BTO RESEARCH REPORT 731

Northern Ireland Lowland Breeding Wader Survey

Katherine Booth Jones, Peadar O'Connell, John Calladine, David Noble, Shane Wolsey, Anne Carrington-Cotton & Chris Wernham

BTO
Looking out for birds

ACKNOWLEDGEMENTS: This work was funded by the Northern Ireland Environment Agency. Thanks to the volunteers, professional fieldworkers and RSPB staff who surveyed the sites, recording counts of breeding waders, field-level habitat characteristics and site-level management and conditions. Thanks also to the landowners who so generously provided access to their land.

Northern Ireland Lowland Breeding Wader Survey

Report of work carried out by the British Trust for Ornithology on behalf of the Northern Ireland Environment Agency

Booth Jones, K., O'Connell, P., Calladine, J., Noble, D., Wolsey, S., Carrington-Cotton, A. & Wernham, C.V.

BTO Research Report 731

© British Trust for Ornithology 2020

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 978–1–912642–21–2

BTO
Looking out for birds

CONTENTS

EXECUTIVE SUMMARY

1. Numbers of breeding waders are falling throughout the UK and increased agricultural intensification is amongst the causes of decline in species such as Lapwing, Common Redshank, Common Snipe and Eurasian Curlew on the island of Ireland. During a tetrad-based survey of Northern Ireland in 1985–87, lowland grasslands held 51% of the total number of breeding wader pairs recorded.

2. In 2018 and 2019 BTO conducted a re-survey of lowland sites to measure changes in the number of breeding wader pairs present and of habitat characteristics in the 30 years since the previous survey, enabling future conservation interventions to be focused at sites of particular significance.

3. Across the two years, 75 sites, each of which typically consisted of seven fields (SD = 6, range 1–32) and covered on average 34 ha (SD = 44 ha), were surveyed in lowland damp grassland regions around Lough Neagh, the Blackwater Catchment, Upper Lough Erne and Lower Lough Erne. A combination of volunteers, professional fieldworkers and RSPB staff surveyed the sites, recording counts of breeding waders, field-level habitat characteristics and site-level management and conditions. The survey methods and data recorded were consistent with those used in the original survey of 1985–87, to enable direct comparisons between the time periods to be made. However, counter to original expectations no habitat data were recoverable from the 1985–87 survey; a comparison of habitat and management conditions between the two time periods was therefore impossible. Only one site was surveyed in the Fairy Water Bogs; therefore, this region was excluded from further analysis.

4. Although survey participants recorded at least one breeding pair of Lapwing, Curlew, Redshank or Snipe at all sites in the late 1980s, 64% of sites showed no evidence of breeding wader presence in 2018–2019. Declines in the number of breeding wader pairs per site were widespread throughout the different regions surveyed, although the Blackwater Catchment was the worst affected, suffering a decline of 98% since 1985–87. Across all sites surveyed between 1985–87 and 2018–19, pairs of Lapwing declined by 70%, Curlew by 80%, Redshank by 76% and Snipe by 71%.

5. Analysis of the change in the number of wader pairs per site recorded during the breeding seasons of 1985–87 and 2018–19 using zero-inflated generalised linear mixed models (GLMMs) revealed that there was a significant decline in breeding waders of all species and collectively across the surveyed sites in all regions, but that the Lower Lough Erne region had retained generally higher numbers of breeding waders than elsewhere.

6. Chi-squared (X^2) contingency tests were carried out to investigate associations between wader presence in the 2018–19 survey and field-level habitat conditions. Wader presence was significantly associated with all the grassland categories (rushes, tussocks, improved). Although flooding was only present in 13% of fields, these fields made up 45% of the total fields with breeding waders present. Flooding and damp areas showed a highly significant association with wader presence, and Curlew were only found in fields that contained both damp and dry conditions. Management and condition characteristics did not differ markedly between the total sample of fields and those fields containing breeding waders.

7. Overall, despite previously being a highly important habitat for breeding Lapwing, Curlew, Redshank and Snipe, lowland damp grasslands in Northern Ireland have undergone a drastic decline in their breeding wader numbers in recent decades. Many sites no longer have breeding waders present on them, although sites to the west of the country are more likely to still hold pairs. In lowland damp grasslands, waders were associated with fields containing both improved and rough grass, and fields with damp or flooded areas were important, although many sites were found to have evidence of draining.

8. A better understanding of predation pressure, habitat use and the overall population of breeding waders across the whole country and, specifically, understudied regions in the west, namely the Sperrins and Fairy Water Bogs, would improve targeting of conservation measures to preserve breeding waders in Northern Ireland.

1. BACKGROUND & AIMS

1.1. THE NEED FOR THE PROJECT

In past centuries, Northern Ireland was rich in wet grassland and peatland habitats suitable for breeding waders (Christie *et al.* 2011; Cooper *et al.* 2009; Partridge & Smith, 1992). Waders such as Northern Lapwing *Vanellus vanellus* (hereafter Lapwing), Common Redshank *Tringa totanus* (hereafter Redshank), Snipe *Gallinago gallinago* and Eurasian Curlew *Numenius arquata* (hereafter Curlew) particularly favour these habitats during the breeding season, and rely on such areas for foraging and nesting sites safe from predators (Evans 2003; Franks *et al.* 2017; Grant *et al.* 1999). The loss of safe, suitable breeding habitat is thought to be a driver of population decline in these species (Bell & Calladine 2017; Franks *et al.* 2017; Pearce-Higgins *et al.* 2017; Smart *et al.* 2006), leading to the Curlew being recognised by some as the UK's highest priority bird species of conservation concern (Brown *et al.* 2015).

Increased agricultural intensification has resulted in Northern Irish wader habitats being lost and degraded by practices such as overgrazing, conversion of wet grasslands to 'improved' (drained) grasslands and peat cutting (Colhoun *et al.* 2015; Cooper & McCann 2002; Cooper *et al.* 2009; Henderson *et al.* 2002; Partridge & Smith 1992). Around 40% of the land area of Northern Ireland is now *Lolium*-dominated improved grassland (Cooper *et al.* 2009) and between 1991–98 the area covered by wet grassland decreased by 37% (Cooper & McCann 2002), largely due to conversion to improved perennial ryegrass.

Much habitat degradation had already occurred in the twentieth century prior to the first surveys of wader numbers in Northern Ireland (Partridge & Smith 1992), with the earliest systematically collected data on breeding waders occurring as part of the first Breeding Birds Atlas (Sharrock, 1976). In 1985, however, the Countryside and Wildlife branch of the Department of Environment (NI) contracted the RSPB to gather information on six key waders (Lapwing, Curlew, Redshank, Snipe, Dunlin *Calidris alpina* and Golden Plover *Pluvialis apricaria*), with the objective of selecting sites for their conservation through the establishment of Areas of Special Scientific Interest (Partridge 1987).

This study was composed of three main survey approaches; two site-based, on lowland (main sites, N = 198 sites) and upland (N = 490 1-km squares) habitats, and one tetrad-based sampling method (N = 146 tetrads). The tetrad-based sampling approach was repeated for Lapwing, Curlew and Snipe in 1999 (Henderson *et al.* 2002) and 2013 (Colhoun *et al.* 2015), and found that the number of breeding pairs of Curlew recorded between 1987 and 2013 had declined by 89%, Lapwing by 84% and Snipe by 80% (Colhoun *et al.* 2015).

Although the tetrad-based approach of the 1987 survey was repeated in 1999 and 2013, the site-based approach has not been revisited and, as a result, little is known about the fate of these particular sites or their wader assemblages. The original survey found that lowland damp grasslands were particularly important to Northern Ireland's breeding waders, with over half the total estimated population being found in these sites (Partridge & Smith 1992). It has therefore been proposed that the lowland sites visited in the original study should be re-surveyed to provide a comparison between the quality of habitat and wader abundance between the 1985–87 survey and the present day, a period that spans 30 years.

1.2. AIMS OF THE PROJECT

In this study a sample of lowland sites visited in the original study were re-surveyed with the aim of:

- providing a comparison of the number of breeding wader pairs on lowland wet grasslands between the 1985–87 survey and 2018–19.
- providing a comparison of the quality of habitat for breeding waders in lowland wet grasslands between the 1985–87 survey and 2018–19.

This information will enable the Northern Ireland Environment Agency (NIEA) to better target management strategies, such as the application of breeding wader agri-environment scheme (AES) options, and site designation to sites of particular importance. Findings will also benefit conservation NGOs and landowners enabling them to focus conservation management strategies to aid the maintenance and recovery of breeding wader populations in Northern Ireland.

2. METHODS

2.1. SITE SELECTION

Some 198 lowland grassland sites were surveyed professionally between 1985 and 1987, and a random sub-sample of these was covered in 2018 and 2019, stratified by the presence of Curlew. Sixty sites were selected that recorded the presence of breeding Curlew in the 1980s, and 30 sites were selected where no Curlew were recorded. Selection was stratified towards Curlew because NIEA was particularly interested in the status of this species, but it was also important to assess changes in a wider suite of breeding waders, as included in the original survey. There were no lowland grassland sites surveyed in the 1980s with a zero count of breeding waders; therefore, all of the sample sites previously held at least one pair of one species. The sites were split between five broad areas: 28 sites around Loughs Neagh and Beg, 23 around Upper Lough Erne, nine around Lower Lough Erne, 11 in the Tyrone Fairy Water Bogs and 19 in the Blackwater Catchment. On average, sites surveyed consisted of seven fields (SD = 6, range 1–32) and covered 34 ha (SD = 44 ha).

2.2. VOLUNTEER ENGAGEMENT AND PROFESSIONAL SURVEYING

In 2018, effort was concentrated on directing volunteers to sites around the Lough Neagh area to help provide baseline data for the new Environmental Farming Scheme, although all sites were available to volunteers to take on. In 2019, all site locations were equally promoted to volunteers. The volunteer response in 2018 was disappointing, so in 2019 volunteer engagement was boosted by posting letters out to members with addresses close to target sites, by communicating via emails, a post on Graham Appleton's 'WaderTales' blog and on social media, and by providing a webpage for the survey on the BTO website (https://www.bto.org/volunteer-surveys/northern-ireland-lowland-breeding-wader-survey). In addition, two training days were provided to introduce volunteers to the methodology and boost participation confidence.

Volunteer uptake of bird surveys in Northern Ireland is lower than in other parts of the UK; therefore it was not unexpected that recruitment of volunteers for a novel survey would be challenging. It is unfortunate that it was not discovered sooner that matching habitat data from the 1985–87 survey was unavailable, as a more moderate and straightforward method of habitat recording may have been more appealing to a wider volunteer base. In some cases, volunteers took on sites and then became ill during the season or were too busy to collect data and did not contact the survey organiser to communicate this. The distribution of sites away from the east of Northern Ireland, where the population density of volunteers is at its highest, may also have contributed to a low uptake, as the majority of sites were west of Lough Neagh (see Figure 3).

To enable a greater coverage of the sub-sample of lowland sites, professional surveying covered 31 sites in 2019, concentrating effort around Lough Neagh, Upper Lough Erne and Blackwater Catchment, where volunteers had already provided partial coverage. The RSPB provided data for the sites that they managed in 2018; seven of eight sites in the Lower Lough Erne area, two from the Lough Neagh area (NW Lough Beg and Portmore Lough), and two from Upper Lough Erne (Sessiagh East and Inishroosk II).

2.3. SURVEY METHODOLOGY

2.3.1. Recording breeding waders

Sites were visited in the morning between 6:00am – 10:00am, at least twice and up to three times between mid-April and mid-June, with at least two weeks between each visit. Ideally, three visits were preferred, as this was directly comparable with the methodology of the original survey. However, if no waders were found on the first two visits there was no need to visit again. Wet and windy weather was avoided.

Fields (following the 1980s delineation of field boundaries, for consistency of site size) were numbered on site maps, and each was covered systematically so that the surveyor walked within 100 m of every point in the field. The numbers of Lapwing, Curlew, Redshank and Snipe observed in each field were assessed in two measures: the total number present, and the number of pairs that could be discerned from behaviours such as displaying or territory defence. For example, a field might contain three individual Lapwing, and two individuals in this group may appear to be in a pair. Therefore the record for this field would be Total = 3, Pair = 1. Snipe are difficult to count, but the total number of individuals seen through flushing was recorded alongside any Snipe that were heard drumming or chipping, which is a male mating display that is used as breeding evidence (Green 1985).

In this study, total numbers of waders were less important than those recorded as potentially breeding, particularly because early in the season waders present in fields may be migrants passing through. Although 'apparent pairs' (hereafter 'pairs') were used as the primary count in further analysis following Partridge

(1987), data on total counts and numbers of putative pairs will both be made available to NIEA.

2.3.2. Definition of breeding pairs

Numbers of pairs on each site were estimated from the total number of individuals and number of pairs recorded by surveyors. Following Colhoun *et al.* (2015), flocks of more than four individual Lapwing or Curlew in any one field were not included in the estimates of pairs unless these were observed showing behaviours such as displaying or territory defence, as these were assumed likely to include non-breeding birds guidelines. While this risks underestimating the number of potential breeders, in reality where numbers of individuals greater than four were observed these were mostly identified as breeding pairs by behavioural cues (with the exception of 12 counts of Lapwing out of 1,001 visits, accounting for a potential of 19 missed pairs). To avoid double counting individuals, counts were aggregated across all fields per visit and the visit with the maximum count was used as the estimate of breeding pairs for the site, as the same individuals will likely have been encountered in different fields on different dates. To ensure compatibility with previous survey methods (Partridge 1987), breeding pairs were defined as follows:

Lapwing:

- Peak flock count (up to four individuals) divided by two and rounded up to the nearest whole number, or;
- Number of assumed pairs recorded by surveyor.
- The larger of these two measures was recorded as the estimate for the site.

Curlew:

- Peak flock count (up to four individuals) divided by two and rounded up to the nearest whole number, or;
- Number of assumed pairs recorded by surveyor.
- The larger of these two measures was recorded as the estimate for the site.

Redshank:

- Average number of birds present across all visits, rounded up to the nearest whole number (i.e. each individual was considered to represent half of a pair). This is consistent with the original survey definition carried out by Partridge (1987), following Green *et al.* (1984).

Snipe:

- The number of drumming or chipping males, multiplied by 1.74 (Green 1985) and rounded up to the nearest whole number.

2.3.3. Habitat measures

Habitat data were collected in 1986, including information on grass condition, tillage, dampness and land use (Partridge (1987) Appendix IV). Habitat mapping data were also collected on habitat types, describing the type of grassland/bog/fen/woodland in the site (Partridge (1987) Appendix V). In 1987, evidence of damage or threats was also recorded e.g. field drainage, peat cutting (Partridge (1987) Appendix V). Examples of the field sheets used for data collection in 1986 and 1987 can be seen in Figures 1 and 2.

Given straightforward methods, the collection of habitat and condition data is possible for volunteer surveyors. However, it can sometimes be the case that while volunteers are willing to count birds, some volunteers are reluctant to make records outside of their sphere of interest, namely habitat characteristics. To ensure that volunteers were willing to collect habitat data, data collection in this study followed the simpler 1986 format (Figure 2) with the relatively straightforward observation of condition from the 1987 format ('damage/threats', Figure 3). The latter was collected to provide information about potential threats to breeding wader habitats, identifying areas that could benefit from conservation intervention, for example through AES options. However, it is recommended that these data are used sensitively, to ensure landowner cooperation with future surveys, and some volunteers (N = 2) were uncomfortable with collecting data of this sort. An example field sheet, including habitat and threat data collection, is shown in Table 1.

At the field level, surveyors were asked to record the following information:

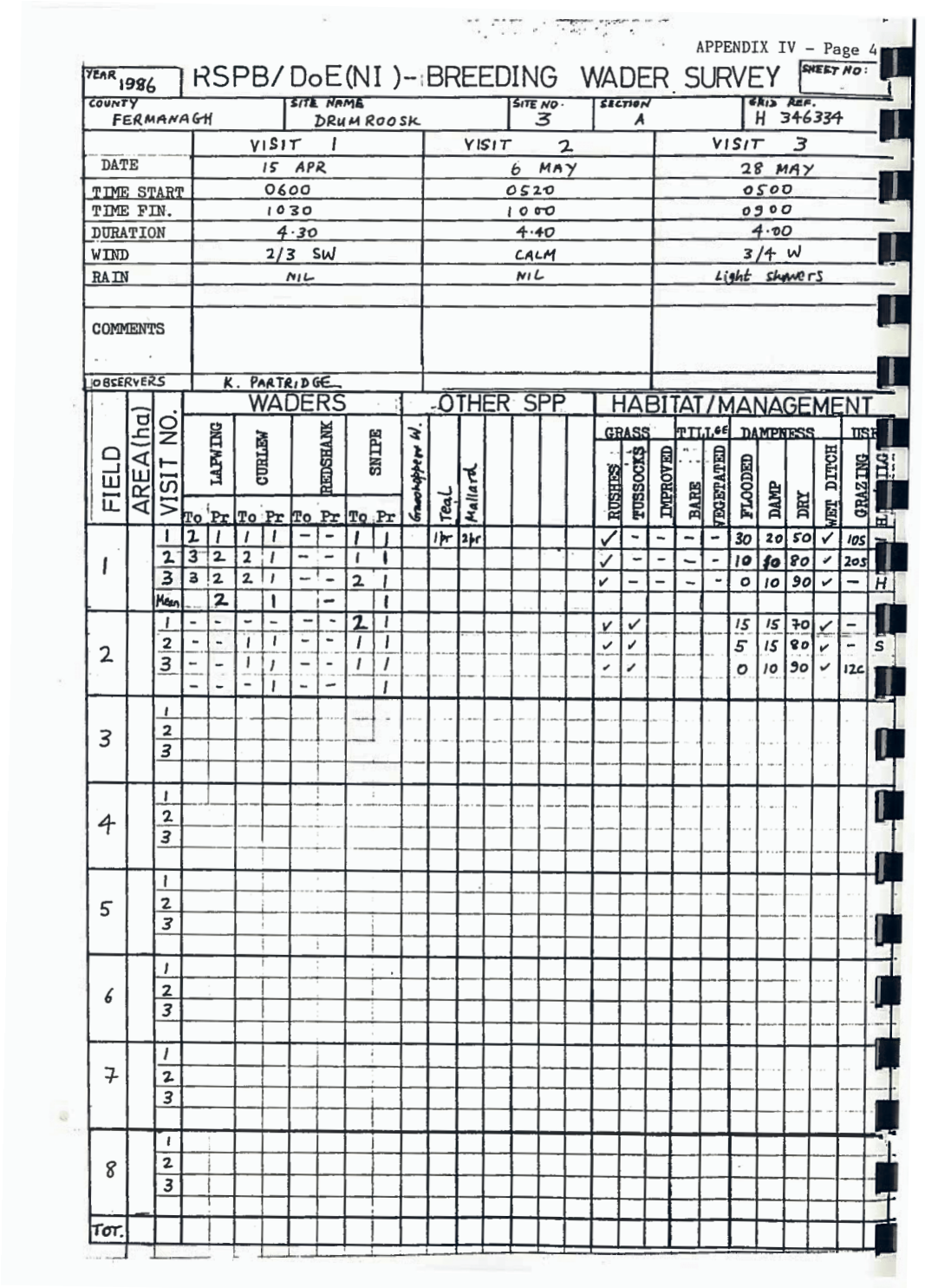
For each field in the site please **tick the appropriate box** for the **Grass** and **Tillage** options:

Grass:

- Rushes – substantial areas of rush.
- Tussocks – rough with well-developed tussocks.
- Improved – improved pasture with few or no tussocks.

Continued on Page 12

Figure 1. Field sheet for the 1986 survey, including data collection options for waders and habitat type and management.



APPENDIX IV – Page 4

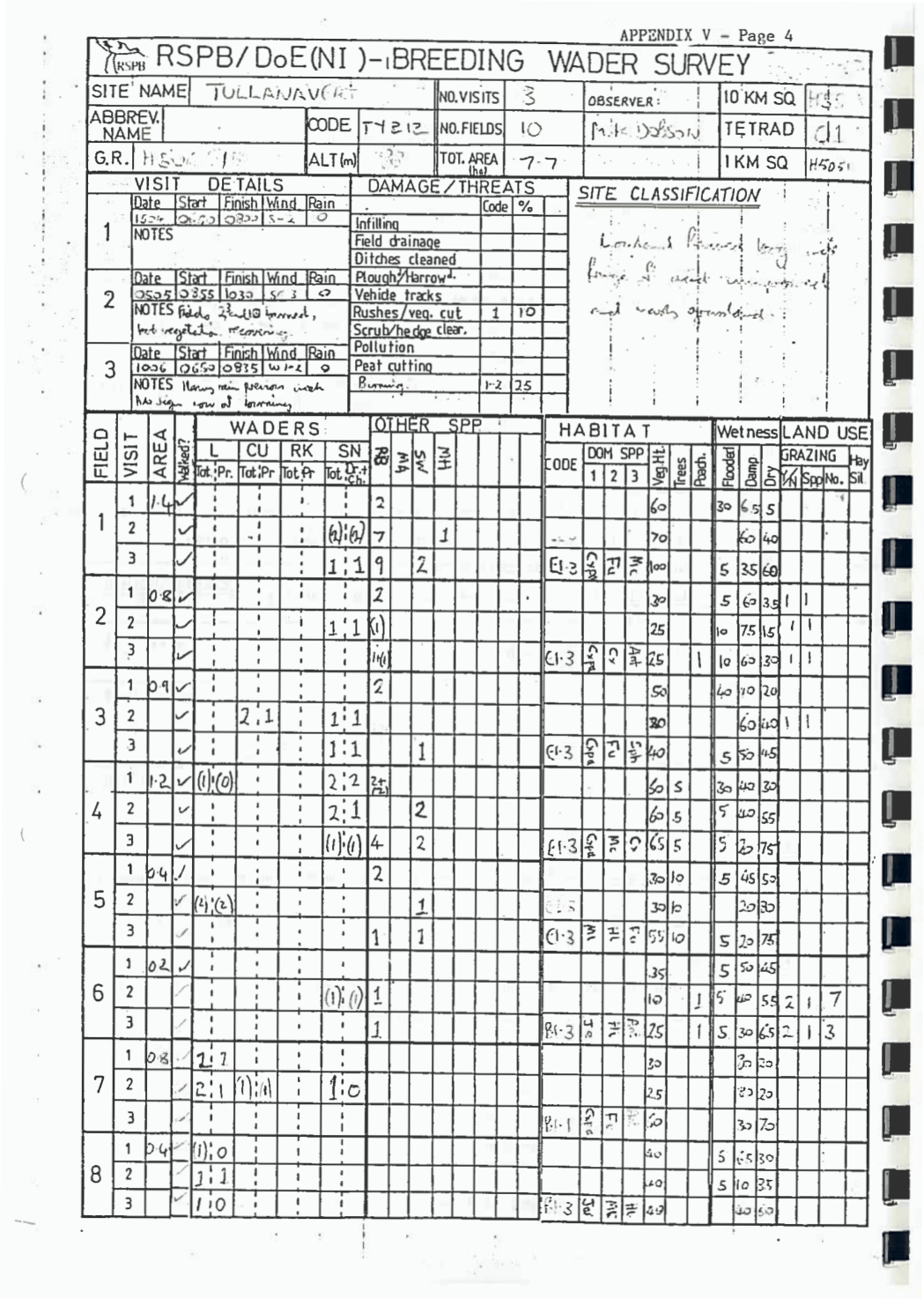
YEAR 1986 — RSPB/DoE(NI)–BREEDING WADER SURVEY — SHEET NO:

COUNTY	SITE NAME	SITE NO.	SECTION	GRID REF.
FERMANAGH	DRUMROOSK	3	A	H 346334

	VISIT 1	VISIT 2	VISIT 3
DATE	15 APR	6 MAY	28 MAY
TIME START	0600	0520	0500
TIME FIN.	1030	1000	0900
DURATION	4·30	4·40	4·00
WIND	2/3 SW	CALM	3/4 W
RAIN	NIL	NIL	Light showers
COMMENTS			
OBSERVERS	K. PARTRIDGE		

FIELD	AREA(ha)	VISIT NO.	WADERS: LAPWING To	LAPWING Pr	CURLEW To	CURLEW Pr	REDSHANK To	REDSHANK Pr	SNIPE To	SNIPE Pr	OTHER SPP: Grey Plover W.	Teal	Mallard	HABITAT/MANAGEMENT: GRASS RUSHES	GRASS TUSSOCKS	TILLAGE IMPROVED	TILLAGE BARE	TILLAGE VEGETATED	DAMPNESS FLOODED	DAMPNESS DAMP	DAMPNESS DRY	WET DITCH	USE GRAZING	USE H
1		1	2	1	1	1	–	–	1	1		1♂	2♂	✓	–	–	1	–	30	20	50	✓	10S	
		2	3	2	2	1	–	–	1	1				✓	–	–	1	–	10	10	80	✓	20S	
		3	3	2	2	1	–	–	2	1				✓	–	–	–	–	0	10	90	✓	–	H
		Mean		2		1		–		1														
2		1	–	–	–	–	–	–	2	1				✓	✓				15	15	70	✓	–	
		2	–	–	1	1	–	–	1	1				✓	✓				5	15	80	✓	–	S
		3	–	–	1	1	–	–	1	1				✓	✓				0	10	90	✓	12C	
			–	–	–	1	–	–		1														
3		1																						
		2																						
		3																						
4		1																						
		2																						
		3																						
5		1																						
		2																						
		3																						
6		1																						
		2																						
		3																						
7		1																						
		2																						
		3																						
8		1																						
		2																						
		3																						
TOT.																								

Figure 2. Field sheet for the 1987 survey, including data collection options for waders, damage/threats and habitat, wetness and land use.



APPENDIX V – Page 4

RSPB/DoE(NI)–BREEDING WADER SURVEY

SITE NAME	TULLANAVERT		NO. VISITS	3	OBSERVER:	10 KM SQ	H55
ABBREV. NAME		CODE	TY212	NO. FIELDS	10		TETRAD	C1
G.R.	H55[illegible]	ALT (m)	[illegible]	TOT. AREA (ha)	7·7		1 KM SQ	H5051

VISIT DETAILS

	Date	Start	Finish	Wind	Rain
1	1504	0900	0930	S-2	0
	NOTES				
2	0505	0355	1030	SE 3	0
	NOTES	Fields 2 and 10 harrowed, but vegetation recovering			
3	1006	0650	0835	W 1-2	0
	NOTES	Many rain pheasants with No sign now of harrowing			

DAMAGE/THREATS

	Code	%
Infilling		
Field drainage		
Ditches cleaned		
Plough/Harrowed		
Vehicle tracks		
Rushes/veg. cut	1	10
Scrub/hedge clear.		
Pollution		
Peat cutting		
Burning	1-2	25

SITE CLASSIFICATION

Lowland [illegible] bog [illegible] and reeds dominated

FIELD	VISIT	AREA	Walked?	WADERS L Tot.	L Pr.	CU Tot.	CU Pr	RK Tot.	RK Fr	SN Tot.	SN Dr.+Ch.	OTHER SPP BB	MA	SW	MH	HABITAT CODE	DOM SPP 1	2	3	Veg. Ht.	Trees	Poach.	Wetness Flooded	Damp	Dry	LAND USE GRAZING Y/N	Spp.	No.	Hay Sil.
1	1	1·4	✓									2								60			30	65	5				
	2		✓							(4)	(4)	7			1					70				60	40				
	3		✓							1	1	9		2		E1·3	Cyn	Fl	Mc	100			5	35	60				
2	1	0·8	✓									2								30			5	60	35	1	1		
	2		✓							1	1	(1)								25			10	75	15	1	1		
	3		✓									1(1)				C1·3	Cyn	Cr	Ant	25	1		10	60	30	1	1		
3	1	0·9	✓									2								50			40	10	20				
	2		✓			2	1			1	1									30				60	40	1	1		
	3		✓							1	1			1		E1·3	Cyn	Fl	Sph	40			5	50	45				
4	1	1·2	✓	(1)	(0)					2	2	2+(2)								60	5		30	40	30				
	2		✓							2	1			2						60	5		5	40	55				
	3		✓							(1)	(1)	4		2		E1·3	Cyn	Mc	Cr	65	5		5	20	75				
5	1	0·4	✓									2								30	10		5	45	50				
	2		✓	(4)	(2)									1						30	10			20	30				
	3		✓									1		1		C1·3	Ant	Ht	Fo	55	10		5	20	75				
6	1	0·2	✓																	35			5	50	45				
	2		✓							(1)	(1)	1								10		1	5	40	55	2	1	7	
	3		✓									1				B1·3	Jun	Ht	Pot	25		1	5	30	65	2	1	3	
7	1	0·8	✓	2	1															30				30	20				
	2		✓	2	1	(1)	(1)			1	0									25				20	20				
	3		✓																										
8	1	0·4	✓	(1)	0															40			5	65	30				
	2		✓	1	1															40			5	10	35				
	3		✓	1	0											B1·3	Jun	Pot	Ht	40				40	60				

Table 1. Example field sheet for resurvey, including space for site management/condition and habitat data collection. Instructions for data collection can be found in Appendix IV and V in the Final Report (see Partridge 1987).

Lowland breeding wader resurvey

County	Site	Site number	Section	Grid reference

Visit details

1	**Date**	**Start**	**Finish**	**Wind**	**Rain**
	Notes				
2	**Date**	**Start**	**Finish**	**Wind**	**Rain**
	Notes				
3	**Date**	**Start**	**Finish**	**Wind**	**Rain**
	Notes				

Management/Condition

	Code	%	
Infilling			
Field drainage			
Ditches cleared			
Ploughed/Harrowed			
Vehicle tracks			
Rushes/veg cut			
Scrub/hedge clear			
Pollution			
Peat Cutting			
Burning			

Field	Area (ha)	Visit number	Waders								Other species					Habitat/Management											
			Lapwing		Curlew		Redshank		Snipe							Grass			Tillage		Dampness				Use	
			To	Pr	To	Pr	To	Pr	To	Pr						Rushes	Tussocks	Improve	Bare	Vegetat	Flooded	Damp	Dry	Wet	Grazing	Hay/sila
1		1																								
		2																								
		3																								
2		1																								
		2																								
		3																								
3		1																								
		2																								
		3																								

Tillage:

- Bare – little or no vegetation cover.
- Vegetation – crops (indicate type if known).

Please **estimate the percentage** of each of the following **Dampness** options:

Dampness:

- Flooded – water over the top of boots.
- Damp – water up to soles of boots.
- Dry – no free water.
- Wet ditch – presence (Y), absence (N)

For land use please use the following **code**:

Land use:

- Grazing (three parts). E.g. a field with 10 cattle would be 2.1.10.
  Grazing status: 0 = ungrazed, 1 = recently grazed, 2 = presently grazed.
  Species: 1 = cattle, 2 = sheep, 3 = horses, 4 = other.
  No: Number of animals (approx.)
- Hay/silage
  1= cut for hay, 2 = silage cutting, 3= unknown.

Table 3. Field sheet instructions for recording weather options.

Wind	Description	Rain	Description
0	Calm	0	Dry
1	Light air	1	Showers
2	Light breeze	2	Continuous rain
3	Gentle breeze	3	Hail
4	Moderate breeze		
5	Fresh breeze		
6	Strong breeze		

Table 2. Field sheet instructions for recording management and condition options.

	Code	%
Infilling	1 = old tipping (vegetation covered) 2 = fresh tipping	% of site affected
Field drainage	1 = underway 2 = recently completed 3 = impending (i.e. pipes present)	% of site affected
Ditches cleaned	0 = overgrown 1 = ditches open 2 = ditches recently cleaned 3 = new ditches	% of total
Ploughed/harrowed	1 = mild 2 = moderate 3 = severe	% of site affected
Vehicle tracks		
Rushes/veg cut		
Scrub/hedges cleared		
Pollution	State type if present	
Peat cutting	1 = recent (hand cutting) 2 = old (hand cutting) 3 = recent (machine cutting) 4 = old (machine cutting)	% of site affected
Other	List and give % if applicable	

2.4. DATA ANALYSIS

2.4.1. Changes in wader abundance between 1985–87 and 2018–19

Temporal change in the estimated number of breeding wader pairs per site was analysed using generalised linear mixed models (GLMMs) in the R package glmmTMB (Brooks *et al.* 2017), which allows for fitting zero-inflated models with Laplace approximation to integrate over random effects. All models included a zero-inflation term to reduce overdispersion and zero-inflation, caused by many counts of no breeding wader pairs in the sites visited in 2018–19. In the case of the Blackwater Catchment region, the only breeding waders to be found in the 2018–19 surveys were three pairs of Snipe recorded in a single site (Table 3), causing models to calculate infinite confidence intervals around estimates for other species in this region, and thus masking the effect of year and region interactions. Therefore, Blackwater Catchment was excluded from further analyses.

Separate models were fitted for all species and for each species separately, with time (Year, two categorical factors: 1985–87, 2018–19) and region (Region, four categorical factors: Lough Neagh, Blackwater Catchment, Upper Lough Erne and Lower Lough Erne) as fixed factors. The log of the site area in hectares (due to the modelling method, below) was tested as both a fixed factor and as an offset (Appendix 1: Table S1), and sites were nested within region as a random factor to account for correlation between measures at the different time periods for the full data set including all species. Sum contrasts were applied to the region factors to condition the region estimates and consequently the year factor estimates on the mean of regional means, rather than the default reference region mean.

Models were tested with Poisson, quasi-Poisson and Negative Binomial distributions with the complimentary log link function, and rejected if the model did not converge or if the observed residuals deviated significantly from the expected residuals, a signal of overdispersion in the data (Hartig 2020, Appendix 1, Table S1). The remaining models were compared using AIC; the model with the lowest value for each species and for the all-species data set being selected as providing the best fit.

2.4.2. Breeding wader association with habitat characteristics in 2018–19

Unfortunately, habitat and site management data from the original survey in the late-1980s could not be located in the NIEA or RSPB archives during the course of this study, and habitat data of sufficient quality were not available from other sources (NIEA, pers.comm.). Due to this, comparisons of habitat and management between the 1985–87 and 2018–19 time periods could not be made. However, it was possible to explore associations between the presence of waders in the 2018–19 survey and the current habitats or land usage present during this survey.

Whilst reviewing the data it was apparent that there were some discrepancies in how the habitat data had been recorded and how surveyors had interpreted recording instructions. For example some surveyors recorded habitat data on each visit whilst others only recorded it on a single visit, some recorded percentages whilst others recorded just presence/absence. For consistency, all habitat and land use data were converted into presence/absence data. The habitat and land use records for each field were only recorded once in the analyses (regardless of the number of visits). Although in practise it was uncommon under most headings, there was a potential for different habitat and land use data to be recorded on different visits. To deal with this a few steps were taken:

1. by converting percentages, where they occurred, to presence/absence of a particular habitat or land use, many discrepancies were removed i.e. where the same habitats were present but in different proportions.

2. in cases where data were only recorded for a single visit, all subsequent visits were assumed to have the same combination of habitats/uses.

3. where differences still existed between visits all categories recorded as present on at least one visit to a field were included in that field's final composition. Mostly this related to changes in the dampness of a site, categories under grass, tillage, hay/silage and woodland/scrub showed only minor changes during visits. This might lead to an over- or under-estimate of the importance of some dampness categories, but as dampness can vary significantly within a short period of time this approach at least identified fields that had the potential to become flooded or damp from those that had less potential.

Waders were assumed to have been breeding in fields if the data complied with the guidance set out in 2.3.2. To look at habitat associations, only the presence or absence of breeding waders was assessed at field level, as the survey methodology did not lend itself well to estimating breeding attempts in individual fields. Chi^2 contingency tests for association were carried out on each habitat/land use category and a pooled wader presence category, termed 'All Species', as well as for Lapwing, Curlew, Redshank and Snipe individually. These tests were used to investigate whether breeding waders disproportionately associated with, or avoided, the available habitat types. The test statistic and any significance were recorded and are provided in Table 5.

In the initial year of surveys, it was noted by some surveyors that areas of the sites were now covered by trees or scrub and there was nowhere in the original field sheet to record this. Therefore in 2019, surveyors were asked to estimate the percentage of woodland/scrub in fields if it was encountered. As a result, woodland/scrub was only recorded in 2019, and any findings associated with this land use only take into account the fields/sites that were counted in 2019.

3. RESULTS

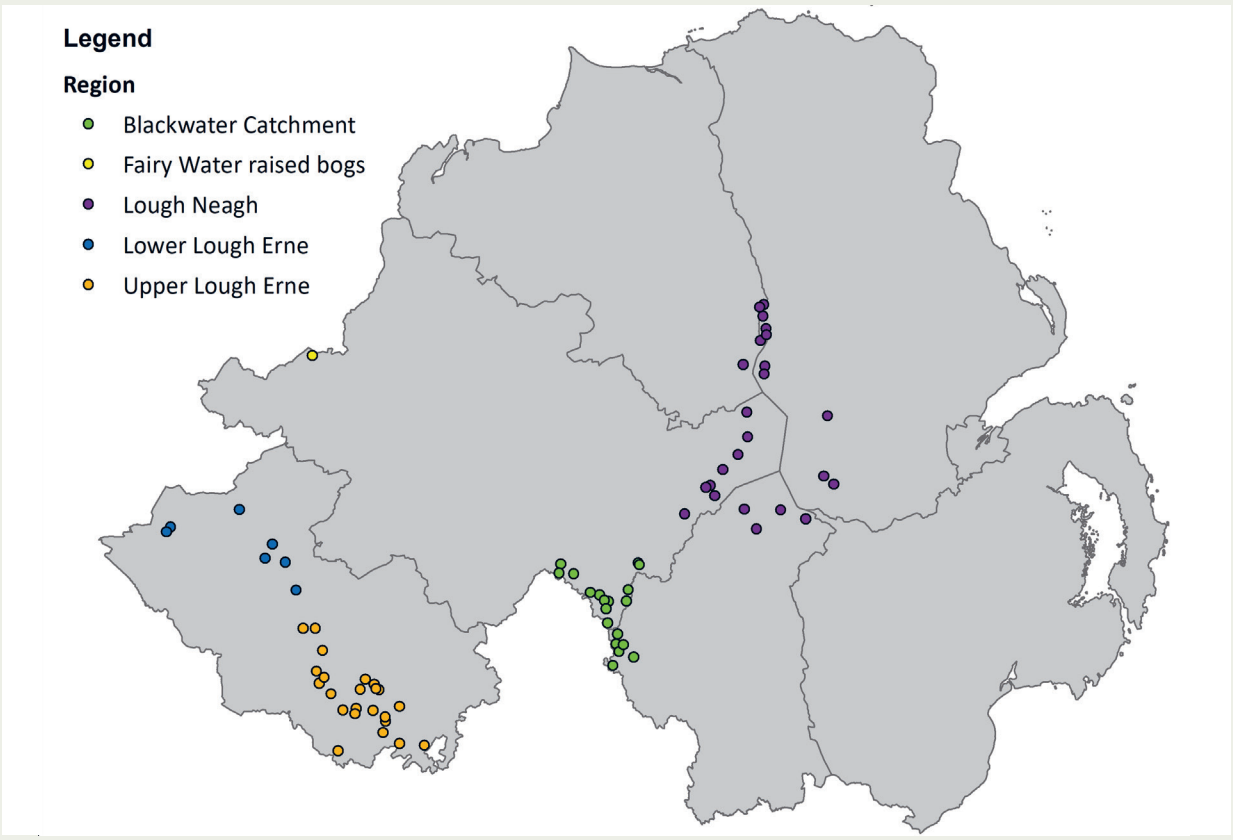
3.1. SITE COVERAGE

In 2018, 19 volunteers expressed interest in the survey. Of these, nine took on one or more sites (13 sites total), but data were only collected on six sites, as not all volunteers who agreed to survey sites actually collected data, and access was denied to one site (Ardean, Lough Neagh). The intensity of effort put into recruiting volunteers in 2019 was significantly increased; as a result 31 sites were taken up by 18 volunteers in 2019, and data were submitted from 27 of these sites. In total therefore, 33 sites received surveying by volunteers in 2018 and 2019. Professional fieldworker effort was targeted around the Blackwater Catchment, Lough Neagh and Upper Lough Erne, which received partial coverage by volunteers, and as a result 31 sites were covered by fieldworkers. The RSPB provided data from 11 of the 12 sites around Lower Lough Erne, Portmore Lough and NW Lough Beg from the Lough Neagh region, and Sessiagh E and Inishroosk II from the Upper Lough Erne region. One Lower Lough Erne site, Lackboy Shore, was managed by the Lough Erne Wildfowlers' Council, and data were not submitted from this site. Data were only received from one site in Fairy Water Bogs, covered by a volunteer.

3.2. CHANGE IN BREEDING WADER NUMBERS BETWEEN 1985–87 AND 2018–19

Although all sites recorded at least one assumed breeding pair of Lapwing, Curlew, Redshank or Snipe in the late 1980s, 64% of sites (N = 48) had a zero count in 2018–2019. Only one site was surveyed in the Fairy Water Bogs region and this region was therefore excluded from further analysis. Declines were widespread throughout the different regions surveyed (Table 4). Across all sites surveyed between 1985–87 and 2018–19, apparent pairs of Lapwing declined by 70%, Curlew declined by 80%, Redshank declined by 76% and Snipe declined by 71%. The Blackwater Catchment was the most severely depleted of all the regions, losing 98% of the total pairs of breeding waders observed in the sites within the region in the late 1980s and, in particular, 100% of the breeding Lapwing and Curlew found there (Table 4). Few sites were surveyed in Lower Lough Erne (N = 7), but of all regions it lost the lowest percentage of breeding waders at its sites between 1985–87 and 2018–19 (35%, Table 4). Notably, 21 pairs of Curlew remained in the Lower Lough Erne study sites, and the number of Redshank pairs persisted at 40 pairs. Curlew was the species to suffer the greatest declines overall, declining by 80% across all the sites, with particularly precipitous declines at Blackwater Catchment and Lough Neagh (97%, Table 4).

Figure 3. Locations of the 75 Northern Irish lowland damp grasslands surveyed in 2018–19.



The results of the GLMMs, which excluded counts from the Blackwater Catchment (see methods), confirmed that there was a significant overall decline in the number of breeding wader pairs recorded on sites between the surveys of 1985–87 and 2018–19, across all species together and individually (all waders: Table 4, Figure 4; each species: Appendix 2, Table S2–S5, Figure 5).

Considering all species together, 'region' had a significant effect on the number of breeding waders per site, with sites in Lower Lough Erne generally supporting the highest densities of breeding waders and Lough Neagh the lowest among the three areas included in the models (Table 4). Rates of decline between the 1985–87 and 2018–19 survey periods were also significantly different between the regions, with the most positive trend Lower Lough Erne (Figure 4; Table 4; 0.96, $P<0.001$), and the most negative trend for Lough Neagh (Figure 4; Table 4; -0.80, $P<0.001$). While not the focus of this study, the estimated effect of 'area' was significant (Table 4; 0.69, $P=0.001$), reflecting the fact that larger sites were more likely to contain breeding waders.

All species of wader, when examined individually, declined across all regions between the two survey periods, but there was insufficient power to detect statistically significant differences for some species at specific regions because of low sample sizes (as suggested by wide confidence intervals; Figure 5). However, declines were significantly steeper for Curlew at Lough Neagh (Figure 5, Table S3; -1.71, $P=0.021$), and for Redshank at Upper Lough Erne (Figure 5, Table S4; -2.07, $P<0.001$) than other regions modelled. In contrast, Lower Lough Erne experienced statistically less decline than the average seen across the modelled regions for Curlew and Redshank (1.83, $P=0.001$ and 1.28, $P<0.001$, respectively).

Table 4. Change in the numbers of pairs of breeding waders recorded across all sites, Blackwater Catchment, Lough Neagh, Lower Lough Erne and Upper Lough Erne.

	Lapwing	Curlew	Redshank	Snipe	All Species
All sites	-70% 260 to 78 pairs	-80% 151 to 30 pairs	-76% 202 to 49 pairs	-71% 683 to 197 pairs	-73% 1,296 to 354 pairs
Blackwater Catchment	-100% 26 to 0 pairs	-100% 17 to 0 pairs	No change 0 to 0 pairs	-96% 78 to 3 pairs	-98% 121 to 3 pairs
Lough Neagh	-74% 107 to 28 pairs	-97% 35 to 1 pairs	-93% 102 to 7 pairs	-94% 225 to 82 pairs	-75% 469 to 118 pairs
Lower Lough Erne	- 31% 42 to 29 pairs	-9% 23 to 21 pairs	No change 40 to 40 pairs	-65% 74 to 26 pairs	-35% 179 to 116 pairs
Upper Lough Erne	-70% 71 to 21 pairs	-83% 46 to 8 pairs	-95% 42 to 2 pairs	-60% 212 to 85 pairs	-77% 371 to 87 pairs

Table 5. Summary of zero-inflated GLMM outputs for the effect of time period (Year), Region, Area (hectares) and the interaction between 'region' and 'year' on counts of four species of breeding waders on lowland grassland sites around Northern Ireland. Coefficients for Upper Lough Erne are subsumed into the intercept.

	Count		
Predictors	*Log-Mean*	*CI*	*p*
(Intercept)	0.13	-0.65 to 0.90	0.753
Year [2018–19]	-1.28	-1.59 to -0.96	**<0.001**
Lough Neagh	-0.30	-0.60 to -0.00	**0.049**
Lower Lough Erne	0.50	0.11 to 0.89	**0.012**
Area_hectares [log]	0.44	0.19 to 0.68	**0.001**
Year [2018–19] : Lough Neagh	-0.80	-1.25 to -0.35	**<0.001**
Year [2018–19] : Lower Lough Erne	0.96	0.54 to 1.39	**<0.001**
Zero-Inflated Model			
(Intercept)	-3.02	-5.42 to -0.62	**0.014**
Random Effects			
σ^2	1.34		
$\tau 00_{Site.Name:Region}$	0.27		
$\tau 00_{Region}$	0.00		
$N_{Site.Name}$	60		
N_{Region}	3		
Observations	456		
Marginal R^2 / Conditional R^2	0.419 / NA		

Figure 4. Plot of mean breeding wader count per site for Lough Neagh, Lower Lough Erne and Upper Lough Erne between the two survey periods (1985–87 and 2018–19) as predicted by the zero-inflated GLMM, with 95% confidence intervals.

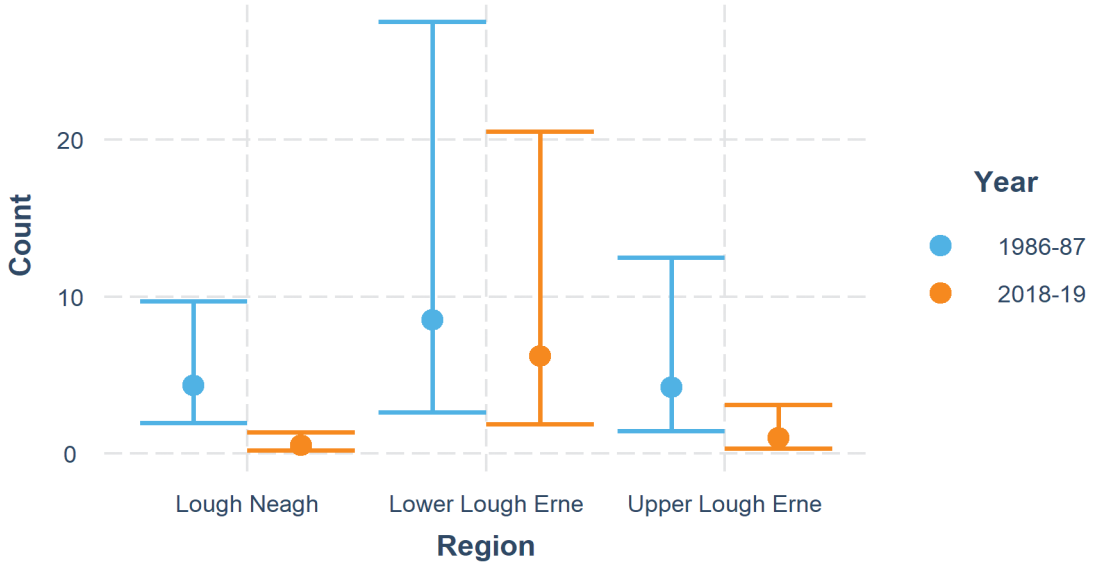
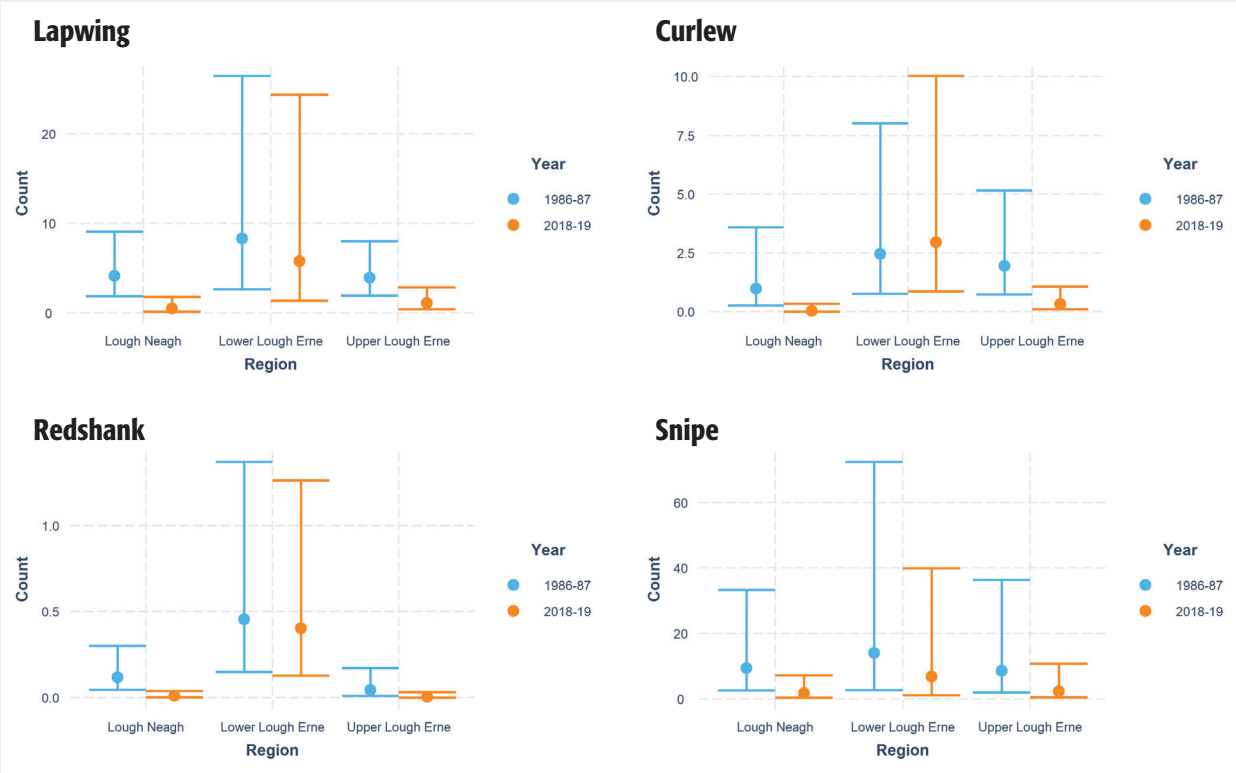


Figure 5. Plots of mean breeding Lapwing (top left), Curlew (top right), Redshank (bottom left) and Snipe (bottom right) count per site for Lough Neagh, Lower Lough Erne and Upper Lough Erne between the two survey periods (1985–87 and 2018–19) as predicted by the GLMMs, with 95% confidence intervals.



3.3. THE ASSOCIATION OF HABITAT CONDITIONS WITH BREEDING WADER PRESENCE'

3.3.1. Habitat characteristics in different study regions

The percentage cover of improved grassland within sites was similar across all regions (Figure 6), although sites in Upper Lough Erne had the highest coverage. Sites in the Blackwater Catchment had the lowest percentage coverage of rushes and tussocks, while having the highest coverage of vegetated tillage fields and fields with woodland/scrub. Lower Lough Erne sites had higher coverage of tussocks and rushes; however, all Lower Lough Erne sites were surveyed in 2018, so there is not a figure of woodland/scrub coverage for this region as this was not assessed in the first year of surveys. No regions had high percentage coverage of bare tillage.

3.3.2. Field-level associations

Of the fields visited, 72% were recorded as containing dry areas, 58% contained 'damp' areas and 13% had flooded areas. The most commonly recorded grass category type was 'improved', with 52% of fields recorded as such. Recording the presence of woodland/scrub was only specifically requested in 2019, therefore woodland/scrub in the 17 sites surveyed in 2018 cannot be assessed. In sites surveyed in 2019, it was found in 19% of fields surveyed.

Only 60 out of the total 552 fields (11%) contained signs of breeding waders in the 2018–19 survey. Following the same procedure carried out in the 1985–87 survey, habitat and management data were also collected for each field (see forms in Figures 1 and 2, and Table 2).

Rushes and tussocks occurred in around 60% of the fields with breeding waders whereas improved grassland occurred in 28% of breeding wader fields visited (Figure 7). However there was a highly significant association between 'all Species' and these three grass categories (see Table 5). At a species level there was some variation, with only Snipe (which made up 50% of 'all Species' records) showing a significant relationship with improved grassland.

No breeding waders were recorded on bare tillage fields. Vegetated tillage occurred in 5% of the fields with breeding waders, this consisted of only three fields (Figure 7). There was a highly significant association between vegetated tillage and 'all Species', but at an individual species level only Snipe showed a significant relationship to this habitat type (Table 5). Flooded and damp fields made up 45% and 88% of the total fields with breeding waders present (Figure 7), and both showed a highly significant association with 'all species' (Table 6). The 'dry' category did not show a highly

Figure 6. The percentage of fields within sites recorded as containing each habitat characteristic in 2018–19, averaged over the regions Blackwater Catchment (green), Lough Neagh (yellow), Lower Lough Erne (blue) and Upper Lough Erne (purple). Woodland/scrub data were not collected for Lower Lough Erne.

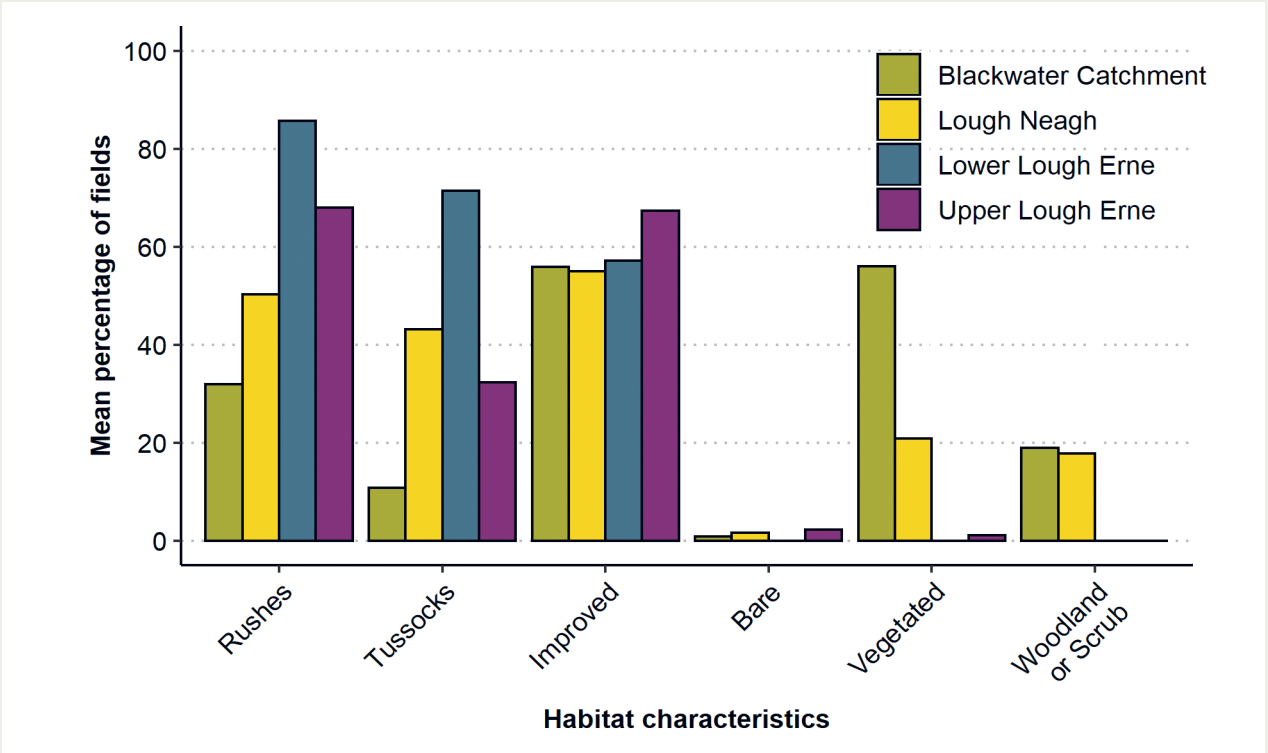


Table 6. Results from Chi² contingency tests of association for 'all species' and each species individually, against the habitat and land use categories recorded during the survey at a field level. The proportion and number of wader fields which contained each category is also provided. Statistical significance is indicated by asterisks: * – significant result at P<0.05, ** – highly significant result at P<0.01.

Habitats/ landuses	Categories	All species (60 fields)	Lapwing (21 fields)	Curlew (11 fields)	Redshank (12 fields)	Snipe (46 fields)
Grass	**Rushes**	**X^2_1=8.51; P=0.004****	**X^2_1=6.65; P=0.010****	**X^2_1=10.01; P=0.002****	**X^2_1=7.69; P=0.006****	X^2_1=2.17; P=0.141
	% wader fields (N):	61.67% (37)	71.43% (15)	90.91% (10)	83.33% (10)	54.35% (25)
	Tussocks	**X^2_1=34.41; P=<0.001****	**X^2_1=10.21; P=0.001****	**X^2_1=9.48; P=0.003****	**X^2_1=11.51; P=0.001****	**X^2_1=32.37; P=<0.001****
	% wader fields (N):	63.33% (38)	61.90% (13)	72.73% (8)	75.00% (9)	67.39% (31)
	Improved	**X^2_1=14.63; P=0.001****	X^2_1=0.67; P=0.412	X^2_1=0.65; P=0.421	X^2_1=3.48; P=0.062	**X^2_1=20.66; P=<0.001****
	% wader fields (N):	28.33% (17)	42.86% (9)	63.64% (7)	25.00% (3)	19.57% (9)
Tillage	**Bare**	X^2_1=N/A	X^2_1=N/A	X^2_1=N/A	X^2_1=N/A	X^2_1=N/A
	% wader fields (N):	0% (0)	0% (0)	0% (0)	0% (0)	0% (0)
	Vegetated	**X^2_1=22.17; P=<0.001****	X^2_1=N/A	X^2_1=N/A	X^2_1=N/A	**X^2_1=17.34; P=<0.001****
	% wader fields (N):	5.00% (3)	0% (0)	0% (0)	0% (0)	4.35% (2)
Dampness	**Flooded**	**X^2_1=57.88; P=<0.001****	**X^2_1=28.57; P=<0.001****	**X^2_1=9.93; P=0.002****	**X^2_1=4.20; P=0.041***	**X^2_1=44.95; P=<0.001****
	% wader fields (N):	45.00% (27)	52.38% (11)	45.45% (5)	33.33% (4)	45.65% (21)
	Damp	**X^2_1=26.02; P=<0.001****	X^2_1=N/A	X^2_1=N/A	**X^2_1=5.83; P=0.0167***	**X^2_1=12.84; P=<0.001****
	% wader fields (N):	88.33% (53)	100% (21)	100% (11)	91.67% (11)	82.61% (38)
	Dry	X^2_1=2.96; P=0.085	X^2_1=N/A	X^2_1=N/A	X^2_1=N/A	X^2_1=0.067; P=0.796
	% wader fields (N):	81.67% (49)	100% (21)	100% (11)	100% (12)	73.91% (34)
	Wet Ditch	**X^2_1=9.41; P=<0.002****	X^2_1=3.82; P=0.051	X^2_1=0.45; P=0.502	X^2_1=0.12; P=0.733	**X^2_1=8.24; P=0.004****
	% wader fields (N):	55.00% (33)	57.14% (12)	27.27% (3)	41.67% (5)	56.52% (26)
Use	**No grazing**	X^2_1=1.78; P=0.183	X^2_1=0; P=0.997	X^2_1=0.14; P=0.711	X^2_1=0.06; P=0.814	X^2_1=3.77; P=0.052
	% wader fields (N):	20.00% (12)	14.29% (3)	18.18% (2)	16.67% (2)	23.91% (11)
	Current/recent grazing	**X^2_1=68.31; P=<0.001****	**X^2_1=50.44; P=<0.001****	**X^2_1=26.27; P=<0.001****	**X^2_1=29.38; P=<0.001****	**X^2_1=34.95; P=<0.001****
	% wader fields (N):	68.33% (41)	90.48% (19)	90.91% (10)	91.67% (11)	60.87% (28)
	Hay/Silage	**X^2_1=11.25; P=<0.001****	**X^2_1=3.92; P=0.048***	X^2_1=0.61; P=0.437	X^2_1=3.70; P=0.054	**X^2_1=17.30; P=<0.001****
	% wader fields (N):	15.00% (9)	14.29% (3)	45.45% (5)	8.33% (1)	6.52% (3)
	Woodland/Scrub (2019 only)	X^2_1=3.49; P=0.062	X^2_1=N/A	X^2_1=N/A	X^2_1=N/A	X^2_1=1.67; P=0.196
	% wader fields (N):	4.17% (1)	0% (0)	0% (0)	0% (0)	6.25% (1)

significant association with 'all species' (Table 6). All Lapwing and all Curlew records were associated with damp and dry conditions. This resulted in zero values in the contingency table thus a X^2 contingency test could not be carried out for these categories for Lapwing or Curlew records. This was also the case for Redshank and the category 'dry'. The small sample sizes, high likelihood of dry areas being recorded in fields and the use of presence/absence rather than proportions, likely explains the apparent reliance on dry fields and perhaps masks the importance of a mixture of damp and dry areas for breeding waders.

Grazing categories were simplified for the analyses into 'no grazing' and current/recent grazing. There was a significant relationship between 'all species' and current/recent grazing but not for no grazing. There was also a highly significant association between 'all species' and hay/silage, although this category is only recorded in 15% of fields containing breeding waders (Table 6).

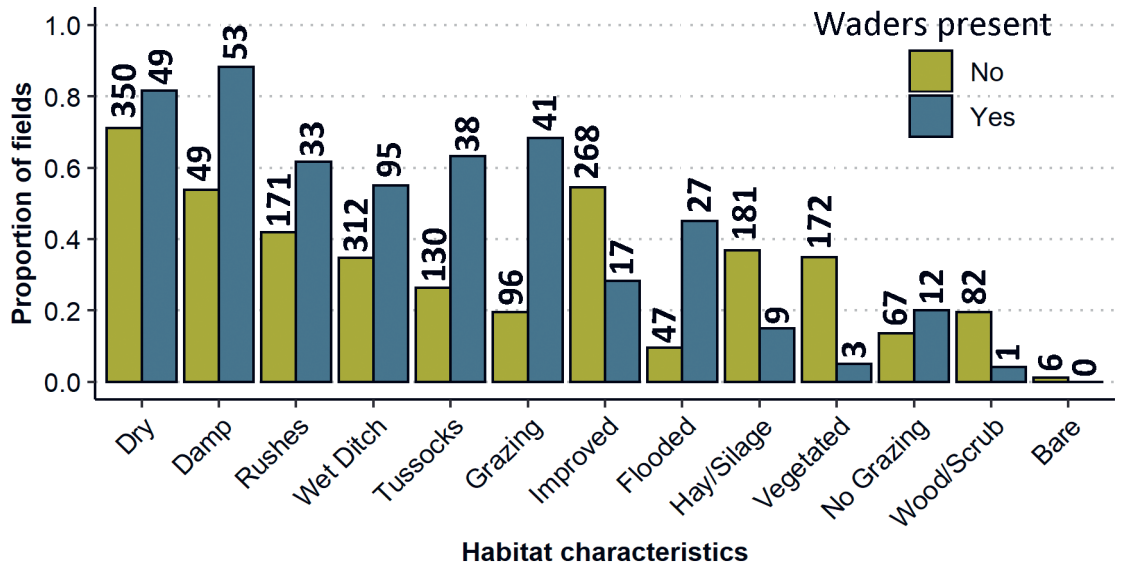
3.3.3. Site level associations.

At the site level management/condition was assessed under the headings in Table 7 where the extent to which these occurred on sites is summarised. Largely, the proportion of sites with different management/condition characteristics with waders present was similar to the proportions of these characteristics in the surveyed sample of sites overall. However, the exceptions were: ditch clearing, where a lower proportion of sites had waders present, and rush cutting and hedge clearing, where a higher proportion of sites had waders present.

Table 7. Management/condition characteristics of all sites surveyed, and of sites with breeding waders present.

	% of all sites	% of wader sites
Infilling	20%	15%
Field drainage	21%	27%
Ditches cleaned	78%	65%
Ploughed/harrowed	7%	8%
Vehicle tracks	30%	35%
Rushes/veg cut	27%	46%
Scrub/hedge cleared	26%	38%
Pollution	11%	12%
Peat cutting	3%	4%

Figure 7. Proportion of fields, with (N = 60) and without (N = 492) breeding waders present, where each of the habitat characteristics were recorded during the 2018–19 survey. Green bars represent visits to fields where breeding waders were absent, blue bars represent where breeding waders were present. The number of fields represented by each bar is inset.



4. DISCUSSION

Previous to the current study, many lowland damp grassland sites distributed around Northern Ireland had not been re-surveyed for breeding waders since the original survey of the late 1980s (Partridge 1987; Partridge & Smith 1992). For the current study, data were received from 75 lowland grassland sites around Northern Ireland, covered by a combination of volunteers, professional surveyors and the RSPB. The results plainly show that although these sites were formerly important to breeding waders in the country during the late 1980s (Partridge 1987), the majority no longer had breeding waders present (64% of sites surveyed), or had fewer individuals or species. The decline in the estimated numbers of breeding pairs per site was similar between the species studied: Curlew (-80%), Lapwing (-70%), Redshank (-76%), and Snipe (-71%).

While this decline was statistically significant between 1985–87 and 2018–19, it varied across the regions studied. The region with the greatest loss of breeding waders was the Blackwater Catchment, where the total number of breeding wader pairs recorded dropped by 98% between 1985–87 and 2018–19. Although the total numbers of pairs of Curlew and Lapwing were low in the 1980s, these were lost completely on the sites surveyed in 2018–19, and the number of recorded pairs of Snipe dropped from 78 to just three retained in one site. RSPB managed sites were the only sites to have increased their breeding wader populations between 1985–87 and 2018–19. However, RSPB managed sites were also concentrated around Lower Lough Erne. Due to its isolated location and network of islands and less-accessible land, likely to limit the intensity of farming and exposure to predators, Lough Erne has historically been valuable to breeding waders and thus has also been a hotspot for conservation action for their preservation. This study found that in particular Redshank were more likely to be found in sites around Lower Lough Erne regardless of the survey period, and that for both Curlew and Redshank, declines were less marked than at the other surveyed areas. The retention of breeding waders on the islands of Lower Lough Erne is likely to be due to a combination of inherently more suitable conditions (including a lesser predation risk) and associated management to maintain those conditions, the two factors clearly not necessarily being independent from each other.

Some decline observed between the original survey and the present study may be due to the less-intensive survey methods applied during 2018–19. The 1985–87 survey was carried out by professional surveyors and each site received three visits, increasing the opportunity to observe breeding pairs at the sites. The 2018–19 survey was simplified to make it more accessible to volunteers, and a third visit was not requested unless waders were observed on one of the first two visits. Final data submitted to the survey revealed that 66% of the total number of surveyed fields were visited twice, while only 15% were surveyed three times. Therefore it is possible that a lack of repeat visits may have resulted in a lower count than would have been achieved with a greater number of repeats. However, it is unlikely that if waders were not observed on the first two visits to a site that they would be present and observable on the third visit, so the difference in methodology is unlikely to have affected the trends observed by this study. Since the original survey, methods for surveying waders have been refined (e.g. Bibby *et al.* 2000; O'Brien & Smith 1992). However, to permit direct comparison, the assumptions of data interpretation were retained as applied in earlier surveys. The original data from this study will be available to NIEA if reinterpretation is needed for future use.

Rushes and tussocks were common in the fields of sites in the sample where breeding waders were present (both found in ~60%), while 28% of fields with breeding waders present were recorded as improved. The presence of waders in a combination of all grass types is to be expected as improved grassland covers a large proportion of the land area of Northern Ireland (40.5%, Cooper *et al.* 2009) and all wader species in the study prefer mosaic habitats with some degree of tussock or rushes for breeding in damp grassland (Durant *et al*. 2008; Franks *et al*. 2017; Henderson *et al*. 2002; Smart *et al.* 2008, 2006; Wilson *et al.* 2001). Individually, the only species to show a significant avoidance of improved grassland was Snipe, which is more typically associated with marshy and tussocky areas. Current or recent grazing was significantly associated with all waders collectively and individually, supporting previous research that some grazing is preferred by all species to maintain a varied sward height (reviewed in Durant *et al.* 2008).

In 2018–19, the incidence of flooding and damp areas was more common in fields where breeding waders were present than in the total sample of fields. Breeding wader presence was significantly associated with all three dampness categories – 'dry', 'damp' and 'flooded' – and with the presence of wet ditches. All 30 breeding pairs of Curlew were found in fields

with damp or flooded areas, while Lapwing presence was associated with flooded areas and wet ditches, Redshank presence with damp areas, and Snipe presence with flooded and damp areas, and with wet ditches. Previous research has shown that all the species recorded in this study prefer breeding in habitats that provide some areas of damp ground and flooded areas, as these provide a source of accessible and abundant invertebrate prey (Henderson *et al.* 2002; Wilson *et al*. 2005, 2004).

The improvement of grassland and making the switch to silage from hay is often accompanied by draining fields and thus reduces the availability of foraging areas for breeding waders and their chicks and is likely to be a factor influencing breeding wader decline across the UK (e.g. Baines 2008; Calladine *et al.* 2014; Laidlaw *et al.* 2013). In Northern Ireland, there was a significant increase in the land cover of improved grassland between 1991 and 1998 (Cooper & McCann 2002), and field drainage (of unspecified type) was recorded in 21% of all the fields visited, and 78% of fields had cleaned drainage ditches. The percentages of fields with breeding waders present which were recorded as undergoing drainage (27%) or had cleaned ditches (65%) were similar to the percentages observed across all fields surveyed (21% and 78%, respectively), suggesting that while drained fields may not provide ideal foraging habitats for breeding waders, these were not avoided in lowland damp grassland sites in Northern Ireland.

Lapwings have evolved strategies such as communal nest defence and predator distraction behaviours to allow them to nest more successfully than the other wader species in this study on less heterogenic fields with shorter sward height; however, no Lapwing were found to be breeding on the fields recorded by this study as bare tillage, although these were few (N = 6). Spring tillage, including bare tillage, bare plough and stubbles, has been shown elsewhere to be occupied by breeding Lapwing (Shrubb 1990; Shrubb *et al.* 1991; Wilson *et al.* 2001) but whether these areas supported sustainable populations in the absence of immigration from more productive areas is unknown; the role of source and sink populations in wader demography requires further attention. The area of arable farmland across Northern Ireland decreased by 15.5% between 1998 and 2007 (Cooper *et al.* 2009), but the majority of lowland mixed arable farmland, where bare tillage would be most likely to be found, is concentrated in eastern Co. Down (Colhoun *et al.* 2017) and was therefore not covered by this study.

The original aim of collecting habitat data alongside breeding wader counts was to compare the suitability of habitat between the current survey and the original survey, to assess which factors have changed and how these might have influenced breeding wader numbers on the sites. It was hoped that the findings would highlight areas of change that may have negatively influenced breeding wader populations, and provide insight into how particular locations that formerly provided habitat to support over half of the total breeding wader population of Northern Ireland may be restored or moved towards increased suitability. The collection of habitat and management data for the 2018–19 survey was therefore matched to the original methods, which were not ideally suited to collection by volunteers. Unfortunately, the original habitat data were lost between the completion of the original survey and the re-survey and it has only been possible to comment on conditions now and their association with wader presence, with the caveat that habitat recording by volunteers was not as consistent as that of professional surveyors.

While this study looks into habitat and site management characteristics, surveyors were not asked to record evidence of predator presence. In Northern Ireland, the main predators of breeding waders are avian predators and Red Fox *Vulpes vulpes* (Grant *et al*. 1999), and in particular Curlew nests may be more exposed and therefore more vulnerable to predation (Zielonka *et al*. 2020). Predation is a major contributor to wader decline in Northern Ireland (Colhoun *et al.* 2015); while no figures are available for the trend in Fox numbers, Hooded Crows *Corvus cornix* have increased by 179% and Buzzards *Buteo buteo* have increased by 1,305% since 1995 (Harris *et al*. 2020). Numbers of Foxes may be high due to the intense and sustained level of lethal control needed to reduce the population (Ainsworth *et al.* 2016; Looney 2003). Therefore, a low level of predator control in Northern Ireland is likely to impact on the productivity of breeding waders and contribute heavily to their decline on lowland wet grasslands. Changes in land use in Northern Ireland, including an increase in sheep grazing, a decrease in rough grassland and an increase in permanent grassland, may also facilitate the population growth of generalist predators such as Foxes and corvids, by increasing the availability of carrion and soil invertebrates, while fragmenting breeding wader habitats and making them more accessible (Grant *et al.* 1999). Additionally, sward heterogeneity is reduced in improved grassland, which may negatively affect the ability of waders to hide nests and chicks (Whittingham & Evans 2004).

5. RECOMMENDATIONS

The results of this study show that breeding waders in Northern Irish lowland damp grasslands have been badly affected by declines since the late 1980s, although these may be less severe around Lower and Upper Lough Erne. Habitat characteristics and land uses that support breeding waders are still present to varying degrees across the regions surveyed. Lowland damp grasslands were the focus of this study, but upland areas of Northern Ireland also support populations of breeding waders. In particular, Glenwherry in the Antrim Hills is a hotspot for breeding waders and these are currently the focus of a programme of landowner engagement, habitat management and surveying initiated by the RSPB in 2011 (www.rspb.org.uk/our-work/conservation/projects/glenwherry-breeding-wader-project). The Sperrins, spanning Co. Tyrone and Co. Londonderry, is another large upland area and was shown to be suffering declines in breeding waders during the last two country-level surveys (Colhoun *et al.* 2015; Henderson *et al.* 2002). Although a former stronghold for Golden Plover in Northern Ireland, a recent survey of the Sperrins did not record any sightings (www.rspb.org.uk/our-work/conservation/projects/co-operation-across-borders-for-biodiversity-cabb). Lying at the south-western edge of the Sperrins, the Fairy Water Bogs were originally included in the site selection for this survey. However, the difficulty in recruiting volunteers to this remote and difficult to access area was insurmountable and only one site was surveyed (Moneygal Bog; no waders were recorded). These two western areas, the uplands of the Sperrins and the adjacent lowland damp grasslands of the Fairy Water Bogs still remain under-surveyed, and would benefit from more detailed study.

The last country-level, tetrad-based survey of breeding waders took place in 2013 (Colhoun *et al.* 2015) and did not include an assessment of habitat association as included in Henderson *et al*. (2002). Repeating the tetrad-based survey at regular intervals is an important priority to monitor changes in the breeding population outside specific lowland damp grassland sites, and this would benefit from repeating the survey of habitat associations to measure how this has changed in the wider countryside.

Similarly to the rest of the UK and Ireland, predation pressure is contributing to the breeding wader decline in Northern Ireland by seriously impacting productivity (Grant *et al.* 1999). Therefore, any future management for waders is likely to involve lethal predator control (see the review of predator management for breeding waders in Ainsworth *et al.* 2016). While the increase in avian predators is well documented by the UK-wide BTO/JNCC/RSPB Breeding Bird Survey (BBS), little is known about the abundance of mammalian predators across the country and their habitat associations. The last study to look closely at the impact of predators on breeding waders (Curlew) in Northern Ireland was carried out between 1993 and 1995 (Grant *et al.* 1999). Therefore, the current level of interaction between potential predators and breeding waders across Northern Ireland, and how much this has changed since the Grant *et al.* (1999) study is unknown. A more detailed understanding of the contact between breeding waders and predators in Northern Ireland may help to identify areas where predation is naturally low, and hence identify areas where wader populations may be most sustainably maintained in the future.

While some studies in Britain are currently beginning to investigate the local movements of Curlew during the breeding season using GPS tracking (Ewing *et al.* 2017), little is known about the movements of any species of breeding wader in the mosaic of small farm holdings found in Northern Ireland, nor the use of wader-specific AES options. The difference in the farming landscape in Northern Ireland to the rest of the UK may mean waders differ in their space use; therefore, the spatial scale of conservation measures may need to be adapted to suit Northern Irish breeding wader populations.

The results of this study add to the body of knowledge of Northern Ireland's breeding waders by revisiting lowland grassland sites not surveyed in over 30 years. The locations of breeding waders identified by surveyors are currently enabling appropriate AES management to be targeted where breeding waders are still present. The results of this study will be consolidated into a review of the current knowledge of breeding waders in Northern Ireland to enable NIEA and conservation bodies to direct future resources to protect Northern Ireland's remaining wader populations.

6. REFERENCES

Ainsworth, G., Calladine, J., Martay, B., Park, K., Redpath, S., Wernham, C., … 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.

Baines, D. (2008). The effects of improvement of upland, marginal grasslands on the breeding success of Lapwings *Vanellus vanellus* and other waders. *Ibis* **131**: 497–506.

Bell, M. V. & Calladine, J. (2017). The decline of a population of farmland breeding waders: a twenty-five-year case study. *Bird Study* **64**: 264–273.

Bibby, C. J., Burgess, N. D., Hill, D. A. & Mustoe, S. (2000). *Bird Census Techniques*. Elsevier.

Brooks, M. E., Kristensen, K., van Benthem, K. J., Magnusson, A., Berg, C. W., Nielsen, A., … Bolker, B. M. (2017). {glmmTMB} Balances Speed and Flexibility Among Packages for Zero-inflated Generalized Linear Mixed Modeling. *The R Journal* **9**: 378–400.

Brown, D., Wilson, J., Douglas, D., Thompson, P., Foster, S., McCulloch, N., … Sheldon, R. (2015). The Eurasian Curlew – the most pressing bird conservation priority in the UK? *British Birds* **108**: 660–668.

Calladine, J., Pakeman, R. J., Humphreys, E., Huband, S. & Fuller, R. J. (2014). Changes in breeding wader assemblages, vegetation and land use within machair environments over three decades. *Bird Study* **61**: 287–300.

Christie, S., Mccann, D., Annett, J., Bankhead, J., Casement, P., Christie, P., … Young, M. (2011). Chapter 18: Status and Changes in the UK Ecosystems and their Services to Society. *The UK National Ecosystem Assessment Technical Report*, 775–894.

Colhoun, K., Mawhinney, K., McLaughlin, M., Barnett, C., McDevitt, A., Bradbury, R. B. & Peach, W. J. (2017). Agri-environment scheme enhances breeding populations of some priority farmland birds in Northern Ireland. *Bird Study* **64**: 545–556.

Colhoun, K., Mawhinney, K. & Peach, W. J. (2015). Population estimates and changes in abundance of breeding waders in Northern Ireland up to 2013. *Bird Study* **62**: 394–403.

Cooper, A. & McCann, T. (2002). *Habitat change in the Northern Ireland countryside: summary report of the northern Ireland countryside survey, 2000*. Environment and Heritage Service. Belfast.

Cooper, A., McCann, T. & Rogers, D. (2009). *Northern Ireland Countryside Survey 2007 : Field Boundary – Summary Report 1998–2007*. Northern Ireland Environment Agency Research and Development Series.

Durant, D., Tichit, M., Fritz, H. & Kernëïs, E. (2008). Field occupancy by breeding Lapwings *Vanellus vanellus* and Redshanks *Tringa totanus* in agricultural wet grasslands. *Agriculture, Ecosystems and Environment* **128**: 146–150.

Evans, K. L. (2003). The potential for interactions between predation and habitat change to cause population declines of farmland birds. *Ibis* **146**: 1–13.

Ewing, S. R., Scragg, E. S., Butcher, N. & Douglas, D. J. T. (2017). GPS tracking reveals temporal patterns in breeding season habitat use and activity of a globally Near Threatened wader, the Eurasian Curlew. *Wader Study* **124**: 206–214.

Franks, S. E., Douglas, D. J. T., Gillings, S. & Pearce-Higgins, J. W. (2017). Environmental correlates of breeding abundance and population change of Eurasian Curlew *Numenius arquata* in Britain. *Bird Study* **64**: 393–409.

Grant, M. C., Orsman, C., Easton, J., Lodge, C., Smith, M., Thompson, G., … Moore, N. (1999). Breeding success and causes of breeding failure of Curlew *Numenius arquata* in Northern Ireland. *Journal of Applied Ecology* **36**: 59–74.

Green, R. E., Johnson, T. & Collins, D. (1984). *An intensive survey of breeding Redshank on The Wash, 1984.* Unpub. Report, Royal Society for the Protection of Birds, Sandy.

Harris, S. J., Massimino, D., Balmer, D. E., Eaton, M. A., Noble, D. G., Pearce-Higgins, J. W., … Gillings, S. (2020). The Breeding Bird Survey 2019. *BTO Research Report* **726**. Thetford.

Hartig, F. (2020). *DHARMa: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models.* Retrieved from http://florianhartig.github.io/DHARMa/

Henderson, I. G. G., Wilson, A. M., Steele, D. & Vickery, J. A. (2002). Population estimates, trends and habitat associations of breeding Lapwing *Vanellus vanellus*, Curlew *Numenius arquata* and Snipe *Gallinago gallinago* in Northern Ireland in 1999. *Bird Study* **49**: 17–25.

Laidlaw, R. A., Smart, J., Smart, M. A. & Gill, J. A. (2013). Managing a food web: impacts on small mammals of managing grasslands for breeding waders. *Animal Conservation* **16**: 207–215.

Looney, D. J. P. (2003). A review of Fox control in north-east Ireland. *The Irish Naturalists' Journal* **27**: 223–228.

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.

Partridge, J. K. (1987). Final Report: Northern Ireland Breeding Wader Survey. *Report to Department of the Environment (Countryside and Wildlife Branch) Northern Ireland.* Sandy.

Partridge, J. K. & Smith, K. W. (1992). Breeding wader populations in Northern Ireland, 1985--87. *Irish Birds* **4**: 497–518.

Pearce-Higgins, J. W., Brown, D. J. & Douglas, D. J. T. (2017). A global threats overview for Numeniini populations: synthesising expert knowledge for a group of declining migratory birds. *Bird Conservation International* **27**: 6–34.

Sharrock, J. T. R. (1976). *The Atlas of Breeding Birds in Britain and Ireland.* T. & A.D. Poyser, Berkhamstead.

Shrubb, M. (1990). Effects of agricultural change on nesting Lapwings *Vanellus vanellus* in England and Wales. *Bird Study* **37**: 115–127.

Shrubb, M., Lack, P. C. & Greenwood, J. J. D. (1991). The numbers and distribution of Lapwings *Vanellus vanellus* nesting in England and Wales in 1987. *Bird Study* **38**: 20–37.

Smart, J., Amar, A., O'Brian, O., Grice, P. & Smith, K. (2008). Changing land management of lowland wet grasslands of the UK: impacts on Snipe abundance and habitat quality. *Animal Conservation* **11**: 339–351.

Smart, J., Gill, J. A., Sutherland, W. J. & Watkinson, A. R. (2006). Grassland-breeding waders: Identifying key habitat requirements for management. *Journal of Applied Ecology* **43**: 454–463.

Whittingham, M. J. & Evans, K. L. (2004). The effects of habitat structure on predation risk of birds in agricultural landscapes. *Ibis* **146**: 210–220.

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.

Wilson, A. M., Vickery, J. A., Brown, A., Langston, R. H. W., Smallshire, D., Wotton, S. & Vanhinsbergh, D. (2005). Changes in the numbers of breeding waders on lowland wet grasslands in England and Wales between 1982 and 2002. *Bird Study* **52**: 55–69.

Wilson, A. M., Vickery, J. A. & Browne, S. J. (2001). Numbers and distribution of Northern Lapwings *Vanellus vanellus* breeding in England and Wales in 1998. *Bird Study* **48**: 2–17.

Zielonka, N. B., Hawkes, R. W., Jones, H., Burnside, R. J., Dolman, P. M., Zielonka, N. B., … Burnside, R. J. (2020). Placement , survival and predator identity of Eurasian Curlew *Numenius arquata* nests on lowland grass-heath. *Bird Study* **66**: 1–13.

APPENDIX 1: MODEL TESTING

Table S1. GLMM fit tested between different distributions and inclusion of area as an offset compared for each species and for the all-species data set. Grey cells highlight models that failed to run correctly, orange cells highlight models that ran with warnings associated with model misspecification (e.g. overdispersion) and green cells highlight the model with the lowest Akaike's Information Criterion (AIC) value, used to assess model fit.

Distribution	Area as offset?	Lapwing	Curlew	Redshank	Snipe	All species
Poisson ("poisson")	Yes	AIC 471.6	Model convergence problem	AIC 348.5	Error with gradient length	AIC 2219.1, Significant outliers (P= 0.02)
	No	Model convergence problem	Model convergence problem	AIC 345.8	Error with gradient length	AIC 2200.4, Kolmogorov–Smirnov test significant deviation (P= 0.05)
Quasi-Poisson ("nbinom1")	Yes	AIC 454.3	AIC 317.8	AIC 334.8	Model convergence problem	AIC 1694.2
	No	AIC 445.3	Model convergence problem	AIC 336.8	AIC 564.9	AIC 1679.1
Negative binomial 2 ("nbinom2")	Yes	AIC 464.8, Overdispersed (P = 0.032)	AIC 326.2	AIC 349.9	Model convergence problem	AIC 1720.9, Overdispersed (P = 0.008)
	No	AIC 458.9	AIC 309.4	AIC 347.8	AIC 583.0	AIC 1716.2

APPENDIX 2: SPECIES LEVEL MODEL OUTPUTS

Table S2. Summary of zero-inflated GLMM outputs for the effect of time period ('year'), 'region', 'area' (hectares) and the interaction between 'region' and 'year' on counts of Lapwing pairs on lowland grassland sites around Northern Ireland. Coefficients for Upper Lough Erne are subsumed into the intercept.

	Count		
Predictors	*Log-Mean*	*CI*	P
(Intercept)	0.47	-0.78 to 1.71	0.462
Year [2018–19]	-1.26	-1.87 to -0.65	**<0.001**
Lough Neagh	-0.20	-0.60 to 0.21	0.341
Lower Lough Erne	0.47	-0.17 to 1.11	0.149
Area_hectares [log]	0.34	-0.01 to 0.69	0.059
Year [2018–19] : Lough Neagh	-0.86	-1.73 to 0.01	0.052
Year [2018–19] : Lower Lough Erne	0.89	-0.03 to 1.81	0.058
Zero-Inflated Model			
(Intercept)	-2.25	-5.10 to 0.60	0.122
Random Effects			
σ^2	0.55		
$\tau 00_{Site.Name:Region}$	0.06		
$\tau 00_{Region}$	0.00		
$N_{Site.Name}$	60		
N_{Region}	3		
Observations	114		
Marginal R^2 / Conditional R^2	0.617 / NA		

Table S3. Summary of zero-inflated GLMM outputs for the effect of time period ('year'), 'region', 'area' (hectares) and the interaction between 'region' and 'year' on counts of Curlew pairs on lowland grassland sites around Northern Ireland. Coefficients for Upper Lough Erne are subsumed into the intercept.

	Count		
Predictors	*Log-Mean*	*CI*	P
(Intercept)	0.42	-0.75 to 1.60	0.477
Year [2018–19]	-1.65	-2.48 to -0.82	**<0.001**
Lough Neagh	-0.47	-1.03 to 0.09	0.098
Lower Lough Erne	0.35	-0.26 to 0.96	0.258
Area_hectares [log]	0.04	-0.29 to 0.36	0.831
Year [2018–19] : Lough Neagh	-1.71	-3.16 to -0.26	**0.021**
Year [2018–19] : Lower Lough Erne	1.83	0.80 to 2.86	**0.001**
Zero-Inflated Model			
(Intercept)	-19.37	-18,072.39 to 18,033.64	0.998
Random Effects			
σ^2	0.99		
$\tau 00_{Site.Name:Region}$	0.16		
$\tau 00_{Region}$	0.00		
$N_{Site.Name}$	60		
N_{Region}	3		
Observations	114		
Marginal R^2 / Conditional R^2	0.703 / NA		

Table S4. Summary of zero-inflated GLMM outputs for the effect of time period ('year'), 'region' and the interaction between 'region' and 'year' on counts of Redshank pairs on lowland grassland sites around Northern Ireland. 'Area' is included as an offset and coefficients for Upper Lough Erne are subsumed into the intercept.

	Count		
Predictors	*Log-Mean*	*CI*	P
(Intercept)	-2.07	-2.85 to -1.29	**<0.001**
Year [2018–19]	-1.73	-2.61 to -0.85	**<0.001**
Lough Neagh	-0.21	-0.67 to 0.25	0.369
Lower Lough Erne	1.28	0.70 to 1.86	**<0.001**
Year [2018–19] : Lough Neagh	-0.80	-1.90 to 0.29	0.151
Year [2018–19] : Lower Lough Erne	1.61	0.59 to 2.63	**0.002**
Zero-Inflated Model			
(Intercept)	-2.21	-6.19 to 1.77	0.276
Random Effects			
σ^2	0.74		
$\tau 00_{Site.Name:Region}$	0.16		
$\tau 00_{Region}$	0.00		
$N_{Site.Name}$	60		
N_{Region}	3		
Observations	114		
Marginal R^2 / Conditional R^2	0.785 / NA		

Table S5. Summary of zero-inflated GLMM outputs for the effect of time period ('year'), 'region', 'area' (hectares) and the interaction between 'region' and 'year' on counts of Snipe pairs on lowland grassland sites around Northern Ireland. Coefficients for Upper Lough Erne are subsumed into the intercept.

	Count		
Predictors	*Log-Mean*	*CI*	P
(Intercept)	-0.18	-1.47 to 1.11	0.786
Year [2018–19]	-1.23	-1.74 to -0.72	**<0.001**
Lough Neagh	-0.36	-0.82 to 0.10	0.125
Lower Lough Erne	0.43	-0.21 to 1.07	0.187
Area_hectares [log]	0.69	0.30 to 1.08	**<0.001**
Year [2018–19] : Lough Neagh	-0.44	-1.15 to 0.27	0.222
Year [2018–19] : Lower Lough Erne	0.51	-0.29 to 1.31	0.213
Zero-Inflated Model			
(Intercept)	-20.17	-10,368.10 to 10,327.76	0.997
Random Effects			
σ^2	0.68		
$\tau 00_{Site.Name:Region}$	0.46		
$\tau 00_{Region}$	0.00		
$N_{Site.Name}$	60		
N_{Region}	3		
Observations	114		
Marginal R^2 / Conditional R^2	0.555 / NA		

Images: Liz Cutting / Hugh Insley / Nigel Clark. Cover image: Liz Cutting

Northern Ireland Lowland Breeding Wader Survey

Numbers of breeding waders are falling throughout the UK and increased agricultural intensification is amongst the causes of decline in species such as Lapwing, Common Redshank, Snipe and Curlew on the island of Ireland. During a tetrad-based survey of Northern Ireland in 1985–87, lowland grasslands held 51% of the total number of breeding wader pairs recorded. In 2018 and 2019, BTO conducted a resurvey of lowland sites to measure changes in the number of breeding wader pairs present and of habitat characteristics in the 30 years since the previous survey, enabling future conservation interventions to be focused at sites of particular significance. Analysis of the change in the number of wader pairs per site recorded during the breeding seasons of 1985–87 and 2018–19 revealed that there was a significant decline in breeding waders of all species and collectively across the surveyed sites in all regions, but that the Lower Lough Erne region had retained generally higher numbers of breeding waders than elsewhere. Overall, despite previously being a highly important habitat for breeding Lapwing, Curlew, Redshank and Snipe, lowland damp grasslands in Northern Ireland have undergone a drastic decline in their breeding wader numbers in recent decades. Many sites no longer have breeding waders present on them, although sites to the west of the country are more likely to still hold pairs. In lowland damp grasslands, waders are associated with fields containing both improved and rough grass, and fields with damp or flooded areas were important, although many sites were found to have evidence of draining. A better understanding of predation pressure, habitat use and the overall population of breeding waders across the whole country and, specifically, understudied regions in the west, namely the Sperrins and Fairy Water Bogs, would improve targeting of conservation measures to preserve breeding waders in Northern Ireland.

Katherine Booth Jones, Peadar O'Connell, John Calladine, David Noble, Shane Wolsey, Anne Carrington-Cotton & Chris Wernham (2020). Northern Ireland Lowland Breeding Wader Survey. BTO Research Report **731**, BTO, Thetford, UK.

ISBN 978–1–912642–21–2

9 781912 642212 >

BTO
NORTHERN
IRELAND