# LIFE 13 BIO/UK/000315

## LIFE Waders for Real

### Deliverable E1 Technical publication on the direct and indirect predator management techniques for wader population stabilisation and increase, including implementation and efficacy of indirect measures

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**Abstract**

A combination of direct and indirect predator management techniques have been used across sites in the Avon Valley to restore breeding wader populations during the LIFE Waders for Real project. Although it near impossible to distinguish the direct impact of each individual management technique in these situations we can report on overall outcomes through using a combined approach.

## Contents

## Background

One of the greatest conservation challenges currently facing wildlife managers in Western Europe, is how to reduce the very high levels of nest and chick predation which are preventing population recovery of ground-nesting birds. This is exemplified by the long-term decline of once common wading bird species like the northern lapwing (*Vanellus vanellus*) and redshank (*Tringa totanus*) which breed in agricultural grasslands, and are inherently vulnerable to generalist mammalian predators, especially the red fox (*Vulpes vulpes*) but also European badger (*Meles meles*).

Historically, efforts to recover populations of wading birds on farmland have focussed on increasing the availability and quality of breeding habitats, especially through agri-environment measures, but it has become clear that without parallel predator management, wader breeding success typically remains poor. Understanding which predators are having the greatest impact at sites is difficult, and it may vary between years. Further, removal of common generalist predators like red fox and carrion crow (*Corvus corone)* through legal control measures, can lead to compensatory nest and chick predation by small mammalian predators like stoat (*Mustela erminea*) (Holy & Belting, 2019) which are harder to control, or by common protected predators, which in the UK include European badger, common buzzard (*Buteo buteo*) and kestrel (*Falco tinnunclus*).

For the inclusion of predation control techniques within a framework of agri-environment measures to be justified, they should be demonstrably effective and proportional in cost to the bird conservation outcomes gained. These costs may include difficult management choices, such as the use of lethal control, or the flooding of productive farmland, to reduce mammalian predation. To reach this goal we need to develop a greater understanding of the environmental and behavioural processes which influence the impact of predators on their prey, and then to design optimum management packages which (a) fit with the objectives and aspirations of private landowners, and (b) have been demonstrated to help ground-nesting bird populations to recover. Lethal control of predators remains controversial and arbitrary arguments for its inclusion within agri-environment will be insufficient to convince Government, and the general public of its real value. It must be justifiable.

**Scope of the report**

This report details the experimental use of several different predation management techniques employed across multiple wader breeding sites during the LIFE Waders for Real (W4R) project, and the effect they had on breeding wader populations in the Avon Valley, between 2015 and 2019. For direct control measures, we mean techniques that directly affect predator's behaviour, so these include both lethal control of predators and non-lethal measures, such as using physical exclusion. For indirect control measures, we mean habitat manipulation aimed at diverting predator attention from sensitive wader breeding areas.

LIFE did not fund any lethal predator control. All culling data in this report originates from a site where waders breed well, and where lethal control of predators is a normal management activity. The data were collected for us by the full-time gamekeeper employed on this private shooting estate. Although, this data only covers only management of fox, that is not to say that control of

magpie (*Pica pica*) and American mink (*Mustela vison*) are routinely controlled on multiple landholdings in the valley, but as there was no funding to monitor the impact of their removal, it's effect on their populations remains unknown.

However, focusing on the fox management allowed analysis of detailed fox culling records and made use of the GWCT's in-house expertise at determining the effect of culling through population

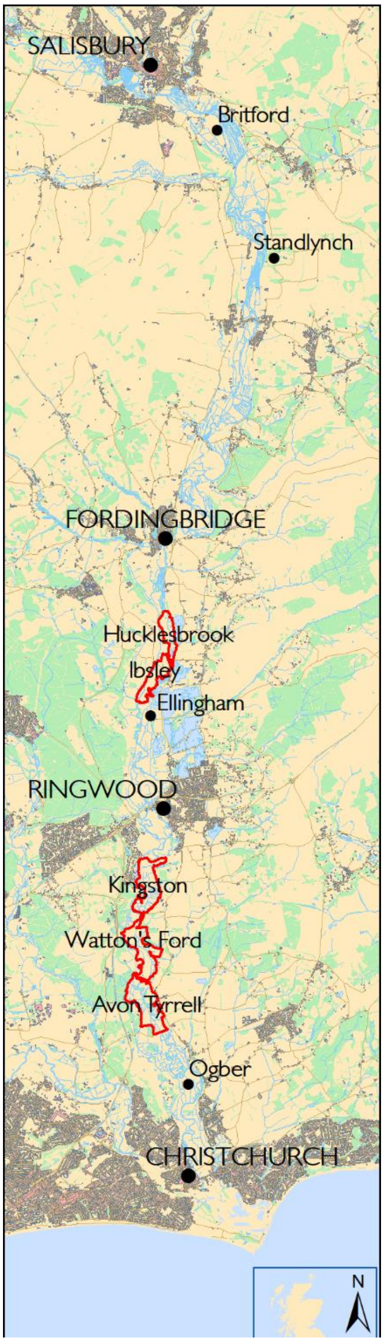


*Figure 1 Map of Avon Valley sites.*

modelling. In addition concentrating on fox management enabled us to utilise parallel W4R fox tracking research to better explore the impact of fox predation on wader populations . This tracking research involved GPS-tagging 37 foxes on the Avon valley river meadows to better understand their spatial ecology in areas where waders breed, with the aim of enlightening wildlife managers on the best options for reducing fox predation risk. Using that data, here, we report on the movements of foxes around electric fences used to protect breeding birds. However, due to the large volume of GPS-location data (>175,000 fixes) gathered during the W4R project, full analysis of fox movement data is incomplete, and we do not attempt to critique the efficacy of indirect measures to reduce predation risk. This will be covered in a different W4R output: deliverable E1, a scientific paper on fox movement around breeding waders.

## Introduction

Monitoring of the lapwing breeding in the Avon Valley in the years prior to the W4R project (2008 – 2015) indicated that poor breeding success, and consequent low levels of recruitment into the breeding population, was the driving factor causing the decline in breeding lapwing in the Avon Valley. The main cause of this poor breeding success was identified as high levels of nest and chick predation (Avon Valley historical paper – A Hoodless in writing). High predation pressure could come from relatively increased predator abundance, but poor-quality habitats can exacerbate predation risk, for example when lack of suitable foraging habitat means chicks are exposed when searching for food. The linear nature of the Avon Valley limits the extent to which the river meadows can be managed for breeding waders, both in terms of being able to create ideal habitat and being able to manage predation-risk. For example, the surrounding land uses could lead to elevated predator numbers in the valley; there are large tracts of forest either side of the valley which harbour un-managed populations of common predators, like foxes and carrion crows. Likewise, there are plentiful anthropogenic food resources associated with human settlements and rural enterprises in the valley, like gamebird releasing and fish farming, which may also support these generalist predators. In addition, there are a large number of riparian landowners and farmers in the valley which leads to a wide variety of river meadow management practices which can influence predator and small mammal prey abundance in different ways.

The LIFE Waders for Real (W4R) project combined several different techniques to increase wader breeding success and consequently facilitate lapwing and redshank population recovery. Direct predator management techniques included the use of nest cages and temporary electric fences to provide physical barriers to mammalian predators, either directly to lapwing nests in the case of the former or to important nesting and chick rearing habitat in the case of the latter. Lethal predator control was utilized on particular sites (Kingston, Watton's Ford and Avon Tyrrell) by estate gamekeepers, and this became more targeted on river meadows used by for breeding waders over the course of the project. Indirect predator management involved purposeful habitat restoration, alongside the provision of targeted advice about sward management and grazing, with the aim of creating habitat which would reduce the likelihood of vulnerable nests and chicks being detected by predators.

The river meadows in the Avon Valley are all privately owned. The majority of our work was across 18 different sites and we worked regularly with around 40 farmers, landowners, gamekeepers and riverkeepers (from now on defined as land managers). This added another level of complexity to wader recovery that differs from a nature reserve situation where management is typically under sole control of one body. Levels of implementation of the different management options differed between sites depending on, environmental factors, land manager ambitions, time and resources. However, working collectively towards an agreed goal of recovering species and habitats allowed for varied input across sites.

Our approach to delivering wader recovery in the Avon Valley was to focus our effort and resources onto four main 'hotspot' sites where the chances of wader recovery were considered to be highest (Figure 1). This gave us the best chance for success with the expectation that if we were able to increase breeding success on these sites, birds would then recolonise neighbouring areas.

These hotspot sites were initially chosen based on a number of criteria:

1. An existing lapwing population, 5-10 pairs
2. Presence of some existing habitat features required by breeding waders
3. Enrolled in an agri-environment scheme for breeding waders
4. Land managers who were eager to improve wader numbers and breeding success.

Hotspot sites received more intensive management compared to other sites, however the monitoring effort for breeding waders remained constant across all sites within the Avon Valley, allowing us to compare breeding success across all sites. A summary of this predator management, undertaken on hotspot and other sites during the project years (2016 – 2019), is shown below (Table 1)

*Table 1 Summary of direct and indirect predator management carried out as part of the W4R project*

| **Hotspot sites (477ha)** | **Other Sites (size?)** |
|---|---|
| *Direct predator management* | |
| Electric fences (effective in 2018 and 2019) | Limited use of fences (two small fences used in 2018) |
| Advice on best practice lethal predator control | Advice on best practice lethal predator control |
| Camera trap feedback on fox movements to aid lethal control | |
| Mink rafts deployed in 2015 and 2016 (detections fed back to keepers) | |
| Nest cages – attempted (trialled in 2015 and 2016) | |
| *Indirect predator management* | |
| Support for derogations and beneficial farming practices to continue | Support for derogations and beneficial farming practices to continue |
| Detailed management plans | General management advice |
| Habitat restoration – ditches and wet features | Some habitat restoration |
| Removal of fence lines and scrub | |
| Advice on sward management and grazing. | |
| On site meetings | |

## Direct predator management techniques

### Nest cages

Nest cages have been used in several wader recovery projects to protect individual wader nests from predators (Figure 2). The aim was to trial these as a non-lethal management option in the Avon Valley to protect isolated lapwing nests where temporary fencing was not appropriate.

*Figure 2 Nesting lapwing sat in nest cage (Larsson, 2010)*

*Nest cage design*

The nest cages used in the W4R project were of the following design:

1. 78.7 cm in diameter
2. 25.cm high
3. 2.5 cm square mesh on top
4. **8.5 cm minimum spacing between bars (this spacing is critical)**

The spacing between the bars is designed to allow easy access in and out by the lapwing whilst also excluding bigger potential predators like crows (Isaksson et al. 2007).

*Deployment of cages to protect nests*

In 2015, nest cages were deployed on two hotspot sites (Kingston and Watton's Ford), with the aim of deploying a cage on a sample of 8 randomly selected lapwing nests per site.

The following protocol was followed for cage deployment:

1. Locate nests as early as possible, ideally when eggs are still being laid.
2. As soon as the clutch is complete, place a cage about 5-10 m from the nest.
3. A day later move it to 2 m from nest.
4. Two days later, put it over the nest.
5. If it is difficult to see the female returning to the nest site, then when putting the cage over the

nest turn one egg around the wrong way. This will tell you if the nest has been visited again, as the female will correct the egg's direction.

6. Do not persist if a bird will not accept the cage after 40 minutes; if the bird does not accept the cage within this time remove the cage.

7. The use of nest cages on redshank nests should be avoided; they take off vertically from the nest and may not be able to escape the cage fast enough to avoid predation (Isaksson et al. 2007).

**How predator-proof are nest cages?**

Prior to field-deployment of nest cages in 2015, we conducted field trials using trail cameras to monitor predator activity around cages. These trials took place during the preceding winter, when out-of-season egg baits maybe less attractive to predators. Therefore, we baited cages with either wild bird carcasses or rabbit carcasses, which are effective at attracting generalist predators during the winter.

Cages were set in multiple locations and habitats, including the river meadows, known to be occupied by a suite of generalist predators including fox, badger, otter, carrion crow, magpie and common buzzard. Our simplistic non-randomised approach resulted in multiple video and photographic recordings of predators around cages (Figure 3). These observations included: otter, brown rat and magpie inside cages; foxes pawing and removing baits from beneath cages; American mink dragging a bait from a cage; three badgers simultaneously pawing at a bait inside a cage and a buzzard feeding on bait outside of a cage. Clearly, these nest cages were not generally predator proof, or obtrusive enough to deter foxes (the predator that was the particular target of management) from accessing baits. This is despite the expectation that foxes, which commonly exhibit neophobia around new objects placed in their territories, would be wary of nest cages. Although it is arguable that meat baits in winter may be more attractive to predators than eggs in spring, from these simple camera studies, we concluded that the effectiveness of nest-cages, used under normal field conditions, would be dependent on the discovery of active nests by predators, and how motivated predators were to gain access.


*Figure 3 Trail camera image of an adult otter inside a meat baited nest cage, confirming that cages were not predator-proof*

**Temporary electric fencing**

Many styles of electric fencing have been used on reserves in order to protect ground nesting birds. The most popular and successful is permanent electric barrier fencing (see White and Hirons 2019),. However, this is not practical in the Avon Valley, so we opted for an 8 strand temporary electric fence design which could be erected at the start of the breeding season and then removed once the area was no longer occupied by breeding waders. Elsewhere, this fence design has been used to protect stone curlew and lapwing nesting on arable farmland and it was shown to improve their breeding success.

These fences were used during the breeding season specifically to restrict or reduce ground predators' access to the nests/ breeding areas of waders. In the W4R project the main predator targeted by fencing was red fox, a key predator of lapwing on wet grassland. Fences will not exclude all predators; avian predators will still have access and not all large mammals will avoid the fenced areas. The aim of fencing is therefore to reduce predation pressure such that productivity is improved to above that required to maintain a stable population. During the W4R project fences were put up around important nesting and chick rearing areas for lapwing and redshank to improve survival.

See - Deliverable C3 Guidance note for farmers on electric fencing to protect wader nests and chicks, for details on equipment and how to set our temporary fence design.

*Where and when to set a fence*

Lapwing pairs begin setting up territories and looking for appropriate nesting sites in early to mid-March and can continue nesting attempts through to June. This is a sensitive and important period in the life cycle of this species. Disturbance during this time could have a detrimental effect on their breeding success, therefore we advise any fencing activity around breeding waders to be minimal and for the fencing process to be carried out as efficiently and as sensitively as possible, to reduce the risk of birds abandoning potential breeding sites/nests. We also advise that prior assessment of fence locations (monitoring of birds and habitat) needs to be carried out sensitively.

Areas to fence were selected using several different factors with the aim of maximising the number of breeding birds protected:

1. An area previously used by breeding lapwing and redshank - for some sites, there may be prior knowledge of which areas of habitat are favoured by breeding lapwing. In any case assessing likely use of fields by potential breeding pairs in late February and early March can help indicate potential fence locations.

2. To include habitat features that can be used to nest/rear chicks - condition assessments of habitat can be used to identify likely breeding locations. Lapwing favour continuous areas of short sward/vegetation for nesting and may also utilise raised areas (i.e. raised ground, hummocks and uneven bare ground) (Figure 4).

3. An area where that will not impact grazing management.

4. An area that will not affect farm access or processes.

5. An area near a vehicular access point – it is often not possible to access wet meadow habitats using vehicles (vehicles may get stuck in soft ground and vehicular traffic can damage diverse wet meadow grassland communities). Choosing fence locations near vehicle

access points therefore minimises the distance that equipment needs to be transported by foot across soft ground.

In the Avon Valley liaison with land managers was required to ensure that the temporary fencing would work alongside farming practices, grazing management and vehicular access. The fences were put around habitat features created as part of the W4R project (such as scrapes in the centre of the field (see **Error! Reference source not found.**)), which provided nesting habitat and brood rearing habitat (see Annex 1 Example temporary electric fence plan and Deliverable D2. Document outlining the effect of habitat actions at hotspots on habitat suitability for waders**)**

Setting temporary electric fencing in wetland habitats can be hazardous. It was important to conduct the setting in a safe but efficient manner, using the following methods and protective clothing.

**Derogation for temporary electric fencing**

A derogation from the local Natural England officer must be obtained in order to use temporary electric fencing on any fields within an Agri-environment option and to manage the vegetation underneath. This derogation is needed as the part of the field within the fence may be managed differently to the rest of the field. However, in practice, fences were not used in fields with livestock and were always removed before any grass-cutting took place.

In order to receive the derogation, we had to answer the following questions from Natural England:

1. When will you be aiming to put the fences up?
2. How long will they be up for?
3. How will the vegetation be maintained to prevent it interfering with the fence?
4. What width of vegetation would you be spraying/cutting around the perimeter of the fence?

Each landowner needed to apply for a separate derogation.

*Figure 4 Habitat types favoured by lapwing for nesting sites (hummock, continuous sward, and raised ground).*

*Figure 5 Temporary electric fence with newly created wet feature inside.*

Fences set in floodplains are always at risk of being flooded. If this does happen then bottom wires which may be submerged were disconnected, the other still connected wires could still create a current through the remainder of the fence.

*Original fence design*

Our fence design was based on the RSPB temporary fence design (White and Hirons 2019) and consisted of 4 large corner posts to keep the fence stable and 8 wire stands running the length of the fence with plastic polystakes dispersed at 8 m intervals. The fence typically covered 1-2 ha of water meadow.

The 8 wire strands were attached to the main post, and then connected so the current of electricity for the fence flows alternately through the 8 wires. Wire 2, 4, 6 and 8 had current and the remaining wires were earthed (Figure 6). The fences were run using a Solar Energisers (Speedrite S500), as long as this remained in sunlight it did not need changing during the breeding season.

Fences were set in two sessions, of no more than 1-hour duration, to minimise disturbance time spent on meadows. A 4-person team ensured the most efficient use of setting time.

*Figure 6 Main corner post with 2 x four-line reel posts holding metal wire reels.*

Fences were checked weekly, voltage measurements taken, and the fence was maintained where needed. Maintenance included reattaching any dislodged wires and re-tensioning and wires that had slackened. Vegetation growth around the fence was not controlled.

Motion activated camera traps were positioned on two of the four corner posts on each fence, facing inwards to detect fence breaches. This did not cover the whole area inside the fence; however, it would pick up most breaches.

The electric fences were taken down once birds were no longer using the area. This meant that minimising the length of time taken to remove the fence was not as critical as for setting the fence. Nevertheless, we aimed to take down the fence efficiently to minimise disturbance to general wildlife in the area.

For more details on how to set a temporary electric fence see Deliverable C3 Guidance note for farmers on electric fencing to protect wader nests and chicks.

*Revised fence design*

In 2019 we revised our fence design and maintenance schedule to make the fences more structurally robust and to manage the vegetation to minimise the voltage losses caused by vegetation growth.

Metal stakes and with plastic polystakes were placed alternately along the fence 8 m apart. The inclusion of metal stakes provided rigidity to the wire fence, while the plastic stakes allowed for flexibility where needed (e.g. over wetter areas/around vegetation).

In order to better manage fence voltage, we revised our fence management such that fence checks were carried out every two - three days. All checks and maintenance were carried out as quickly and efficiently as possible, with the aim of ensuring the fence voltage was kept above 5kV.

When arriving on site, we measured the voltage of the fence using a MV Digital Fence Voltmeter near the main fence post. If the voltage reading is below 5kV, there were several possible maintenance actions which were used to increase voltage. The protocol used in the field is listed below:

1. Check solar panel is working and all solar panel connectors are attached correctly.
2. Consider the weather conditions. Weather will affect the performance of the solar panel, so a slight drop in performance may be a lack of battery charge through a reduction in solar energy. In this case it may be that no remedial action can be taken; the voltage will improve when conditions become more favourable.
3. Ensure the wires are taut. Any sag in the wires could mean strands are touching and the circuit is shorting. It is also beneficial to keep wires taut generally to ensure the fence is structurally effective against any mammalian attempts to breach the fence.
4. Check wires have not come out of their insulator holders on the plastic and metal stakes. Deer can sometimes attempt to jump the fence and disturb the metal and plastic stakes.

Check vegetation length as growth will reduce voltage performance (see ***Vegetation management*** below).

Our revised design is outlined in - Deliverable C3 Guidance note for farmers on electric fencing to protect wader nests and chicks.

*Vegetation management*

Vegetation rapidly grows through the spring and summer months. If vegetation is touching the wires voltage will be reduced due to the fence short-circuiting.

In 2018 we did not manage the vegetation growth under the fences, this meant that as the grass grew we saw a dramatic drop in voltage, rendering some of the fences ineffective, below 5kv (see blue points in Figure 7).

In 2019 the *W4R* management protocol was revised to include vegetation management (under natural England derogation) alongside the more regular checks. A 1 m strip of vegetation was strimmed under the fence line at the beginning of the season and then once or twice during the spring when required (when vegetation began touching first two sets of wires). Strimming was chosen to control vegetation rather than herbicide as farmers were concerned about the effect of spraying on weed abundance. We used a 36v Lithium-Ion 2.0 Ah battery strimmer (with back up battery as the power duration is not exceptionally long) to cut vegetation, as this tool does not produce much noise and reduces disturbance (Figure 8).

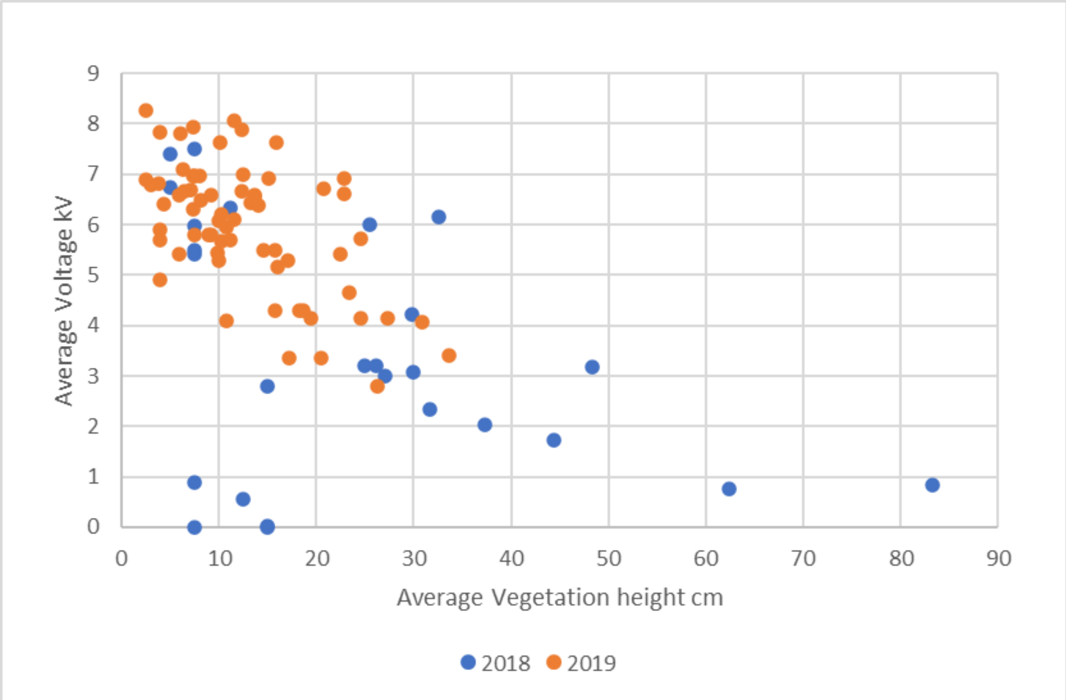



*Figure 7  Voltage of electric fences in relation to average vegetation height around the electric fence.*

*Figure 8 Strimming of vegetation under fence wires to mitigate against voltage loss*

## Lethal predator control: Bisterne Estate – a case study

Methods for direct predator management include lethal control. While lethal control was not undertaken as part of the *Waders for Real (W4R)* project, some of the river meadow hotspot sites were located within gamekeepered shooting estates where predators (foxes, mustelids and corvids) were being legally culled. Any response of wader populations to the non-lethal predator management implemented for *W4R* must be understood alongside knowledge of the lethal control undertaken on these sites, as effective predator culling would mean the other methods were not being fully tested. A fence cannot exclude a fox that isn't there! Likewise, ineffective culling will increase the challenge to the non-lethal methods.

The Kingston and Watton's Ford hotspot sites (1.09 km$^2$ and 1.15 km$^2$, respectively) were located on the 4,000-acre (16 km$^2$) Bisterne Estate. The gamekeeper maintained daily fox culling records at our request, detailing culling effort, and the numbers of foxes detected and killed by different methods. Comparable mustelid and corvid culling data were not recorded. 334 foxes were killed across the estate between January 2015 and June 2019. Using these data and a Bayesian state-space population model developed at GWCT (Porteus et al. 2019), fox density within the estate was estimated on a fortnight-by-fortnight basis (Figure 9).

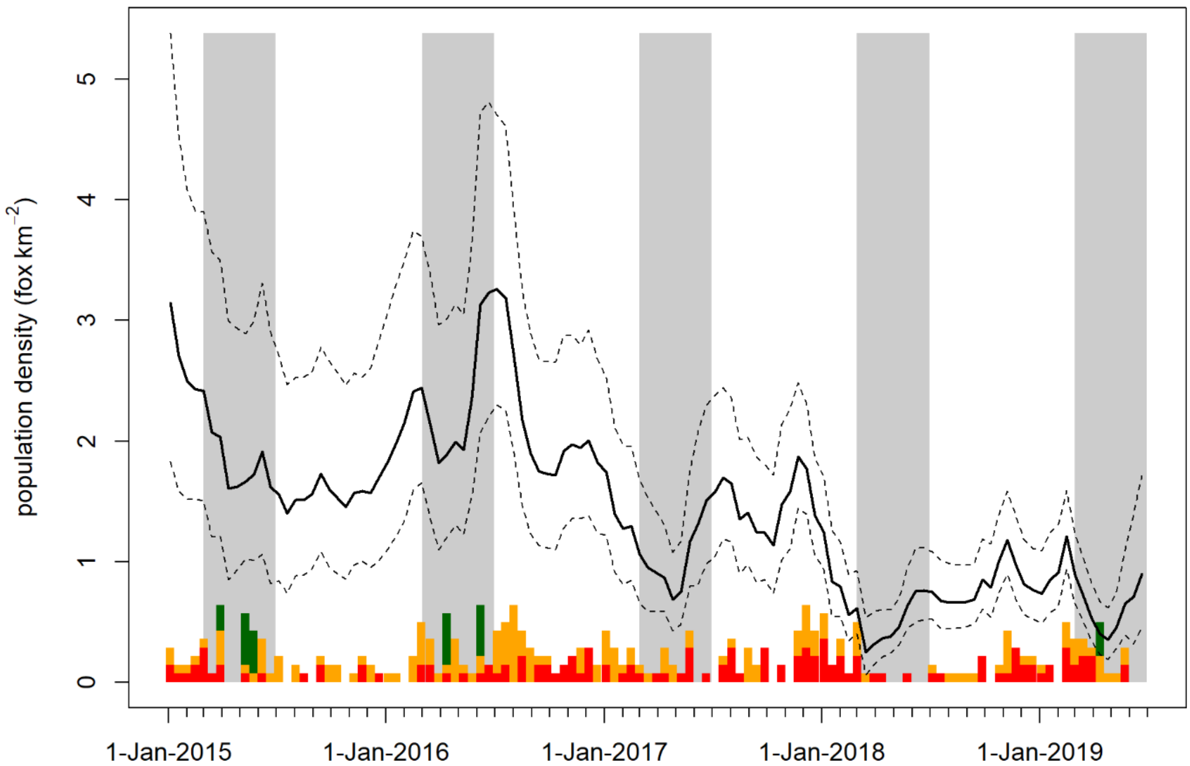



*Figure 9 Estimates of fortnightly fox density (median = solid line, 80% CI = dashed line) across the Bisterne Estate and the foxes killed by different methods: lamping (red bars), cubs killed at earths (green bars) and other methods (yellow bars). Wader nesting (March-June) is shaded grey for reference.*

From 2017 onwards, fox density was heavily suppressed by culling, particularly during the critical March-June season when waders are nesting, which was made a special aim by the gamekeeper as a result of *W4R*.  The estimated carrying capacity of the estate, at 7.9 fox/km$^2$, is a measure of the number of foxes that would be present in the absence of culling.  This carrying capacity is comparable to the highest estimates from a published study of 22 estates, indicating the abundant food resources available on the estate for foxes.  The relevance of the cull to wader conservation can be appreciated by comparing the fox density during the wader nesting period to the carrying capacity (Table 2). In the final two years of *W4R*, the gamekeeper was keeping the fox population across the whole estate below 10% of what it would otherwise have been.  This correlated to the highest lapwing and redshank breeding pair counts on the estate and good lapwing productivity.

While fox density is not a direct measure of predation pressure on breeding waders, having so few foxes on the estate during the nesting season is highly likely to be beneficial.  The later years when fox culling was particularly effective is also when the hotspot habitat improvement work had been completed and more nesting habitat was enclosed by temporary electric fences (Table 2). Determining which of the lethal and non-lethal methods is most important is not possible without a complex experimental design, but the data from Bisterne highlight that a management package which includes habitat improvement, exclusion fencing, and lethal control can achieve positive results for breeding waders.

*Table 2 Bisterne Estate 2015-2019. Mean fox density (N) estimates during wader nesting season (March-June) across the estate compared to estimated fox carrying capacity (K); electric fenced area across the hotspot sites (Kingston and Watton's Ford) and % of lapwing nesting inside the fenced area; and lapwing and redshank pair count and lapwing productivity across the hotspot sites.*

| Year | $N_{[Mar-Jun]}$ (fox/km$^2$) | $N_{[Mar-Jun]}/K$ (%) | Fenced area (ha) | % Lapwing nests fenced | Lapwing pairs | Redshank pairs | Lapwing productivity (chicks/pair) |
|---|---|---|---|---|---|---|---|
| 2015 | 1.85 | 23 | 0 | 0 | 21 | 4 | 0.48 |
| 2016 | 2.31 | 29 | 1.37 | 0 | 24 | 7 | 0.75 |
| 2017 | 1.02 | 13 | 2.43 | 4 | 18 | 10 | 0.70 |
| 2018 | 0.50 | 6 | 5.71 | 17 | 26 | 15 | 0.60 |
| 2019 | 0.62 | 8 | 9.84 | 27 | 31 | 11 | 1.17 |

## Indirect predator management techniques

### Habitat management and restoration

Habitat restoration was instigated at hotspot sites based on management plans produced for each hotspot site and agreed on by NE, EA, landowners and farmers. Management plans were specific to each site but were based on general principles required for wader recovery; to create nesting and brood rearing habitat and to reduce predator pressure. Specific management strategies are detailed below.

*Fence, scrub and tree removal*

Lapwing prefer to nest in habitats with an open aspect so approaching predators can be seen. In addition, the presence of taller trees and other structures can provide perches for avian predators which may take wader eggs or chicks. We therefore aimed to reduce field enclosure, and create more favourable nesting habitat, in the Avon Valley by removing old fence lines along with willow and alder scrub. Ditch lines were also cleared of willow scrub and vegetation was cleared in places where ditches were no longer flowing. Solitary dead trees were also removed as they were used as perching posts by avian predators.

*Wet features*

Restoration and creation of wet features in the form of scrapes, foot drains and ditches provide extremely important foraging habitat for lapwing and redshank when raising chicks, as these areas are rich in invertebrate food, and the soft ground facilitates feeding. Scrapes have been added within fields to create chick foraging habitats away from linear features and the main river channel. In addition, to increase the area wet features available, side ditches that had been separated were joined back to the main carrier channel and ditches that had dried out completely were re-dug. This habitat creation reduced chick predation risk by limiting the distance chicks had to travel to forage and by creating a more complex habitat structure, which provides areas of cover for protection from avian predators alongside open areas for foraging. In addition, many predators, particularly foxes, use linear features to move through the landscape. Therefore, chicks are generally exposed to a larger number of potential predators if their only option is to feed at the river's edge. Creating non-linear wet features therefore facilitates predator avoidance.

Sward management and stocking

Grazed fields are generally better for biodiversity than hay fields except where flora are the conservation priority. Light year-round grazing can be beneficial, but the type of livestock is important, cattle are preferable to horses and older, docile stock are essential rather than young stock during the spring. Summer hay cut is crucial to maintain sward for following spring, sometimes two cuts is possible. Derogations were supported for early cutting in fields where no birds were breeding.

Maintaining a short sward in spring can be important in reducing predation as it allows nesting waders to better see approaching predators.

For more information on habitat restoration and creation see Deliverable D2 Document outlining the effect of habitat actions at hotspots on habitat suitability for waders.

## Results of management techniques

### Direct predator management techniques

*Nest cages*

Once we started deploying cages it became apparent that lapwings were taking a long time to accept them. We attempted with 10 different lapwing nests in 2015 and only one female accepted the cage and returned to the nest. Two more nests were attempted in 2016, these were not accepted by the female lapwing. If, after waiting 45 minutes, the cage was not accepted it was removed to avoid clutch desertion. The one protected nest in 2015 did hatch.

Deploying temporary nest cages is very time consuming, especially in areas where you can only access by foot, the nest needs to be visited regularly and the cages are heavy to carry to isolated locations. Regular visits to nests can be detrimental to nest survival so this needs to be a consideration when deciding whether to use cages. Consequently, the decision was made that this was not an appropriate management technique for this situation.

In spring 2016, we experimented with different designs of nest excluder (slightly wider bar widths, cages with mesh sides but made of finer gauge wire) in order to find a design that was more readily accepted, however this was still very time consuming and we were not confident with the acceptance rate.

*Electric fences*

Although temporary electric fences were deployed from 2016, there were initially reservations from land managers about the use of fences and this caused delays in their deployment (see Table 3). In spring 2018 we were able to put out seven temporary electric fences giving an overall perimeter of 3146 m and protecting 8.17 ha of breeding wader habitat. However, extreme weather conditions in early April meant that most of the fenced areas were flooded during the first two weeks of April, causing birds to nest elsewhere. As fences were located around previous nesting and chick foraging sites and new wet features, these areas tended to be naturally low lying, and therefore were some of the first areas to flood in the extreme weather seen in early April 2018. This flooding also increased our fence maintenance time to make sure they were effective in time for when the waters retreated.

In 2019 we successfully deployed 8 temporary electric fences, protecting 11.46 ha of breeding wader habitat, we also monitored 14 lapwing nests inside fences (Table 3).

*Table 3 Total area fenced each year, split between hotspot sites and other sites, in hectares.*

| Year | Fenced area ha - Hotspots | Fenced area ha - other sites | Nest monitored fenced | Nests monitored unfenced |
|---|---|---|---|---|
| 2015 | 0 | 0 | 0 | 56 |
| 2016 | 1.37 (1) | 0 | 0 | 64 |
| 2017 | 3.05 (3) | 0 | 2 | 49 |
| 2018 | 6.75 (5) | 1.42 (2) | 5 (2 on other sites) | 24 |
| 2019 | 11.46 (8) | 0 | 14 | 37 |

Fences were designed to restrict access by mammalian predators, predominantly foxes, however we hoped badger and otter access would also be restricted. Use of camera traps across hotspot sites show presence of all three species on each site, however there were very few breaches detected by camera traps inside fences (Table 4).

*Table 4 Fences breaches captured on camera traps*

| Mammal | 2018 | 2019 |
|---|---|---|
| Fox | 1 | 0 |
| Badger | 1 | 2 |
| Otter | 0 | 0 |
| Hare | 18 | 19 |
| Cat | 0 | 0 |
| Dog | 0 | 0 |
| All deer species | 39 | 43 |
| Cattle | 1 | 0 |
| Unknown mammal | 1 | 4 |

Our detailed monitoring of lapwing nests carried out throughout the project allowed us to look at the survival of nests protected by electric fences compared to those outside the fences. Our data indicated that those nests within fences had a higher chance of survival compared to those outside fences (Table 5).

*Table 5 Lapwing nest survival inside and outside electric fences.*

| Nest Survival | 2019 | 2018 |
|---|---|---|
| Unfenced area | 67.5 % (n=25) | 50 % (n=12) |
| Fenced area | 100 % (n=14) | 60 % (n=3) |

In 2019 29% of lapwing chick sightings were inside electric fences. This indicates that the fenced area covered a considerable amount of the appropriate nesting and chick rearing habitat (Table 6).

*Table 6 Total chick sightings inside and outside electric fences.*

| Chick sightings | 2019 | 2018 |
|---|---|---|
| Unfenced area | 103 | 55 |
| Fence area | 43 | 4 |
| **Total** | **146** | **59** |

### *Fox movements around fences*

*Introduction*

Nest camera studies of waders breeding on wet grassland sites across Western Europe have revealed foxes to be the principal predator (MacDonald and Bolton 2008; Mason et al. 2017). Predator-exclusion fences can offer nesting birds considerable protection against foxes (Malpas et al. 2013) but until now, the value of temporary electric fences used on river meadows was poorly understood. In addition to evaluating fence performance across multiple sites in the Avon Valley, by comparing Lapwing nest survival and productivity within fenced and unfenced areas, a further ambition of *W4R* was to assess how fox-proof these fences are, by analysing location-data from GPS-tagged foxes, whose territories included fenced areas.

*Outcomes*

To reliably determine if, or when, fence breaches occurred, an understanding of the accuracy of fixes obtained from the GPS-collars used (Tellus Ultra-Light, Followit) was required. GPS-collars were fitted to a well-trained dog, who was lead-walked along multiple transect routes through the same river meadow areas where foxes were tagged. Using a collared dog as a model tagged fox, and a portable high-precision Trimble GPS unit to delineate transects, the tests revealed that 'active' fixes were accurate to within 5 m (for details see Appendix in deliverable E1: scientific paper on fox movement).

In both 2018 and 2019, two temporary 8-strand electric fences were set on the Somerley Estate in target areas of wader nesting habitat where foxes were tagged (Table 7). GPS collars recorded the location of each fox on a 10-minute fix schedule. Fox activity around areas before and after fences were set was determined by counting the number of fix locations for each fox that were inside the fenced area and in the immediate vicinity around the fence using 5 m, 10 m, and 25 m buffers around the fence line. Locations inside a fence were also categorised as being <5 m or >5 m from the fence line. Due to the combined precision limits of the GPS collars and the handheld Garmin GPS used to delineate the fences, a fix located <5 m inside the fence could have been on the fence line; likewise, a fix located <5 m outside of the fence could have been inside. Each fence was set for approximately one month in areas where at least two tagged foxes had been active. Sustained activity around a live fence was determined by searching for occasions of two or more sequential fix locations near to the fence.

*Table 7 Area, perimeter of electric fences and duration they were set where tagged foxes were active on the Somerley Estate, which included the Hucklesbrook/Ibsley hotspot site.*

| Fence | Area (ha) | Perimeter (m) | Date set | Date removed | Nights set |
|---|---|---|---|---|---|
| Ellingham 2 | 0.33 | 240 | 25/05/2018 | 29/06/2018 | 34 |
| Ellingham 4 | 1.09 | 475 | 25/05/2018 | 29/06/2018 | 34 |
| Hucklesbrook 3 | 0.75 | 405 | 06/06/2019 | 04/07/2019 | 28 |
| Ibsley 8 | 0.84 | 371 | 06/06/2019 | 04/07/2019 | 28 |

Given the aim of understanding fox movement around fences protecting breeding waders, the fences were set around active nests or in the best locations possible. However, the tagged foxes spent only a small proportion of their time in the vicinity of these fenced areas, with a maximum of 3.3% of total fixes for each fox being within 25m of a fenced area (Table 8).

*Table 8 Fox activity in areas around electric fences before and after live fences were set, as determined by GPS tagging. Locations inside a fence were also categorised as <5m or >5m from the fence line, as given GPS precision the former could have been outside the line. Locations in the vicinity of the fence were categorised in 5m, 10m, and 25m buffers from the line to indicate activity around the fenced area. The number of days tagged and number of fixes for each tagged fox during the unfenced and live-fenced periods are shown to indicate availability.*

| Fence | Fox | Live | Days | Fixes | Inside | <5m in | 5m out | 10m out | 25m out |
|---|---|---|---|---|---|---|---|---|---|
| Ellingham 2 | S18M03 | No | 60 | 3109 | 1 | 0 | 0 | 0 | 7 |
| | | Yes | 34 | 3264 | 0 | 0 | 2 | 5 | 14 |
| | S18M04 | No | 51 | 1769 | 0 | 0 | 1 | 2 | 3 |
| | | Yes | 34 | 3265 | 0 | 0 | 0 | 1 | 3 |
| Ellingham 4 | S18M03 | No | 60 | 3112 | 0 | 0 | 1 | 1 | 6 |
| | | Yes | 34 | 3261 | 0 | 0 | 2 | 3 | 7 |
| | S18M04 | No | 51 | 1773 | 1 | 0 | 1 | 3 | 7 |
| | | Yes | 34 | 3261 | 4 | 1 | 0 | 3 | 16 |
| Hucklesbrook 3 | S19F01 | No | 64 | 4045 | 13 | 2 | 8 | 17 | 64 |
| | | Yes | 20 | 2290 | 1 | 1 | 2 | 2 | 32 |
| | S19F03 | No | 19 | 813 | 0 | 0 | 0 | 1 | 2 |
| | | Yes | 0* | 0 | 0 | 0 | 0 | 0 | 0 |
| | S19F06 | No | 14 | 1990 | 0 | 0 | 0 | 0 | 0 |
| | | Yes | 27 | 3655 | 0 | 0 | 0 | 0 | 5 |
| | S19M02 | No | 52 | 6336 | 52 | 20 | 48 | 79 | 106 |
| | | Yes | 28 | 3727 | 2 | 2 | 2 | 4 | 24 |
| Ibsley 8 | S19F05 | No | 22 | 3080 | 2 | 1 | 0 | 0 | 2 |
| | | Yes | 14 | 1958 | 0 | 0 | 1 | 1 | 6 |
| | S19M04 | No | 22 | 3119 | 4 | 0 | 1 | 2 | 7 |
| | | Yes | 8 | 972 | 0 | 0 | 0 | 0 | 2 |

* Last GPS fix before battery failed on 08/05/2019.

In 2018, two tagged male foxes (S18M03 and S18M04) and at least two untagged adult foxes (detected on trail cameras and from high-seat watches) were active around both Ellingham fence areas before and after fences were set. The construction of both fences followed the discovery of active Lapwing nests within each fenced area in May. The exact positioning of fence-lines was influenced by a desire to avoid running wires over hollows in the ground (to minimise the risk of predators pushing underneath); through long vegetation to minimise loss of power, and to include open patches of soft mud for foraging chicks. Because nests were discovered late in the season, the meadow vegetation around Ellingham 2 fence was already tall, and the lapwing monitoring team chose not to physically cut it, to avoid over-disturbance of the nesting birds. Fence Ellingham 4 included a single lapwing nest and was located on a tightly grazed grass meadow, previously occupied by cattle.

S18M03 showed greater activity in locations around the fence perimeter area after fences were set (Figure 10). On one night the fox was located within 10m of the Ellingham 2 fence, then 40 minutes later appeared within 5 m of the Ellingham 4 fence after travelling directly between them.  While this fox was never located inside a live fence, despite being within 25 m of one on 21 occasions, it was located within 5 m of a fence line on four occasions.  During the fenced period there were only six separate occasions where there were two sequential fixes around fenced areas, indicating S18M03 spent little sustained time near fences.

S18M04 was most active around the Ellingham 4 fence and appeared to breach it on 4 out of the 20 occasions when within 25 m of it (Figure 10). Three of the four locations inside the fence were >5 m from the fence line (7.2m – 20.5m inside); these were assumed to reflect true breaches of the fence. All occurred on different nights. The other location was <5 m inside the fence line, which was not considered a confirmed breach. No breaches came from the four separate occasions of two or more sequential fixes, indicating that S18M04 also spent little sustained time near fences.


*Figure 10 Activity of S18M03 (red circles) and S18M04 (blue circles) around the Ellingham 4 electric fence in 2018.  Map shows fox locations in the area before (left, dashed black line) and after (right, solid black line) the fence was set in buffered areas: 5m inside, 5m outside, 10m outside, and 25m outside the fence line.*

Although the Ellingham 2 fence, which was the smallest of these fences, was not shown breached by tagged foxes, it was breached by a badger (04/06/18) and an untagged fox (12/06/18) as evidenced by their recording by trail cameras fixed on corner posts, to detect predator activity inside the fence. Similarly, fresh fox scat and the remains of an avian carcase (probably woodpigeon) was discovered inside the Ellingham 4 fence on 08/06/18 (Figure 11). Roe deer – which are reputed to be highly sensitive to electric fences – were recorded inside both fences on multiple occasions.

*Figure 11 Fox scat and avian prey remains found inside Ellingham 4 fence. Fence wires can be seen against the sky.*

Following breaches by foxes and a badger in 2018, this fence design was improved in 2019, and maintenance effort was increased. This involved interspersing metal fencing stakes into the plastic stakes used previously to add rigidity, increasing the voltage check schedule to every 3 days, and use of a quiet battery-powered strimmer to clear vegetation away from the fence wires. Four foxes (three female (S19F01, S19F03, S19F06) and one male (S19M02) were active around the Hucklesbrook 3 fence (Figure 12). Although this fence did not include any active wader nests as it was set late in the season, its location was purposefully selected to encircle an example of prime wader breeding habitat, and the fenced area was accessible to a pair of Redshank with unfledged chicks. Both S19F01 and S19M02 were regularly active across this area before it was fenced, but after the fence was set their movements were noticeably restricted to outside the fence. There was one apparent breach by S19F01 and two apparent breaches by S19M02, but all of these were <5 m inside the fence line so are not confirmed breaches. S19F01 and S19M02 were each located twice within 5 m of the fence line. S19M02 was much less active around the area when the fence was set. S19F01 had four separate occasions of two or more sequential fixes within 25 m of the fence (total 13 fixes), but the longest period of sequential fixes (60 mins) did not indicate sustained activity around the fence as these locations were during the day when the fox was inactive at a resting spot in a rush-bed on the east side of the fence. S19M02 had eight occasions of two or more sequential fixes (total 10 fixes). On two of these occasions the fox was <10 m from the fence for 20 minutes, including both apparent breaches where locations were <5 m inside the fence. All other sequential locations within 25 m of the fence were >10 m from the fence. S19F06 was within 25m for three sequential fixes on one occasion.


*Figure 12 Activity of S19F01 (red circles), S19F03 (purple circles), S19F06 (yellow circles), and S19M02 (cyan circles) in the area around the Hucklesbrook 3 electric fence in 2019. Map shows fox locations in the area before (left, dashed black line) and after (right, solid black line) the fence was set in buffered areas: 5m inside, 5m outside, 10m outside, and 25m outside the fence line.*

The Ibsley 8 fence was situated on the edge of two fox territories, female S19F05 and male S19M04. This fence was sited within a grass meadow and included three large wader scrapes which had been created at the start of the W4R project to improve chick-foraging habitat in an area previously used by nesting Lapwing. The scrapes remained dry throughout the fenced period. Activity of these foxes around this fenced area was infrequent, with only one location within 5 m of the live fence. There were only two sequential fixes around the fenced area, both by S19F05.

Although only on a handful of occasions, the other fences used on hotspot sites around wader nesting habitats were encountered by tagged foxes. During the W4R project, increasing numbers of these fences were live from March onwards in areas where waders regularly nested, but they were only encountered by tagged foxes in 2019. On Somerley, S19M01 came within 25 m of the live Ibsley 3 fence (which protected 5 pairs of nesting Lapwing) on one occasion. Analysis of home-range use by this fox, suggests the fenced area fell on the boundary of its territory. On the Bisterne Estate, S19F02 (tagged on Somerley but subsequently dispersed) was located <5m inside the live Wattons Ford 8(2) fence on two sequential fixes. As the fence was located next to the Wattons Ford 8(1) fence, these locations were within 25 m of that fence. While these fixes could indicate a breach, the fox was probably moving along the vehicle track separating these two fences.

*Research and Management implications*

Analysis of fox location-data around temporary electric fences was a key research ambition in 2018 and 2019, but 16 tagged fox territories rarely included active wader nesting areas suitable for electric fencing. For example, 3 resident adult foxes tagged on the Hucklesbrook hotspot site in 2019, tending five cubs, regularly occupied an area of marsh where four pairs of Lapwing and 1 pair of Redshank nested (Figure 13) but the ground conditions here (very wet, multiple ditches, poor access) prevented installation of an operational electric fence.  This situation illustrates a potential problem with temporary electric fencing as a management tool for protecting breeding waders.

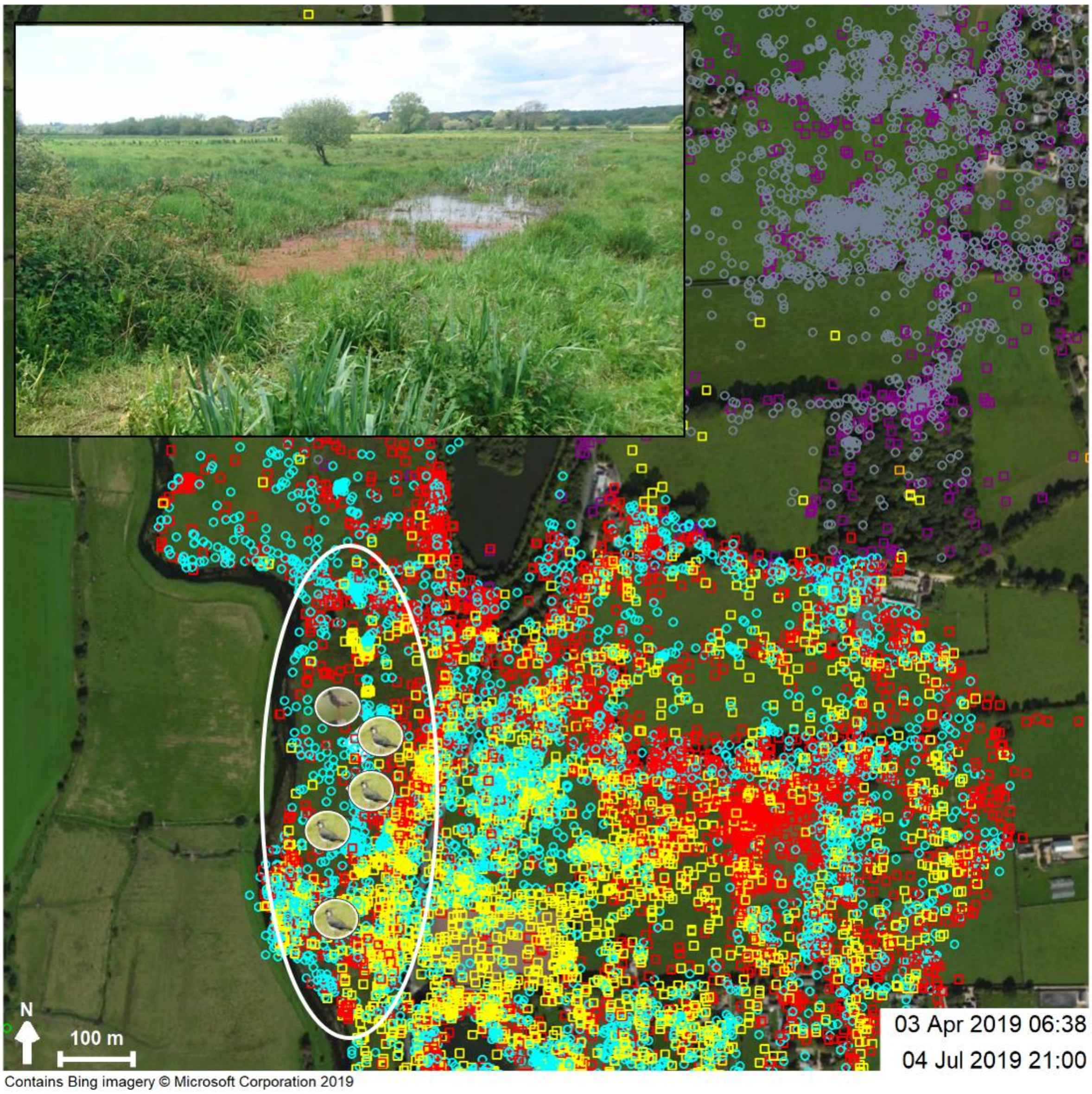



*Figure 13 Despite 16 foxes GPS-tagged on Somerley Estate where waders were breeding in 2018-19, opportunities for studying their movements around electric fences were limited. For example, in 2019, 4 pairs of Lapwing and 1 pair of Redshank nested on river meadows occupied by three adult foxes (light blue circles show the locations of a tagged male, yellow squares and red squares the*

*locations of two females) yet the nesting area (picture inset) was considered unsuitable for an electric fence.*

Catching foxes for tagging purposes isn't easy, and territory boundaries only become apparent after a period of tracking; therefore, catching the 'right' foxes in terms of those that may threaten waders, and subsequently challenge electric fences, is largely a matter of luck. This highlights the scale of study required to fully understand the movements of foxes around electric fences, by analysing fox GPS-tagging data.

Motivation is a key determinant of whether a fox breaches a fence. The main driver is likely to relate to the availability of food resource inside the fence. In 2018, the Ellingham 4 fence was confirmed breached ≥3 times, on different nights, by a resident tagged male fox. A single pair of Lapwing nested inside the fenced area, and the grass sward was too short to support an abundance of field voles. However, the fence was located adjacent to the main River Avon, and >100 Greylag and Canada geese with attendant, noisy goslings were regularly recorded inside the fence, both feeding and resting (Figure 14). This regular and abundant prey resource is likely to have sufficiently motivated hunting foxes to challenge the fence and may explain the observed breaches.


*Figure 14 Field observations and camera-traps recorded regular goose activity inside the Ellingham 4 fence, which was breached by foxes on >3 occasions. The fence perimeter can just be seen in the background (corner post in top right).*

It is encouraging that no confirmed breaches of the Hucklesbrook 3 fence occurred in 2019, but it's important to note that this fence was erected on 6$^{th}$ June, which is late in the nesting season. Prior to that, foxes S19F01 and S19M02 were regularly active in the unfenced area, but it's plausible that without the attractive scent and sound of breeding waders and wildfowl, they were less motivated to breach the fence.  Although we have no reason to believe this was the case, it's possible that untagged foxes did breach the fence.

If a fenced area restricts fox access to important resources (e.g. food, secure rest sites, dependant cubs), or from protecting those resources from foxes in adjacent territories, then the fence size, location and temporal use in relation to a resident fox's home-range, may influence the likelihood of a breach, more than the exact design of the fence.  In such circumstances, any shortfalls in a fence's deterrent power, e.g. temporary loss of voltage, may be exploited, which highlights the need for very regular fence maintenance checks. An improvement would be for temporary electric fences to have designed-in remote alarm systems, to provide notification of any loss of power in the fence, as soon as it occurs, to prevent likelihood of a breach. We are currently unaware of such a fence monitoring system, but one could be developed using GSM-type technology.

## Indirect predator management techniques

*Habitat restoration*

Habitat works commenced in August 2015 and continued until March 2019, with some work being conducted on five hotspot sites. This included work on the four original hotspot sites (Hucklesbrook-Ibsley, Kingston, Avon Tyrell and Watton's Ford) and work on one of the new hotspots identified as part of the project extensions (Standlynch). In the project extension habitat work at an additional new hotspot site (Ogber) was proposed.

*Wet feature creation*

We have added new, or restored existing, wet features in 200 ha of fields across our original four hotspot sites. This has created wet grassland habitat better suited to lapwing and redshank nesting/brood rearing due to the increase in accessible wet features (ditches/scrapes). The amount of suitable wet features has at least doubled compared to what was originally available per field, this exceeds our original proposal of improving 120 ha of habitat for breeding lapwing and redshank (Table 9).

In addition, we have been able to improve habitat on two sites adjacent to hotspot sites, creating 17 ha of fields with new or restored wet features. On these sites we have again at least doubled the amount of in field wet feature available to breeding waders (Table 9).

Finally, we carried out additional management on the new hotspot sites (identified as part of the project extension); 12 ha of fields with restored wet features were created at the Standlynch hotspot site (Table 9).

*Table 9 Amount of wet feature added, and wet feature restored across sites.*

| Site | Scrape added (m²) | Ditch reprofiled (m) | Ditch added (m) | Fields with wet features added (ha) | Site Area (ha) |
|---|---|---|---|---|---|
| Avon Tyrell North – Hotspot site | 998 | 866 | 83 | 34 | 132 |
| Hucklesbrook – Hotspot site | 1955 | 2463 | 1603 | 53 | 53 |
| Ibsley – Hotspot site | 1090 | 0 | 0 | 30 | 68 |
| Kingston – Hotspot site | 4937 | 0 | 0 | 45 | 109 |
| Watton's Ford – Hotspot site | 1377 | 349 | 0 | 38 | 115 |
| Sopley Island – Adjacent site | 562 | 738 | 0 | 9 | 40 |
| Avon Tyrell South – Adjacent site | 0 | 110 | 0 | 8 | 78 |
| Standlynch – New hotspot site 2018 | 285 | 2226 | 0 | 12 | 64 |
| Hotspot total | 10357 | 3678 | 1686 | 200 | 477 |
| Hotspot average | 1773.7 | 984 | 281 | 35.3 | 90.2 |
| **Total** | **11204** | **6752** | **1686** | **229** | **659** |

Each hotspot site has received on average 281 m of new ditching and 984 m of reprofiled ditching. This included 1718 m of ditch re-profiling at the new hotspot site Standlynch in the winter of 2018/2019.

In addition, 1773.7 m² of scrapes were created on average on each hotspot (Table 9). This measurement is not directly comparable with the proposed 1000 m of new of new boundary ditching and 1000 m of in-field carrier/wet feature restoration. However, we are confident that the management we have undertaken has had achieved the same overall outcome, especially when the overall amount habitat now made appropriate for breeding waders is considered.

*Tree, scrub and field boundary removal*

Each hotspot had an average of 2.5 large dead trees removed (not including scrub removal). On the new Standlynch hotspot site it was possible to remove two trees during the winter of 2018/2019. However, on this site it was not possible to remove the dead oak as proposed due to its importance for roosting bats. In addition, we were also unable to remove the willows due to access issues. Old disused fence lines were increasing field enclosure specifically on one hotspot site (Ibsley). Consequently over 1 km of fence line was removed from that site (Table 10).

*Table 10 Amount of field boundary opened across sites.*

| Site | Fence Removed (m) | Trees removed | Site Area (ha) |
|---|---|---|---|
| Avon Tyrell North – Hotspot site | 0 | 0 | 132 |
| Hucklesbrook – Hotspot site | 0 | 0 | 53 |
| Ibsley – Hotspot site | 1012 | 5 | 68 |
| Kingston – Hotspot site | 0 | 3 | 109 |
| Watton's Ford – Hotspot site | 0 | 5 | 115 |
| Sopley Island – Adjacent site | 0 | 0 | 40 |
| Avon Tyrell South – Adjacent site | 0 | 0 | 78 |
| Standlynch – New hotspot site | 0 | 2 | 64 |
| Hotspot total | 1012 | 13 | 477 |
| Hotspot average | 168.6667 | 2.5 | 90.16667 |
| **Total** | **1012** | **15** | **659** |

*Grazing and sward management*

In collaboration with Natural England, the landowners and the farmers, we modified the grazing and sward management on a site by site basis in order to create suitable conditions for breeding waders

Working alongside Natural England, we have encouraged an increase in livestock numbers on some sites, particularly Hucklesbrook. Hucklesbrook is now grazed by up to 30 horses and 10 cattle between May and July, this has resulted in maintenance of a shorter sward, which is more suitable for lapwing.

Many of the fields at Kingston were improved agriculturally in the 1970s, leading to denser grass swards. These swards therefore require cutting in late summer and aftermath grazing to ensure suitable sward structures for lapwing and redshank in spring. This management is conducted by the landowner, however prior to the project the timing of the grazing was unsuitable for breeding lapwing. A large free ranging herd of approximately 90 young cattle were introduced from late May/early June; these young and energetic cattle were a particular issue for late lapwing clutches and small chicks as they caused disturbance and increased the risk of trampling. Through negotiation with the livestock manager, we ensured that the site was grazed in smaller units, which facilitates more flexibility. In addition, the livestock manager now consults with project ecologists before livestock are introduced so up to date information about breeding waders can be taken into account. This means the introduction of cattle to fields with breeding waders can be postponed until later in the season.

There was a similar issue at another hotspot site (Watton's). As on Kingston, young cattle (in this case young bullocks) were introduced to fields before the waders had finished breeding. This again has largely been resolved through better liaison with the livestock manager. In addition, the landowner has made it a high priority to make sure a hay cut is taken off the key fields on this site and that the fields are heavily aftermath grazed. This has meant an appropriate sward is maintained coming into the following spring.

On the Avon Tyrell sites grazing is mainly carried out by two tenant farmers and the swards were largely appropriate for breeding waders. In this case the tenants were advised by Natural England to lower the stocking density, but we were able to support the tenants in maintaining a higher stocking density. The project provided evidence of good breeding wader success, despite the higher stocking density. We believe this is down to the type of stock; older cattle who do not disturb nests and chicks.

## Effects on lapwing breeding success

The Waders for Real project was a practical restoration project, therefore sites received a combination of management techniques, rather than having an experimental design where different sites received specific management techniques in order to compare responses. This means it is not possible to distinguish the specific effects of each separate management technique. Therefore, we must look at the effects of the techniques combined and their effects on breeding waders.

Although the project started at the start of 2015, most management techniques began after this first breeding season. Habitat restoration did not begin until autumn 2015, no electric fences were used and there had been limited advice on habitat management and lethal predator control.

We have not counted the lapwing results for spring 2015 as 'during the project', we feel it more appropriate to count during the project outcomes as 2016 – 2019.

An increase in lapwing productivity of 0.22 chicks per pair was seen across all sites during the course of the LIFE Waders for Real project, bringing the average productivity on hotspot sites to 0.7, the value required to maintain a stable population (Table 11). This is a great achievement over the 5 years of the project and highlights the work not only put in by the Waders for Real team, but the land managers and farmers who were responsible for altering management practices and increasing awareness of how to farm alongside breeding waders.

*Table 11 Lapwing productivity over the project.*

| | All sites productivity | Increase | Hotspot productivity | Increase | Other sites Productivity | Increase |
|---|---|---|---|---|---|---|
| Before project (2007 - | 0.48 | | 0.51 | | 0.47 | |
| During project (2016 – 2019) | 0.70 | 0.22 | 0.75 | 0.24 | 0.53 | 0.06 |

This increase in productivity was predominantly seen on hotspot sites where most management techniques were used. An increase in productivity on hotspot sites of 0.24 was observed compared to 0.06 on other sites.

## Financial cost of predator management

*Table 12 Cost of direct and indirect predator management techniques used in the W4R project.*

| | Nest cage | Electric Fence 500m | Habitat (wet features and scrub/fence removal) |
|---|---|---|---|
| Cost per unit | £179.52 | £2,118.24 | £2439.5 |
| Duration of kit | 5 year | 5 year | 5 year |
| Cost per season | £35.90 | £423.65 | £487.9 |
| Number L/RK pair protected | 2 | 5 | 22.25 |
| Daily staff rate | £109 | £109 | £109 |
| Staff time per season (days) | 1 | 4.33 | 3.8 |
| Volunteer time (days) | 0 | (3.8 could be possible) | 12 (volunteer time used for scrub and fence removal) |
| Staff cost | £109 | £471.97 | £327.00 |
| Cost per lapwing/redshank pair per season | £72.45 | £179.12 (£96.28 if volunteer time used where staff not essential) | £40.54 (£99.33 if we were unable to use volunteer time for scrub and fence removal). |

Based on the work we have done across our hotspot sites we have been able to put crude calculations together on the cost of our work. This includes staff time and capital costs for using temporary fences and habitat management (Table 12).

The cost of management on hotspot sites in order to increase breeding success by 0.24 chicks per pair to reach 0.75 is £219.66 per lapwing/redshank pair. This calculation does not include the cost of lethal predator control, which was present on most hotspot sites, or an advisor/facilitator.

An advisor role has been paramount throughout the project, to keep motivation among the farmer group and advise on best practice and management options. This advisor role needs to be a part time role by a qualified professional, therefore requires a suitable salary.

## Discussion

Determining which of the direct and indirect methods is most important is not possible without a complex experimental design. However, we have documented here that the use of a management package which includes habitat improvement, exclusion fencing, and lethal control can achieve positive results for breeding waders.

For our case in the Avon Valley we quickly learnt that temporary nest cages were not an appropriate management technique. This process was extremely time-consuming when fields could only be accessed on foot, it required frequent visits to nests sites, which could in itself impact nest survival, and on almost all occasions the lapwing would not accept the cage once it was placed on the nest.

Temporary electric fences proved much more successful. In the locations which are suitable for breeding waders and have access for setting and maintenance they can provide increased nesting survival. Fence location is extremely important and there are locations that are inappropriate for a temporary electric fence. It is important that the fence is monitored regularly (every 3 days) in order to maintain voltage and vegetation must be managed around the fence to avoid a drop in voltage. Temporary electric fences are more useful around appropriate nesting and chick rearing habitat, for example a large scrape in the middle of a field. As once chicks have hatched, they are very mobile and will move to the appropriate habitat, therefore it needs to be incorporated inside the fence. Our fox tagging data indicates that no tagged foxes breached fences in 2019 (although we cannot be sure that untagged foxes did not breach the fence), this gives confidence that this is an appropriate fence design for this style of management.

Temporary electric fences will only be effective if there is already appropriate habitat available for nesting and chick rearing. They are also most cost effective when used to protect a colony of nesting waders. Temporary electric fences also provide protection against protected predators, i.e. badgers and otters and provide a good management option alongside lethal predator control of foxes.

The Bisterne Estate comprises of the Kingston and Watton's Ford hotspot sites. This is the most appropriate example where the most management was input. Including a large amount of habitat restoration, changes in habitat management (grazing and cutting regimes), use of temporary electric fences and increased targeted predator control. Table 13 shows an increase in productivity of 0.33 between the project years and the years before the project. This increase takes the average productivity value during the project to 0.82 chicks per pair; this figure is indicative of population recovery as it is above the 0.7 chicks per pair required to maintain a population.

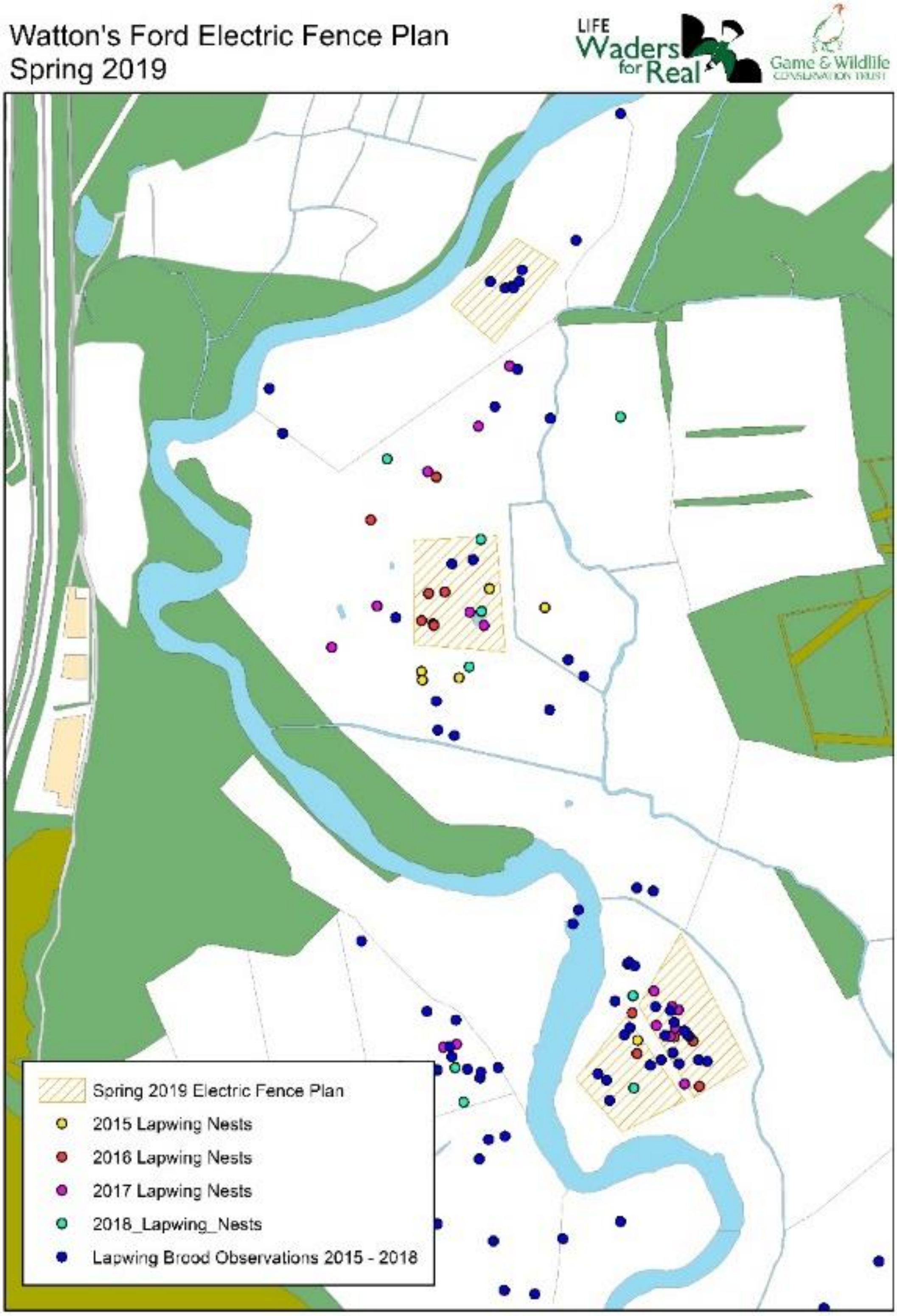
*Table 13 Productivity before and during the project on Bisterne Estate.*

| | Bisterne productivity | Increase |
|---|---|---|
| Before project (2007 -2015) | 0.49 | |
| During project (2016 – 2019) | 0.82 | 0.33 |

Again we are unable to determine exactly what effects each management option has on a breeding wader population, however we can confidently say that a combination of these management techniques can be put together to achieve wader population stabilization and start to achieve population recovery.

## Annexes

### Annex 1 Example temporary electric fence plan



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