetation management on their outer side to reduce the amount of vegetation touching live wires. In the case of combination fences, it is best to leave a wide enough gap between the fence and ditch or other boundary, to enable easy mechanical management of vegetation on its outside, while a gap of > 8 m will be needed between fences and, for example IDB (internal Drainage Board) ditches, to allow vehicle access for ditch maintenance. It is also more difficult to install fences that are free of gaps and other weak points where they traverse more uneven ground.

Smaller gauge mesh fences can have negative impacts on wildlife that are unable to pass through the mesh, for example ducklings (Pietz & Krapu 1994) and larger wader chicks that may then become separated from their parents. This should be a consideration when planning any permanent predator fences.

There are additional issues to consider when installing permanent predator-exclusion fencing in areas where Beavers are present, as described in Section 4.10.

Temporary electric fencing

In the case of temporary electric fencing, the size of the area fenced will be a trade-off between not fencing too small an area around a nest, versus the extra time (and cost of materials) needed to fence a larger area, and during which birds are kept off the nest. Other considerations are the ability to carry the larger quantity of materials needed to fence a larger area and, in the case of multi-strand fencing, the length of wire on an individual reel.

The short-lived nature of temporary fencing, and the relatively small areas of land enclosed by it, mean that temporary electric fencing is unlikely to unduly impede the movement of other wildlife. However, temporary electric strand fences, which have their lowest wire set close to the ground, and especially electrified mesh fences, can on rare occasions entangle/electrocute small animals such as amphibians and European Hedgehogs *Erinaceus europaeus*. This should obviously also be borne in mind, and electric mesh fencing not be installed, for example close to waterbodies where there is a greater risk of it negatively impacting on other wildlife. In particular, it is important to avoid fencing any areas that support Natterjack Toads *Epidalea calamita* and Great Crested Newts *Triturus cristatus*, which have special protection under the Wildlife and Countryside Act 1981 and the Conservation (Natural Habitats) Regulations 1994.

4.3. General principles of using electric fencing

Electric fences deter animals from attempting to breach them by giving them an unpleasant, but physically undamaging, electric shock. Most animals, after receiving an electric shock from a fence once or twice, will then avoid it. This is why it is important to not turn off electric fences when Foxes or Badgers are nearby and active, as it will reduce their association between touching the fence and receiving a shock. Therefore, any length of electric fencing constructed should go live (including the earthing arrangement) as soon as it is installed to ensure any animal touching the fence always receives a shock. Similarly, it is usually best to keep the electric strands of combination fences live throughout the year rather than just during the breeding season, although there are reasons mentioned later on why this may not always be practical or indeed desirable.

An electric fence contains the following components. First, mains electricity or a battery that is connected to an energiser that produces a regular pulse of electricity. The energiser is earthed by connecting it by a wire to an earth stake driven into the ground. Nowadays, batteries for electric fences are usually also connected to a small solar panel to help maintain their charge. There are two different configurations of additional wires from the energiser.

In the **Ground Earth Return System** (Fig. 10a), the current leaves the energizer and moves along the fence wires. When an animal touches the fence, it feels a shock as the brief pulse of electric current goes through its body, into the soil, and back to the energizer via the earth system, so completing the circuit. This system works well in moist soils that conduct electricity well. However, dry peat and sandy soils and shingle are poor conductors of electricity and provide a less effective earthing system. With these types of substrate there are three options: 1) Use additional earth rods to better earth the system; 2) Choose a better location for the earth system, such as damp soil; 3) Use a **Fence Wire Earth Return System** (Fig. 10b). This requires a fence to have alternating electric and earth wires that are closely spaced relative to an animal's body size. This ensures that an animal trying to push through the fence makes firm contact with both a live and earth wire simultaneously and receives a shock as the current passes through the animal between where it touches the live and earth wires.

There is a risk, though, with the Fence Wire Earth Return System, that in high winds wires can get tangled, meaning the earth wire then shorts out the entire fence. This problem is reduced with the use of new, high tensile wiring but can still become an issue as a fence ages. It is also worth remembering that the entire mesh netting on the fence is effectively the earth – an animal may touch this at the same time as it touches a live wire, increasing the shock that it receives.

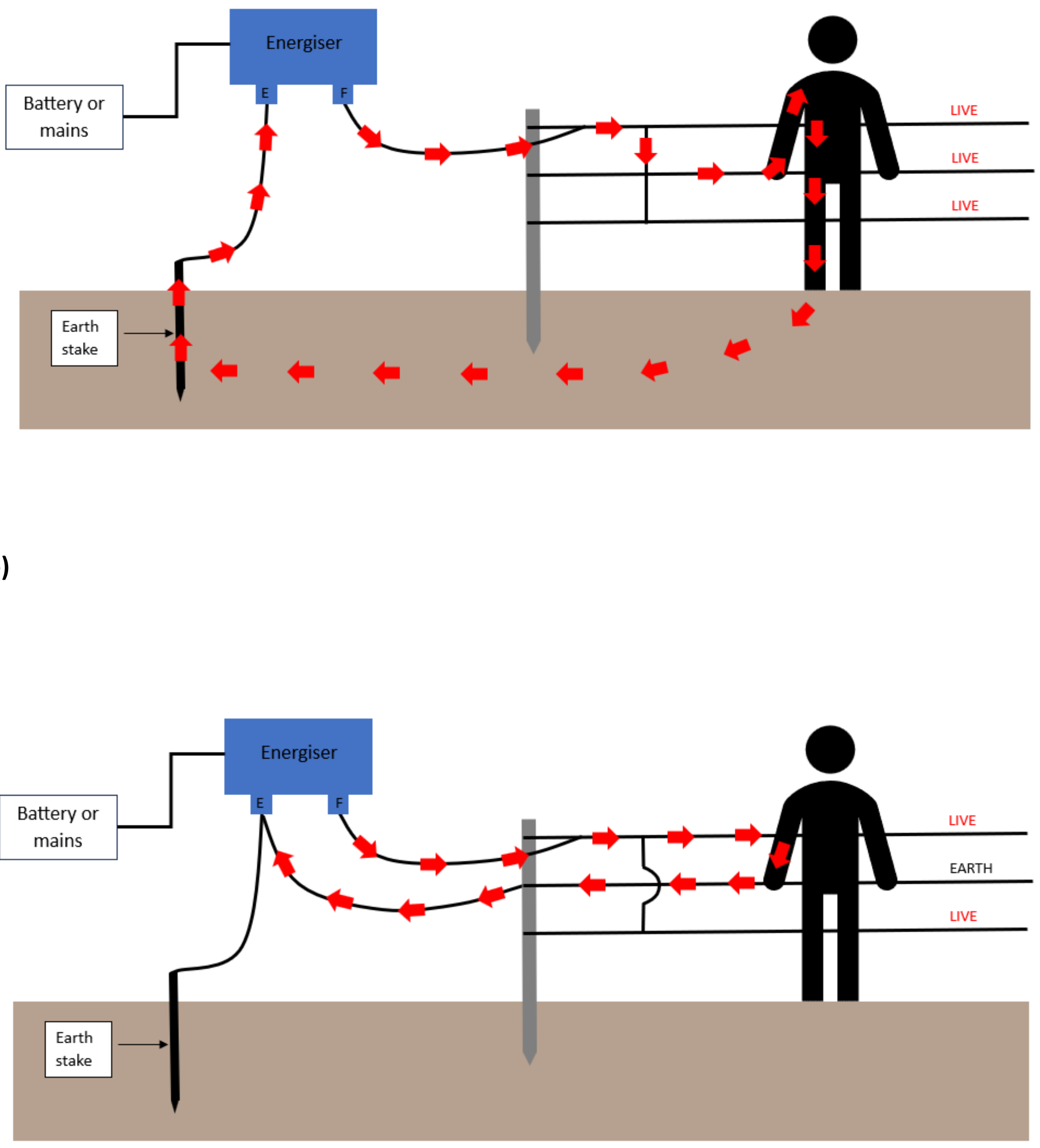
An animal will only be dissuaded from touching the wires of an electric fence if it receives a sufficiently large electric shock, typically of between 5,000 and 10,000 Volts. The maximum voltage allowed by law for an electric fence in the UK is 13,000 Volts (see Section 5.5).

A range of factors determine the voltage of a live wire. These are:

1) The power of the battery.
2) The type and settings of the energiser.
3) The length and number of live wires in the fence.
4) How well the circuit is earthed.
5) How much current is lost while the electricity passes through the live wire(s) of the fence due to poor insulation, including due to vegetation touching the live wires.

Choices of battery, energiser and solar panels are discussed in Sections 5.1-5.3. **Health and Safety requirements, including regarding the location of electric fences, are given in Section 5.5.**

(a)



(b)

Fig. 10. Electric fence systems **(a)** Ground Earth Return System; **(b)** Fence Wire Earth Return System. On the energsier, E indicates the earth terminal and F indicates the fence terminal. The red arrows show the flow of the current when (a), a person touches a live wire with their hand, and (b) when a person simultaneously touces both a live and earth wire with their hand and arm. Re-drawn from Hirons & White (2017).

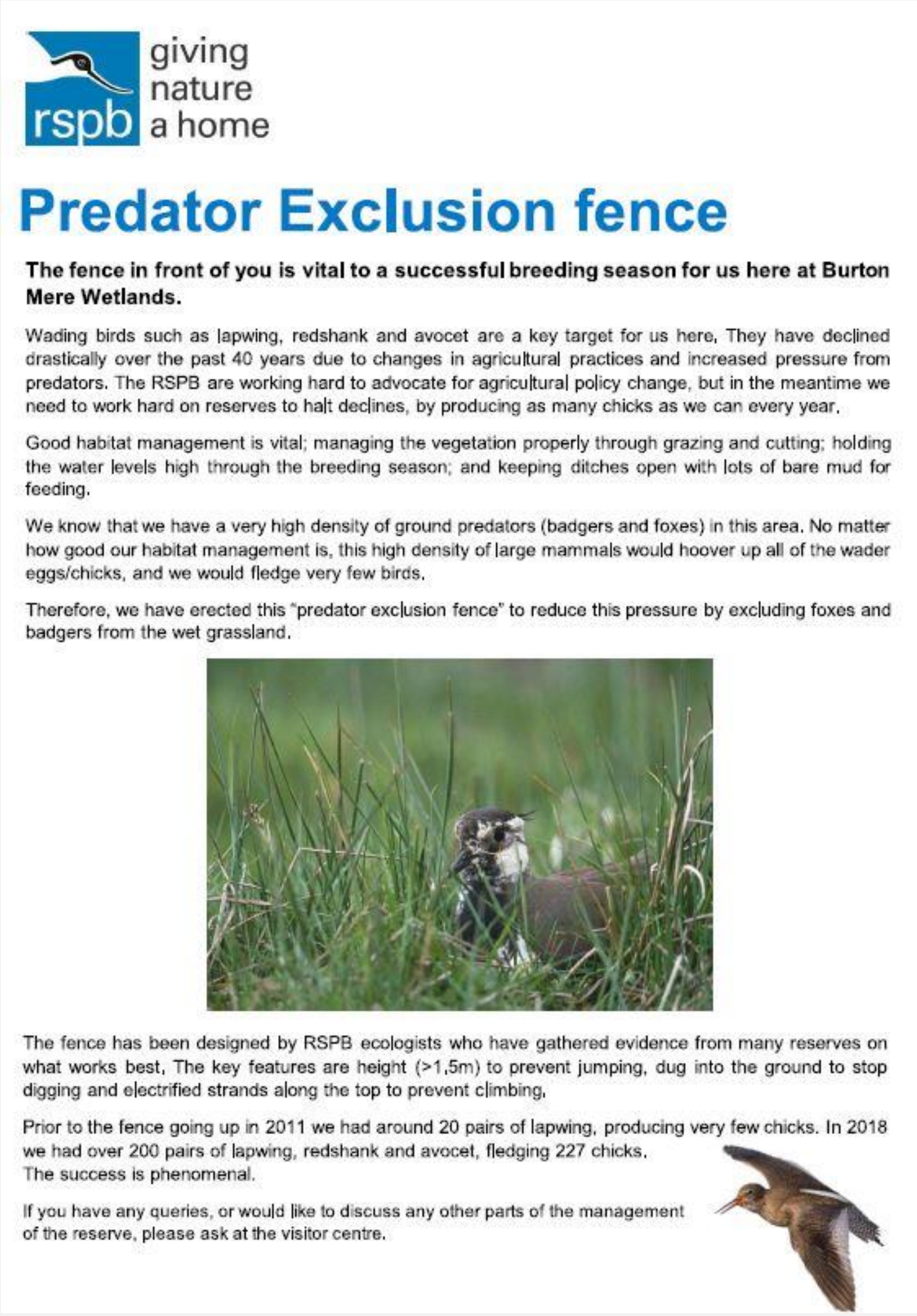
4.4. Use of contractors

As described in Section 6, there are many ways that predator-exclusion fences can fail and allow the entry of Foxes and Badgers, particularly in the case of combination fences, and some of these are due to poor installation. Not many contractors have experience of installing predator-exclusion fences, so it is important to use contractors who have a good track record of installing them. It should go without saying that it is always best to speak to people at other sites who have had fences recently installed, before choosing a contractor.

Good oversight of contractors is also important, together with the need for 'bespoke' solutions, for example where a fence crosses a ditch. It is also important to agree a 'snagging' period, so that errors can be rectified once the fence has been thoroughly checked on completion.

4.5. Communicating with local people & visitors

It is important to communicate well with local people and visitors, both verbally and through signage (e.g. Fig. 11) particularly when installing visually intrusive barrier fences, and to explain why predator-fences are used and their benefits. People may be particularly concerned about predator fences restricting the movement of Brown Hares *Lepus europaeus* and Irish Hares *Lepus timidus hibernicus* (see Section 4.7), while bird photographers are likely to be concerned about barrier fences restricting photographic opportunities.



giving nature a home

rspb

Predator Exclusion fence

The fence in front of you is vital to a successful breeding season for us here at Burton Mere Wetlands.

Wading birds such as lapwing, redshank and avocet are a key target for us here. They have declined drastically over the past 40 years due to changes in agricultural practices and increased pressure from predators. The RSPB are working hard to advocate for agricultural policy change, but in the meantime we need to work hard on reserves to halt declines, by producing as many chicks as we can every year.

Good habitat management is vital; managing the vegetation properly through grazing and cutting; holding the water levels high through the breeding season; and keeping ditches open with lots of bare mud for feeding.

We know that we have a very high density of ground predators (badgers and foxes) in this area. No matter how good our habitat management is, this high density of large mammals would hoover up all of the wader eggs/chicks, and we would fledge very few birds.

Therefore, we have erected this "predator exclusion fence" to reduce this pressure by excluding foxes and badgers from the wet grassland.

The fence has been designed by RSPB ecologists who have gathered evidence from many reserves on what works best. The key features are height (>1,5m) to prevent jumping, dug into the ground to stop digging and electrified strands along the top to prevent climbing.

Prior to the fence going up in 2011 we had around 20 pairs of lapwing, producing very few chicks. In 2018 we had over 200 pairs of lapwing, redshank and avocet, fledging 227 chicks.
The success is phenomenal.

If you have any queries, or would like to discuss any other parts of the management of the reserve, please ask at the visitor centre.

Fig. 11. Predator-exclusion fence signage at Burton Mere Wetlands.

4.6. Regularly checking fences

It is important to regularly check the entire length of fences for signs of Foxes and Badgers trying to, or succeeding in, breaching them, and to regularly check that live wires have a sufficiently high voltage. Hand-held fence testing devices can be used to check the voltage. These can include fault finding functions that indicate the likely direction of a fault on the wire and, more importantly, an on/off function that allows the whole fence to be turned off when a fault is found. This saves a huge amount of time walking back and forth to the energiser.

It is also important to place trail cameras at key locations within the fenced area to check for the presence of any animals that have gained entry, check for footprints and scats, signs of predated birds and to use thermal imagers. 'Scat pads' can also be used - Foxes like to defaecate on something and providing, for example a lump of wood on which they can do so, can help detect their presence. Sand pits can also be used to detect their prints for tracks. Both scat pads and sand pits are best located at gateways and ditch crossings inside the fence.

To increase the chances of detecting the presence of a predator, it is best to employ a combination of techniques. At sites where breaches have occurred frequently, regular thermal imaging has been carried out at least once a week prior to and during the breeding season, with Fox control being undertaken within the fenced area as well as outside it between January and the end of March.

The effectiveness of permanent predator-exclusion fences inevitably declines over time due to corrosion of their metal mesh, rotting of wooden fence posts and, in the case of combination fences, failing of insulators. Many new fences have also been breached during the first year or so following installation. There seem to be two main reasons for these early failures. First, any gaps resulting from poor installation are likely to be quickly found and exploited by Foxes and Badgers. Second, if a fence is installed across a path that Badgers have been regularly using, they will usually make particular effort to continue using that path by breaking through or burrowing beneath any fence installed across it. It can also be surprisingly easy to fence animals in when the fence is first installed. This is especially the case with larger fenced areas and those that contain vegetation cover in which they can hide, or high, dry ground in which they can burrow (see earlier).

4.7. Brown & Irish Hares within permanently predator-fenced areas

Brown and Irish Hares occur within predator-fenced areas at a number of sites, and concern has sometimes been expressed that the fence prevents mixing and dispersal of animals and limits gene flow with negative impacts on the hares. While leverets have frequently been observed pushing through gaps in the recommended mesh of predator exclusion fences, adult hares are unlikely to be able to pass through. Brown and Irish Hares clearly benefit from predator-exclusion fences, often increasing to high densities within them and presumably benefitting from the lack of Foxes, one of their main predators. At some sites, gates in the predator fence are left open outside of the wader breeding season to allow hares to move in and out of the fenced area. Gates are then typically re-closed by late February. Obviously, care is needed to ensure that no Foxes or Badgers are trapped within the fenced area when the gates are re-closed.

4.8. Naturalised geese, Black-headed Gulls & other bird species within fenced areas

At many sites, the exclusion of Foxes and Badgers from within predator-fenced areas has resulted in them supporting very high densities of nesting Greylag Geese *Anser anser*, Canada Geese *Branta canadensis* and Black-headed Gulls *Chroicocephalus ridibundus* (Table 2). These geese typically nest at high densities along edges ditches within fenced areas and can have very high productivity. For example, in 2023 the 61 pairs of Canada Geese within the predator-fenced Rimmer's and Sutton's Marshes at Marshside fledged an estimated 5.4 young per pair. Meanwhile, at Cattawade Marshes in 2022-23, mean productivity of Canada Geese was 6.1 young per pair within the fenced area, compared to 1.4 on the unfenced areas of the reserve.

Black-headed Gulls have often first nested on islands and amongst emergent vegetation in water bodies within fenced areas, their typical nesting habitat. However, as numbers have increased, they have often then have spread out and nested as single pairs and small groups across the grassland, an atypical nesting habitat for them.

There is trail camera evidence of Greylag and Canada Geese trampling wader eggs within fenced areas, while territorial geese may also displace nesting waders and their grazing activity reduce the structural diversity of wet grassland swards (Fig. 12). Black-headed Gulls also take some wader eggs and chicks, although this is thought to be largely opportunistic. Large breeding colonies of Black-headed Gulls will, though, also displace nesting waders. Conversely, Black-headed Gulls may help protect nearby waders from avian predation by crows and raptors by group mobbing, while also providing an alternative food source of eggs and of chicks for a range of predatory species. The impacts of Black-headed Gull colonies within predator fences are therefore likely to vary between sites and years.

Predator-fenced areas can also attract large numbers of loafing large gulls, particularly near landfill sites and other sources of locally abundant food and the coast. At some sites, large gulls are also attracted to feed on the high densities of goslings within predator-fenced areas. Again, large gulls may also displace nesting waders and predate their eggs and chicks.

Nesting geese and Black-headed Gulls have typically shown different population trends within different fenced areas. At some sites, the numbers of breeding Black-headed Gulls have increased but then declined and then vacated the fenced grassland for no apparent reason. Meanwhile, densities of nesting geese are typically still increasing within fenced areas, or their numbers have plateaued at a high density.

Fig. 12. High densities of Canada and Greylag Geese within the predator-exclusion fence at Saltholme in June 2023. *Photo by Gavin Thomas.*

At two sites, Crossens Inner Marsh and Northward Hill, predator fence gates were left open during winter 2024/25, and then closed just prior to the breeding season, with the aim that the fenced area does not become known to geese as a safe haven from Foxes. At Northward Hill, leaving the gates open between January and mid-Marsh reduced numbers of nesting Greylag and Canada Geese the following spring from about 100 to 10 pairs. A Fox was seen twice predating geese inside the fence at Northward Hill while the gates were open. The trial at Crossens Inner Marsh did not reduce numbers of nesting geese. Leaving the gates open obviously runs the risk of Badgers entering the fenced area, which may then be very difficult to tempt back out if the fenced area contains suitable areas for them to establish a sett in (see page 35).

At some sites, Pied Avocets have also learnt that, due to the absence of Foxes and Badgers, it is also safe to nest on grassland or bare ground within the fenced areas, instead of just on their more typical low islands in lagoons preference.

Table 2. The highest recorded densities of nesting geese and Black-headed Gulls within predator-fenced areas of wet grassland on RSPB reserves

Reserve/fenced area	Area fenced (ha)	Maximum breeding density within fenced area (pairs per km^2)		
		Canada Goose	Greylag Goose	Black-headed Gull
Marshside – Rimmer's & Sutton's Marshes	105	73	41	798
Northward Hill - Richardson's Scrape	29	208	417	1,563
Otmoor – Big Otmoor	43	137	91	135
Saltholme – main reserve	90	95	13	1,460
Cattawade Marshes - Barnfield	16	150	38	0

4.9. European Badgers

Badgers pose particular challenges regarding the use of predator-exclusion fencing and encouraging them to vacate predator-fenced areas can be difficult. Badgers are likely to particularly difficult to exclude where a predator fence has been installed across one of their well-established routes, as they will often then go to great lengths to breach the fence so as to continue using that particular route.

If a Badger, or Badgers, have gained entry to a fenced area, the first thing to do is to try to locate where they are gaining access. Placing a trail camera at this point can establish whether they have left the fenced area, and if this is found to be the case, securing the weak point in the fence can be enough to prevent them getting back in.

If this does not work, then the next step is to install one-way Badger gates, such as off-the-shelf 'Tornado Metal Badger Gates 300 x 200.' These should be installed at, or as close as possible, to where they have gained entry. It is worth trying to entice Badgers to exit through one-way gates by leaving bait - peanuts or peanut butter - on the outside of the fence close to these gates. Badgers are strong, intelligent animals though, and can learn how to open one-way gates from the 'wrong' side and re-enter the fenced area (Fig. 13). Therefore, once an animal, or animals, are thought to have vacated the fenced area, it is worth securely fastening the one-way gates shut. It has sometimes taken years to encourage Badgers to leave a fenced area, so the main priority is obviously to minimise the chance of them gaining entry in the first place.

Fig. 13 a - d. A Badger opening a one-way gate from the outside to gain access to a predator-fenced area.

4.10. Eurasian Beavers

The presence of Eurasian Beavers, which are a protected species in the UK, will increasingly need to be taken into consideration when installing predator-exclusion fences.

Digging a trench in which to install the buried mesh apron of a combination or barrier fence risks injuring Beavers in their underground burrows. These can typically extend up to about 20 m from the edge of a ditch or other water body (Campbell-Palmer *et al*. 2016) and, since their entrance is underwater, it is not always possible to detect the presence of burrows. Therefore, where Beavers are present, fences with buried aprons should not be installed within an appropriate distance of water bodies agreed with the relevant statutory conservation body, and the protocol for digging the trench also agreed with them. The latter is likely to make installation slower and therefore more expensive. In England, it is also likely a license will be required from Natural England and that somebody with a CL51 Beaver licence is present on site to oversee installation, particularly if fences are located close to water. Electric wires should not be installed below about 1.2 m above ground level, due to the risk of Beavers biting them.

Installing predator fences may reduce the area over which Beavers can forage and also runs the risk of separating individuals from the rest of their family. Therefore, where Beavers are present, fences should be designed so they can move freely into and out of the fenced area. One option, yet to be tested, is to have wide-enough, water-filled culverts beneath crossings through which Beavers can swim, and that remain completely submerged to prevent access by Foxes and Badgers. It is also recommended that a plan is put in place for if any Beavers become trapped within the fenced area.

For obvious reasons, where Beavers are present fences should have metal rather than wooden posts.

5. Choosing electric fence components & electrical Health & Safety (reproduced from Hirons & White 2017)

As described in Section 4.3, crucial components of electric fences, be they combination fences (Section 5.2.) or temporary electric fences (Section 5.4), are their battery or mains-powered energiser, and its earthing rod(s). The majority of electric fence problems arise from these two sources, the energiser not producing a sufficiently high voltage and/or the underground rod(s) being or incorrect specification or not well installed.

5.1. Energisers

The energiser converts low voltage electricity (AC or DC) into repetitive high voltage pulses lasting 500 µs (microseconds) at one second intervals and delivers them along the entire length of the fence line. Energisers can be mains or battery operated, although the latest dual-powered energisers offer the best of both worlds and can either be plugged into the 240 volt main supply or connected to a 12-volt rechargeable battery. The best models have a digital display of the fence voltage and ground leakage (earthing).

Because the pulses of electricity are very short and the fence itself is not a complete circuit, energisers consume very little energy regardless of power output. Typically, a one joule energiser will draw 4 watts - a tenth of that of the power required by a 40 watt light bulb. However, energy consumption will increase the more the fence is challenged e.g. the more vegetation that touches its live wires, the more power the fence will consume.

Power supply
Under most circumstances, the location of the fence will dictate the decision between a mains or battery powered energiser. If remote from a mains supply, the only option will be a battery powered unit. A battery powered energiser will require either a battery charger and two batteries (one to be charged and the other one 'working') or a solar panel that continuously charges the battery during daylight, or even small wind turbines (see below). A higher powered energiser may require a battery change as often as every two weeks or even more frequently.

Where there is a choice, mains operated energisers are preferable. Running costs are lower, they are more effective, and it avoids the problems associated with, and time taken, changing batteries, while you also get less reduction in voltage if vegetation touches the wires. Whenever possible, a mains-powered energiser should always be sited inside a building. However, mains operated energisers still need a separate earthing system (earth stakes). It is illegal to earth the energiser to the mains supply or water pipes and a special underground cable is needed to connect the energiser to the electric fence. It is possible to run high voltage insulated cable up to 500 m from an energiser to the fence without significant power loss, but running a cable over long distances can prove expensive.

Battery energisers should be installed close to the fence and off the ground to protect them from moisture and invertebrates getting inside. Usually, energisers and batteries are located outside the fence to prevent them being damaged by livestock. However, an energiser positioned inside the fence will be better protected from vandalism and theft. Suppliers sell vandal proof, ventilated, galvanised, lockable metal boxes to house the energiser and battery.

Battery energisers clip directly onto the electric fence or earth post. The latest deep cycle, lead-acid batteries coupled to a 45 watt solar panel can prevent battery drain sufficiently for an energiser to power a temporary electric fence for a whole season without the need for a battery change (see below).

Choosing the most suitable energiser

The energiser must deliver a sufficient shock to deter an animal. Environmental, fence and ground conditions will all influence the level of shock received. Therefore, the power output should be selected based on the following considerations:

- Location of the energiser – whether or not there is access to A/C power.
- Type of animal to be excluded.
- Length of the electric fence & its number of wire strands.
- The conductivity of the wire.
- Whether vegetation is likely to touch the fence.
- Soil conditions for earthing.

Higher powered energisers will burn off a fair amount of vegetation touching live wires but should not be used as a substitute for vegetation management.

Output power

The power of an electric fence energiser is measured in joules (given as either stored or output). Stored joules relate to the energy (power) stored inside the energizer. Output joules relates to how much energy (power) can travel from the energizer onto the fence line, powering the electric fence. Output joules are about 70 % of the stored joules. Usually, the output joules of an energiser are its selling point.

In an electric fence system, a high voltage is important for ensuring that an electrical charge can find its way through the fur of the animals it is intended to exclude. The more or thicker the fur, the greater the voltage required.

The longer the fence line, and the more load on the fence, the more work the energiser has to do to maintain a sufficiently high voltage by transferring the stored energy to it. There comes a point where the maximum amount of energy is being transferred to the fence, but the resulting voltage is too low to repel the animal (the voltage needs to be maintained in the range 5,000 – 10,000 volts to deter Foxes and Badgers). Check the voltage at the furthest point from the energiser. Some drop in voltage, say 1,500 to 2,000 volts is normal. A more than 2,000 volt drop could mean that your charger is underpowered for the fence.

Various rules of thumb are quoted for the power of energiser needed to maintain a secure voltage along an electric fence, but these seldom agree with one another. These vary from a minimum of 1 joule of output per 1.6 km of fence regardless of how many strands of wire, to 1 joule per 9 km of wire (each strand of a multi-wire fence to be added up separately). Kencove Farm Fence Supplies recommend at least a 6 joule unit with an open circuit voltage of 9,500 volts.

Fence manufacturers usually specify how many kilometres of fence their different energisers will power effectively. However, energiser manufactures and dealers tend to overestimate the length of fence an energiser will power securely. Therefore, it is difficult to recommend a particular power of energiser other than to say it wise to choose a higher powered energiser than you think you will need.

Table 3 provides a rough guide to the specification of the energiser needed to power a particular length of fence under different conditions. A minimum of 10 joules is required to 'burn off' grass as it comes into contact with the fence - the ability to 'burn-off' grass is extremely important for keeping lower wires free of vegetation to maintain full power along the entire length of fence. The length of fence is the total length of conducting wire used in the fence. An energiser capable of powering 4 km length of fence can be used on either 2 km fence containing two live wires, or 1 km of fence containing four live wires. **For safety reasons, two energisers should never be attached to the same length of fence.**

Table 3. The approximate length of fence energised by battery and mains energisers of different power, and with different amounts of vegetation touching the live wires

Power source	Power (stored joules)	Open-line output (volts)	Estimated battery life (days)*	Fence length (km)		
				No vegetation	Average vegetation	Tall vegetation
12v 75Ah battery energiser	1.6	9,500	35	22	3.5	1.3
	2.0	9,500	26	25	4.0	1.5
	3.75	9,500	12	35	7.5	4
	5.4	9,500	7	40	11	6
220/230v mains energiser	1.4	10,200	N/A	12	2.5	-
	2.5	11,000	N/A	20	3.5	0.75
	5.4	10,200	N/A	35	11	4
	7.5	9,500	N/A	30	7	3
	14.0	9,500	N/A	53	15	5
	18.5	9,600	N/A	70	20	7
	26.0	10,000	N/A	100	26	10

*Battery life and recharge times assumes that only 75 % of the fully charged capacity is used before recharging. Batteries should never be run flat.

**Length of fence line which can be energised is based on multi-wire fencing constructed with 2.5 mm high tensile galvanised wire. Use the figures for 'average vegetation' when calculating the distance for polywire, which is less conductive than high tensile wire.

The most powerful energisers are mains powered. Energisers with an output in excess of 5 joules are not recommended under UK Health and Safety Codes of Practice. However, almost all manufacturers sell energisers more powerful than this (Table 5). Rappa also sell Speedrite Energisers with up to 36 joules stored output, with the proviso that these are for 'professional use only'. These have powered fences on several RSPB reserves.

Table 4. The most powerful mains energisers sold by some well-known suppliers

Distributor/manufacture	Output (stored joules)
Gallagher	7.0
Voss	7.6
Hotline	12.0
Rappa	15.0

Table 5. Specification of energisers that have been used for fences at some RSPB reserves

Reserve	Power source	Energiser	Power (stored joules)	Length of fence (km)	Number of live wires	Total length of live wires in fence (km)
Rainham Marshes	Mains	Speedrite 20000R	34	4.2	5	21
Greylake	Mains	Speedrite 36000R	36	5.0	5	25
Minsmere	Mains	Speedrite Panther 9800	14	2.0	3	6.0
Otmoor	Mains	Speedrite 6000	6.0	2.8	3	8.4
Greylake	Battery	Speedrite 6000i	6.0	5.0	6	21
Cattawade Marshes	Battery	Speedrite 6000	6.0	1.7	4	6.8
Minsmere	Battery	Hotline HLB500 Falcon	1.7	0.6	4	2.6
Cors Ddyga	Battery	Speedrite 3000	3.0	1.7	2	3.4
Cors Ddyga	Battery	Speedrite 1000	1.0	1.7	1	1.7

Power supply for battery-powered energisers

Battery energisers are designed to provide the optimum performance, whilst also maintaining battery life. In general, battery powered energisers are less powerful than mains powered energisers. However, a battery (110 Ah) powered energiser (1.5 J) is easily capable of running galvanised steel strained-wire fences over 1 km, maintaining a high voltage level (> 6 kV) for periods of up to one month. Electrified netting has much greater electrical resistance than strained, galvanised steel wire and requires a more powerful energiser (and more frequent battery changes if battery powered), than an equivalent strained wire fence. A guide to the performance of different battery powered fence energisers is given in Table 6 below.

Table 6. A guide to the performance of different battery-powered fence energisers for steel strand fences.

Stored joules	Voltage in kV (500 Ohms resistance)	12 V battery amp-hours	Minimum days before recharging*	Maximum fence length (km)		Number of 1m long earth stakes required
				With no vegetation touching wires	With some vegetation touching wires	
0.8	3.5	85	22	4	2	2
1.45	4.3	85	15	10	3	3
2.6	5.8	85	9	18	6	4
7	6.8	105	4	25	15	5

*The 12 V battery needs to be recharged after the number of days indicated. This is necessary to prevent battery damage through deep discharging.

The number of days of battery life given as the minimum in Table 4 can be extended by selecting the lower power settings available on some energisers. Some have a night-time setting which reduces power output in the daytime. Switching from high to low power extends battery life between charges by about 75 %. Energisers also have built in power conservation features that prevent permanent damage to the battery: when the battery voltage drops to 11.5 volts, the unit slows to half speed to conserve power; when the battery needs recharging the pulse interval is extended to conserve battery energy.

5.2. Batteries

Most energisers run off conventional 'wet' lead acid batteries. Generally, these energisers are more powerful than dry battery versions and can power longer fences. The required voltage is specified by the energiser manufacturer. The capacity of the battery can be determined from the proposed usage and method of charging. The higher the Ampere hour (A/h) rating, the longer the period between recharges.

Batteries that are not designed for cyclic discharge and recharge (e.g. car starter batteries) will deteriorate rapidly if not maintained at or near full charge. To run an electric fence, the battery must be designed for cyclic discharge and re-charge. These are marketed as 'leisure' batteries or 'marine' batteries. They are intermediate between a 'starting' battery and a proper deep cycle battery (see below). When not in use they should be trickle-charged occasionally to prevent deep discharge, otherwise they will have to be replaced every year. All RSPB reserves with battery-powered predator exclusion fences use conventional lead acid 'leisure' batteries. However, the latest technologies are capable of powering a temporary steel strand electric fence all season without a battery change (see below).

Deep-cycle batteries
Traditional lead acid batteries dominate more modern battery technologies, mainly due to their lower cost, predictable performance, and high reliability.

Deep cycle, lead-acid batteries were designed to store power for off-grid solar and wind power systems. They have far heavier and stronger lead plates inside than 'leisure' batteries, which makes them more expensive but better able to withstand a deep discharge. Batteries designed for 'leisure' applications are now available. Sealed Gel (electrolyte in a gel-type substance) batteries can complete around 400 to 500 discharge cycles (to 80% depth of discharge), are maintenance free and do not leak acid, which makes them easier to install and transport than conventional lead-acid batteries.

A further development is 'solar' batteries. These are deep cycle 12 V batteries with a very high charge and discharge efficiency (90 to 95 %), which are optimised to be able to be charged with very little current to take maximum advantage of any available energy (see http://www.solarwind.co.uk/deep-cycle-dryfit-batteries-battery-uk.html).

A 200 Ah 12 V deep cycle gel battery charged by a 45 w solar panel with a Speedrite 3000 energiser (supplied by Rappa) could power a temporary, steel strand, electric fence all season without a battery change.

5.3. Solar panels and wind turbines

Solar panels can be used to continuously charge a battery during daylight to maintain power levels and extend battery life, with energisers powered by a 12 V battery. Solar panels should be positioned in open areas and close to the battery, face south and be angled towards the sun (90 degrees to the incident light is optimum).

Solar panels are very reliable, especially if used with an appropriate regulator ('charge controller') to protect the battery from being overcharged and to prevent reverse current drain. Expert advice should be obtained before selecting a regulator to ensure that it is compatible with both the solar panel and battery and does not consume more power than the panel produces. The latest solar panels employ crystalline silicon technology to provide 'all weather' charging, even in the low light conditions found in the UK. They are robust and water resistant and are appropriate for all kinds of battery-powered electric fencing. Most come with a 20 year cell performance warranty guaranteeing that the cell degradation rate will be no greater than 20 % in 20 years.

Two small wind turbines have been used to help charge the fences at Northward Hill.

5.4. Connecting the energiser to the fence

The cable that carries the electric pulse from the energiser to the fence needs to be specifically for electric fences, with insulation rated for up to 20,000 volts (most fence chargers emit from 5,000 to 10,000 volts) - the same degree of insulation as on automobile spark plugs. By using cable designed for electric fences, you avoid the electricity leakage that results when you connect the charger to the fence with standard household electric cable, whose insulation is rated for only 600 volts. When attaching the cable to the fence itself, it is important to use a connector clamp rather than just wrapping the cable wire around the fence; cable connected by wrapping comes loose more easily or loses power due to oxidation or corrosion build up. All fence manufacturers sell connector clamps designed to work optimally with their product.

5.5. Electrical Health & Safety

There are many important Health and Safety requirements regarding fences that contain electric wires, as summarised below.

Safety requirements

- Electric fence systems should comply to British and European Standards BS EN61011: 1992 (Mains powered) and BS EN61011-2: 1992 (Battery powered).
- British Standards require energy output to be less than 5.0 J and voltage to be less than 10 kV.

Fence positioning

- Fence lines should not lie within 2 m of telephone lines or within 15 m of power cables. If in doubt, consult the relevant authority.
- Fence earthing systems should be positioned at least 10 m away from any electricity supply earth trip.
- Electric fences must not be installed within 2.5 m of metallic equipment and services (e.g. water pipes/troughs).
- Avoid running electric fences parallel with any overhead power or communication lines, as this can cause dangerously high voltage on the fence line.
- If the fence must cross overhead power or communication lines, it must do so at right angles and the fence must not exceed 2 m in height.
- It is illegal to have two parallel electrified fences within 2 m or each other.
- For any two separate electric animal fences, each supplied from a separate energiser independently timed, the distance between the wires of the two electric animal fences should be at least 2.5 m.
- If the electric fence intersects a Public Right of Way (PRoW) you must provide a non-electrified gate or stile so the fence can be crossed. Allow persons to pass through areas of public access by means of insulated gates, gate handles and insulated stiles.

Energisers

- Two energisers should never be attached to a single length of fence.
- The energiser must be turned off if there is a danger of flooding.
- Each energiser in use should be connected to a separate earth stake. No household wiring or plumbing should ever be used for earthing.
- If possible, an energiser should be installed indoors in a position which is free from any risk of damage.
- If mounted outdoors, the energiser should be mounted on a substantial structure in a position free from risk of mechanical damage.
- Except for low output battery operated energisers, the energiser earth electrode should penetrate the ground to a depth of at least 1 m.

- A distance of 10m needs to be maintained between the energiser earth spike and any other earthing system such as the power supply system protective earth or the telecommunication system earth.

Warning signs indicating the presence of electric wires should be installed where:

- The general public has access to the fenced area. Here, warning signs should be attached to the fence at intervals of no greater than 90 m.
- An electric fence runs *alongside* a PRoW. Here, the location of electric wires should be clearly identified using warning signs spaced no more than 50 m apart from one another.
- An electric fence *crosses* a PRoW. Here, the location of electric wires should be clearly identified using warning signs spaced no more than 10 m apart.

The above signs should be at least 100 mm x 200 mm in size, yellow with permanent black inscription on both sides and should use the words "ELECTRIC FENCE" and be clamped to the fence.

Further information on electric fencing, including when fencing close to footpaths, can be found on the following websites:

https://www.nfuonline.com/updates-and-information/key-considerations-for-fencing-footpaths/
https://forums.horseandhound.co.uk/threads/electric-fencing-along-foot-path.740973/
https://gemimarket.uk/warning-sign-for-electric-fence/79-warning-signs-in-pvc-for-electric-fences-8053017262734.html
https://professional-electrician.com/technical/electric-fence-controllers/

6. Design & use of different types of predator-exclusion fences & floating rope barriers

6.1. Combination fences

Design, specifications & installation

The basic, recommended design of a combination fence is shown in Fig. 14. Virtually all combination fences in place on RSPB reserves have so far used wooden fence posts. 'Postsavers' have sometimes been used to increase the longevity of wooden fence posts. These consist of a plastic sleeve that has been impregnated with bitumen on its inner side. This is fixed to the section of the fence post that is in the upper soil, the section of a fence post that is most vulnerable to rotting. Some more recent fences have used metal posts, and these are now recommended as they are expected to last far longer than wooden posts, and typically have a guarantee of 30 years. While metal fence posts themselves are more expensive than wooden ones, there are also nevertheless some cost savings when installing metal fences. First, fewer fence posts are needed in a metal fence system because the tension of wires is greater. Second, metal fence posts can be installed using a handheld, post knocker, rather than requiring the use of heavy and expensive machinery.

The recommended width of fence mesh is 5 cm between its vertical wires. Young/small Foxes can pass through the 7.6 cm gap between vertical wires of the next size up of mesh (Fig. 15). It is important not to use mesh that has *hinged joints*, as the vertical wires of this type of mesh can be forced apart laterally by Badgers to create a gap large enough for them to pass through, and which Foxes may also then use (Fig. 16). Mesh should instead have 'Torus' knots which cannot be easily forced apart. Mesh types with 5 cm between their vertical wires that we recommend are Tornado High Tensile Badger Netting or Hampton HNHT (both have 2.5 mm diameter wires and are suitable for preventing access by both Badgers and Foxes) or else Hampton HNLHT (which has 2.0 mm diameter wires and is cheaper than HNHT). It is important *not* to use *Low Tensile* mesh e.g. Tornado RL23/240/5, as its thinner wires can be easily forced wide enough apart by animals (probably Badgers and possibly also Beavers) to allow at least Foxes and possibly also Badgers through.

As with all types of predator-exclusion fence, it is important that the mesh on fences and gates is secured to their *outer* side, and that the horizontal stays are on the inside of the fence, so that animals cannot gain purchase on either.

The arrangement of the mesh apron has varied between fences. Badgers are far more likely than Foxes to dig beneath fences, and so it is particularly important to install a suitably deep, buried mesh apron where Badgers are an issue. The standard design is for the mesh to extend about 40 cm outwards below ground, as shown in Fig. 14a. This will mean that any animal digging downwards at the base of the fence will eventually be prevented by the mesh. Check the fence line after installation to make sure that your contractor has dug in the apron really well and covered it with soil properly. At some sites, the mesh apron has instead been laid out horizontally on the surface of the ground by a similar distance and pegged in place (Fig. 14b). Pegging the mesh on the surface of the ground is less expensive than burying it, but assumed to be less effective, since an animal is likely to start digging on the outer edge of the horizontal mesh as shown by an X in Fig. 16b, and then continue digging beneath it and under the fence. Pegging the mesh on the surface may be the best approach where unexploded ordnance is present, to avoid having to dig a trench in which to bury the apron. Digging a trench to bury the mesh may result in more initial growth of tall, weedy vegetation, such as thistles, that risks touching the live wires.

At Coveney Byall Fen, where Badgers have repeatedly dug beneath combination fences that have the standard depth of mesh apron, Tornado Netting with 5 cm between its vertical wires has been buried vertically downwards to a depth of 90 cm below ground level, as shown in Fig. 17. This is obviously far more expensive than the standard design but is expected to be far more effective against burrowing Badgers.

Buried mesh usually corrodes more quickly than mesh above ground due to the wetter conditions, although the rate of corrosion will vary depending particularly on soil type and wetness. Mesh typically corrodes more rapidly in more acidic and wetter soil, especially where the bottom of a fence lies in standing water. Where corrosion has occurred, sections of mesh can be temporarily mended using chicken wire, while some sites have replaced corroded sections of mesh in water with PVC-coated, galvanised, welded wire mesh that has 50 mm x 50 mm square mesh holes (e.g. Green PVC Welded Wire Mesh 0.9m x 25m (50mm hole) 2.8/2.3mm). This is more expensive than Tornado Netting but is likely to be a more cost-effective option for new fences whose mesh sits in water or wet soil and is thereby more vulnerable to corrosion. Care should be taken not to bend PVC-coated mesh too much as this may break the PVC coating and allow the metal beneath to corrode.

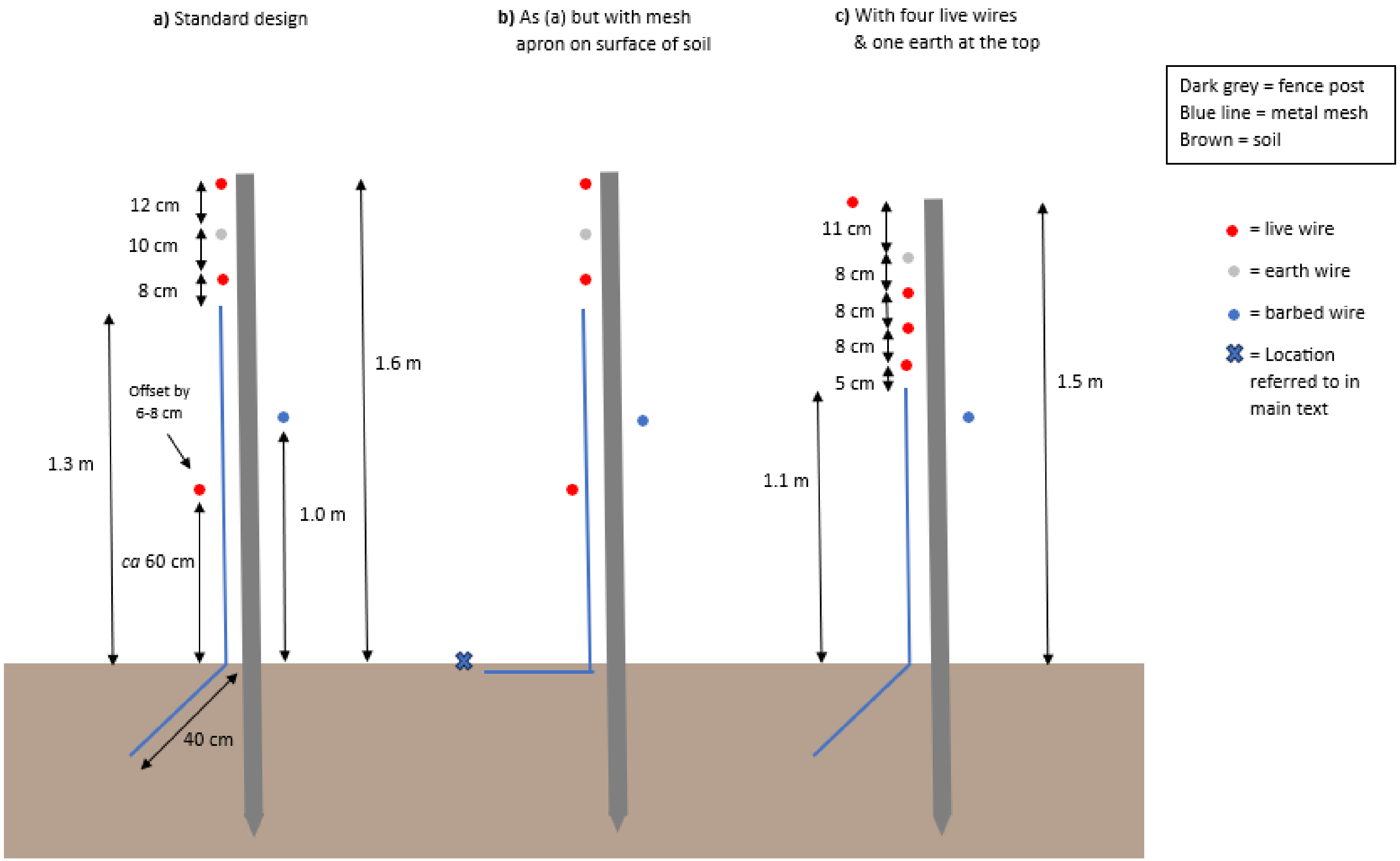


Fig. 14. Recommended designs of combination fences. The outside of the fence is to the left. In older fences that have 7.6 cm between the vertical wires of the mesh (not recommended - see text) the offset wire shown at *ca* 60 cm off the ground needs to be just below the lowest vertical gap between the mesh of 15.5 cm, otherwise a Fox can squeeze through the 7.6 x 15.5 cm gap in the mesh (Fig. 17).

(a)

(b)

Fig. 15. Trail camera images of a smallish Fox easily passing through a gap in Tornado Netting that has 7.6 cm between its vertical wires.

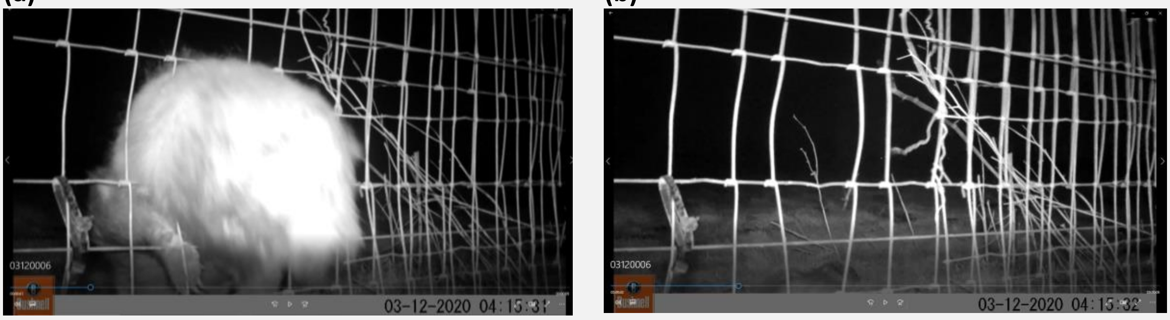
Fences should use box strainer systems as shown on a barrier fence in Fig. 24, rather than angle strainer systems, as the former maintain the tension of the fence and its wires better.

There is a range of designs for the arrangement of wires on the rest of the outside of the fence. The standard design described by Hirons & White (2017), and which most sites have used, is shown in Fig. 14a and also Fig. 1. This has two high tensile, galvanised, steel live wires with an earth between them above the top of the mesh, and a single offset live wire at approximately 0.60 m above ground level on the outside of the fence (but see further information on the exact height of this in the caption for Figure 14). It is important to ensure that the gaps between the top wires are not wider than those shown in Fig. 14a, and that these wires do not sag and create larger gaps, as this can allow Foxes in particular through. It is also worth installing one or two high tensile electric wires, or strands of barbed wire, on the inside of the fence to deter cattle from rubbing against and damaging the fence, set at about 1 m above ground level if one wire, or at about 0.8 and 1.2 m above ground level if two wires are used.

The lack of live wires close to ground level in the designs shown in Fig. 14 removes the risk of small, non-target species, for example amphibians and Hedgehogs, from receiving an electric shock. Such low-level live wires are also very difficult to keep clear of vegetation growth.

An alternative design of top wires has been used at Rainham Marshes (Figs. 14c & 18), where Foxes had been seen jumping between the top wires of the standard design shown in Fig. 14a. The fence at Rainham Marshes has four live wires, and one earth wire, above the mesh. These are more closely spaced than in the standard design, to further reduce the ability of Foxes to push through between them, with this closer spacing enabled by the stacking of the fence's Versalok insulators. Since it is hoped that this four live wire configuration of wires at the top of the fence will be more effective against Foxes, the mid-height offset live wire aimed at deterring Foxes from climbing the fence has not been included, to avoid the management burden needed to prevent vegetation from touching this lower live wire.

(a) **(b)**



(c)

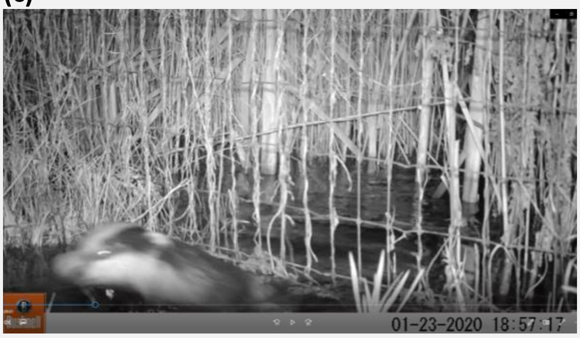


Fig. 16. Trail camera images of Badgers breaching combination fences. **(a)** A Badger squeezing through a gap it has made by forcing apart the vertical wires of mesh with hinged, rather than knotted, joints. **(b)** The gap in the mesh created by the Badger. **(c)** A Badger emerging from having swum underwater through a hole it has dug beneath a combination fence. This fence has a standard mesh apron similar to that shown in Fig. 14a.

Fig. 17. Installing the underground mesh of a combination fence at Coveney Byall Fen. The left hand photo shows the digging of a trench on the outside of the fence using a 'V' bucket on a mini-digger. Initially, trenches were dug before posts were installed, but the knocking in of the posts in the peaty soil caused too much damage to the trench.

The right hand photo shows installation of chain-link mesh to 0.9 m below ground level, although Tornada mesh with 5 cm gaps between its vertical wires is now used instead. The mesh is attached to the bottom of the upper mesh using c-rings installed using a battery-operated stapling tool. Once completed, the trench is re-filled. *Photos by Jonathan Taylor.*

Fig. 18. Views from the outside of a combination fence at Rainham Marshes that has metal fence posts with four live, high tensile, galvanised, steel wires and an earth wire above its mesh, as shown in Fig. 16c. The black, Versalok insulators (see close-up on right hand photo) are stacked to reduce the gap between the live wires to 8 cm. *Photos by Jamie Smith.*

As already discussed in Section 4.2, there is a natural desire to want to locate combination fences close to field edges to maximise the proportion of the field enclosed by the fence and open to livestock grazing. However, it is important to leave a sufficiently wide strip of land on the outside of the fence, for example between the fence and the ditch edge, to allow easy mechanical vegetation management or else grazing management. This is to both prevent vegetation touching the outer wires of the fence and reducing their voltage, and to allow easier checking of the outer wires and for signs of breaches and any other damage to the fence. **RSPB policy is to further reduce the already very small amount of herbicide used on our reserves**, and so we would want to avoid using herbicide to suppress vegetation. Information on the use of herbicides is available on the Herbicide Reduction section of the Ecology & Archaeology team Sharepoint site on the RSPB Intranet. Spraying herbicide close to water bodies is something that we would, in any case, want to avoid and would require a derogation regarding cross-compliance.

Conversely, locating a combination fence very close to a ditch edge (e.g. Fig. 19) may make it more difficult for a Fox or Badger to breach it. This is because, as explained for underwater/in-ditch fences, a Fox will have to attempt to jump over the fence from a starting position in the water, while a Badger would have to dig a hole beneath the water to pass underneath the fence, although Badgers will sometimes do this (Fig. 16c). It will be less practical, and indeed probably less necessary, to deeply bury an outwardly-extending underground mesh apron beneath fences close to ditch edges. As mentioned earlier, mesh buried in wet soil will also corrode more quickly.

A further variation in design has been used for a combination fence installed along the edge of water at Hesketh Out Marsh East, which encloses saline lagoons and upper saltmarsh in an area of managed realignment (Fig. 19b). This has 140 cm high mesh with 5 cm between its vertical wires, and a single high tensile, galvanised steel, live wire set 5-8 cm above the mesh. This design has, as of the start of 2025, excluded Foxes during the three breeding seasons it has been in place. This design contains elements of both a combination fence and underwater/in-ditch fence. A practical issue with this design and its location is the difficulty of removing debris that gets caught around the top live wire of the fence on high tides and during winter storms. The top wire is switched off outside the breeding season. The debris has to be carefully removed while standing on a boat along the adjacent ditch.

There are two main recommended designs of gates for combination fences. The first is a standard gate covered with the same type of mesh, and similar number and height of live wires running across it, as the rest of the fence, and with bungees used to detach and re-attach each live wire when the gate is opened and closed (Fig. 20). On/off switches can be wired into the electrics next to a gate, meaning the gate wires can be isolated when the gate is in use. This design, although widely used and effective, introduces the risk of the voltage falling below the required level due to the live wires attached to the bungees sagging and touching the gate.

The second design consists of a metal gate again covered with same type of mesh as the rest of the fence, but with the mesh extending to a higher level above the gate, either as a floppy mesh top (Fig. 21) or as an outwardly-angled, rigid, mesh-covered top as used on gates for barrier fences (Fig. 25). It should be noted that there can be a sizeable gap between the vertical top of a combination fence, and an angled top of a gate, which needs to be filled with mesh to prevent Foxes from jumping/climbing through.

The mesh tops of both designs need to extend to 1.8 - 1.9 m above ground level, the highest a Fox can jump. Floppy mesh tops work because they bend back down towards the climbing animal, making it impossible them to climb over. Both floppy and outwardly-angled, rigid, mesh tops appear equally effective. Meanwhile, the electric wire completing the circuit of the rest of these types of fence is buried beneath the gate. The advantage of these types of fence are that the absence of electric wires across them again reduces the risk of the live wires sagging and touching the gate and reducing their voltage, and it is quicker and easier to open and close gates.

A third, innovative gate design has been used at Rainham Marshes (Fig. 22). This also has the practical advantage of not having loose, detachable live wires running across the gate. The lower two thirds of the gate is covered by metal mesh on its outside, while the top third of the gate has a smooth metal panel across it which provides no grip for any animal attempting to climb over it. In addition, there is also a dead-end, live ‘bar’ running across the top of the gate to further deter animals from climbing/jumping over.

(a)

(b)

Fig. 19. Examples of combination fences installed along the edge of standing water. **(a)** A standard design combination fence installed along a ditch edge at Coveney Byall Fen. **(b)** A 140 cm high mesh fence with a single high tensile, galvanised, steel, live wire running along its top installed to enclose an area of saline lagoons and islands within an area of managed realignment at Hesketh Out Marsh East. *Photos by Malcolm Ausden.*

Fig. 20. A typical wooden gate in a combination fence at Otmoor, which has the three live wires of the rest of the fence running across it, two at the top and one halfway up the gate. These live wires can be detached and re-attached using the black bungees when the gate is opened and closed (see close-up to the left). *Photos by David Wilding.*

Fig. 21. A standard design of gate through a combination fence, comprising a metal gate with mesh on its outside and a ‘floppy’ mesh top extending to about 1.9 m above ground level, at Coveney Byall Fen. The outside of the gate is to the right. The live wire running along the combination fence is buried beneath the gateway, the gate itself not containing any electric wires. *Photo by Jonathan Taylor.*

Fig. 22. An innovative design of gate through a combination fence at Rainham Marshes. The lower two thirds of the gate is covered by metal mesh on their outside, while the top third of the gate has a smooth metal panel across it. There is also a dead-end, live 'bar' running across the top of the gate to further deter animals from climbing/jumping over (see close-up below). The outside of the fence is to the right.

The electric wire needed to complete the circuit of the electric wires of the fence is buried in an armoured cable beneath the concrete railway sleeper below the gate. *Photos by Jamie Smith.*

As is the case with all gates within predator fences, it is also important to prevent Foxes and Badgers from squeezing or digging beneath the closed gate. The usual approach is to place a wooden or concrete sleeper beneath the closed gate, or else a concrete plinth or wire mesh. It is also important to fill any small gaps around the gate using mesh.

Ongoing checking, maintenance & longevity of fences

The frequency of checking combination fences varies between sites, depending on the age and condition of the fence, and its risk of being breached. At most sites, walk-round inspections of the entire fence are made weekly and daily checks carried out to ensure its wires maintain a suitably high voltage. As previously mentioned, any weak points in a fence will often be quickly exploited by determined animals and eternal vigilance is key to keeping the fenced area predator-free. On older fences, it can be worth carrying out an additional 'fingertip' check of the fence in February, to identify even the smallest issues, so they can be rectified before the breeding season.

Vegetation on the outer, ungrazed sides of combination fences is often a challenge, especially on lush fertile ground as rapid spring growth can touch lower live wires and reduce the current running through the fence, thus reducing its effectiveness. Vegetation should be managed to prevent this happening, using a strimmer, but not a brushcutter, as the latter can easily damage fence mesh. Brambles and branches of trees close to the fence should also be regularly cut back.

Where possible, efforts should be made when planning a combination fence, to assess whether livestock can be used to graze around the fence's outer perimeter. This has been achieved at Saltholme where the new predator fence was set back from existing field boundaries to effectively create a series of narrow grazing paddocks that sheep could be grazed in. This has hugely reduced the drain on staff time required by managing vegetation through mechanical means and also removes the need for use of herbicides to control vegetation that was difficult to cut.

The earliest that site staff have first reported significant age-related issues with combination fences are as follows:

- Insulators falling out after five years.
- Insulators burning through or corroding and the first signs corrosion of mesh at ground level after seven years.
- Rotting wooden fence posts after eight to ten years.

Three combination fences on RSPB reserves have so far had to be replaced, one after nine breeding seasons and the other two after twelve breeding seasons, while ten combination fences have (by the start of 2025) still been in operation for twelve or more breeding seasons. These older fences are now requiring considerable amounts of work to maintain their effectiveness. The oldest combination fence on an RSPB reserve has, so far (at the start of 2025) been in operation for fifteen breeding seasons, although this has had many of its posts and some of its strainers replaced after twelve years.

Reported reasons for the failure of combination fences during their lifetime include:

- Low voltage of electric wires, particularly caused by: vegetation touching them; live wires falling out of insulators and earthing on the fence line; insulators burning through; live wires hanging loose and touching the rest of the fence, including live wires connected to gate bungees; and poor earthing, especially during hot, dry conditions. Also, electric wires corroding and snapping.

- Foxes and Badgers squeezing through holes in the fence mesh due to poor fence installation leaving larger gaps in the mesh; small Foxes squeezing through small gaps in the mesh;

corrosion of the mesh of old fences underground and close to ground level, and especially where water levels fluctuate; damage to the wire mesh from using brushcutters to cut vegetation close to the fence; rotting of wooden fence posts and associated distortion of the fence mesh; Badgers pushing through and widening vertical wires of mesh that have unsuitable moveable mesh knots - see earlier text.

- Foxes squeezing or jumping through gaps in the mesh around gates and squeezing through small gaps beneath them. Gateposts may move as the ground dries out, creating gaps through which animals can gain access.

- Foxes jumping over the fence, despite the presence of live wires running along the top of it.

- Badgers digging beneath the mesh apron of the fence. This does not appear to be a big issue with Foxes, although they may sometimes use holes beneath the fence excavated by Badgers.

- European Rabbits *Oryctolagus cuniculus* (hereafter referred to as Rabbits) burrowing beneath the fence and creating holes that Foxes or Badgers may then use.

- Foxes in particular gaining entry to inside the fence when gates are accidentally left open, particularly by graziers.

6.2. Barrier fences

Design, specifications & installation

There is far less variation in best practice design of barrier fences, compared to combination fences. Typical barrier fences have 1.6 m high metal mesh with a *ca* 40 cm high 'floppy' mesh top, resulting in an overall fence height of between 1.9 m and 2.0 m above ground level, plus a mesh apron (Fig. 23). We recommend using the same types of mesh with 5 cm gaps between their vertical wires as described on page 46 for combination fences.

While the top of the mesh of the fence needs to be at least 1.8 m above ground level (the height that a Fox can jump) it need be no higher than 2.0 m and fences higher than this are likely to require planning permission (see earlier). The only significant variations in best practice design concern the fence's mesh apron, with considerations and options being the same as described on page 45 for combination fences. Badgers are much more likely than Foxes to dig beneath fences, so it is particularly important to have a deeply enough buried mesh apron where Badgers are present.

Assuming that sufficient funding is available, we recommend using more expensive, metal Deltapost, Versalok or similar fencing systems, rather than wooden fence posts, in order to increase fence longevity. As with combination fences, barrier fences should also use box strainer systems as shown in Fig. 24, rather than angle strainer systems, as the former maintain the tension of the fence and its wires better. A novel approach used by the fencing contractor at Shorne Marshes East to increase the strength of the joints between the horizontal stays and strainer posts, has been to weld metal balls onto strainer posts that fit snugly into the ends of the hollow stays (Fig. 24c).

The fence system's box strainer posts should be installed at every change in direction of the fence with, along straight sections, pairs of strainer posts and their horizontal stays installed ideally at 50 m intervals and no further than 100 m apart. Setting them at 50 m intervals will increase costs but is considered important for the integrity and longevity of the fence. Standard strainer posts are only long enough to fit 60 cm into the ground and may need to be longer on sandy and other looser soils, where there is greater potential for them to move. Intermediate posts should be set at 4 m intervals and extend to 1.6 m above ground level. It is recommended to use Deltapost galvanised cranks, or a similar equivalent, fixed to the top of each intermediate and strainer post and secured on their external face. The mesh connected to the angled cranks puts a lot of pressure on them, so it is important that the self-tapping screws that attach the cranks to the posts are large enough.

As with all types of predator fence, the posts and stays should be on the inner side of the mesh to prevent Foxes and Badgers from gaining purchase on them. Also, as with all types of predator fencing, it is important for the mesh to be attached to the *outside* of the fence posts, and with any stays also being on the inner-facing side of the mesh, to also prevent Foxes or Badgers from gaining purchase on these.

It is worth installing barbed wire to the grazed side(s) of the fence to discourage cattle from rubbing against and damaging it. Alternatively, one or two high tensile strands secured to the grazed side(s) of strainers and intermediates can be installed at about 1 m above ground level (or 0.8 m and 1.2 m if two wires are used).

Although barrier fences are visually very obvious from most angles, there is evidence of birds occasionally flying into them and dying from the impact. Therefore, barrier fences should not be installed perpendicular to frequently used flight paths of birds. Locating a barrier fence close to a high bank, such as a sea wall, may lessen its visual impact, but locating it too close risks allowing a Fox to jump over it from the higher elevation of the bank.

There is more or less only one best practice design of gates in barrier fences, this comprising a mesh-covered gate with an outwardly-angled rigid or floppy mesh top, and with the height of the top of the mesh again being 1.80 - 1.95 m above ground level (Fig. 25). A recommended gate type is a Tornado 12' x 6' galvanised deer gate with its associated galvanised gate posts plus a cranked mesh top with the same specification of mesh as the rest of the fence welded onto it. This is best fixed to beneath the top of the gate so that the total height of the gate does not exceed 2.0 m (Fig. 25a). Note that this type of gate is made with 7.6 cm wide mesh, rather than the recommended 5 cm wide mesh so would allow very small Foxes through. Again, fence posts may need to be longer than the standard specification to prevent them from moving and allowing gaps to form around the gate. As with combination fences, it is important to install a wooden or concrete sleeper or plinth, or else wire mesh, beneath the closed gate to prevent Foxes or Badgers from squeezing and digging beneath it.

At Frampton Marsh, visitors need to pass through a section of barrier fence to reach a hide. The pedestrian gate through which visitors pass, and the sections of barrier fence either side of them, have been designed to be more visually attractive than typical sections of barrier fence, are shown in Fig. 26.

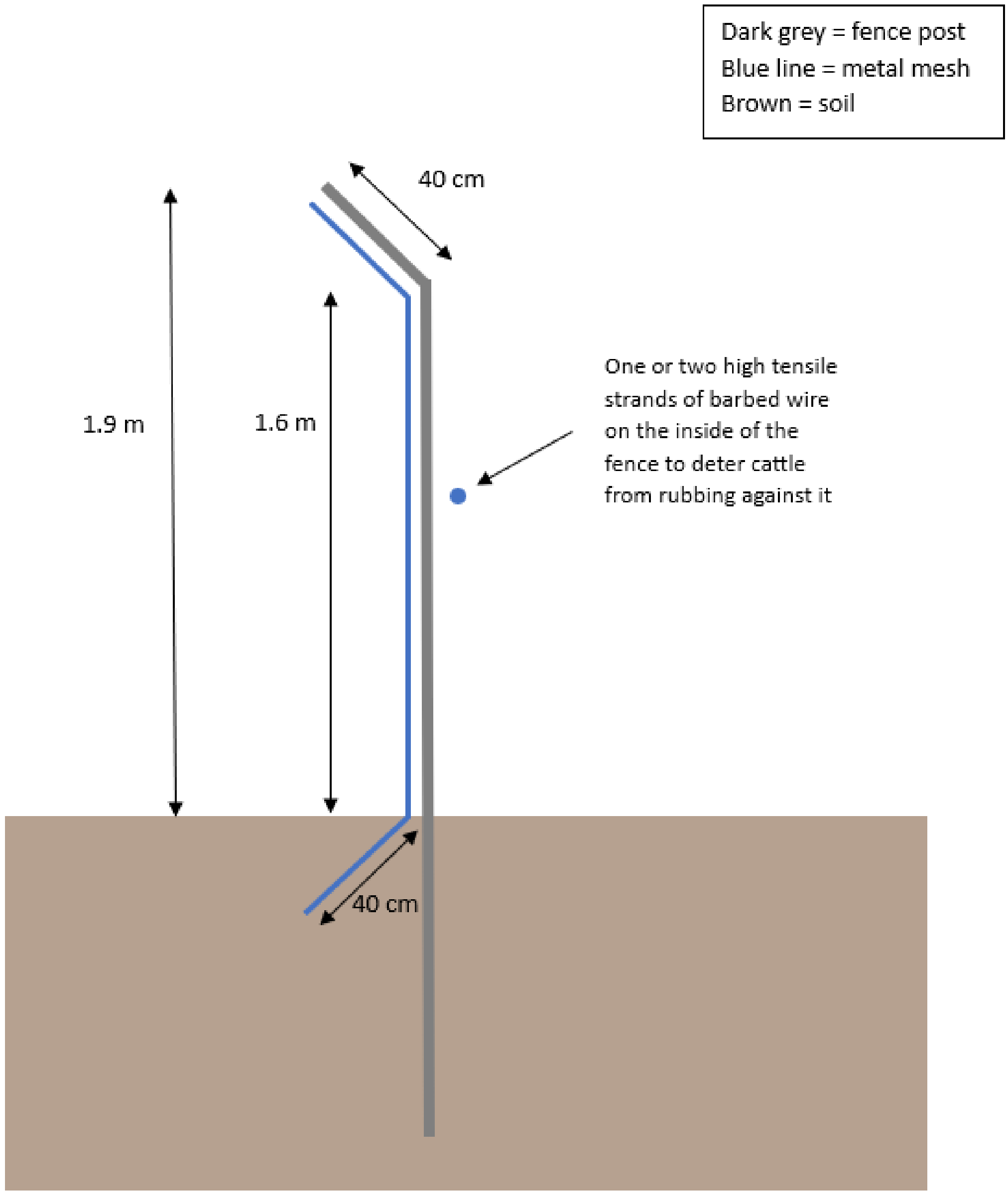


Fig. 23. Best practice design of a metal barrier fence. The outside of the fence is to the left.

(a)

(c)

(b)

Fig. 24. Box strainer systems at **(a)** the corner of a barrier fence and **(b)** along a straight section of fence, both showing the horizontal stay and diagonal wire (slightly easier to see in b) between the strainer posts.

(c) A novel feature added by the contractor here has been to weld a metal ball onto the strainer post. This ball is inserted into the hollow stay, thereby increasing the strength of the join. An 'unused' welded, metal ball can be seen on the left centre of the photo.

Also note in (c) the very secure attachment of the outwardly angled crank to the strainer post. The cranks themselves are attached to intermediate posts using their standard, self-tapping screws. *Photos by Malcolm Ausden.*

Ongoing checking, maintenance & longevity of fences

Because of their absence of electric wires, barrier fences do not require such regular checking as combination fences. Despite this, it is nevertheless still important to regularly walk the fence line to check for any damage or signs of Foxes or Badgers having breached the fence or attempted to do so. It is also important to prevent woody vegetation such as Brambles *Rubus fruticosus* agg. from growing through and potentially distorting the mesh, and to prevent this and other vegetation from obscuring areas where Foxes or Badgers may gain access through, or beneath, the fence. As with combination fences, vegetation near the fence should be cut using a strimmer, rather than brushcutter, to avoid damaging the mesh.

We have only limited information on the longevity of barrier fences, as very few have been in place on reserves for more than a few years. Issues that have so far been noted with them are:

- Loosening and falling off of the angled cranks from as little as two years after installation.
- Tornado Netting corroding through at the bottom of the fence where it sits in freshwater.

While barrier fences are undoubtedly far more effective than combination fences at preventing Foxes or Badgers from climbing or jumping *over* them (and may even be more or less 100 % effective at this), other parts of barrier fences are vulnerable to being breached in similar ways to combination fences due to:

- Foxes and Badgers squeezing through holes in the fence mesh.
- Foxes squeezing through small gaps next to and beneath gates. Gates may move as the ground dries out, creating gaps through which animals can gain access.
- Badgers digging beneath the mesh apron of the fence. This does not appear to be a big issue with Foxes, although they may use holes beneath fences excavated by Badgers.
- Foxes in particular gaining entry to inside the fence when gates are accidentally left open, particularly by graziers.

(a)

(b)

Fig. 25. Two slightly different variations in the design of gateway through sections of barrier fence **(a)** A modified Tornado 12' x 6' galvanised deer gate with an outwardly angled mesh top welded onto it, so that the top of the gate remains just below 2.0 m above ground level (see main text). The photo also shows the concrete plinth below the closed gate. This gate at Shorne Marshes East had only just been installed when the photo was taken, and the gaps between the gate and the fence either side were yet to be filled with mesh. **(b)** A mesh-covered gate with a rigid, outward facing-angled mesh top at Wallasea Island extending to 1.95 m above ground level. *Photos by Malcolm Ausden.*

(a)

(b)

Fig. 26. (a) A pedestrian gate through an above-ground section of barrier fence that is connected to underwater fencing either side of it at Frampton Marsh. The upright wooden posts have been designed to prevent Foxes from climbing over them, but also to be more aesthetically pleasing than a typical metal barrier fence. They consist of 1.8 m high, half round, smooth pine posts with a floppy mesh top. The gate **(b)** is self-closing and comprises galvanised 1.2 m x 1.8 m frames with one inch weldmesh and an outwardly-angled mesh top. *Photos by Toby Collett.*

6.3. Underwater/in-ditch fences

Design, specifications & installation

The basic design of underwater/in-ditch fences is very simple and comprises metal mesh attached to fence posts driven into the substrate (Fig. 27). However, as will be explained, the effectiveness of fences in ditches and lagoons also depends on the water body being of suitable depth and, in the case of ditches, also wide enough.

The mesh of an underwater/in-ditch fence only needs to protrude a minimum of about 30 cm above the height of the water. This may not seem very high, but fences with this height of mesh above the water clearly work – Foxes and Badgers simply appear unable to climb or jump over even a fairly low fence from a swimming position. It is not necessary to extend the mesh to the bottom of the water, as both Foxes and Badgers typically avoid putting their heads underwater and so are unlikely to swim under the fence (see section on floating rope barriers). Nevertheless, the bottom of the mesh still needs to extend far enough down that, if the water level falls ever very low, it does not expose a gap between the surface of the water and bottom of the mesh, through which a Fox or Badger could swim or wade with its head above water.

It is not necessary to include barbed or electric wires above the mesh, and such wires could potentially result in mammals or birds getting caught on them. Barbed wire fences in general are thought to be responsible for a significant number of deaths of wild birds (e.g. Allen & Ramirez 1990).

Two design options have been used to try to increase the effectiveness of in-ditch fences. The first is to angle the fence slightly outwards instead of vertically, and the second is to install an outwardly-angled cranked floppy mesh top to the fence, as described for barrier fences. We do not know how necessary either of these modifications are in terms of preventing access by Foxes or Badgers, but in situations where it is especially important to exclude these animals, then these modifications would probably be worthwhile. Adding an outwardly angled floppy mesh top may be a solution to preventing Otters and, in continental Europe, Common Racoon Dogs, from climbing over in-ditch fences. The mesh of these fences would also need to extend down to the bottom of the water.

It is more difficult to install outwardly-angled, rather than vertical, fence posts, and contractors may be unwilling to do so. It is also only practical to attach mesh to the *inside* side of outwardly-angled fence posts. It is worth noting that none of the underwater fences that have been in place longest, those at Sussex Wildlife Trust's Rye Harbour Nature Reserve, Hodbarrow and Wallasea Island, have either outwardly-angled posts nor floppy mesh tops, yet all have been very effective at preventing access by Foxes and Badgers (see Box 3).

Key considerations regarding the fence itself are the choice of fence posts and specification of the mesh. Fence posts can be either wood (e.g. chestnut which lasts well in water), recycled plastic or metal, ideally driven about 1 m into the substrate. As with combination and barrier fences, the choice of materials is again a trade-off between their initial cost and the fence's expected longevity. Recycled plastic fence posts, although more expensive, are expected to last far longer than chestnut posts, although as of 2024 we do not yet have experience of recycled plastic fence posts being in place for more than five years.

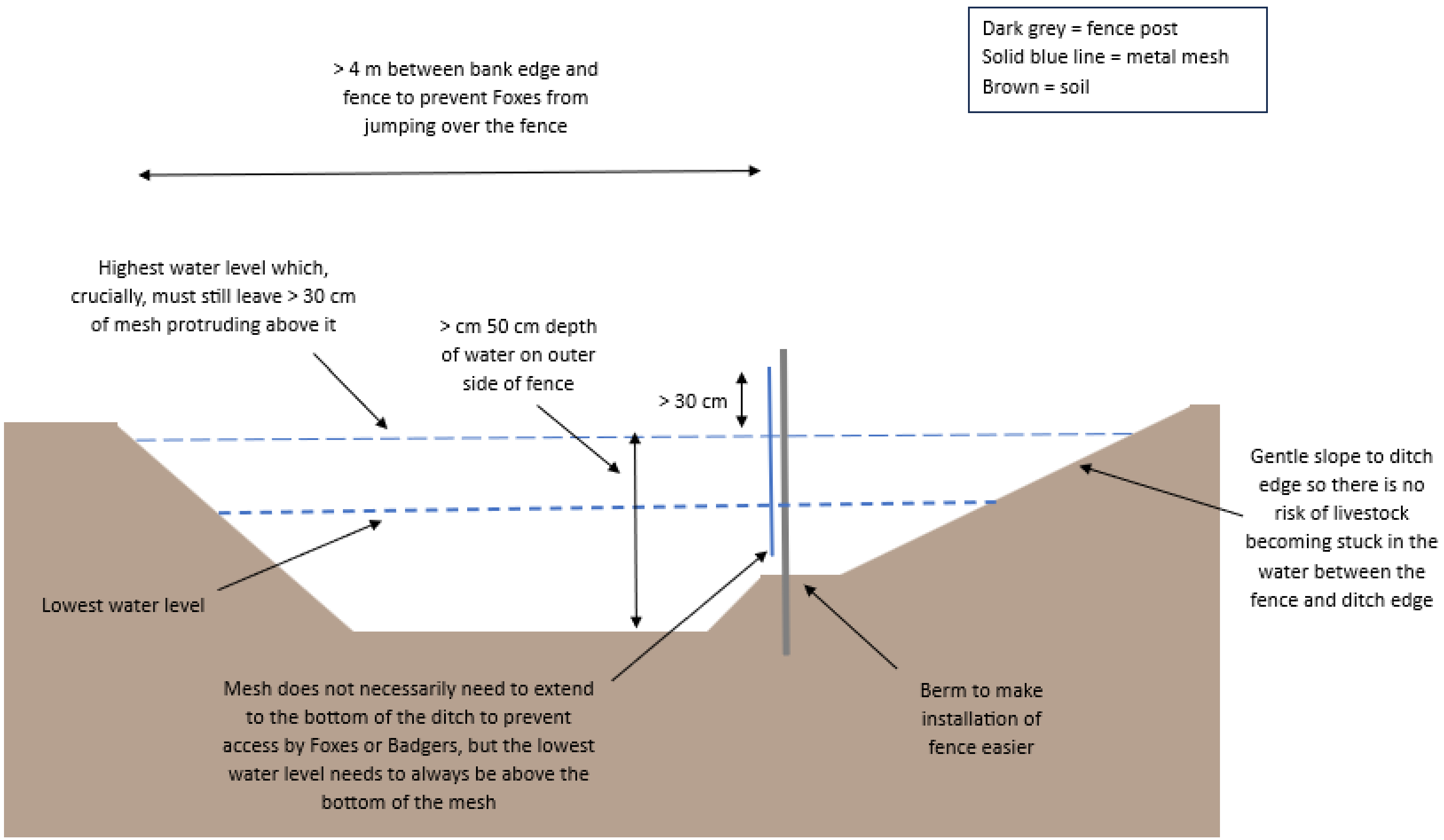


Fig. 27. The design and dimensions of an underwater/in-ditch predator-exclusion fence and its ditch. The outside of the fenced area is to the left.

The recommended mesh has been, as for barrier and combination fences, types with 5 cm gaps between their vertical wires, such as Tornado High Tensile Otter Netting – see page 44. However, there is increasing concern regarding the rate of corrosion of this, and other types of mesh, set in both fresh and brackish/saline water. Corrosion of mesh is usually worst in the zone of the fence that experiences repeated wetting and drying and, for whatever reason, has tended to be worse where the mesh is close to/amongst emergent vegetation.

Corrosion rates have varied between different sites and settings and will be described later on in this section. Staff at some sites are currently exploring the use of more expensive, PVC-coated, galvanised welded wire mesh with 5 cm x 5 cm mesh holes to prolong the life of the fence and also PVC-coated V Mesh Security fencing (Fig. 28). A slight concern with the use of rolls of PVC-coated mesh is that unrolling them might damage their PVC-coating and make the metal beneath vulnerable to corrosion. This is not the case with V Mesh fencing which is manufactured and transported in flat panels. The alternative is to use Tornado Netting but accept that sections of the mesh will have to be patched up possibly as frequently as every five years or so. Thicker wire mesh (2.5 mm instead of 2.0 mm wide) may last longer before it corrodes through but is more expensive.

An alternative approach worth investigating would be to install outwardly-angled, low mesh fencing, with or without an angled/floppy mesh overhang, on the inner bank of suitably deep and wide ditches. This would have the base of its mesh just above water level, so that the mesh does not corrode, or at least only corrodes to a limited extent at the very base of the fence. Any animal swimming across the ditch would still find it difficult to gain sufficient purchase to jump over the low fence, the outward angled fence and mesh overhang would make it difficult to climb over the fence, while the water near to the base of the fence would mean that an animal is unlikely to dig beneath it.

As with all types of predator fencing, it is better to use box rather than angle strainer systems (see earlier), and important to attach the mesh to the outer side of the fence posts (but see above for outwardly-angled fence posts), and to place stays on the inside of the fence so that Foxes and Badgers cannot gain purchase on them.

If an underwater/in-ditch predator-exclusion fence is intended to exclude Otters, then the only measures likely to succeed are to use mesh with 5 cm wide gaps between its vertical wires and which extends right down to the bottom of the ditch, while also having a floppy mesh top to prevent them from climbing over, as described earlier.

When installing fences in ditches, critical considerations are the ditch's width, depth and profile. Ditches need to be more than 50 cm deep (the height of an adult Fox's shoulder) on the outer side of the fence, so that a Fox or Badger is swimming when it approaches the fence, and there needs to be at least 4 m between the fence and the outer edge of the ditch – the horizontal distance that a Fox can jump – see Fig. 27. It is probably also important for the ditch to be this wide where smaller deer species are present, to reduce the risk of them trying to jump over the ditch and catching their leg(s) in the fence mesh. Where this is a concern, the ditch should be widened and/or high visibility tape added to the top of the fence. Any reprofiling and widening of ditches needed to accommodate in-ditch fences may prove expensive.

There also needs to be confidence that the water in the ditch can be maintained at a sufficient level, particularly during the breeding season i.e. not falling so low that a Fox, or less likely a Badger, can wade across the ditch when approaching the fence, or that exposes a gap between the surface of the water and bottom of the mesh (see earlier), or else rising so high that Foxes or Badgers could swim above the top of the fence.

Ditches also have to be of a sufficient depth and width so that dense, coarse vegetation such as rushes cannot grow next to the fence and potentially facilitate an animal's passage over it. This has happened with an in-ditch fence at Wombwell Ings in the Dearne Valley where the ditch was not made deep or wide enough by contractors to accommodate a fully effective fence.

At Wallasea Island, the underwater/in-ditch fence was installed in a specially constructed ditch, with the levels designed so that the top of the fence is lower than surrounding land levels. This means that the fence is not visible at all as you look across the open landscape, in the same way as a ha-ha (Fig. 29). It is useful to have a berm on the inner side of the ditch along which the fence posts can be more easily installed and, where possible, to be able to lower the ditch water level to allow for easier contractor access and any required maintenance and mesh checking.

There has been concern expressed that if an underwater/in-ditch fence is located close to the side of a steep-sided ditch, there is a risk that livestock may become trapped in the water between the fence and ditch edge. To reduce this risk, ditches in which fences are installed should have a shallow slope on the grazed, inner side of the ditch as shown in Fig. 27. This will also provide more valuable feeding habitat for waders and most other wildlife but will not be so suitable for European Water Voles *Arvicola amphibius*. Livestock becoming stuck in ditches containing in-ditch fences has not proved to be a big issue, but we are aware of two instances of bulls getting stuck between an in-ditch fence and the side of the ditch, with in one case the bull causing considerable damage to the fence.

We are also not aware of any evidence of birds colliding with the above water sections of underwater/in-ditch fences and the risk of this happening is probably very low, due to the low height of the fences and because they run parallel with the side of the ditch. The highest risk of collision would probably be where a section of fence runs at right angles across a ditch, for example where a fence in a north-south running ditch crosses an east-west running ditch. In these situations, it may be prudent to again mark the top of the fence with white or other high visibility tape to minimise the risk of, for example a Mute Swan *Cygnus olor* or Great Cormorant *Phalacrocorax carbo* hitting the fence while taking off along, in this case, the east-west running ditch.

Where in-ditch fences meet crossings, then either similar types of gates can be used as in barrier fences (Fig. 25) or else unelectrified gates with floppy mesh tops as used in combination fences (Fig. 21). In both cases, the 'wings' of the gates that extend into the ditch and join the in-ditch fencing also need to be protected with mesh and have a floppy mesh top, as shown in Fig. 30.

When installing underwater fences to protect islands, or groups of islands, in shallow lagoons (Figs. 28 & 31), it may be necessary to dig a deeper trench within the lagoon to ensure that the outer side of it is in deep enough water. It is also useful to be able to access islands to carry out management on them. This can be achieved by including a short panel of fence that can be easily lifted up and removed as shown in Fig. 31b-c.

(a)

(b)

Fig. 28. Underwater fences made from V Mesh panels protecting nesting islands. **(a)** At Lancashire Wildlife Trust's Seaforth NR where fence posts have been driven into the substrate; **(b)** At Hodbarrow, where the tall panels are fixed to posts with metal plates welded to their bases which sit on the channel bed. The fence is a zig-zag shape to give it stability, and sits in water below an elevated sea bank, and so does not interrupt the view of the tern colony it protects. This photograph was taken in November, when water levels were higher than during the breeding season. *Photos by Gavin Thomas.*

Fig. 29. A section of underwater fencing with chestnut posts in a specially-constructed ditch on Wallasea Island, with levels designed so that the top of the fence is below ground level and thereby invisible as you look across the landscape. This is part of an underwater fence that has successfully protected an area comprising 86 ha of wet grassland and 17 ha of saline lagoons from Foxes and Badgers. The outside of the fence is to the right. *Photo by Malcolm Ausden.*

(a)

(b)

Fig. 30. Two different transitions from barrier fencing around gates over crossings, to in-ditch fencing. **(a)** Shows a fairly standard wing of a gate at Wallasea Island but which is covered in mesh that has 5cm gaps between its vertical wires, and with mesh also attached to outwardly angled cranks. **(b)** Wings at Frampton Marsh made of the same half round, smooth pine posts as shown in Fig. 24, which are covered by mesh that has 5 cm gaps between its vertical wires, with this mesh also extending upwards to form a floppy top. In both cases, the outside of the fence is on the near side. *Photos by Malcolm Ausden (top) & Toby Collett (bottom).*

Ongoing checking, maintenance & longevity of fences

One of the greatest benefits of underwater/in-ditch fences is that they require little if any regular maintenance. However, as with all types of permanent predator fence, it is still prudent to regularly walk the length of the fence to check for any signs of damage, and particularly to check around gates for signs of Foxes or Badgers breaching or attempting to breach them. Due to the low mesh height above water, when waterbodies freeze over it is relatively easy for Foxes and Badgers to jump or climb the fence, so extra vigilance is required after freezing conditions to establish whether any animals have gained access to inside the fenced area. Badgers are, though, unlikely to be active during weather cold enough for ditches to freeze.

Rotational management of ditches to remove accumulated sediment and set back succession can be carried out by carefully scooping out sediment and vegetation from the outer side of the ditch, using standard, wildlife-friendly ditch clearance methods. There is no reason to believe that growth of Common Reed or other tall vegetation in the ditch will reduce the effectiveness of in-ditch fences, unless it becomes sufficiently dense and matted close to and over the fence to allow Foxes or Badgers to climb over it, as has been the case at Wombwell Ings as described earlier.

The components of underwater/in-ditch predator fences that have failed first are the wire joiners, known as gripples, which connect different sections of mesh, and the mesh itself. At Wallasea, the wire joiners first started to fail after five years, with about a third of them failing after six years. These could not be directly replaced because this would have required re-tensioning of the mesh, and so offcuts of fence were used to fill any space that had formed between the two lengths of mesh, or else separate sections were secured using cable ties.

We are, perhaps unsurprisingly, reaching the stage now where corrosion of predator fence mesh in water is becoming a great concern. At Frampton Marsh, sections of standard Tornado Netting in fresh and slightly brackish water had corroded right through after just five breeding seasons, while sections of the same mesh that lie more or less permanently in water at the base of a barrier fence at Bower's Marsh had also corroded through after five breeding seasons. This contrasts with the same type of Tornado Netting showing no signs of corrosion (other than browning of wires in the zone of fluctuating water levels) in saline water at Wallasea Island after nine breeding seasons, and metal pig netting having been used in saline lagoons at Rye Harbour Nature Reserve for ten years with no signs of significant corrosion. Meanwhile, Tornado Netting that has been in fresh and very slightly brackish water for 12 years at Elmley NNR has only had to have about 15 % of its mesh replaced over that period, where it has corroded around the water line. It is possible that subtle changes in the manufacturing process of even the same specification of mesh may have affected its vulnerability to corrosion.

While wooden fence posts are expected to fail more rapidly than their metal or plastic equivalents, chestnut posts used in the oldest underwater/in-ditch fences have so far remained structurally intact. There has been little or no sign of decay of them after 12 years in fresh or only slightly brackish water at Elmley NNR, ten years in saline water at Rye Harbour Nature Reserve, and nine breeding seasons in saline water on Wallasea Island.

(a)

(b)

(c)

Fig. 31. Underwater fencing protecting nesting islands on Wallasea Island and constructed using metal Deltaposts and Tornado Netting with 5 cm gaps between vertical wires. **(a)** The fence comprises long, straight sections rather than curves which, although less visually attractive, increases the strength and resilience of the fence.

(b) Shows a detachable panel within the Wallasea fence being lifted up and removed to allow access to the islands for vegetation management, with **(c)** a close-up showing how the panel is attached to the posts either side of it by resting a metal bar from the panel on an 'L-shaped' hook either side. *Photos by Malcolm Ausden.*

6.4. Temporary electric fences

There are two types of temporary electric fencing – strand and electrified netting. The latter is easier to install and does not require tensioning of wires which can be difficult to get right, as described below. Also, because the bottom two horizontal wires of electrified netting receive no electric current, it can also be more easily used on slightly uneven ground. However, the disadvantages of electrified netting are that it is more visually obtrusive than strand fences and creates more of a physical barrier. Hence its presence may be more off-putting to open-ground birds and may restrict the movement of chicks out of the fenced area. There is also a greater risk of birds and other animals becoming entangled in electrified netting than in a strand fence.

Temporary strand fences

People have used numerous designs of temporary strand fences, with these using either high tensile, galvanised, steel wire or polywire (polythene twine interwoven with steel strands); different numbers (from two to nine) and spacing of wires/strands; and using only live wires or alternating live and earth wires. A wide range of these different designs are described in Hirons & White (2017).

The number of wires/strands is a trade-off between the assumed greater effectiveness of fences with more strands at deterring Foxes and Badgers, versus the increased time spent installing fences with more wires, and thereby increased length of time that birds are kept off their nest. Having alternate live and earth wires should increase the chance that an animal jumping or climbing the fence will receive a deterrent shock through being in better contact with both live and earth wires, rather than just with live wires. Set against this, installing alternate live and earth wires will again be more time-consuming. Furthermore, an animal receiving a shock by touching a lower live wire while exploring the outside of the fence, will usually be sufficient to prevent it from attempting to breach the fence during the relatively short period of time that it is in place to protect an individual nest.

The following account describes the use of six-strand, high tensile, galvanised, steel wire fencing used at Otmoor to protect individual Curlew nests (see Figs. 8 & 32). This design is quick to install and has proved highly effective. At Otmoor, the experienced team of staff and volunteers are able to install a fence around a nest and vacate the area in as quickly as just 20 minutes, and at most 30 minutes. A video showing this can be found at Curlew Recovery Partnership - nest fencing guide (youtube.com). We also describe some modifications to this basic design that are used at Minsmere to protect nesting Stone-curlews.

Installing temporary strand fencing will obviously keep adult birds off the nest for a short period, so it should only be carried out in benign weather, avoiding rain to prevent eggs from chilling, windy conditions, or hot days when eggs could overheat. Fences should also not be installed within two to three hours of dusk to avoid the risk of birds not returning to incubate before nightfall.

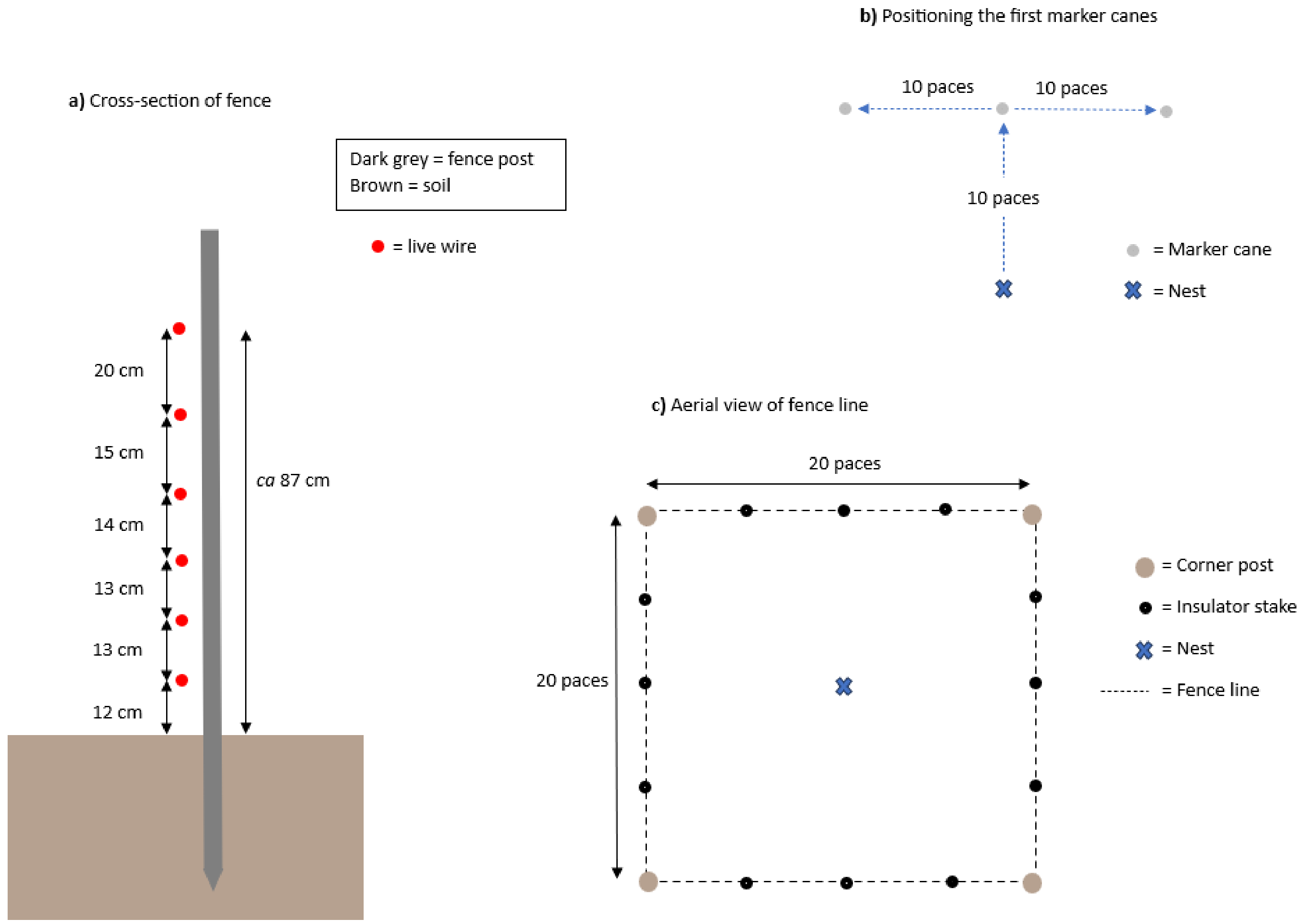


Fig. 32. Design of six-strand temporary electric fencing used to protect individual Curlew nests. In (a), the outside of the fence is to the left.

The key to quick and efficient fence installation at Otmoor is for each member of the small team to have a clear task to complete, while also having a named leader who knows which jobs need to be done well, and who can direct and delegate. Having too large a team can create a muddle and end up taking more time. For less experienced teams, it is important to practice the installation of temporary electric fences elsewhere, before first installing fencing around a nest.

First, locate the exact location of the nest before the team visits to install the fencing, to reduce the length of time spent looking for it when the fence is subsequently deployed. Mark the nest by placing a small branch on the ground at a distance of about ten paces either side of the nest, to avoid the risk of drawing the attention of Carrion/Hooded Crows and other nest predators to it. It is commonly suggested to only place a temporary fence around a nest once the full clutch has been laid, since birds are less likely to desert a full clutch. However, where nest predation rates are very high, waiting until a full clutch is laid risks the uncompleted clutch being predated before the fence is in place. In these situations, the benefits of fencing an incomplete clutch as soon as it is found are likely to outweigh any risk of desertion.

Prepare the fencing equipment as much as possible before visiting the nest to install the fence, for example by attaching the insulators to the stakes of the electric fence at the correct heights and fastening the energiser to its stand and testing it. Also, make a checklist to ensure that no unused fence components and tools are left behind. Minimise the weight of materials and tools carried, both for Health and Safety reasons, but also to speed up deployment. The 2025 price of material needed to install a single fence of the specification and size described below is about £400. This does not include the cost of tools (Table 7).

Table 7. Equipment and tools needed to construct and install a 15 x 15m six-strand temporary electric fence around a Curlew nest.

Equipment	Tools
• One reel of galvanised steel wire • Four wooden corner posts • Twelve nails • 24 screw-in insulators • Twelve steel insulating stakes & their plastic insulators • Two 12 volt 75Ah leisure batteries • One energiser capable of producing pulses of >5,000 volts & associated cables • One energiser support stake • One earth stake • One 12-volt battery charger	• Strimmer/brushcutter & PPE • Post driver plus hard hats • Lump/sledge-hammer • Drill & insulator attachment • Height bar • Screwdriver • Hammer • Wire cutters • Voltmeter/multimeter

When approaching the nest to install the fencing, check for potential avian predators, particularly Carrion/Hooded Crows perched on nearby trees whose attention may be drawn towards the nest during fence installation, and that could predate the eggs before the adult returns to incubate. Also, record the time that the incubating bird leaves the nest to keep track of how long the nest has been left unincubated. Then cover the eggs with a hat or light coat to prevent them from chilling or overheating, and to also make the location of the nest clear to the rest of the team. Next, walk ten paces away from the nest, install a marker cane, and then walk ten paces either side of this to install canes that mark out two of the corners of the fence (Fig. 33b). Repeat the process on the other side of the nest to mark the other two corners of the fence, thereby forming a square of marker posts each about 15 m apart (one pace is typically about 0.7 m).

Then use a strimmer to cut the vegetation along the four lines between the four posts where the fence will run and knock in a 2.5 m high by 5 cm wide post at each of the four corners using a lump hammer/sledgehammer and post driver. Larger corner posts are not needed and are heavier and more time consuming to carry a long distance. Also lay out the insulating stakes in their approximate locations just outside the intended fence line. On soft ground it may be necessary to brace the four corner posts using another wooden corner post inserted at 45 degrees on the inside of the post and attached to the corner post with a jubilee clip.

Next, one person drills two holes in each corner post in which to attach the bottom two screw-in insulators. This allows the other members of the team to get on with laying out the bottom two wires of the fence and attaching them to the insulator stakes, while the first person drills and attaches the remaining four insulators on each post. It is quickest to mark the height of each drill hole using a 'height guide' – a piece of wood that has the height of each drill hole required for each insulator marked on it, and that can be held next to the post. Once the bottom wire has been installed, loop the wire around the bottom insulator and the insulator above it on the corner post, and then walk around the fence line again to lay out and attach the next circuit of wire to the posts and insulator stakes. It is recommended to use metal rather than plastic insulator stakes, as the insulators on the former can be slid up and down the post to vary the distance between wires if required, for example by raising them slightly higher if the fence crosses a flooded area. Plastic insulator stakes have fixed points on which to attach the electric wires, meaning that the height of wires can only be changed by moving them to a different fixed point on the post.

It is usually recommended to hammer in six-inch nails to the tops of the corner posts to dissuade avian predators from perching on these. In the case of Curlews and Carrion/Hooded Crows, the crows are able to perch on these nails and, in any case Curlews are generally able to chase them off.

Once all of the wires have been laid out and attached to the posts and insulator stakes, fix the wire to the anchor stake inside the fence and tighten the wire. The key thing is having wires tight enough so that they do not sag, but not so tight that the upper wires pull the corner posts inwards causing the crucial lower wires to sag, making it easier for both animals to push between them while also increasing the risk of them touching more vegetation and reducing their voltage. Then find the dampest ground inside the fence and hammer in the earth stake, ideally to a depth of about a metre if possible. If the ground is dry, you may need to use more earth stakes joined by cables to provide sufficient earthing.

Then install the energiser (with it switched off) next to the earth stake, connect the earth wire to the earth stake, positive and negative wires to the battery which is itself connected to a small solar panel to keep it charged, and the other wire to the fence. **See Section 5.5 for electrical Health and Safety.** If using crocodile clips for connections, then make sure that the wire touches the metal teeth of the clips, as some clips do not have metal at the back of their jaws. The battery, solar panel and energiser are usually placed inside, rather than outside, the temporary electric fence to prevent them from being damaged by livestock outside it.

Then remove the hat or light coat that covers the eggs, taking care not to leave an obvious trail to the nest that predators may notice. It may be useful to place a data logger beneath the nest cup to determine the time of predation if it occurs. If at night, then it must be mammalian suggesting that the fence was breached by a Fox or Badger, but if in the day it could be mammalian or avian, although more likely the latter.

Finally, once everybody is out of the fenced area, turn on the energiser. It is recommended to use the normal, rather than power saving, setting as the latter tends to use less power at night when it is most needed to deter Foxes and Badgers. Then test the voltage of the fence using a fence tester. If everything is OK, pick up all of the equipment, making sure you have got everything using the checklist, and leave the area.

It is often recommended to wait nearby to check that the adult bird returns to the nest and, if it has not done so after an hour, consider removing the fence. However, experience of Curlews is that they are very wary of returning to the nest while people are close enough to view them. Therefore, it is instead recommended to move away from the area completely - far enough to not be able to see the parent birds - to allow them to return. Based on experience, in the case of Curlews, it is extremely unlikely that adult birds will not return to the nest.

Thereafter, check the fence about once a week to ensure that the voltage of the wire does not fall too low and to change the battery if required. The fence only needs to remain effective for the relatively short period between it being installed and the chicks hatching. Most vegetation that grows up during that period is likely to be burnt off by the wires, rather than cause a significant reduction in voltage. However, if a significant amount of vegetation touches the lower wires, then this should be cut, ideally quickly using hand shears to lower the height of any small areas of long vegetation. Usually, any problem with low voltage can be rectified by replacing the battery.

It is generally recommended to remove the electric wires just before chicks are expected to hatch to allow them to move out of the area unharmed, as chicks risk being electrocuted by touching the lower live wires of the fence. This appears to be rare, though, and many chicks certainly pass through temporary fences unharmed. It is therefore a trade-off between the benefit of removing the fence to allow chicks to leave the area unharmed, and the risk of removing the fencing increasing the risk of the nest being predated just before the chicks hatch. To dismantle the electric fence, use a winding reel to recover the wire and prevent it from twisting and kinking.

Variations on the basic design of temporary strand fencing, and the methods of installing it, are used at Minsmere for temporary fencing around larger (0.6 - 1.5 ha) Stone-curlew plots. Here, on plots that are occupied by breeding Stone-curlews most years, corner posts are left *in situ* all year round, and wires re-attached each year just before the breeding season and removed after the end of it. Plastic piping is wrapped around three of the corner posts, with insulators used on the post at the start and end of the wire(s), as it is quicker and easier to wrap and tension the wire around the piping, especially if it has ridges. Either the whole post can be covered with the piping (Fig. 33), or else the piping split and wrapped around the outside of the post. Pigeon spikes are used on the tops of corner posts to prevent crows and raptors from perching on them e.g. https://www.birdspikesonline.co.uk/Bird-Spikes/Defender4-Pigeon-Spikes-Plastic?srsltid=AfmBOoq9RxSTc9twd3DfqNttO_o90lSoBhWROvCvNqfc4EqspszKY6i-

The fences at Minsmere comprise seven strands of multistrand wire plus a top strand of white 'rope', to make the fence visible to deer that are common in the area. The bottom wire is usually an earth to prevent shorting out due to vegetation touching it. Because these plots are in short, open grassland that is easily accessible to vehicles, the wires can be dispensed and re-wound using a Rappa electric fence towed trailer system (https://www.rappa.co.uk/). They can also be dispensed and re-wound in using a 'wheelbarrow-type' contraption and/or using handheld reels as described for Otmoor. Also, as described at Otmoor, when the fence is installed the nest is covered with a jacket or other item of clothing, both so it is clear where the nest is and to keep the eggs warm.

Fig. 33. A permanent, wooden corner post covered in ridged, plastic piping around which electric wires are wound when installing electric strand around Stone-curlew plots. The plastic piping is the same as that used in water management. *Photo by Mel Kemp*.

As with all electric wires, excessive vegetation growth touching the wires can reduce the voltage, this being a potentially bigger issue in the case of Minsmere since the fences at Minsmere are in place for a longer period – from late winter/early spring until late summer – due to the prolonged nesting period of Stone-curlews. Vegetation along fence lines at Minsmere is managed using a strimmer. A warning light system can be used to indicate whether the electric fence is still working, and which can be seen from a distance, thereby saving time and potential disturbance.

The temporary fences at Minsmere prevent most Foxes from entering but are far less effective against Badgers. Deer can jump over the wires and Rabbits and Stone-curlew chicks can move beneath the wires into and out of the fenced areas. Stone-curlew chicks tend to remain for a long time within fenced areas, as the fence protects the entirety of the plots and thereby a large proportion of nearby good quality chick-rearing habitat, and in doing so remain safer from Foxes. Branches and other material can be placed within the fenced area to provide cover for Stone-curlew chicks if this is otherwise lacking.

Electrified netting fences

These consist simply of standard electrified netting (sheep or goat netting is recommended) held in place by its associated plastic posts, an energiser, solar panel and back-up leisure battery (Fig. 34).

Fig. 34. Electrified netting used to protect foredunes hosting breeding Kentish Plovers *Charadrius alexandrinus*, Arctic Terns *Sterna paradisaea* and Little Terns on Romo in the Danish Wadden Sea. The mesh barrier is bolstered by two offset live wires. Guidance on protecting nests of beach-nesting birds will be available at https://www.rspb.org.uk/helping-nature/what-we-do/protecting-species-and-habitats/projects/life-on-the-edge. *Photo by Gavin Thomas*.

Electrified netting does not require tensioning of wires and so does not need to be installed in straight lines like strand fencing. When used to protect Stone-curlews, it is therefore much easier to include or exclude Rabbit warrens from the fenced area, although netting may need to cross Rabbit warrens where they occur at high density, and to position the netting around Common Nettles *Urtica dioica* and shrubs that can provide cover for chicks. Also, because the bottom wire of the netting receives no electric current, the electrified netting can be used on slightly uneven ground, while the netting can be easily moved and/or added too if a pair of Stone-curlews fail or there is a second nest close to the original nest site. At Minsmere, the team use a minimum of four 50 m lengths of electrified netting to protect a 50 m x 50 m area around a Stone-curlew nest, and which can be installed and electrified within 60-90 minutes. It is sometimes necessary to use a spade to dig up and remove vegetation from along the fence line and to fill in gaps beneath the netting.

In the case of Stone-curlews, adult birds will fly into the fenced area to feed their chicks, but chicks also appear very able to leave the fenced area through the netting.

6.5. Floating rope barriers

Floating rope barriers are a recent innovation used to protect ground-nesting birds on islands from mammalian predation, and have so far appeared to be effective, as described on page 24. There are still relatively few examples on RSPB reserves, with those at Fen Drayton Lakes, Dungeness and Saltholme having been in place the longest.

An easily deployed design of floating rope has been developed and used at Dungeness (Fig. 35). This consists of 8 mm diameter polypropylene rope cut into 25 m lengths to make installation more manageable, and with small gill net floats installed at one metre intervals along it. These floats can be bought from commercial fishing suppliers (e.g. GF-20 Gill Net Floats from the company Advanced Netting). A small length of 8 mm diameter braided rope is tied in a constrictor knot at either end of the float to keep them evenly spaced and prevent them from moving. The ends of each 25 m section of rope are tied into a D-shackle which is used to connect the individual sections of rope once they are deployed. Once each section of rope is finished it is coiled and tied up to prevent it from becoming tangled (Fig. 35c).

These 25 m sections of rope are attached to one another as the rope is deployed from a boat. The floating section of the rope is held in place using engineering bricks (which have large holes in) as anchors (Fig. 35b). Each brick is attached to a length of polypropylene rope that runs through the holes in it and is attached to the floating section of the rope via a D-shackle. Where the polypropylene rope passes through the holes in the brick, it is run through a section of hosepipe to reduce chaffing. There needs to be sufficient length of rope between the D-shackle and brick to allow for water movement and so that the floating section of the rope is not too taught. This is important since, as described on page 22, floating rope barriers are assumed to be most effective if the rope is slack, meaning that a swimming Fox or Badger keeps on pushing against it, rather than being able to push over the top of a more taught rope. In 2024, the materials needed to make 1,760 m of this design of floating rope cost about £4.60 per metre of rope.

In exposed locations with strong winds and wave action, it can be worth installing fence posts in the water on the inner side of the rope (see Fig. 35a) to help prevent it from dragging its anchors and washing ashore. In these situations, it may save time to dismantle the sections of the rope after the end of the breeding season and store them inside until the following spring, to prevent the rope from continually being washed ashore by autumn and winter storms.

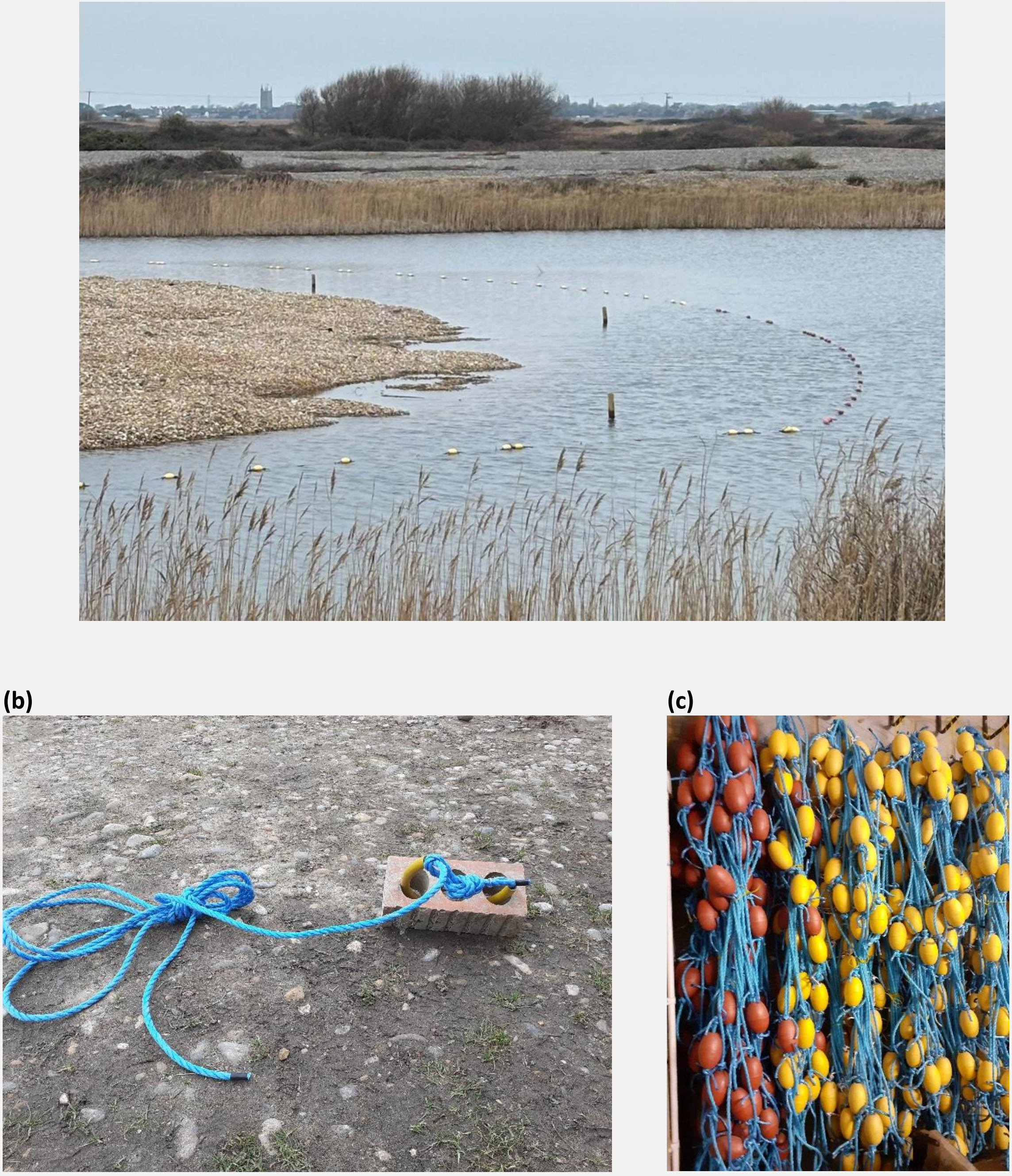
If used in narrow ditches, then the floating rope would need to be kept more taut to prevent the wind blowing it, or a swimming animal pushing it, up against the bank. As mentioned earlier, there is a greater risk that a swimming animal could push over the top of a more taught rope. A possible solution would be to still keep the floating rope taut, but to use larger and closer spaced floats to help prevent a swimming animal from pushing over the top of it (see Fig. 4).

At Fen Drayton Lakes, post-breeding flocks of Greylag Geese in July and August have damaged the design of floating rope described above by pecking at it. This resulted in the loss of many of the constrictor knots so that floats were no longer in position, some floats having chunks missing from them, and sections of the rope had broken apart. It is likely that the geese damaged the rope due to them pecking at algae growing on the rope knots. Meanwhile, another floating rope at the site which used the same floats but were held in position using hog rings rather than knots, has remained undamaged by geese.

The floating rope at Saltholme is located in the reserve's Main Lake and protects a series of small islands that host breeding Common Terns and Black-headed Gulls. During lockdown in spring 2020, a Fox swam out to the islands and decimated the colony. No visitor presence on the reserve around this time led to more Fox activity in this area of the reserve and water levels in the Main Lake were unusually low, both likely contributary factors. The floating rope was deployed prior to the following breeding season with visitor levels back to normal and water levels raised. Due to the shallow east end of the lake, digging of a ditch was required in places so the rope sat in deep enough water to be effective. Furthermore, the small size of the lake (5 ha) means that the islands are quite close to the shore and therefore no distance for a swimming Fox to cover. Despite these shortcomings and a return of breeding gulls and terns to the islands, i.e. a desirable Fox food source, there has been no Fox predation of the islands since the rope was put in place.

In July 2024, a floating rope barrier was hastily installed on The Mere at Old Moor in the Dearne Valley in response to a Fox that was swimming out to the islands to predate the hundreds of Black-headed Gull eggs and chicks on them. It was successful for a time, but highlighted the determination and intellect of these animals, as the Fox was quick to exploit the main weak point along the line of the rope where it was sat in shallow water and was able to get over it. Modifications will be required, in particular deepening of the shallow areas to ensure the entire length of the floating rope barrier lies in deep enough water.

(a)



(b) (c)

Fig. 35. Floating rope barrier used to protect nesting islands at Dungeness. **(a)** A section of floating rope barrier with fence posts in the water on the inner side of it to help prevent the rope from washing ashore plus. **(b)** A close-up showing a section of rope attached to a brick as an anchor. **(c)** Lengths of the floating rope coiled and stored inside during winter to prevent them from being washed ashore during winter storms, before being re-deployed the following spring. *Photos by Craig Edwards*.

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Appendix 1. The effectiveness of combination fences on RSPB wet grassland reserves

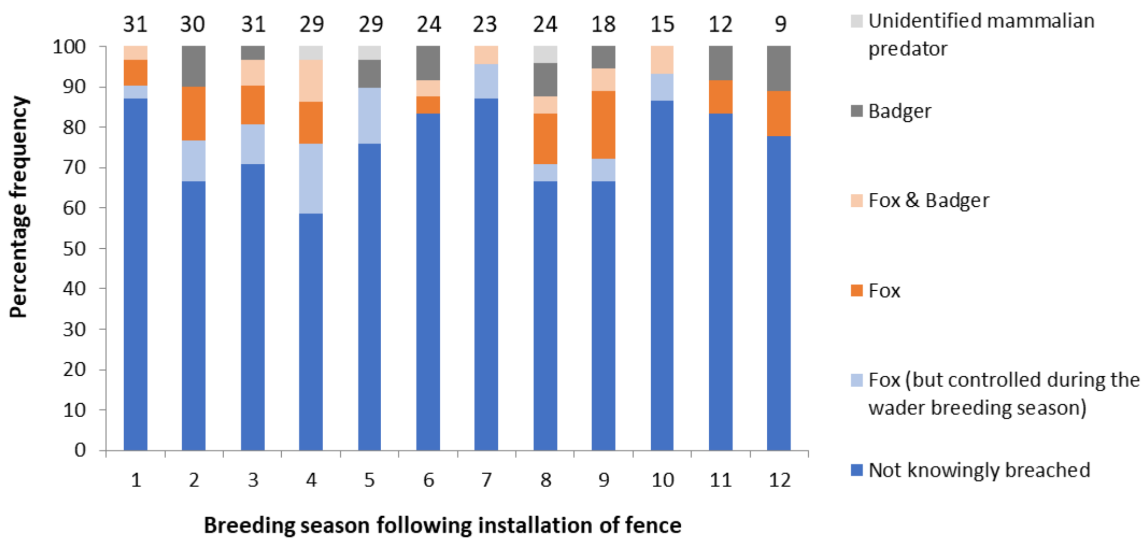
To analyse the effectiveness of combination fences, we first investigated the frequency at which fences are thought to have remained free of Foxes and Badgers during the breeding season, and how this changes over time since installation. To do this we collated information from reserve annual reports on whether fences were knowingly breached and, if so, by which species and whether in the case of Foxes the animal(s) inside the fence were shot. Staff on RSPB reserves monitor the effectiveness of fences by regularly inspecting them for signs of them having been breached, while also using trail cameras and thermal imagers and checking for footprints. In addition, at some sites data loggers and nest cameras are used to identify, respectively, the timing of predation (night-time means it must be mammalian) and the identity of the nest predator involved.

The results of this are shown in Box A1. Overall, during the twelve years following installation of a combination fence, on average an individual fence remained free of both Foxes and Badgers during the wader breeding season in 76 % of years i.e. a Fox and/or Badger was known to have been present within a combination fence during the wader breeding season in about one in every four years. Foxes were known to be present within fences twice as often as Badgers – 18 % of years compared to 9 %. When Foxes were found to be within a fenced area, in 46 % of years this Fox (or in very rare cases, Foxes) were shot before the end of the wader breeding season, and often within a few days of first being recorded. During the twelve years since installation of combination fences, an average of 0.57 Foxes have been shot within fenced areas per year per km^2 of land enclosed by fences i.e. one Fox shot within fenced areas each year for every 175 ha of land protected by fences.

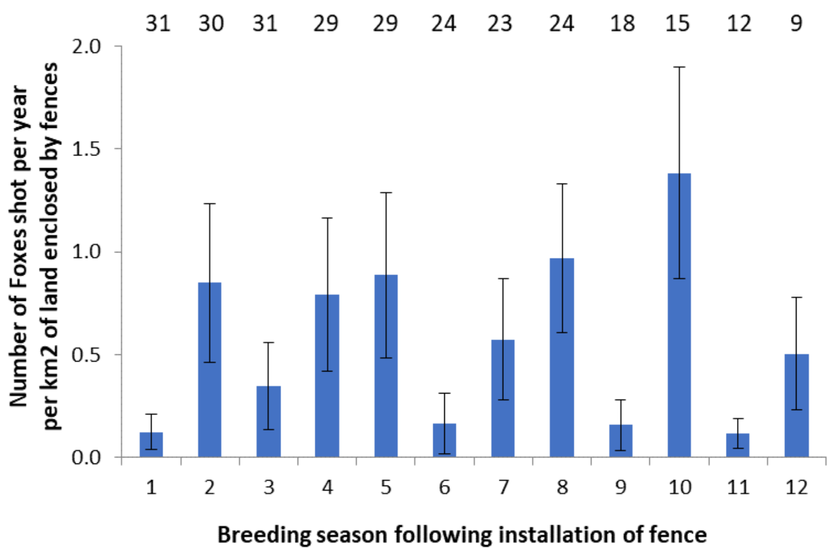
The graph shows no obvious change in the effectiveness of fences at excluding Foxes and Badgers in relation to the length of time since they were installed.

Box A1. The effectiveness of combination fences on RSPB wet grassland reserves at excluding Foxes and Badgers during the main wader breeding season (1 April to 15 July)

(a) The percentage frequency of wader breeding season Foxes and Badgers have been recorded within combination fences



(b) Mean numbers of Foxes shot within combination fences per year. Bars show means + one standard error



Figures in the graphs above are from all 31 combination fences that have been in place on RSPB wet grassland reserves for five or more breeding seasons. The number of sites contributing to the figures for each year are shown at the top of the graph, there being fewer fences that have been in place for longer periods of time (note the small number of sites contributing to the figures on the right hand side of the graphs). One of the fences for which data are included only operated for nine years, before being replaced. On rare occasions, particularly due to COVID-19 restrictions in 2020, information on fence effectiveness was not available for a particular site. ‘Unidentified mammalian predator’ refers to where there was evidence of mammalian predation on wader nests, for example because it was known to have happened at night as determined by data loggers, but the species involved was not identified. ‘Fox and Badger’ includes occasions when both were known to be present within the fence during the wader breeding season, even if the Fox(es) were controlled.

We next looked at changes in Lapwing productivity in relation to the installation of combination fences. Lapwing is the only widespread wet grassland-breeding wader species for which it is possible to obtain reasonable measures of productivity. For this analysis, we wanted to minimise as far as possible the effects of changes in productivity and especially breeding populations resulting from habitat restoration measures put in place in the first few years following acquisition, for example raising of water levels, creation of foot drains and other wet features, and changes in grazing regime.

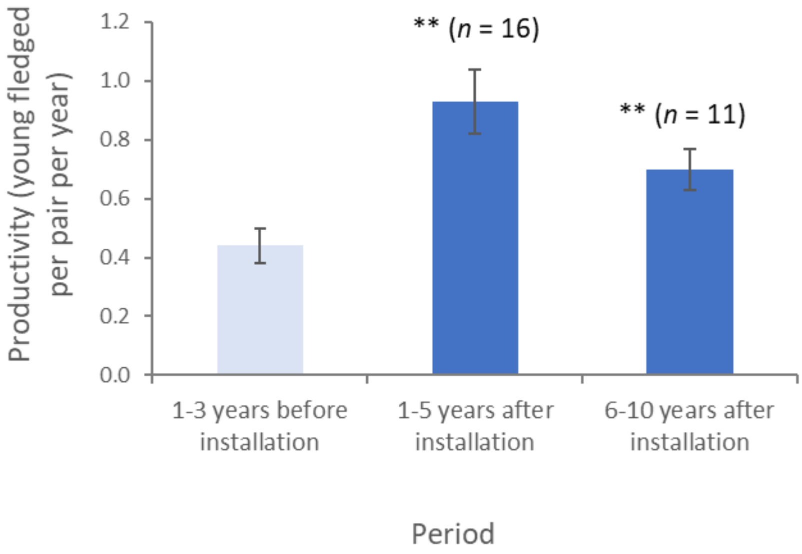
Previous analysis has shown that numbers of both breeding Lapwings and Redshank typically increase during the first six years following acquisition of land for wet grassland restoration by the RSPB (Ausden *et al*. 2019). Therefore, we only included sites where combination fences had been installed in the sixth or later year following acquisition. We also only included fences that had been in place for five or more breeding seasons. These criteria resulted in a total of seventeen fences being included in the analysis. We cannot, though, exclude any effects of habitat improvements that have taken place at these sites following the installation of fences.

Lapwing breeding productivity has not always been monitored each year at sites prior to the installation of predator fences, so for pre-fence productivity we used the mean productivity during the three years prior to installation. All sites included in the analysis had measured Lapwing productivity in at least two of these three years. At all sites, only a proportion of the area of wet grassland was enclosed by a predator fence, and Lapwing chicks and fledglings can move freely in and out of fenced areas. This meant that it is only possible to estimate Lapwing productivity *for a site as a whole*, rather than for just within the fenced area. It was also only practical to use breeding population figures for whole sites, rather than for birds just nesting within a fenced area. At the 16 sites included in the analysis, combination fences enclosed a mean of 49 % of the total area of grassland present.

Mean Lapwing breeding productivity was higher across the entirety of sites following the installation of combination fences than prior to this (Fig. A1). Lapwing productivity tended to be highest during the five years or so following installation of fences but then declined slightly but still remained higher than prior to fence installation.

It is thought that Lapwings need to produce between 0.6 - 0.8 fledged young per year to maintain a stable population in the absence of immigration or emigration (MacDonald & Bolton 2008). As shown in Fig. A1 and Table A1, mean Lapwing breeding productivity was markedly below this level at these sites during the three years prior to the introduction of the fencing, above this level during the first five years following installation of fences, and then slightly lower thereafter although still higher than prior to fence installation.

Fig. A1. Changes in Lapwing breeding productivity in relation to when combination fences were installed



The graphs show changes in Lapwing productivity on RSPB lowland wet grassland reserves before and after installation of combination fences that have been in place for five or more years. Bars show means $\pm$ one standard error. Asterisks indicate significant differences in productivity between before and after fence installation using paired t-tests, ** = $P < 0.01$, and n the number of sites in each comparison.

Figures are for whole sites, not just fenced areas, which protect an average of 49 % of the area of wet grassland at each site.