BTO RESEARCH REPORT 810

# Trialling farmer wader counts and bioacoustics to aid agri-environment scheme evaluation

Jarrett, D., Wilson, M., Ledwith, A. & Noyes, P.

Birds Science People

**ACKNOWLEDGEMENTS:** Thanks to our project partners, the Yorkshire Dales National Park Authority (YDNPA), for providing the funding for this work through Defra's Farming in Protected Landscapes programme, providing the training and coordination for YDNPA volunteers, and wider support for the project. Thank you to the farms who participated in this study, counting waders, deploying acoustic devices, and allowing volunteer access to farms. Thanks to the YDNPA volunteers for many hours of wader surveys which made this study possible: Alistair Beveridge, Andrew Watts, Bruce Stainsby, Cath Wilson, Kathryn Lillistone, Mark Bowen, Michael Thorniley-Walker, Neil Smeeton, Richard Candeland and Stuart Probst. Thank you to Dr Sarah Marley from Scotland's Rural College (SRUC) for supervising and supporting the master's project which produced the BirdNet Analyzer accuracy sections of this research report. Thank you to Rich Bunce Walking Photographer for helping capture the fieldwork through your wonderful photography. Thank you to the Curlew Recovery Partnership (CRP) and Natural England (NE) for the funding and project coordination of the CRP's Curlew Solutions Trial, funded through NE's Species Recovery Programme, used in this report for the Curlew vocal activity case studies.

# Trialling farmer wader counts and bioacoustics to aid agri-environment scheme evaluation

**Jarrett, D.[1], Wilson, M.[1], Ledwith, A.[2] & Noyes, P.[3]**

[1] BTO Scotland, [2] Scotland's Rural College (SRUC), [3] British Trust of Ornithology

BTO Research Report 810

This report is one of a series of three produced by the British Trust for Ornithology (BTO) and Yorkshire Dales National Park (YDNPA) under a project funded by Defra's Farming in Protected Landscapes programme.



BTO, The Nunnery, Thetford, Norfolk IP24 2PU
Tel: +44 (0)1842 750050 Email: info@bto.org
Registered Charity Number 216652 (England & Wales), SC039193 (Scotland).

ISBN 978-1-918170-11-5

YORKSHIRE DALES National Park Authority

SRUC

Department for Environment Food & Rural Affairs

Farming in Protected Landscapes programme

BTO Birds Science People

# Contents

## Executive Summary

1. Farmland breeding wader populations have declined drastically in recent decades. Since 1994 in the UK we have lost over half of our breeding Curlews, Lapwings, and Redshanks. These declines are associated with a range of factors, including increased rates of predation, afforestation, and the intensification of field management in farmed landscapes.
2. The primary tool by which wader conservation is delivered in farmed landscapes is agri-environment schemes (AES), whereby payments incentivise land managers to conduct beneficial management for species or habitats. Assessments of the effectiveness of AES measures to date have been based on infrequent, large-scale surveys which do not produce landscape- or intervention-specific evidence to facilitate local adaptations to the design of AES.
3. At 10 participating farms in the Yorkshire Dales National Park we trialled two methods that could help to evaluate the effectiveness of AES measures at regional scales. Firstly, we mailed pre-programmed acoustic recorders to be deployed on farms and used a free-to-use, automated classifier (based on a machine-learning architecture trained on large libraries of manually identified reference recordings) to produce evidence on the presence of wader species in areas under AES options. Secondly, we asked farmers to record the presence of five species of wader on a weekly basis on their farm, and provided guidance and a recording form (the Wader Calendar).
4. Experienced volunteer bird surveyors also carried out breeding wader surveys at the 10 participating farms to produce a validation dataset to compare with data obtained from the two trial approaches.
5. In 2024, the Wader Calendar was completed across the breeding season on seven of the 10 participating farms, and the acoustic recorder approach successfully gathered data across the breeding season at nine out of 10 participating farms, with one device failing for unknown reasons at the other farm in May.
6. The peak of a three-day rolling mean of a species' call activity across the breeding season correlated with the peak number of pairs recorded at a site. We also tested if weekly variation in numbers recorded on the Wader Calendar correlated with numbers recorded by volunteer surveyors in those weeks, but found no statistically significant association.
7. The Wader Calendar was not completed every week, making seasonal inferences difficult. However, at each farm, the peak counts of individuals recorded across the breeding season from the Wader Calendar were highly comparable to peak counts obtained from the volunteer surveys.
8. While the methods underpinning both approaches need refinement, there is potential to use either approach to provide timely, accurate data on the presence and abundance of farmland breeding waders. Either of these approaches could generate comparable annual data that would be complementary to periodic large-scale assessments of AES, potentially in a more cost-efficient manner.
9. To effectively scale either approach, sufficient resources would be required for engagement with participating land managers, coordination, and collation of data. A farmer-targeted monitoring smartphone app might encourage participation in the Wader Calendar and significantly reduce data collation time but would require significant capital investment. If the acoustic approach were rolled out a larger-scale, significant ongoing resources would be needed to establish a robust approach to data storage, analyses and reporting.

# 1. Introduction

## 1.1. Importance of English farmland to breeding waders

Farmland covers 70% of UK land mass (Defra 2023) and is a key habitat for breeding waders such as Curlew *Numenius arquata*, Lapwing *Vanellus vanellus*, Redshank *Tringa totanus*, Oystercatcher *Haematopus ostralegus*, and Common Snipe *Gallinago gallinago* (Calladine *et al.* 2022). These populations are internationally significant: for example, the UK is estimated to support up to 27% of the global breeding population of Curlew, and up to 30% of the global breeding population of Oystercatcher (Brown *et al*. 2015). However, since 1994 there have been rapid declines of breeding Curlew (-51%), Lapwing (-53%), and Redshank (-45%) populations (Heywood *et al.* 2023).

These declines are driven by a suite of interactive factors: i) the intensification of silage management and tillage has caused increased rates of nest destruction (Wilson *et al.* 2004); ii) field drainage and increased intensity of farming operations have reduced the extent and quality of habitat; iii) forestry planting in agricultural landscapes with breeding wader populations has caused direct habitat loss (Wilson *et al.* 2014); and iv) declines in the extent and intensity of predator management in agricultural landscapes have led to increased numbers and activity of generalist predators, such as Raven *Corvus corax*, Carrion Crow *Corvus corone*, Badger *Meles meles*, Red Fox *Vulpes vulpes*, Pine Marten *Martes martes*, Stoat *Mustela erminea* and Weasel *Mustela nivalis* (Ainsworth *et al*. 2016, Roos *et al.* 2018). Additionally, the simplification of habitats and intensification of grassland management may have made nests more susceptible to predation (Laidlaw *et al.* 2017), while the establishment of plantation forests and farm woodlands provide more den or nest sites for nest predators within and in the vicinity of farmed landscapes (Wilson *et al.* 2014, McGrory *et al.* 2024). Halting farmland wader declines is thus a complex challenge involving a wide range of inter-related drivers.

## 1.2. Agri-environmental schemes for breeding waders

Wader conservation measures in farmland are primarily delivered via agri-environment schemes (AES), whereby farmers or landowners are paid to deliver interventions aimed at improving habitat suitability for waders. AES options targeting breeding waders in grasslands and wet meadows have been offered to UK farmers since the late 1980s (Smart *et al.* 2013). Following exit from the European Union, a new AES scheme called ELM (Environmental Land Management) is being developed to support and incentivise environmentally-friendly farming in England (Department for Environment, Food & Rural Affairs 2022). The ELM scheme presents an opportunity to improve outcomes for breeding wader populations.

Evidence for the effectiveness of AES interventions for breeding waders to date is mixed (Verhulst *et al.* 2007, O'Brien & Wilson 2011, Smart *et al.* 2014, Franks *et al.* 2018). Some studies have found that farms and fields under AES have higher occupancy of breeding waders than those where options are not undertaken (O'Brien & Wilson 2011), but that this is most likely because management is deployed in areas with the highest densities of these birds (Verhulst *et al.* 2007). A review of the impact of different wader options across Europe suggested that delayed mowing, improving the quality or availability of wet features, adjusting stocking levels and managing predators did increase occupancy where these options were deployed (Franks *et al.* 2018), but these findings should be interpreted with caution, as local increases in occurrence or abundance of breeding waders could be due to redistribution of birds rather than any overall impacts on population size or growth rates (Smart *et al.* 2014).

An additional factor to consider when assessing the potential effectiveness of AES is that, although predation is now the key factor causing decline or preventing recovery of wader populations across much of Europe, AES have to date been mainly focused on the management of habitat or livestock stocking levels, rather than predator management. There do appear to have been some positive impacts of AES at relatively local scales, but these are likely to have been dwarfed by the magnitude of declines on areas not under AES measures (Franks *et al*. 2018).

Assessments of the effectiveness of AES typically aggregate data from lots of sites across many different contexts, which can limit their relevance to designing or improving interventions adapted to particular landscapes (such as the Yorkshire Dales). This can make AES policy prescriptions poorly suited to addressing region-specific problems and challenges. An improved understanding of how outcomes of AES vary between different landscapes, regions or types of management could help policymakers and managers to design AES prescriptions that are flexible enough to be adapted to local conditions. However, monitoring and evaluation of AES performance at sufficient scale and resolution to deliver this level of understanding is challenging. Gathering data on wader breeding productivity is time-consuming, requires skilled and experienced fieldworkers, and often only yields approximate information on breeding success (Jarrett *et al.* 2024). This means that using professional fieldworkers to carry out sufficient wader monitoring to inform local AES design and delivery is likely to be prohibitively costly.

In this report we assess two alternative approaches to gathering breeding wader data: i) training and supporting farmers to use a 'Wader Calendar' monitoring approach, in which farmers record numbers of wader present on their farm on a weekly basis; and ii) using acoustic recorders to assess the presence of key species across the breeding season, from which information about breeding wader productivity can be inferred.

# 2. Methods

## 2.1. Participating farms

In January 2022, the Yorkshire Dales National Park Authority (YDNPA) invited landowners and managers to participate in a wader research project in partnership with the British Trust for Ornithology (BTO). This project was focused on co-designing potential wader ELM options and trialling novel farmer-led monitoring methods. BTO contacted participating individuals to explain the project further and invite them to a 30-minute online video presentation and questions session. One individual who did not own a computer was contacted by telephone instead. Most participating farms were located in Wensleydale, but three were situated in other parts of the Yorkshire Dales National Park (YDNP) (near Clapham, Long Preston, and Beamsley). Farms in the study area incorporated a range of grassland habitats and management, but all involved one or more types of livestock farming.

## 2.2. Volunteer wader census surveys

At all study sites where farmer-led monitoring was trialled, and in each year these trials were carried out (2022, 2023, and 2024), local volunteers undertook wader surveys following the methods of O'Brien & Smith (1992). All of these volunteers were trained by the YDNPA and had previous experience carrying out similar surveys, identifying the target wader species, and recognising key wader behaviours. We collated, checked, and digitised the volunteer surveys, and obtained an estimate of pairs from each site by halving the highest count of individuals recorded at a site (and rounding up).

## 2.3. Wader Calendar

### 2.3.1. Wader Calendar farmer participation

In order to trial farmer-led monitoring, we asked participating farmers to fill in a 'Wader Calendar' (Noyes & Wilson 2022) recording form in the spring and summer of 2022, 2023, and 2024. Participating farmers were asked to complete these forms without financial incentive in 2022 and 2023. In 2022 and 2023, the Wader Calendar recording form comprised a single sheet of A4 paper on which farmers were asked to record approximate numbers of each of five target wader species encountered on their farm each week (Figure 1). For each species, farmers were asked for three different estimates relating to the number of adults seen or heard on their farm:

1. Total Count: total number of individuals
2. Displaying/'singing': number of birds displaying and/or 'singing' (signs they have territories/nests)

3. Alarm-calling/with young: number observed repeatedly alarm-calling, 'mobbing' and/or seen with young (signs they are chick-rearing)

The form also included a section aimed at capturing some basic farm management information from farmers.

In 2024, we made several changes to the Wader Calendar (Figure 2). The calendar was expanded from one page of A4 to a booklet with one page per week to allow counts for individual fields to be recorded, rather than being aggregated for the whole farm or monitored area. We also expanded the management information section to allow farmers to record: i) field use; ii) stock movements; iii) farmyard manure and slurry spreading; iv) grass cut dates for each field; and v) predator control effort (at a farm level). Considering the elevated level of detail requested, in 2024 we offered farmers a flat-fee of £400, based on a compensatory hourly rate of £50 based on an estimate that it would take around eight hours per season to complete the form.

There was no strict survey methodology, but farmers were asked to either keep counts of birds as they went about farm work or to make counts at set times in the week. Farmers were asked to provide details on how they kept their counts in the method section on the recording form, and to keep the method as consistent as possible between weeks and years. Farmers had previously reported that this approach only takes a few minutes each week when counting is done while undertaking other farm-based activities (Noyes & Wilson 2022).

BTO staff provided training to landowners and managers on how to carry out Wader Calendar surveys. This training was delivered in late winter in 2022 (virtually) and 2023 (during an in-person event held at the Dales Countryside Museum, Hawes, UK), but no training was provided in 2024 (when the format of the Wader Calendar was changed). Participants were then left to complete their Wader Calendars over the spring and summer with minimal support. In 2023 and 2024, the project coordinator provided an optional WhatsApp group for participating farmers to allow them to ask the coordinator questions and to provide each other with support and encouragement.

#### 2.3.2. Wader Calendar data

In this report we summarise data from completed Wader Calendars in 2024 as this was the year with the most completed and returned forms. In 2024, farmers were asked to record a 'total' count of potential breeders (column 'T', Figure 2), and a count of breeding birds (column B, Figure 2). However, as the intended distinction between these two columns was not consistently understood by different participants, we used the highest number of each species recorded per week in either of these columns. We converted this value to an estimated number of pairs at a site by halving the highest number of individuals recorded across each Wader Calendar week (and rounding up).

We then used a linear mixed model (with species as a random effect) to assess the extent to which the peak Wader Calendar count predicted the peak volunteer survey count for each species. Additionally, to evaluate whether variation in recorded levels of activity across the breeding season correlated between the two datasets, at each site we extracted the Wader Calendar count for the week of a volunteer survey and ran a linear mixed model (with species as a random effect) to assess the extent to which the Wader Calendar counts predicted the periodic volunteer surveys at matched dates.

**Figure 1. The 2023 Wader Calendar recording form (the same form was used in 2022, with week start dates adjusted for the differences between years).**


Each week, estimate the following number of adults of each wader species:

- **Total Count:** total number on your farm/survey area
- **Displaying/singing:** number displaying and/or 'singing'
- **Alarm-calling/with young:** number repeatedly alarm-calling, 'mobbing', and/or seen with young.

Please note any chicks or fledged young seen in Notes column.

There is no strict methodology. Please keep the method you use to monitor waders as consistent between weeks and years as is reasonably possible. Include an outline of your methods in the Notes section overleaf.

☐ **Tick this box if you saw no waders on your farm April-July (no need to enter zeroes below) – please still enter Farm Details overleaf!**

| Week Start | Curlew | | | Lapwing | | | Oystercatcher | | | Redshank | | | Snipe | | | Other ( ) | | | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total count | Displaying/ Singing | Alarming/ with young | Total count | Displaying/ Singing | Alarming/ with young | Total count | Displaying/ Singing | Alarming/ with young | Total count | Displaying/ Singing | Alarming/ with young | Total count | Displaying/ Singing | Alarming/ with young | Total count | Displaying/ Singing | Alarming/ with young | |
| **Example** | 12 | 2 | 1 | 6 | 0 | 6 | ✓ | ✓ | 0 | 3 | 0 | 0 | 0 | 0 | 0 | | | | 3 small Lapwing chicks |
| **27 March** | | | | | | | | | | | | | | | | | | | |
| **3 April** | | | | | | | | | | | | | | | | | | | |
| **10 April** | | | | | | | | | | | | | | | | | | | |
| **17 April** | | | | | | | | | | | | | | | | | | | |
| **24 April** | | | | | | | | | | | | | | | | | | | |
| **1 May** | | | | | | | | | | | | | | | | | | | |
| **8 May** | | | | | | | | | | | | | | | | | | | |
| **15 May** | | | | | | | | | | | | | | | | | | | |
| **22 May** | | | | | | | | | | | | | | | | | | | |
| **29 May** | | | | | | | | | | | | | | | | | | | |
| **5 June** | | | | | | | | | | | | | | | | | | | |
| **12 June** | | | | | | | | | | | | | | | | | | | |
| **19 June** | | | | | | | | | | | | | | | | | | | |
| **26 June** | | | | | | | | | | | | | | | | | | | |
| **3 July** | | | | | | | | | | | | | | | | | | | |
| **10 July** | | | | | | | | | | | | | | | | | | | |
| **17 July** | | | | | | | | | | | | | | | | | | | |
| **24 July** | | | | | | | | | | | | | | | | | | | |

**Figure 2. Wader Calendar form (for week 1) used in 2024. The move to field-by-field recording meant that there was one page of records for every week.**

Week 1: Monday 31st March to Sunday 6th April

- Please tick the relevant box if: □ I did not observe any waders in any field this week or □ I did not undertake counts this week
- We will assume any blank cells = 0 (unless you tick latter box above), so there is no need to fill in a 0 for every cell if your estimate was 0
- If you didn't look out for a species, or did not visit a field, please strike out that row or column with a solid line (i.e. ———)

| Field number | Curlew | | Lapwing | | Oystercatcher | | Redshank | | Snipe | | Other | | Date and time of count (approx. is fine) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T | B | T | B | T | B | T | B | T | B | T | B | | |
| Field 1 | | | | | | | | | | | | | | |
| Field 2 | | | | | | | | | | | | | | |
| Field 3 | | | | | | | | | | | | | | |
| Field 4 | | | | | | | | | | | | | | |
| Field 5 | | | | | | | | | | | | | | |
| Field 6 | | | | | | | | | | | | | | |
| Field 7 | | | | | | | | | | | | | | |
| Field 8 | | | | | | | | | | | | | | |
| Field 9 | | | | | | | | | | | | | | |
| Field 10 | | | | | | | | | | | | | | |
| Field 11 | | | | | | | | | | | | | | |
| Field 12 | | | | | | | | | | | | | | |
| Field 13 | | | | | | | | | | | | | | |
| Field 14 | | | | | | | | | | | | | | |
| Field 15 | | | | | | | | | | | | | | |

## 2.4. Acoustic monitoring

### 2.4.1 Data collection

BTO staff configured AudioMoth acoustic recorders (Open Acoustic Devices 2024) to record from 1 May to end of June in 2022 and 8 April to end of July in 2023 and 2024. One five-minute recording per hour was scheduled across the whole recording period, generating 24 five-minute samples every day. The hardware used varied in two important aspects between 2022 and 2023/2024:

- 2022: the devices were housed in waterproof plastic bags and 32 GB SD cards were used.
- 2023 and 2024: the devices were housed in standard AudioMoth waterproof cases and 64 GB SD cards were used.

With guidance from BTO staff, landowners or managers at participating farms deployed these bioacoustic recorders at locations of their choosing (hereafter referred to as the 'recording location'), where they believed waders nested, on the edge of a field. We asked farms participating in multiple years to use the same recording location in all years. We provided bioacoustic recorders to 10 farms in 2022, six in 2023, and 10 in 2024. We asked farmers to record the following details about their deployments on a standardised form:

- Date of deployment.
- 10-figure grid reference, or equivalent, of recording location.
- What the bioacoustic recorder was affixed to (e.g. fencepost, gatepost, or wall).
- Date of collection.

### 2.4.2. Data analysis

We used BirdNet Analyzer (BirdNet) (Kahl *et al.* 2021) to detect and summarise wader vocal activity, and a BTO call type classifier for Eurasian Curlew (henceforth CC; BTO 2024a) to categorise these calls into four types (based on descriptions in CRP 2021):

- Display: territorial bubbling song, self-advertisement or aggressive challenge.
- Contact: a rich, loud, ringing 'COUR-li…COUR-li…COUR-li…', which serves as general warning, contact and excitement call.
- Alarm: a harsh, guttural 'yak-ak-ak', indicating high anxiety for nest or young – more common late in incubation or during chick-rearing.
- Other: calls that did not fall into the categories above.

BirdNet analysis operates at a temporal resolution of three-seconds, with the program splitting up each recording into three-second clips. It assigns a species identity and confidence score (reflecting the likelihood that a classification is correct) to each bird call it detects in each three-second clip, and outputs 'selection tables' that summarise this information for each individual recording. Each row in these tables corresponds to a classified detection in a three-second clip, with columns providing species, start and end times of the clip, and confidence score (between 0 and 1, with 0 being lowest confidence and 1 being the highest). We considered all wader classifications with a confidence score of 0.3 or higher to be reliable. BirdNet performs well for breeding wader calls in the UK uplands and this threshold will result in a very low proportion of false positives (Jarrett & Willis 2025).

We summarised wader vocal activity as the total length of clips (in seconds) in which wader calls were detected (hereafter referred to as 'vocal activity'). Some calls (or partial calls) detected in three-second clips may have been shorter than three seconds, so this measure of vocal activity does not equate precisely to the total duration of calls. Nevertheless, it provides a broadly consistent and comparable measure of vocal activity.

### 2.4.3. BirdNET Analyzer accuracy

We manually validated a sample of 305 WAV files. These were the 04:00, 07:00, 12:00, 16:00, and 21:00 recordings from a random day selected from each week of recorder deployment at each of the farms (Table 1).

**Table 1. Number of wav files and respective BirdNET Selection Tables in sample for checking, five per each week in the recording period (all from one randomly selected day in that week).**

| | Farm references | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **Total** |
| **Sample size** | 45 | 30 | 45 | 45 | 15 | 10 | 45 | 50 | 10 | 10 | 305 |

We manually checked and verified the species of all detections classified as wader calls by the BirdNET Analyzer in each of these 305 files by listening to the relevant three-second segment (and occasionally the few seconds before or after) file playback. We also listened to each of these 305 files from start to end, noting and classifying each wader call we detected. Every file was checked by the same individual who was familiar with the common call types of each target species.

### 2.4.5. Wader vocal activity and volunteer survey comparison

We used the data from volunteer survey visits to estimate the density of territorial birds for each species in the area around each AudioMoth location. We used quartic kernels to make these density maps with a radius of 750 m for Curlew and Oystercatcher, and 500 m for Lapwing and Redshank (Jarrett & Willis 2025). We extracted the density estimate at the AudioMoth location for each survey visit. We then used linear mixed models to assess correlation between the density estimate obtained from volunteer surveys and the acoustic data. Our first analysis assessed whether the mean number of detections from a three-day window around each volunteer survey visit corresponded with the density of birds recorded during volunteer surveys. Mean detections were calculated as the average number of positive classifications per rolling 72-hour period – i.e. over 360 minutes of recording (72*5 mins). Our second analysis used peak vocalisation rate across the whole breeding season, calculated as the three-day rolling mean of daily positive classifications for each species/site combination. This analysis assessed whether peak vocalisation rates for each site could be used to predict the peak count from volunteer surveys. Because we wanted to compare how well both the volunteer counts and the Wader Calendar counts correlated with the acoustic data, we did not use the density estimate for this analysis, because we could not make a comparable density estimate with the Wader Calendar data.

#### 2.4.6. Curlew vocal activity case studies

We selected three case studies to illustrate the association between Curlew vocal activity and breeding outcomes. Each case study was non-randomly selected by the authors, drawing on detailed knowledge of Curlew breeding outcomes near recording locations obtained during fieldwork from a separate project, the Curlew Solutions Trial (CST). CST fieldwork included nest-finding, and monitoring using known clutch completion dates or egg measurements (to estimate hatch date), temperature loggers, nest cameras, and nest monitoring visits every seven to 10 days to record nest survival and outcomes, and twice-weekly brood monitoring visits to record chick survival and outcomes. We selected three recording locations situated near confirmed Curlew breeding attempts for which CST monitoring data were available. For two of these breeding attempts, at least one chick fledged, and for one no chicks fledged.

## 3. Results

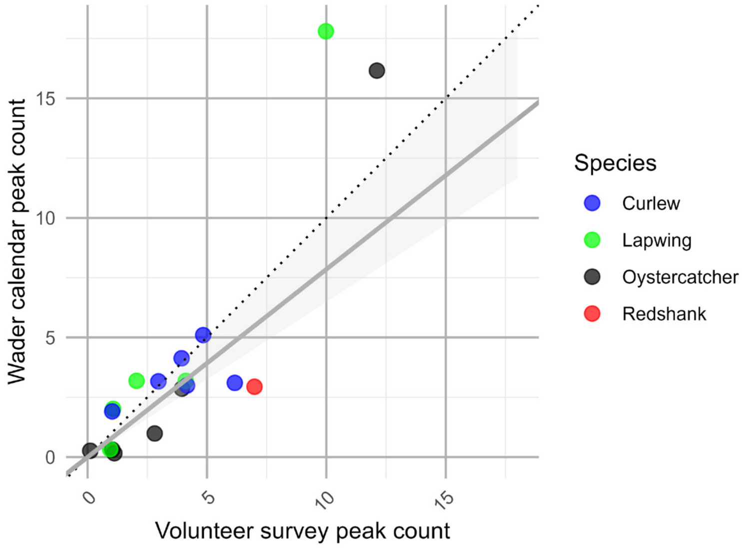
### 3.1. Farmer wader counts using the Wader Calendar

The return rate completed Wader Calendar forms varied between years. In 2022, six out of 12 participating farms returned at least partially complete Wader Calendar forms (three out of 12 returned fully completed forms). In 2023, eight out of 10 participating farms returned at least partially complete Wader Calendar forms, and five out of 10 returned fully completed forms. In 2024 (after the introduction of payments for the return of completed forms), nine out of 10 of farms returned at least partially complete Wader Calendar forms, and seven out of 10 farms returned fully complete forms (See Appendix 3).

Volunteer surveys were carried out at 10 participating farms, with survey visits carried out across the breeding season. At six out of 10 farms, five visits were carried out, and at the other four farms at least two visits were carried out (See Appendix 1). The most recorded species was Curlew (est. 50 pairs), followed by Oystercatcher (33 pairs), Lapwing (25 pairs) and Redshank (seven pairs). The Wader Calendar was completed by seven of the 10 participating farms. The most-recorded species was Curlew, of which 28 pairs were recorded. On the volunteer surveys, 33 pairs were recorded at equivalent sites.

The peak number of individuals recorded on any survey across the breeding season for all species was 1.27 times higher (95% confidence intervals: 1.01–1.54) on the volunteer surveys compared to the Wader Calendar surveys (Figure 3). This pattern appeared to be consistent across all species and sites, although the sample of sites where volunteer surveys and Wader Calendar surveys were completed is small (seven). Curlew, Oystercatcher were present at all seven sites, while Lapwing (six) and Redshank (one) were present at fewer sites.

**Figure 3. The relationship between peak estimates of pairs of each species recorded by farmers using the Wader Calendar approach and by volunteers carrying out a standardised wader survey. The grey line shows a linear regression with 95% confidence intervals. Counts on the dashed line would indicate parity between the two approaches. Counts to the right of the dashed line indicate that more pairs were counted on the volunteer surveys (and vice versa).**




### 3.2. Passive acoustic monitoring

The success of passive acoustic recorder deployment also varied between years. In 2022 (when the bioacoustic recorders were placed inside waterproof bags), six out of 10 recorders were irreversibly damaged due to water damage, and stopped recording before the planned recording period (two months) finished; the remaining four recorded for the full period and were not damaged. In 2023 (after introduction of waterproof protective cases), six out of seven recorded for the planned recording period (four months); the other was damaged by presumed livestock trampling. In 2024 (after the introduction of waterproof protective cases, and payments for the deployment and return of recorders), nine out of 10 recorded for the planned recording period (four months) with the other recorder failing due to an unknown technical failure.

Manual validation of the BirdNET Analyzer classifier showed high performance for most species, with consistently strong recall (≥ 0.90) and high precision (≥ 0.94) for Curlew, Lapwing, Oystercatcher and Snipe (Table 2). In contrast, Redshank performance differed markedly from the other species. Although recall remained high (0.97), precision was substantially lower (0.52), reflecting a high rate of false-positive detections, many of which were actually Curlew vocalisations.

**Table 2. BirdNET Analyzer performance metrics for five breeding wader species based on 305 manually validated recordings. 'Precision' indicates the proportion of automated detections that were correct, while recall indicates the proportion of total confirmed calls that were detected by the classifier.**

| Species | True Positives | False Positives | False Negatives | Total Confirmed Calls | Precision | Recall |
|---|---|---|---|---|---|---|
| **Curlew** | 1,228 | 80 | 138 | 1,366 | 0.94 | 0.90 |
| **Lapwing** | 261 | 15 | 1 | 262 | 0.95 | 1.00 |
| **Oystercatcher** | 435 | 26 | 3 | 438 | 0.94 | 0.99 |
| **Redshank** | 30 | 28 | 1 | 31 | 0.52 | 0.97 |
| **Snipe** | 169 | 16 | 0 | 169 | 0.91 | 1.00 |

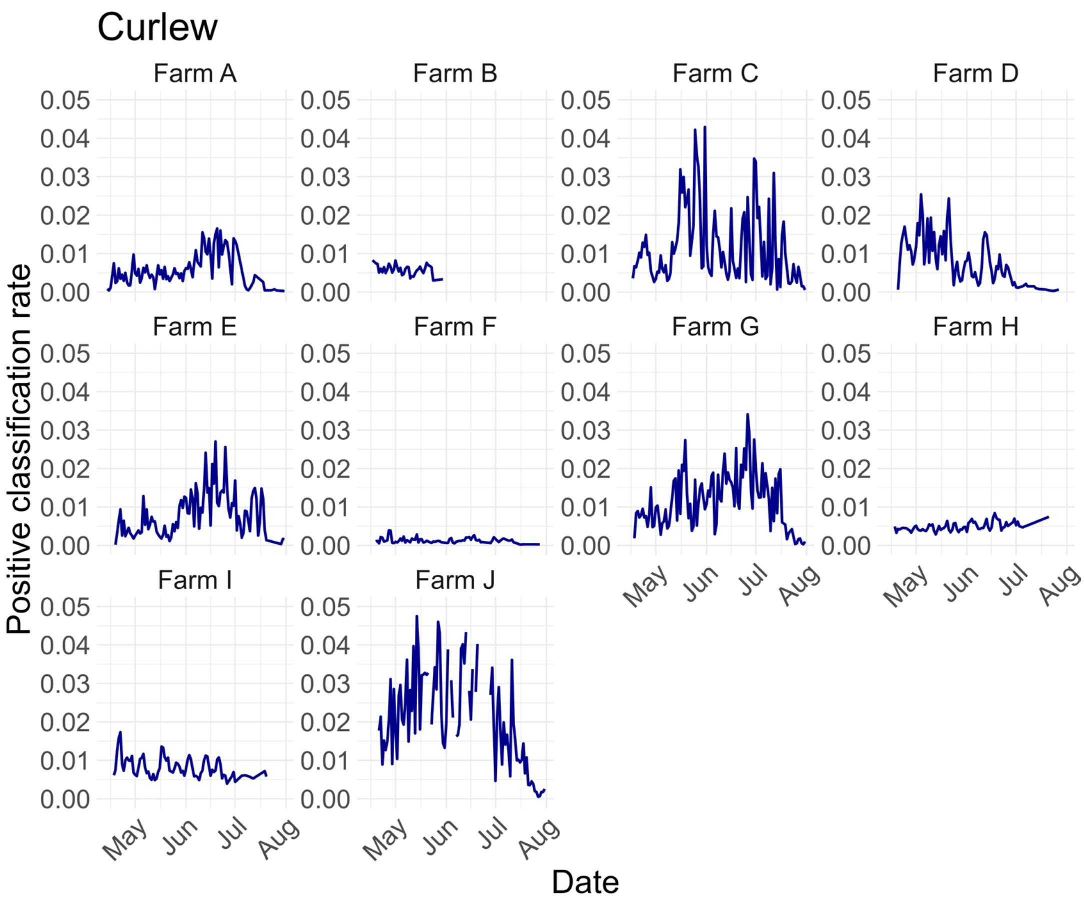
Analysis of the acoustic data in 2024 revealed similar patterns to the volunteer survey data. For example, Farm C had the highest estimate of breeding pairs for Lapwing, Redshank, and Oystercatcher on the volunteer surveys and also had the highest peak of the three-day rolling mean of vocal activity for these species (Figure 4). The site with the highest peak of Curlew vocal activity (Figure 4) had a high density of Curlews around the acoustic recorder but didn't have the highest estimate of breeding pairs. Species peaks in three-day rolling means from the acoustic data were significantly correlated with the peak volunteer counts ($R^2 = 0.76$, $p < 0.001$, Figure 6).

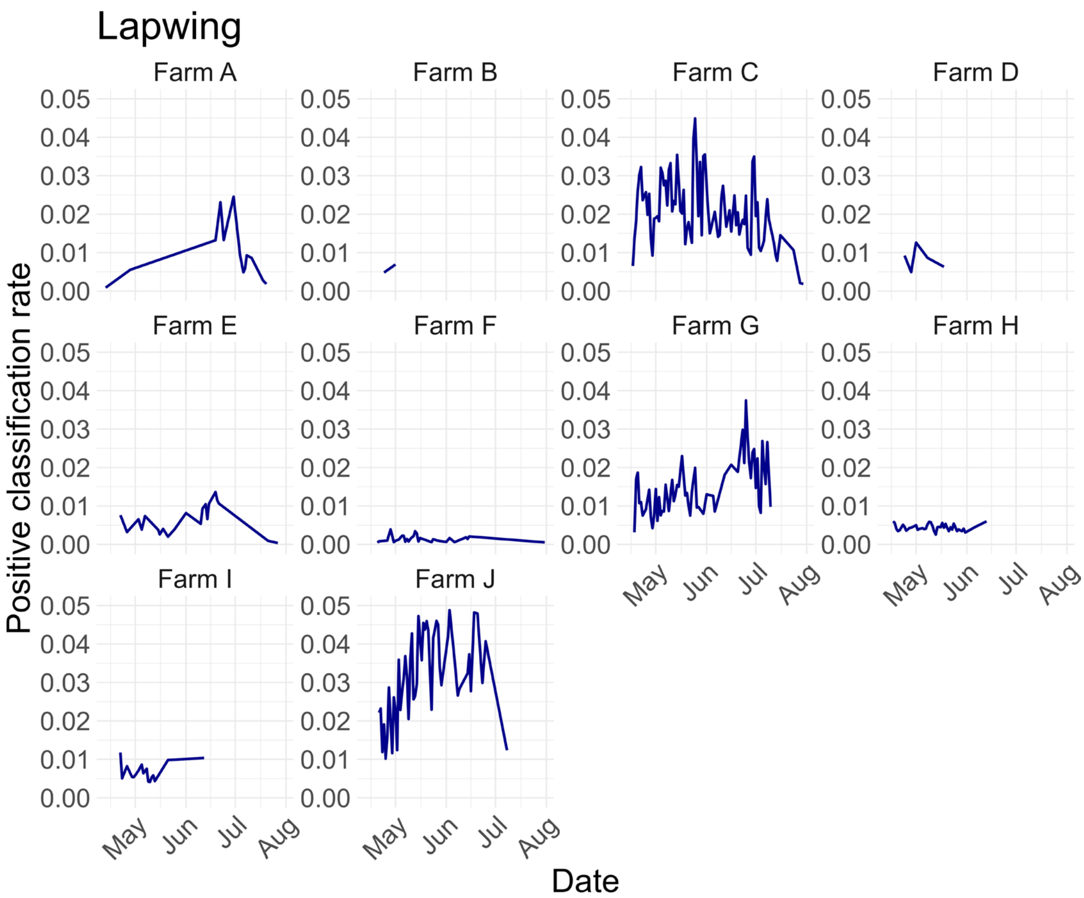
Pearson's correlation analysis revealed significant relationships between wader abundance measures from our three surveys. Volunteer surveyor peak counts and wader farm calendar peak counts showed the strongest correlation ($R^2 = 0.90$, $p < 0.001$), indicating substantial agreement between volunteer field surveys and the farmer counts. Species peaks in three-day rolling means from the acoustic data were better correlated with peak volunteer counts than with the peak of the Wader Calendar farmer counts ($R^2 = 0.54$, $p < 0.05$).

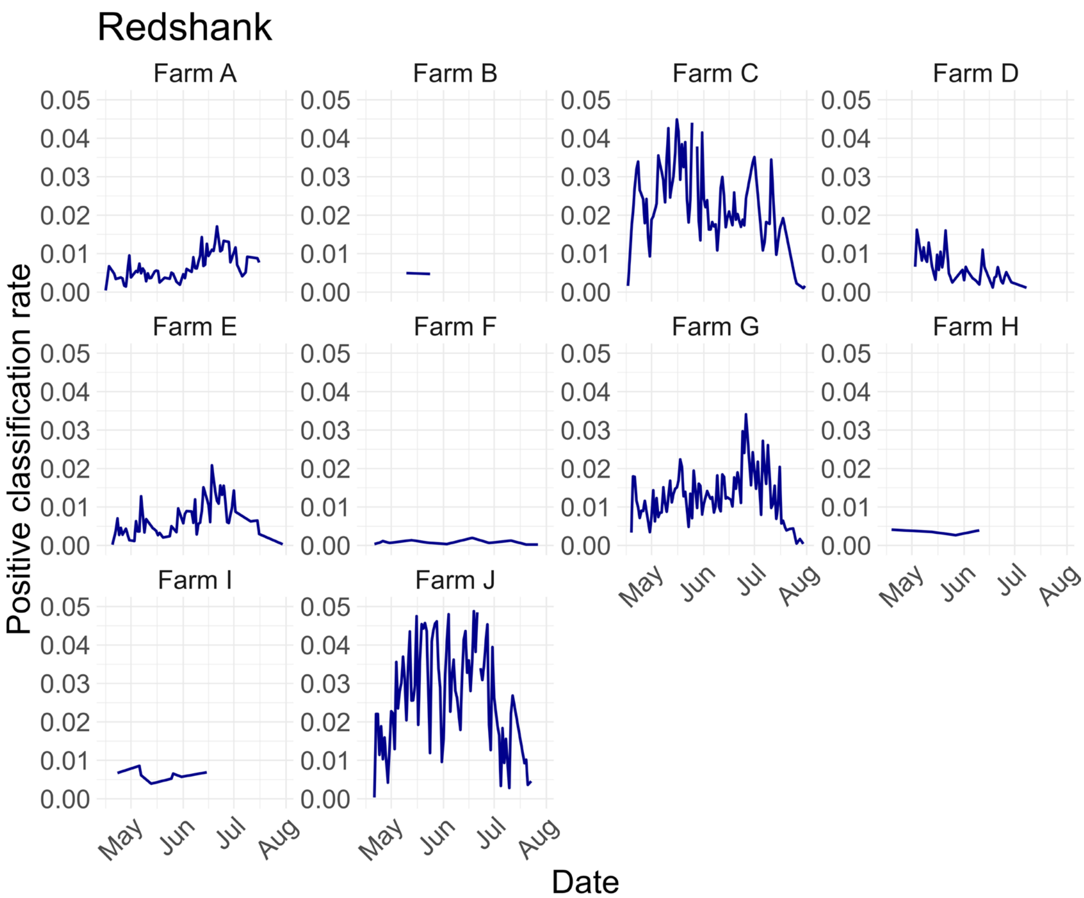
The relationship between the density of each species recorded on an individual survey and the acoustic activity around that survey date was weak (Figure 5) and there was only a weak (but statistically significant) association between the variables for Curlew ($R^2 = 0.17$, $p = 0.01$). For Lapwing ($R^2 = 0.01$) and Oystercatcher ($R^2 = 0.04$) there were no discernible relationships.

Analysis of seasonal variation in rates of different Curlew call types at three sites where Curlew breeding outcomes were known (Figures 7, 8 and 9) suggests that differences in seasonal variation of particular call types (particularly contact and alarm calls) could be used to infer whether or not Curlew bred successfully in the area monitored by a recorder.

**Figure 4. Three day rolling means of total daily positive classification rate for Oystercatcher, Lapwing, Redshank and Curlew across the breeding season at each study site. The recorder at Farm B stopped recording due to a technical failure. For each species, the y-axis scale is consistent to facilitate direct comparison between each site.**




Lapwing
Farm A
Farm B
Farm C
Farm D
Farm E
Farm F
Farm G
Farm H
Farm I
Farm J
0.05
0.04
0.03
0.02
0.01
0.00
May
Jun
Jul
Aug
Positive classification rate
Date


Redshank
Farm A
Farm B
Farm C
Farm D
Farm E
Farm F
Farm G
Farm H
Farm I
Farm J
0.05
0.04
0.03
0.02
0.01
0.00
May
Jun
Jul
Aug
Positive classification rate
Date

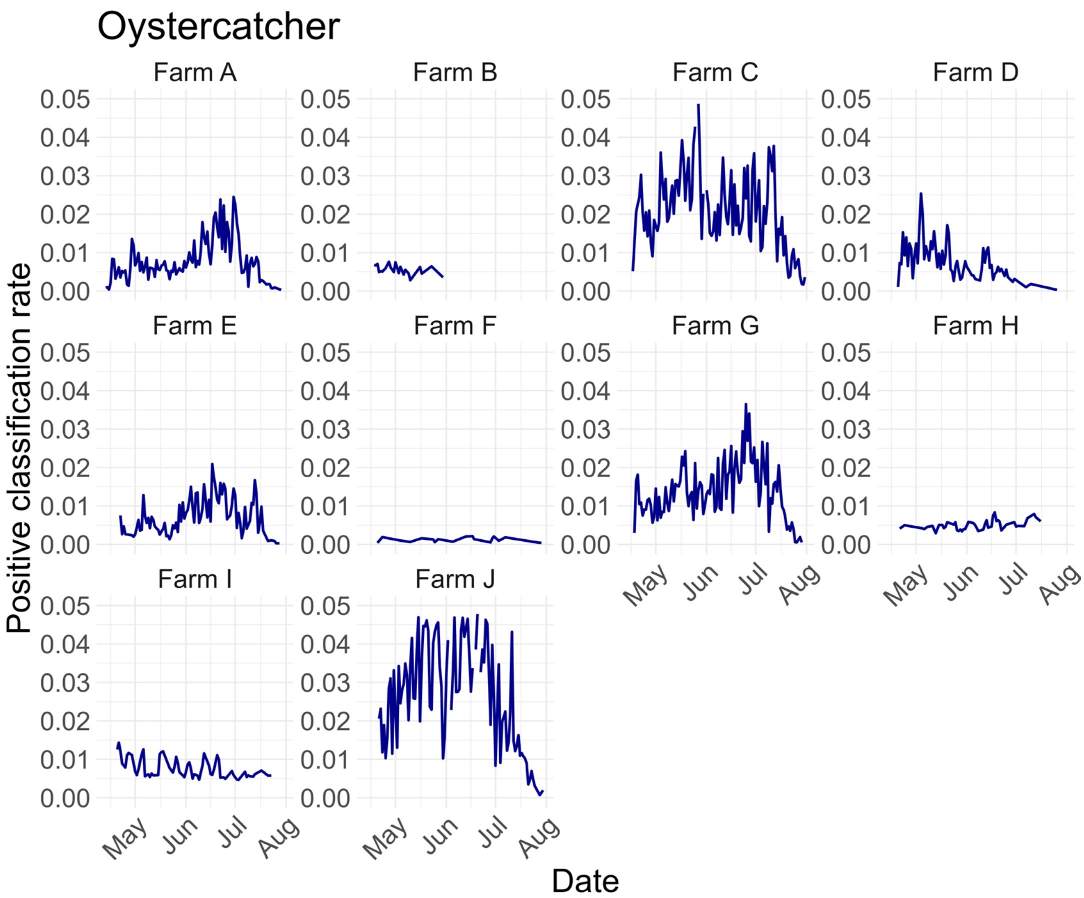



**Figure 5. Correlation between wader species density (for Curlew, Oystercatcher and Lapwing) at the recording location at each survey date and the three-day mean of vocal activity (taking the survey date as the middle day of the three day period). No regression line is fitted for Lapwing and Oystercatcher because of the weak relationship between the variables.**

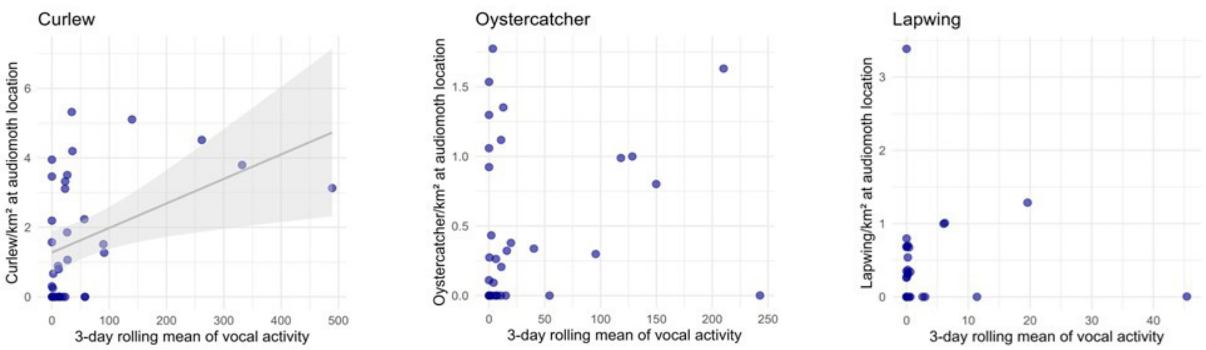


**Figure 6. Correlation between peaks (across the whole breeding season) for each species in the volunteer survey counts and the peak in the three-day rolling average of vocal activity. The x- and y-axes are both logged because the data are right-skewed.**

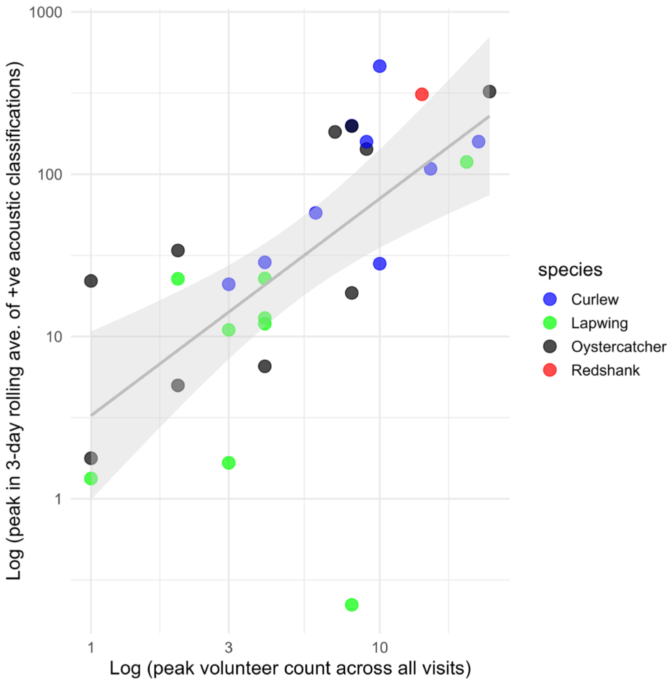
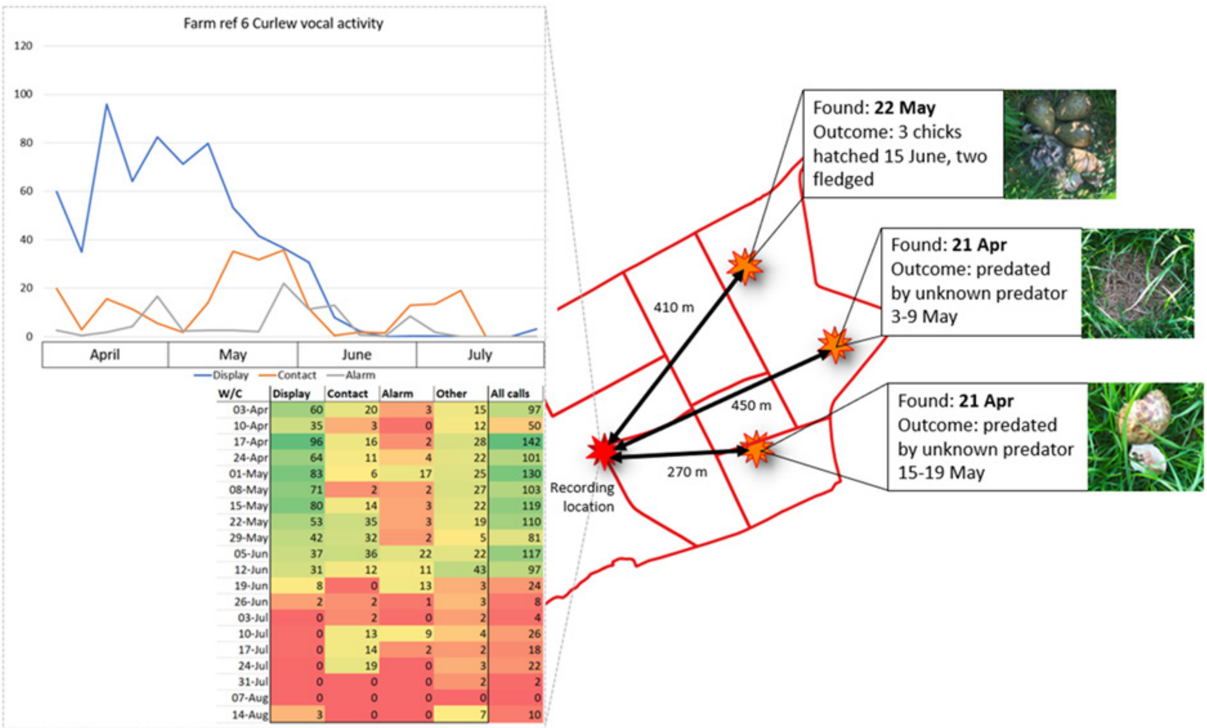
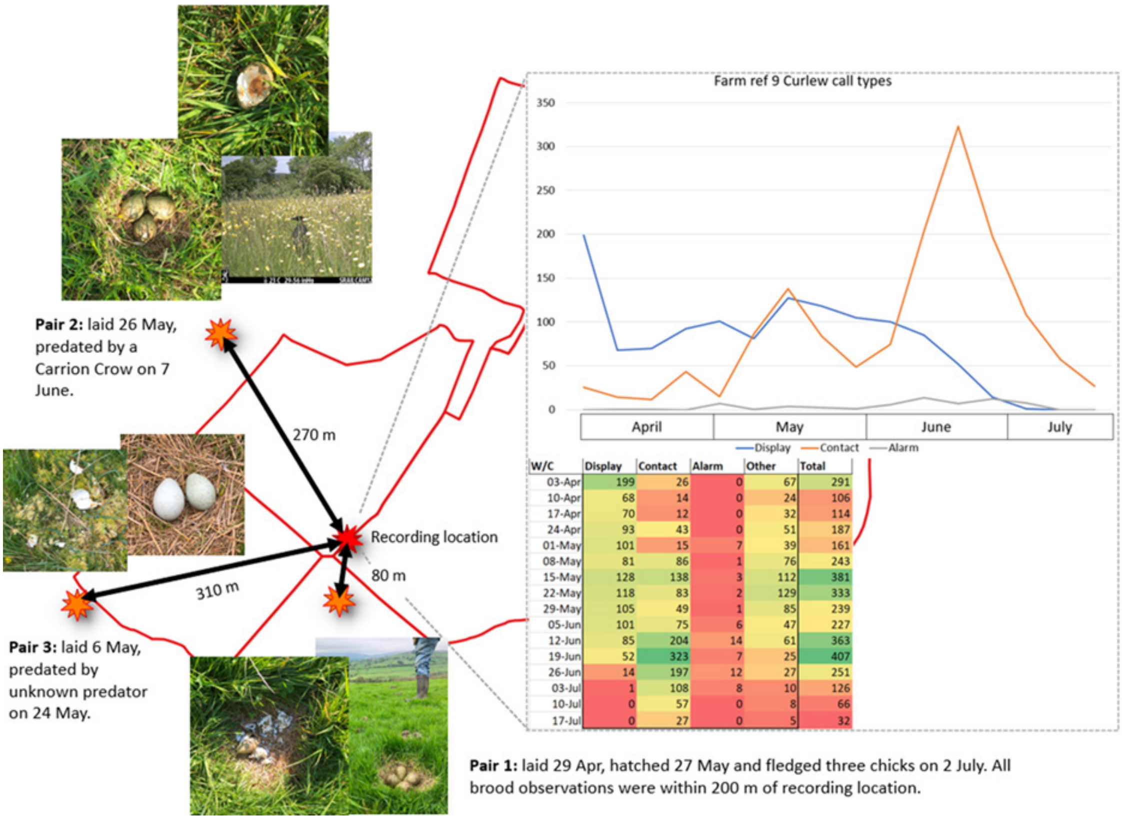



**Figure 7. Curlew call activity example 1. One pair fledged young at this site. The nest hatched relatively late (15 June). There was a second spike in contact calling towards the expected fledging date as chicks become more independent.**



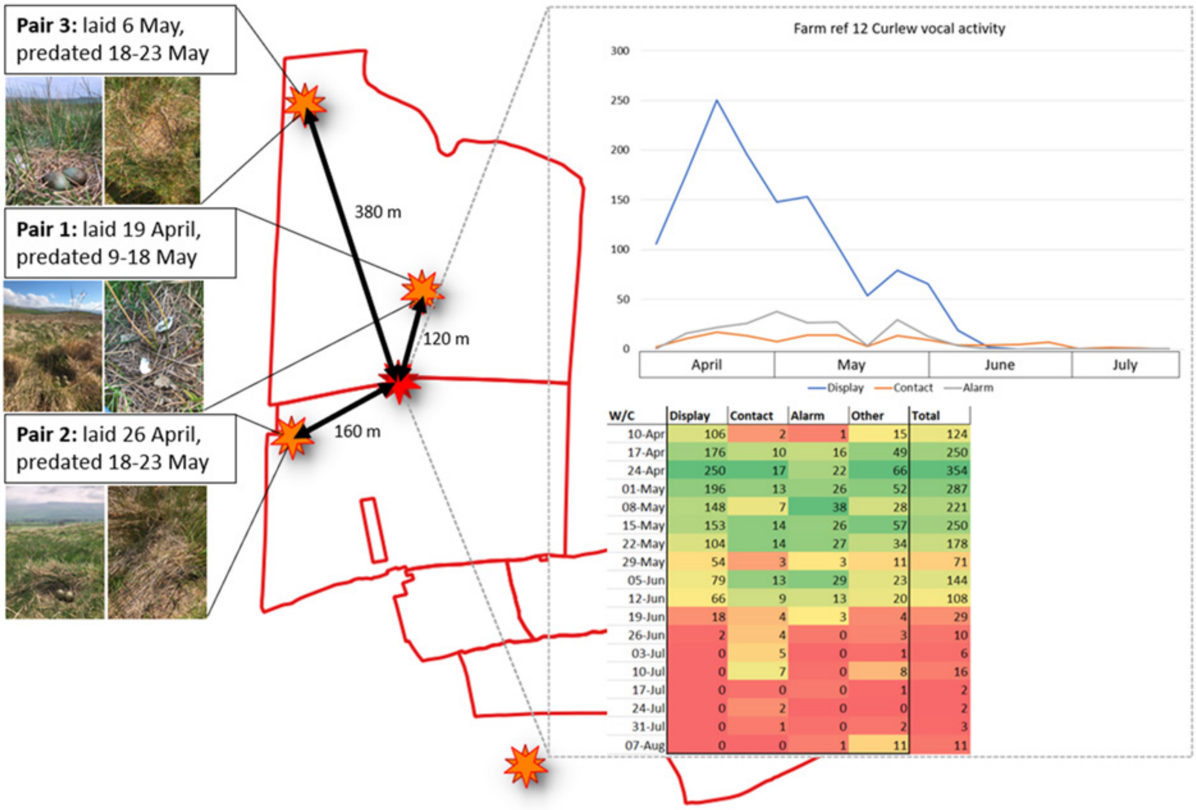
| W/C | Display | Contact | Alarm | Other | All calls |
|---|---|---|---|---|---|
| 03-Apr | 60 | 20 | 3 | 15 | 97 |
| 10-Apr | 35 | 3 | 0 | 12 | 50 |
| 17-Apr | 96 | 16 | 2 | 28 | 142 |
| 24-Apr | 64 | 11 | 4 | 22 | 101 |
| 01-May | 83 | 6 | 17 | 25 | 130 |
| 08-May | 71 | 2 | 2 | 27 | 103 |
| 15-May | 80 | 14 | 3 | 22 | 119 |
| 22-May | 53 | 35 | 3 | 19 | 110 |
| 29-May | 42 | 32 | 2 | 5 | 81 |
| 05-Jun | 37 | 36 | 22 | 22 | 117 |
| 12-Jun | 31 | 12 | 11 | 43 | 97 |
| 19-Jun | 8 | 0 | 13 | 3 | 24 |
| 26-Jun | 2 | 2 | 1 | 3 | 8 |
| 03-Jul | 0 | 2 | 0 | 2 | 4 |
| 10-Jul | 0 | 13 | 9 | 4 | 26 |
| 17-Jul | 0 | 14 | 2 | 2 | 18 |
| 24-Jul | 0 | 19 | 0 | 3 | 22 |
| 31-Jul | 0 | 0 | 0 | 2 | 2 |
| 07-Aug | 0 | 0 | 0 | 0 | 0 |
| 14-Aug | 3 | 0 | 0 | 7 | 10 |

**Figure 8. Curlew call activity example 2. One pair fledged young at this farm in early July. Alarm calling is regular until early July and then ceases. There is also a large second spike in contact calling during the second half of the brood rearing period as chicks become more independent.**




| W/C | Display | Contact | Alarm | Other | Total |
|---|---|---|---|---|---|
| 03-Apr | 199 | 26 | 0 | 67 | 291 |
| 10-Apr | 68 | 14 | 0 | 24 | 106 |
| 17-Apr | 70 | 12 | 0 | 32 | 114 |
| 24-Apr | 93 | 43 | 0 | 51 | 187 |
| 01-May | 101 | 15 | 7 | 39 | 161 |
| 08-May | 81 | 86 | 1 | 76 | 243 |
| 15-May | 128 | 138 | 3 | 112 | 381 |
| 22-May | 118 | 83 | 2 | 129 | 333 |
| 29-May | 105 | 49 | 1 | 85 | 239 |
| 05-Jun | 101 | 75 | 6 | 47 | 227 |
| 12-Jun | 85 | 204 | 14 | 61 | 363 |
| 19-Jun | 52 | 323 | 7 | 25 | 407 |
| 26-Jun | 14 | 197 | 12 | 27 | 251 |
| 03-Jul | 1 | 108 | 8 | 10 | 126 |
| 10-Jul | 0 | 57 | 0 | 8 | 66 |
| 17-Jul | 0 | 27 | 0 | 5 | 32 |

**Figure 9. Curlew call activity example 3. All nests were predated at this farm and alarm calling activity declined in early June and was not recorded after w/c 19 June. Note that there is no second spike (in June/ July) of contact calling or alarm calling.**




| W/C | Display | Contact | Alarm | Other | Total |
|---|---|---|---|---|---|
| 10-Apr | 106 | 2 | 1 | 15 | 124 |
| 17-Apr | 176 | 10 | 16 | 49 | 250 |
| 24-Apr | 250 | 17 | 22 | 66 | 354 |
| 01-May | 196 | 13 | 26 | 52 | 287 |
| 08-May | 148 | 7 | 38 | 28 | 221 |
| 15-May | 153 | 14 | 26 | 57 | 250 |
| 22-May | 104 | 14 | 27 | 34 | 178 |
| 29-May | 54 | 3 | 3 | 11 | 71 |
| 05-Jun | 79 | 13 | 29 | 23 | 144 |
| 12-Jun | 66 | 9 | 13 | 20 | 108 |
| 19-Jun | 18 | 4 | 3 | 4 | 29 |
| 26-Jun | 2 | 4 | 0 | 3 | 10 |
| 03-Jul | 0 | 5 | 0 | 1 | 6 |
| 10-Jul | 0 | 7 | 0 | 8 | 16 |
| 17-Jul | 0 | 0 | 0 | 1 | 2 |
| 24-Jul | 0 | 2 | 0 | 0 | 2 |
| 31-Jul | 0 | 1 | 0 | 2 | 3 |
| 07-Aug | 0 | 0 | 1 | 11 | 11 |

## 4. Discussion

This study demonstrates that both the Wader Calendar approach and passive acoustic monitoring have the potential to generate information that can be used to monitor and evaluate AES outcomes. Both trials generated data that can be used to confirm the presence of wader species breeding at each site: there was strong correlation between the abundance data produced by the peak counts of species recorded on the Wader Calendar and the volunteer wader surveys. The peak of the three-day rolling mean of vocal activity was positively correlated with the peak number of pairs estimated in the traditional surveys carried out by volunteer fieldworkers.

### 4.1. Wader Calendar

These trials assessed the potential for the Wader Calendar approach to be used to support AES monitoring and evaluation. Overall, our findings show that farmers may be willing to keep and submit detailed records of waders. Participation in the Wader Calendar survey was highest in 2024, when forms required more detail and time to complete than in previous years, but farmers were financially compensated for carrying out the survey. It should be noted that the farms involved in this project were self-selected and so are not necessarily representative of farmers across the YDNP, nor in general. Importantly, however, participating farmers are probably typical of farmers who are likely to engage with wader-focused AES options in the YDNP. Overall, the trial demonstrated that the Wader Calendar can produce outputs that are largely consistent with wader survey outputs traditionally used for assessing land and monitoring outcomes for AES.

On the 2024 form, farmers were asked to separately record 'total' numbers of birds (excluding flocks) and 'breeding' birds, following the rule that 'breeding' birds could not exceed 'total' birds. However, this was not done consistently, with some participants misunderstanding the intended distinction between 'total' and 'breeding' birds. This suggests that recording forms for this kind of survey should be kept as simple and self-explanatory as possible. We recommend that future iterations of the Wader Calendar should only ask for one weekly count of adult birds. When only considering the peak count of total birds recorded (whether the highest count was in the 'total' or 'breeding' birds column), there was a high degree of correlation between the farmer data and the volunteer data. Estimates of abundance can vary substantially between individual surveyors, particularly those with different levels of survey experience (Sauer *et al.* 1994). At least some of the variation between abundance estimates based on volunteer surveys and those based on farm wader calendars may be due to observer differences, and additionally in some instances there was some variation in the area covered by the farmers and volunteer surveyors.

The 2024 Wader Calendar also collected wader-relevant land management data from farmers. Recording wader data on a weekly basis and at the resolution of individual fields generates information that could be useful for improving our understanding of effects of livestock on breeding waders. However, the high frequency and granularity of this recording could disincentivise some farmers from participating. Recording at a whole-farm rather than individual field level might restrict the extent to which Wader Calendar data can be used to evidence field occupancy for AES applications or evaluate outcomes from AES prescriptions focused on individual fields. However, if recording at a farm (or other survey area) level results in wider participation or higher return rates of completed survey forms, this may ultimately deliver information that is better-suited to assessing the effectiveness of AES interventions. It may be that the best strategy is to maintain a two-tier approach, accommodating those farmers who are willing and able to record information at the level of individual fields, while providing a simplified recording option for those who prefer to record at a whole-farm level.

The success of the Wader Calendar approach in this project demonstrates that it could be useful in regional wader projects where there is someone available to engage with and advise participants, as was the case in this study. In this context, information gathered via Wader Calendars could contribute to evaluating interventions delivered by wader conservation projects. As well as providing oversight and guidance to projects wanting to use Wader Calendar recording in this way, BTO would be well-placed to take opportunities for analysis of combined datasets from multiple projects which could enable more robust and far-reaching conclusions than the findings of any one project.

The participating farmers provided feedback on their participation as part of another study (Noyes *et al.* in draft). They reported that the £400 payment was sufficient to encourage participation. Some suggested that a recording app would make it easier to gather data, while they were divided on whether they preferred the simpler farm level form used in 2022 and 2023 or the more detailed field-by-field form used in 2024.

### 4.2. Passive acoustic monitoring

Participating farmers deployed, collected and returned the acoustic recorders with minimal guidance and support from the project coordinator. The deployment locations were chosen by participants and in 2024 no recorders were lost or stolen, although one recorder stopped recording in May due to technical failure. BirdNet and the BTO Acoustic Pipeline both provide user-friendly interfaces that allow large volumes of audio data to be analysed, producing outputs (.csv files) that can be interpreted by anyone able to analyse data in spreadsheet software like Microsoft Excel as well as in dedicated statistical packages like R.

There was good consistency between estimates based on maximum counts from the bioacoustic data and the volunteer surveys (Figure 6). However, there was little or no correspondence between counts from individual surveys and mean vocal activity from the three-day period around the survey date. An important factor to bear in mind is that, during volunteer surveys, many waders in the survey area will have been responding to the presence of the surveyor, which could increase their detectability. In contrast, most of the passive acoustic recordings happen in the absence of humans or other perceived predators, such that vocalisation rates on acoustic devices depend more on background rates of vocal activity than on immediate responses to disturbance. Over the course of a breeding season, variation in background vocalisation rates and responsiveness to intruders will not necessarily follow the same pattern (Figure 5).

Projects incorporating an element of passive acoustic monitoring need to carefully consider their requirements for data storage and processing. The recording schedule we used (five-minute recordings every 60 minutes) produced 120 minutes of acoustic data per recorder per day. Assuming a minimum of 140 days of recording per season, this intensity of sampling will result in 3,360 recordings (16,800 minutes) per deployment. Recording at a sampling rate of 16 Khz (which is the minimum required to make sure that high-frequency bird vocalisations are captured) this is equivalent to around 60 GB of data per site per year. BirdNet is open-source software and is free to use regardless of dataset size. However, for passive acoustic monitoring to be incorporated into AES, the length of time required to process data would need to be considered (approximately eight hours for a 60 GB dataset on a laptop with 32GB RAM and a quad-core 2.4 GHz processor). Additionally, a key challenge for long-term, large-scale acoustic projects is determining how to incorporate the regular refinement of classifiers like BirdNet into projects which are intended to produce long-term trends (Jarrett *et al.* 2025). Long-term storage of raw acoustic data would be required to facilitate re-analysis with updated classifiers, and in a context where there were a large number of participating sites, this would necessitate significant long-term data storage capacity.

Passive acoustic monitoring could support wader AES monitoring in remote, upland farmland, where monitoring by bird surveyors is logistically more difficult or expensive than in lowland farmland nearer towns and cities (such as the YDNP). The total price of an AudioMoth recorder together with its case, postage, SD card (reusable), and batteries is likely to be considerably less than the cost of an in-person wader survey. For this amount, passive acoustic monitoring can provide 1) evidence of occupancy and abundance for fields in wader-relevant AES options, and 2) crude measures of productivity that could be used to evaluate the outcomes of AES options when combining data from large number of sites.

Our approach of mailing pre-programmed acoustic recorders directly to farmers, could be expanded to a larger group of farmers, estate workers, landowners and volunteers. When packaged in a prepaid, padded envelope, both the AudioMoth recorder and case (Open Acoustic Devices 2024) and the Songmeter Micro (Wildlife Acoustics 2024) which has similar capabilities, will fit into UK post boxes and most letter boxes, simplifying the distribution and return of devices in rural projects. Following the success of a larger-scale trial, this approach could be scaled up to support monitoring and evaluation of regional or national wader AES options.

Farmers were generally positive regarding the bioacoustic recorder deployment and felt the £100 payment in 2024 was sufficient for receiving the recorder, deploying it at target fields, and collecting it later.

### 4.3. Curlew productivity monitoring using the Curlew call classifier

It may be possible to use patterns of Curlew vocalisations across the breeding season to make inferences about breeding season productivity (Figures 7, 8 and 9). At present there is no standardised process for automated classification of breeding outcomes based on seasonal variation in call types. However, this approach holds potential – not only to inform conservation of breeding Curlew and other wader species, but for a range of other species for which breeding status and behaviour can be inferred from vocalisations (Teixeira *et al.* 2019).

### 4.4. Summary of acoustic approach

Acoustic monitoring of waders on farmland could contribute to the Yorkshire Dales National Park Management Plan (YDNPA 2025) objectives and vision. Delivery of robust population trends for breeding waders is a key part of this plan, but is difficult to achieve based on the local volunteer BTO/JNCC/RSPB Breeding Bird Survey (BBS) alone. Passive acoustic monitoring data could provide a useful source of supplementary data, and could complement BTO's wider bioacoustic monitoring research, which includes consideration of how acoustic data might be used alongside and in combination with BBS data.

Further work is required to optimise both the design of passive acoustic monitoring approaches and interpretation of the information they generate. It would be useful to have a better understanding of the effective detection range of acoustic recorders, for different species and in environments with different levels and types of background noise. This would help to inform the design of passive acoustic surveys and the interpretation of the data they collected; as would understanding the effect of factors like topography, habitat, elevation, and human disturbance on vocalisation behaviour and detectability. As well as breeding densities and outcomes, which were the focus of this project, acoustic recorders could also provide useful data about how birds use sites for feeding and roosting.

## 5. References

Ainsworth, G., Calladine, J., Martay, B., Park, K., Redpath, S., Wernham, C., Wilson, M. & Young, J. 2016. *Understanding Predation. A review bringing together natural science and local knowledge of recent wild bird population changes and their drivers in Scotland.* Moorland Forum, Dumfries.

Brown, D., Wilson, J., Douglas, D., Thompson, P., Foster, S., McCulloch, N., Phillips, J., Stroud, D., Whitehead, S., Crockford, N. & Sheldon, R. 2015. The Eurasian Curlew – the most pressing bird conservation priority in the UK. *British Birds* **108**: 660–668.

Calladine, J., Border, J., O'Connell, P. & Wilson, M.W. 2022. Modelling important areas for breeding waders as a tool to target conservation and minimise conflicts with land use change. *Journal of Nature Conservation* **70**: 10.1016/j.jnc.2022.126267

Department for Environment, Food & Rural Affairs 2022. Environmental land management schemes: outcomes. Available at: https://www.gov.uk/government/publications/environmental-land-management-schemes-outcomes/environmental-land-management-schemes-outcomes (Accessed: 26 February 2026).

Eglington, S.M., Bolton, M., Smart, M.A., Sutherland, W.J., Watkinson, A.R. & Gill, J.A. 2010. Managing water levels on wet grasslands to improve foraging conditions for breeding Northern Lapwing *Vanellus vanellus. Journal of Applied Ecology* **47**: 451–458.

Franks, S.E., Roodbergen, M., Teunissen, W., Carrington Cotton, A. & Pearce-Higgins, J. W. 2018. Evaluating the effectiveness of conservation measures for European grassland-breeding waders. *Ecology and Evolution* **8**: 10,555–10,568.

Heywood, J.J.N., Massimino, D., Balmer, D.E., Kelly, L., Noble, D.G., Pearce-Higgins, J.W., Woodcock, P., Wotton, S., Gillings, S. & Harris, S. 2023. *The Breeding Bird Survey 2022. BTO Research Report* **756**, British Trust for Ornithology, Thetford.

Jarrett, D. & Willis, S.G. 2025. Acoustic detection rate can outperform traditional survey approaches in estimating relative densities of breeding waders. *Ibis* **167**: 562–574.

Jarrett, D., Lehikoinen, A. & Willis, S.G. 2024. Monitoring wader breeding productivity. *Ibis* **166**: 780–800.

Jarrett, D., Barnett, R., Bradfer-Lawrence, T., Froidevaux, J.S.P., Gibb, K., Guinet, P., Greenhalgh, J., Heath, B., Johnston, A., Lahoz Monfort, J.J., Rogers, A., Willis, S.G. & Metcalf, O. 2025. Mitigating bias in long-term terrestrial ecoacoustic studies. *Journal of Applied Ecology* **62**: 761–772.

Kahl, S., Wood, C.M., Eibl, M. & Klinck, H. 2021. BirdNET: a deep learning solution for avian diversity monitoring. *Ecological Informatics* **61**: 101236.

Laidlaw, R.A., Smart, J., Smart, M.A. & Gill, J. A. 2017. Scenarios of habitat management options to reduce predator impacts on nesting waders. *Journal of Applied Ecology* **54**: 1,219–1,229.

McGrory, R.E., Briers, R.A., Tomlin, C., Findlay, M.A., Kerslake, L.J., Riddle, N. & White, P.J. 2024. Impacts of forest extent, configuration and landscape context on presence of declining breeding Eurasian Curlew *Numenius arquata* and implications for planning new woodland. *Forest Ecology and Management* **572**: e122281.

Noyes, P., Winn, V., Jarrett, D., Fawcett, H. & Wilson, M. (in draft). Can agri-environment schemes in England support Curlew recovery? A review of current scheme structure with farmer perspectives.

Noyes, P. & Wilson, M. 2022. *Wader Calendar 2021 Report.* BTO Research Report to Working for Waders. British Trust for Ornithology, Thetford.

Roos, S., Smart, J., Gibbons, D.W. & Wilson, J.D. 2018. A review of predation as a limiting factor for bird populations in mesopredator-rich landscapes: a case study of the UK. *Biological Reviews* **93**: 1,915–1,937.

Sauer, J.R., Peterjohn, B.G. & Link, W.A. 1994. Observer differences in the North American breeding bird survey. *The Auk* **111**: 50–62.

Smart, J., Wotton, S.R., Dillon, I.A., Cooke, A.I., Diack, I., Drewitt, A.L., Grice, P.V. & Gregory, R.D. 2014. Synergies between site protection and agri-environment schemes for the conservation of waders on lowland wet grasslands. *Ibis* **156**: 576–590.

Smart, J., Bolton, M., Hunter, F., Quayle, H., Thomas, G. & Gregory, R.D. 2013. Managing uplands for biodiversity: do agri-environment schemes deliver benefits for breeding Lapwing *Vanellus vanellus*? *Journal of Applied Ecology* **50**: 794–804.

O'Brien, M. & Smith, K. 1992. Changes in the status of waders breeding on wet lowland grasslands in England and Wales between 1982 and 1989. *Bird Study* **39**: 165–176.

O'Brien, M. & Wilson, J.D. 2011. Population changes of breeding waders on farmland in relation to agri-environment management. *Bird Study* **58**: 399–408.

Verhulst, J., Kleijn, D. & Berendse, F. 2007. Direct and indirect effects of the most widely implemented Dutch agri-environment schemes on breeding waders. *Journal of Applied Ecology* **44**: 70–80.

Wilson, J.D., Anderson, R., Bailey, S., Chetcuti, J., Cowie, N.R., Hancock, M.H., Quine, C.P., Russell, N., Stephen, L. & Thompson, D.B. 2014. Modelling edge effects of mature forest plantations on peatland waders informs landscape-scale conservation. *Journal of Applied Ecology* **51**: 204–213.

Wilson, A.M., Ausden, M. & Milsom, T.P. 2004. Changes in breeding wader populations on lowland wet grasslands in England and Wales: causes and potential solutions. *Ibis* **146**: 32–40.

Yorkshire Dales National Park Authority. 2025. *Yorkshire Dales National Park Management Plan 2025–2030.* Available at: https://www.yorkshiredales.org.uk/wp-content/uploads/sites/13/2025/12/Yorkshire-Dales-National-Park-Management-Plan-2025-2030-v2.pdf (Accessed: 26 February 2026)

# 6. Appendix

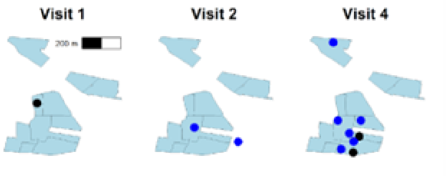
**Appendix 1. Dates of volunteer survey visits.**

| Farm name | Visit 1 date | Visit 2 date | Visit 3 date | Visit 4 date | Visit 5 date |
|---|---|---|---|---|---|
| Farm A | 11/04/2024 | 02/05/2024 | 02/06/2024 | 20/06/2024 | 15/07/2024 |
| Farm B | 17/04/2024 | 08/05/2024 | – | 24/06/2024 | 19/07/2024 |
| Farm C | 14/04/2024 | – | 02/06/2024 | – | – |
| Farm D | 19/04/2024 | 09/05/2024 | 30/05/2024 | 20/06/2024 | 17/07/2024 |
| Farm E | 29/04/2024 | – | 01/06/2024 | – | – |
| Farm F | 14/04/2024 | 06/05/2024 | 02/06/2024 | 20/06/2024 | 13/07/2024 |
| Farm G | 17/04/2024 | – | 08/06/2024 | – | – |
| Farm H | 11/04/2024 | 11/05/2024 | 02/06/2024 | 18/06/2024 | 15/07/2024 |
| Farm I | 12/04/2024 & 16/04/2024 | 05/05/2024 | 31/05/2024 & 01/06/2024 | 19/06/2024 & 24/06/2024 | 15/07/2024 |
| Farm J | 14/04/2024 | 08/05/2024 | 01/06/2024 | 21/06/2024 | 21/07/2024 |

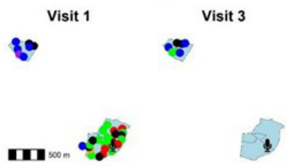
**Appendix 2. Visit maps for each volunteer farm surveys. The location of sightings of individuals of each target species shown in coloured dots and the location of the audio recorder is also shown.**

**Farm A**

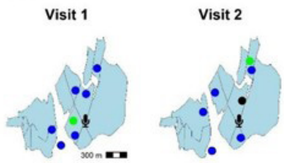

**Farm B**



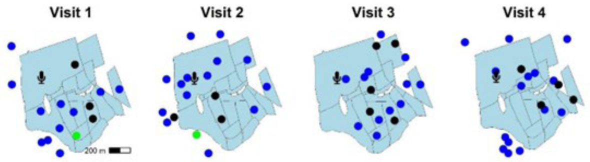

**Farm C**




**Farm D**

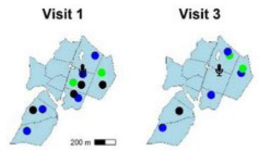


**Farm E**



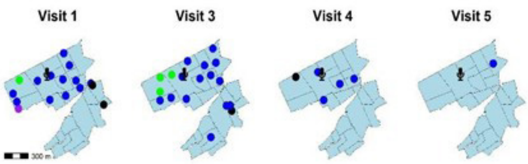

**Farm F**


**Farm G**



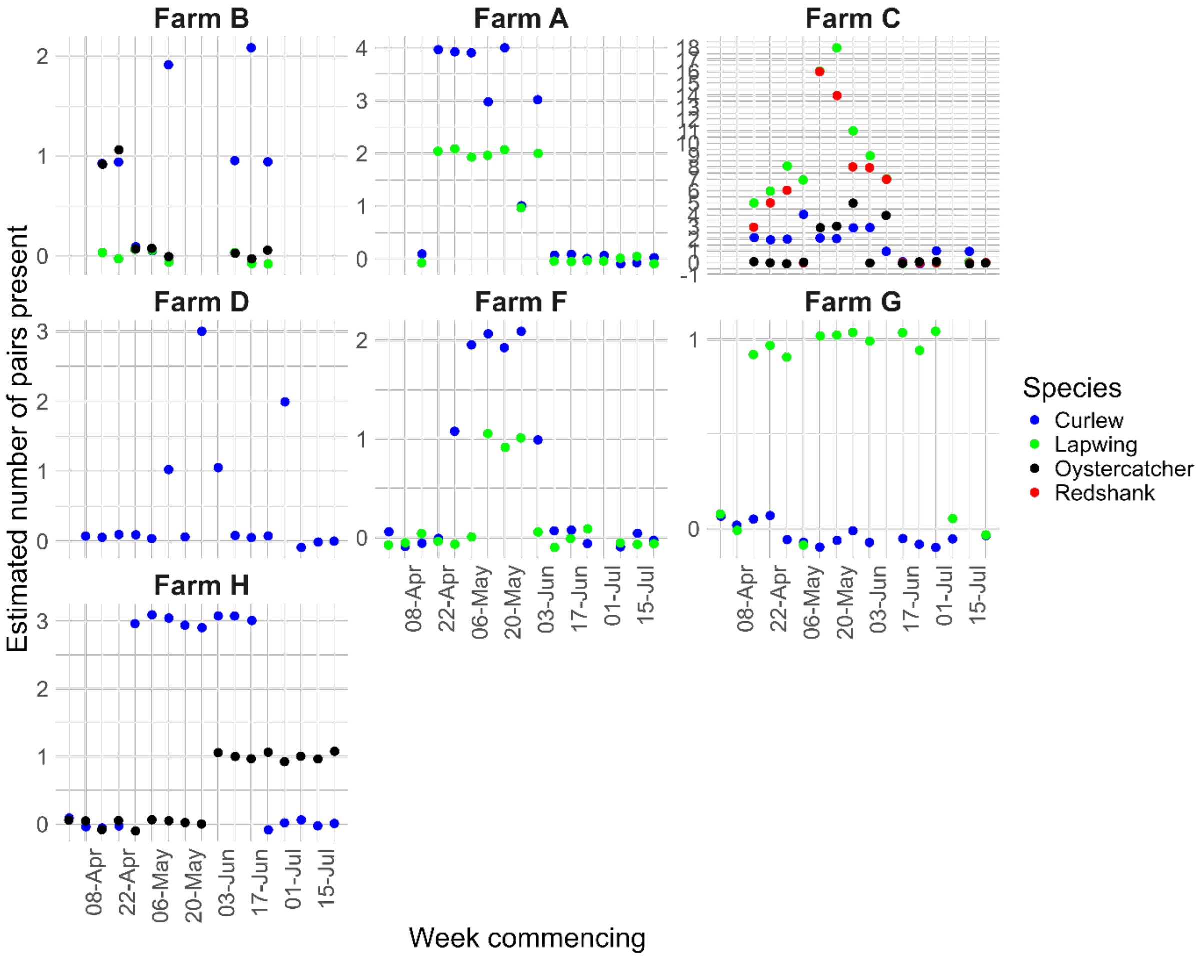

**Farm H**


**Farm I**




**Farm J**

**Appendix 3. Wader Calendar data. Each dot represents a weekly estimate of present breeding pairs – the number of recorded individuals per week is divided by two to obtain the estimate of pairs.**



Front cover: Lapwing chick, by David Scott / BTO; back cover: Redshank, by Liz Cutting / BTO

## Trialling farmer wader counts and bioacoustics to aid agri-environment scheme evaluation

The primary tool by which wader conservation is delivered in farmed landscapes is agri-environment schemes, whereby payments incentivise land managers to conduct beneficial management for species or habitats. Assessments of the effectiveness of such schemes have been based on infrequent, large-scale surveys which do not produce landscape- or intervention-specific evidence to facilitate local adaptations to the design of agri-environment schemes. This report details work carried out at 10 participating farms in the Yorkshire Dales National Park, where we trialled two methods that could help to evaluate the effectiveness of scheme measures at regional scales.

Suggested citation: Jarrett, D., Wilson, M., Ledwith, A. & Noyes, P. 2026. Trialling farmer wader counts and bioacoustics to aid agri-environment scheme evaluation. *BTO Research Report* **810**, BTO, Thetford, UK.

YORKSHIRE DALES
National Park Authority

SRUC

ISBN 978-1-918170-11-5

Department
for Environment
Food & Rural Affairs

Farming in Protected
Landscapes programme

BTO
Birds
Science
People