Factors influencing wader recovery in a non-reserve, river valley landscape

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Abstract

Waders breeding on farmland in Northern Europe have been declining for at least 50 years owing to field drainage and the intensification of agricultural practices. Low breeding productivity has been identified as the demographic driver, but despite the introduction of agri-environment schemes (AES) since the early 1990s, wader populations have continued to decline.

In many cases, AES agreements and management prescriptions have probably created ecological traps, with the cues used by breeding adults for selection of nesting sites becoming decoupled from the factors determining reproductive success. This is especially likely outside nature reserves, where there is fragmented land ownership and less control over all factors influencing wader productivity.

We monitored the effect on Northern lapwing *Vanellus vanellus* and common redshank *Tringa totanus* of an EU-funded wader recovery project in a non-reserve, river floodplain in southern England.

Results – improved lapwing breeding success, increased lapwing and redshank numbers. Winter rainfall has a large influence on lapwing breeding success and spring settlement patterns in this river valley situation.
Detail of effects of wet features and predator management.

Lessons learned, what could be achieved with continuation of management, what measures would help realise a greater population increase.

Introduction

Farmland bird populations have declined dramatically across Northern Europe since the 1960s (Chamberlain et al. 2000; Donald et al. 2001). Numbers of waders breeding on lowland wet grassland have been in decline for at least as long, with reductions in Northern lapwing *Vanellus vanellus*, common redshank *Tringa totanus*, common snipe *Gallinago gallinago*, black-tailed godwit *Limosa limosa*, Eurasian curlew *Numenius arquata*, Eurasian oystercatcher *Haematopus ostralegus* and ruff *Calidris pugnax* particularly evident since the late 1980s (Wilson et al. 2005; Lawicki et al. 2011; Kentie et al. 2015). The loss and degradation of suitable habitats resulting from agricultural intensification is well documented, with drainage, increased livestock rates, earlier mowing and conversion to arable implicated as the main issues for these waders (McCracken & Tallowin 2004; Wilson et al. 2004). In most cases, the demographic driver of declines has been identified as low breeding productivity, rather than a reduction in adult survival (Roodbergen et al. 2012), and more recent evidence from several studies suggests that predation of wader eggs and chicks is an important factor in wader declines (MacDonald & Bolton, 2008a; Teunissen et al. 2008; Schekkerman et al. 2009; Roos et al. 2018). The impact of predation on wader productivity is likely to be higher now than at the start of declines owing to lower availability of optimal habitat (Kentie et al. 2015), but also an increase in numbers of generalist predators (Lawicki et al. 2011; Roos et al. 2018).

Wader numbers have declined owing to the failure of breeding pairs to fledge enough young over many years (Roodbergen et al. 2012; Plard et al. 2019). Waders breeding on grassland all nest on the ground and their chicks are precocial, with most requiring areas of short vegetation or exposed mud supporting plentiful invertebrates, along with patches of taller vegetation affording cover for hiding nearby (Devereux ref?). Both nests and chicks are vulnerable to a range of generalist predators (MacDonald & Bolton 2008b), which may locate them more easily in sub-optimal habitats. Agricultural intensification has degraded chick-rearing habitats by reducing the availability of invertebrate food (ref), with the knock-on effect that hungry chicks may be more susceptible to predation. Methods for creating and maintaining suitable breeding habitat are well established and the effectiveness of individual habitat restoration measures, such as tree and scrub removal to maintain an open landscape, control of grazing to ensure suitable sward height and creation of shallow ditches to provide muddy margins for chicks, have been documented. EXPAND AND REFERENCE – REFER TO FRANKS PAPER. The importance of predation management has become more widely accepted during the last decade, but opinions differ on how best to implement it and which measures are most effective.

Agri-environment schemes have been introduced in several countries since the early 1990s, with options targeted specifically at addressing habitat for breeding waders, but these have failed to reverse large-scale population declines (Kleijn et al. 2001; Franks et al. 2018). It seems that schemes have not resulted in enough chick-rearing habitat and protection from predation, resulting in contractions of wader populations towards nature reserves (Smart et al. 2014). However, high levels of predation are now limiting population recovery efforts, even on reserves with optimal habitat, and it is becoming clear that in most cases habitat restoration alone is insufficient to ensure the levels of breeding success necessary for stable or increasing wader populations (Plard et al. 2019). Indeed, there is a risk that failure to implement predation management alongside habitat measures as part of wader recovery projects may result in the creation of population sinks.

The Avon Valley, running from Salisbury south to Christchurch, UK (51°04’N, 1°48’W to 50°44’N, 1°46’W) has historically supported nationally important populations of lapwing, redshank and snipe, which breed on the floodplain pastures and meadows (ref). The wet grassland has been protected from intensive management and conversion to arable land with the introduction of agri-environment schemes since 1993 and designation of the lower half of the valley as a Site of Special Scientific Interest (SSSI) and Special Protection Area (SPA). In common with other lowland wet grassland sites throughout Britain, however, numbers of breeding waders in the Avon Valley have declined dramatically since the early 1980s, with declines of 64% in lapwing, 75% in redshank and 97% in snipe during 1982-2002 (Wilson et al. 2005). The Avon Valley is an interesting example of a non-reserve situation where multiple land ownership and the lack of control over all factors influencing wader breeding success have made effective management for breeding waders harder than on nature reserves. Despite agri-environment options to improve habitat and ensure appropriate levels of grazing in spring, monitoring of lapwing productivity during 2007-2014 indicated that nest predation and insufficient wet features for broods were important in the decline of breeding pairs (Hoodless et al. in prep).

There is now increased recognition that active intervention is required to safeguard key populations of breeding waders and that a complete package delivering nesting areas, brood-rearing habitat and reduced levels of predation is required to ensure high levels of productivity. The aim of this study was to document changes in Lapwing breeding success and lapwing and redshank pair numbers resulting from a wader recovery project involving farmer engagement and targeted site management within the Avon Valley. Using data collected using standard methods during four years of new management and nine years prior to project implementation, we aimed to evaluate the effectiveness of a novel 'hotspot' management approach. We examine factors influencing lapwing breeding success and make recommendations for instigating wader recovery in non-reserve landscapes.

Methods

Study area

The study took place on the lower half of the Avon Valley, between Downton and Christchurch. The floodplain here varies from c.350 m to 1,100 m wide and the mixture of grazed pasture and hay fields vary in size between c.5 ha and 14 ha. Most are prone to, at least partial, winter inundation. The Avon Valley is important for wildlife and its SSSI and SPA designations reflect its value for a wide range of species, including breeding waders, wintering wildfowl, otters *Lutra lutra* and certain insects, molluscs and plants of national importance. Many areas of grassland within the valley have been subject to agricultural improvement and have lost much of their botanical interest, but there are limited areas of more diverse swards. Hence, while much of the valley grassland falls into the MG9 (*Holcus lanatus-Deschampsia caespitosa*) and MG10 (*Holcus lanatus-Juncus effusus*) NVC communities, MG8 (*Cynosurus cristatus-Caltha palustris*) is still present in certain locations. The floodplain is adjoined by patches of alder *Alnus glutinosa* woodland and mixed farmland bounded by mature oak *Quercus robur* and ash *Fraxinus excelsior* trees, and patches of brambles *Rubus fruticosus* and blackthorn *Prunus spinosa* scrub.

Two agri-environment schemes have operated in the Avon Valley, both of which had options which paid farmers for measures aimed at benefitting breeding waders. These included capital works such as ditch maintenance and removing trees and willow *Salix* spp. scrub from field boundaries, and reducing livestock densities during April-June. The Environmentally Sensitive Area (ESA) scheme ran for ten years from 1993 and the Higher Level Stewardship (HLS) scheme has been running since 2003.

Project management and study design

Annual wader monitoring across 22 farms, covered in whole or part, between Downton and Christchurch commenced in 2007. Data for 2007-2014 indicated that lapwing breeding success was too low to sustain a stable population without immigration (Hoodless et al. in prep). The LIFE+ Waders for Real project was initiated in autumn 2014 and issues concerning habitat suitability and predation were discussed with farmers. Because breeding wader densities were low relative to those on most nature reserves, resources were targeted at four 'hotspots' which each supported 9-25 pairs of lapwings during 2013-2014. These sites covered parts of eight farms, seven of which were in the HLS scheme, with land managers who were prepared to alter their management to increase wader numbers.

Management at hotspot sites included selective tree removal and willow *Salix* spp. clearance, as well as removal of derelict stock fences, to open field boundaries and create more attractive nesting areas (Table 1). This also removed some potential avian predator perches. Overgrown ditches were cleared of tall vegetation and reprofiled, and footdrains and scrapes were created within fields to provide more areas for broods to forage. Temporary electric fences (1.1 m tall, eight-strand alternating live and neutral wire fence, powered by a xxxxx 12V solar energiser; Rappa Ltd, UK) were erected around favoured nesting areas in March-early April to exclude foxes *Vulpes vulpes* and badgers *Meles meles*. Lethal control effort directed at foxes and carrion crows *Corvus corone* was increased at two hotspots during the project. The first habitat works commenced in October 2015 and hence hotspot sites were regarded as having new management for 2016-2019.

Parts of 14 farms were grouped into ten control sites because they experienced no change in management or only very limited habitat works (Table 1). Wader survey effort remained constant across all sites and methods were the same during all years, with the exception that samples of lapwing chicks were radio-tracked during 2015-2019, mainly on hotspots (Grayshon et al. in prep). This possibly resulted in slightly higher disturbance of broods, but care was taken not to approach broods closely more than once every ten days (ref).
Explain distribution of sites and distances between managed and control sites. Add a map – figure 1?

Wader surveys
At least two morning bird surveys of each site were conducted during April-mid-May 2007-2019, following standard wader survey methodology (O'Brien & Smith 1992), to determine the number of lapwing and redshank pairs using each field. From late March, weekly visits were made to each site to search for lapwing nests and broods, and the numbers, sexes and locations of lapwings were noted. This information was used to confirm or amend the pair estimates for each field derived from the complete surveys. Lapwing and redshank did not breed at all sites in all years and during 2007-2014 lapwing breeding success was not monitored at one or two sites with fewer than five pairs.

Nest monitoring
Each year a sample of lapwing nests was located from late March by observing sitting birds from vantage points at field edges. Nest locations were recorded using a hand-held GPS and detailed sketch maps. Occasionally, short garden canes (green, 30 cm) were placed as markers at least 10 m from certain nests to aid relocation. Marking nests in this way has been shown to have no effect on nest outcome (Galbraith 1987). Nests were only approached when first located and on all subsequent visits they were monitored at a distance using a telescope or binoculars, to check for the presence of an incubating adult. Visits were made to fields with lapwings present at weekly intervals to monitor nest survival. Eggs were measured and weighed when clutches were first located and egg-laying and hatching dates were estimated from egg density using the equations derived by Galbraith (1988a,b) when neither were known. Temperature loggers (iButton, Maxim Integrated Products Ltd) glued to a nail were inserted into the middle of the nest between the eggs. Loggers were programmed to record temperature every 15 minutes and enabled the timing of clutch failure or hatching to be estimated. Nest outcome was confirmed as eggs hatched, deserted, or predated from signs at the nest when the adult bird was no longer sitting. In some cases, it was possible to distinguish instances of bird and mammal predation based on characteristic remains (ref).

Estimation of brood survival and young fledged per pair

Lapwings produce distinctive alarm calls when they have chicks (Cramp & Simmons 1983) and observations of adult behaviour enabled the presence or absence of a brood to be determined for each pair of adults on each visit to a field. Weekly observations enabled estimation of the number of broods that survived to fledging. As a minimum in all years, we determined whether each pair of lapwings hatched a clutch of eggs and, if so, whether it managed to fledge at least one chick. Brood size and approximate chick age were estimated whenever chicks were seen (refs). This information was used in combination with pair location and the interval between visits to estimate dates of chick mortality or fledging.

Field attributes and habitat measures

Field sizes, sizes of areas with new management, the lengths of existing and new wet features, and areas enclosed by electric fences were determined using the GIS package ArcGIS xx (ref). Standing water in fields was estimated to the nearest 5% on visits during the first half of April. Thirty measures of sward height (to 1 cm), soil softness (using a standard penetrometer to 0.25 kgF), and dominant vegetation type were recorded in the latter half of April and again in the latter half of May in xx–xx of the main fields used by waders each year. Average livestock density (LU/ha) during April and May was calculated from records of the number of livestock present on all visits to a field.

Monthly rainfall totals were obtained from the Met Office historic station dataset for Hurn (50°47'N, 1°50'W), which lies 3 km to the west of the southern half of the floodplain (https://www.metoffice.gov.uk/pub/data/weather/uk/climate/stationdata/hurndata.txt).

Statistical analysis

We examined the effect of the new management at hotspot sites on measures of lapwing breeding success within a generalized linear model (GLM) framework at the site-year level. We first compared the variation explained by site and year, and then examined the effect of replacing year with the variables November-April rainfall and May rainfall. The effect of management was examined with data from all study years and then restricted to project years. All models included site, year or rainfall variables, and management as fixed effects. It was not possible to include interactions because lapwings did not nest on all sites in all years and because management was aliased with site and year. Dependent variables tested were the proportion of pairs hatching a brood (i.e. pairs that hatched a brood as the dependent variable, a binomial error distribution and number of pairs as the number of binomial trials), the proportion of pairs fledging a brood (pairs that fledged a brood as the dependent variable, a binomial error distribution and number of pairs monitored to completion as the number of binomial trials), and young fledged per pair (number of chicks fledged as the dependent variable, a Poisson error distribution, log link function and $\log_e$(number of pairs) as the offset). Overdispersion in models was corrected by the inclusion of a dispersion parameter equivalent to the deviance divided by the degrees of freedom.

Daily nest survival rates were estimated by the Mayfield method (Mayfield 1961, 1975). Incubation was assumed to last 25 days on average and egg-laying to take 6 days (Galbraith 1988b). Daily nest survival rates were modelled at the site-year level using logistic regression, with total days of nest exposure as the number of binomial trials and days that the nest survived as the number of successes (Aebischer ref).

For analysis of change in the number of breeding birds, the logarithmic ratio of change in numbers of pairs between consecutive years was calculated as the dependent variable. Because there were no breeding pairs in some site-years, 0.5 was added to all numbers of pairs before the logarithmic ratio of change was calculated. If management was effective, an increase in breeding numbers could result from improved breeding success in previous years or from increased settlement of pairs in the current year in response to improved habitat or perceived safety from predators (Fontaine & Martin 2006). We therefore examined change in pair numbers in relation to site management in the current year and the previous year. For previous-year effects, a one-year lag was used to reflect the typical recruitment age for lapwing and redshank (Peach et al. 1994). GLMs with Normal errors and an identity link function were performed, with site and year included in all models as structural variables. Site management, previous winter (November-March) rainfall, and, for lapwing, productivity (fledged chick/pair) in the previous year were each tested separately as explanatory variables. Standard errors from the log scale were approximately back-transformed using Taylor series linearization (Seber 1982).

Field-year level analysis to examine effects of sward height, soil penetrability, presence of wet features, opening up of boundaries, predator management. Include farm as a random factor.
Could include avian predator sightings as a variable. Or use corvid sightings and mammal encounter rates on trail cameras as a measure of predator control efficiency.
Conduct an analysis of the same fields, paired before and after implementation of management. Examine change in pair numbers and breeding success.
Breeding success in relation to winter rainfall at hotspot sites– does the relationship differ before and after management?

Analyses were conducted in Genstat 19.1 (Lawes Agricultural Trust 20xx). Mean values are presented with standard errors unless stated otherwise.

Results

Comparability of hotspot and control sites

Wader densities and lapwing breeding success on hotspot and control sites prior to the start of the project. Both similar – provide evidence.

Lapwing breeding success

In initial models using data for all study years, with just farm and year as factors, year was significant and explained more deviance for all three lapwing breeding success variables than farm. Farm did not explain a significant amount of the variation in any of the breeding success variables. When year was substituted by November-April rainfall and May rainfall, these variables had a significant influence on the proportion of lapwing pairs fledging broods (November-April rain Wald $X^2_1 = 15.16$, $P < 0.001$; May rain Wald $X^2_1 = 9.77$, $P = 0.002$) and the number of chicks fledged per pair (November-April rain Wald $X^2_1 = 13.82$, $P < 0.001$; May rain Wald $X^2_1 = 4.00$, $P = 0.047$) (Fig.1).

Justify use of rainfall variables – year partially confounded when all years tested, rainfall more biological significance.

Tests of project management in models including site and the rainfall variables indicated a 49% increase in lapwing productivity at managed sites (P = 0.037, Table 2, Fig.2). When the analysis was restricted to the project years, the proportion of pairs hatching a brood was 45% higher at managed sites (P = 0.030), and overall productivity was 60% higher, although the difference was not significant for the latter variable with this lower number of years (Table 2).

Long-term effects of predator control in the Avon Valley.

Lapwing nest survival

Lapwing nest survival calculated from daily exposure was significantly higher for managed site-years than control site-years.

Examine any change in the frequency of diurnal and nocturnal clutch predation, especially in relation to electric fences.

Change in number of wader pairs

At the valley level, the mean rate of change in lapwing pairs was negative in the years prior to the start of the project (-11.0 ± 11.8% per annum) and positive during project years (13.6 ± 16.7% per annum), but the difference was not significant ($F_{1,10}$ = 1.44, P = 0.257) (Fig.3). Annual change in total lapwing pairs for the valley was not related to overall productivity the previous year ($F_{1,10}$ = 2.86, P = 0.122), but was positively related to November-March rainfall ($F_{1,10}$ = 5.89, P = 0.036) (Fig.4).

Analysed at the site level, annual change in lapwing pairs was not related to management in the current year ($F_{1,153}$ = 0.04, P = 0.832), nor the previous year ($F_{1,153}$ = 0.35, P = 0.554). There was no relationship between annual change in lapwings pairs and productivity (chick/pair) the previous year ($F_{1,129}$ = 0.71, P = 0.401), but we found a weak indication that the change in pairs was positively influenced by the proportion of pairs fledging a brood in the previous year ($F_{1,112}$ = 2.77, P = 0.099). Predator control in the previous year had no influence on change in lapwing pairs ($F_{3,151}$ = 0.07, P = 0.974). Substituting November-March rainfall for year revealed a positive relationship with annual change in lapwing pairs ($F_{1,164}$ = 4.11, P = 0.044).

Change in redshank pairs

Field-level effects of wet features and electric fencing

Lapwing breeding success at the field level, modelled with wet feature length and presence/absence of electric fence.

Compare lapwing breeding success before and after management for the subset of fields managed during the project.

Compare numbers of lapwing and redshank pairs before and after management for the subset of managed fields.

Make the link between winter rainfall and the suitability of in-field wet features for broods in late April-May.

Discussion

Monitoring data gathered on lapwing breeding success since 2007 indicated that poor breeding success was the driving factor for the decline in breeding lapwing in the Avon Valley, with the main cause being high levels of nest and chick predation and consequent low levels of recruitment into the breeding population. High predation pressure could come from increased predator abundance, but poor-quality habitats can exacerbate predation risk, especially when chicks are forcedly exposed when searching for food. The linear nature of the Avon Valley restricts idealistic management of the river meadows where waders breed, both in terms of being able to create ideal habitat and managing predation-risk. For example, there are large tracts of forest land either side of the valley which harbour unmanaged populations of common predators, like foxes and carrion crows, and plentiful anthropogenic food resources associated with human settlements and rural enterprises like gamebird releasing and fish farming, may benefit those species. Also, the net result of a large number of riparian landowners and farmers in the valley is leads to a variety of river meadow management practices which can influence predator and small mammal prey abundance.

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

The project approach to delivering wader recovery in the Avon Valley was to focus effort and resources onto four main 'hotspot' sites. This gave us the best chance for success with the expectation that if we were able to increase breeding success on these sites, birds would then recolonise neighbouring areas.

Winter rainfall has a large influence on numbers of lapwings settling in the Avon Valley each spring and clearly affects the suitability of chick rearing areas. As well as maintaining current footdrains and scrapes, future work should focus of ways of getting water onto fields in dry springs. Discuss current abstraction limits and the feasibility of pumping water as on many reserves.

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Table 1. Summary of site details, bird numbers and the management on hotspot sites and comparison farms.

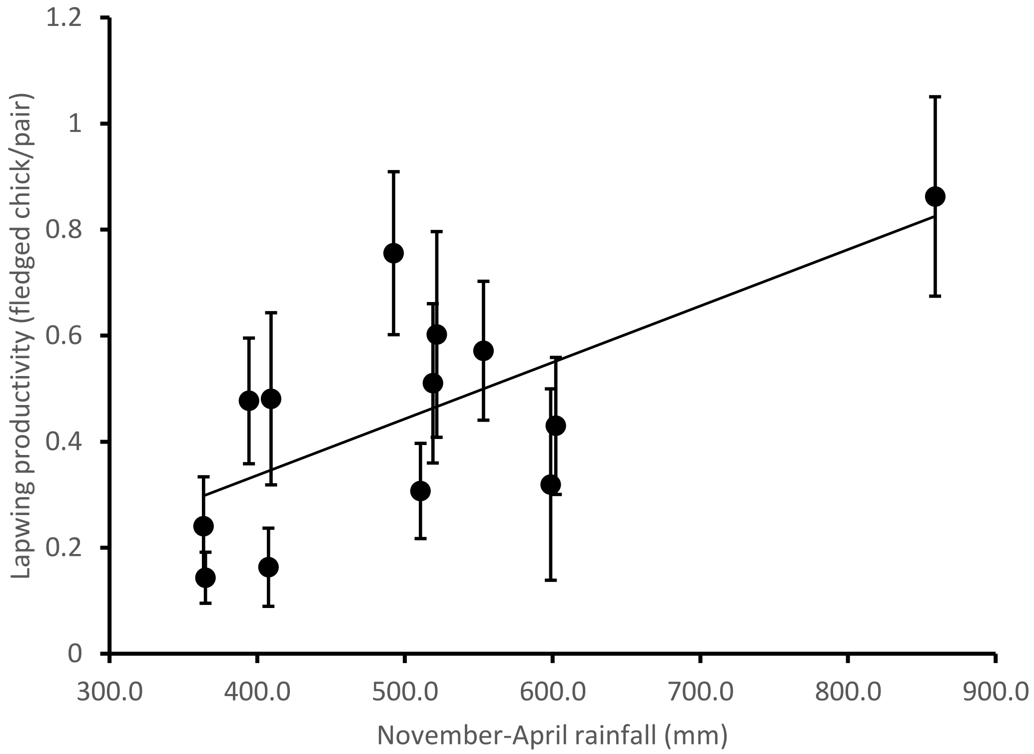
Parameter	Hotspot sites Total (mean ± SE per site)	Control sites Total (mean ± SE per site)
Size of site (ha)		
Pairs of lapwing at start of project		
Pairs of redshank at start of project		
Management advice	Detailed plans, site meetings	General advice
	Support for derogations and beneficial practices	Support for derogations and beneficial practices
Field boundaries		
Stock fence removed (m)	1,259	0
Boundary willows removed (m)	6,014	0
Trees felled	15	0
Wet features		
Ditches restored (m)	3,519	2,088
Footdrains created (m)	1,686	0
Scrapes dug (m^2)	10,023	2,019
Predator management		
Electric fences	2016 1 fence, 1.37 ha 2017 3 fences, 3.05 ha 2018 5 fences, 6.75 ha 2019 8 fences, 11.46 ha	2018 2 fences, 1.42 ha
Management advice	Advice on best practice lethal predator control Feedback on fox detections on trail cameras to aid lethal control	No assistance

Table 2. Effects of management on lapwing breeding success. GLM models including site, November-April rain and May rain as structural variables.

Period	Variable	Managed sites Mean ± SE	Control sites Mean ± SE	Wald X^2	P
All years	Proportion of pairs hatching broods	0.66 ± 0.06	0.59 ± 0.03	0.84	0.362
All years	Proportion of pairs fledging broods	0.32 ± 0.04	0.25 ± 0.02	2.24	0.137
All years	Fledged young per pair	0.64 ± 0.11	0.43 ± 0.04	4.42	0.037
Project years	Proportion of pairs hatching broods	0.71 ± 0.05	0.49 ± 0.08	5.03	0.030
Project years	Proportion of pairs fledging broods	0.35 ± 0.05	0.23 ± 0.06	2.31	0.136
Project years	Fledged young per pair	0.67 ± 0.12	0.42 ± 0.12	2.45	0.124

Figure 1. Effects of November-April rainfall (a) and May rainfall (b) on lapwing productivity (fledged chick/pair). Points are means ± SE.

(a)



(b)

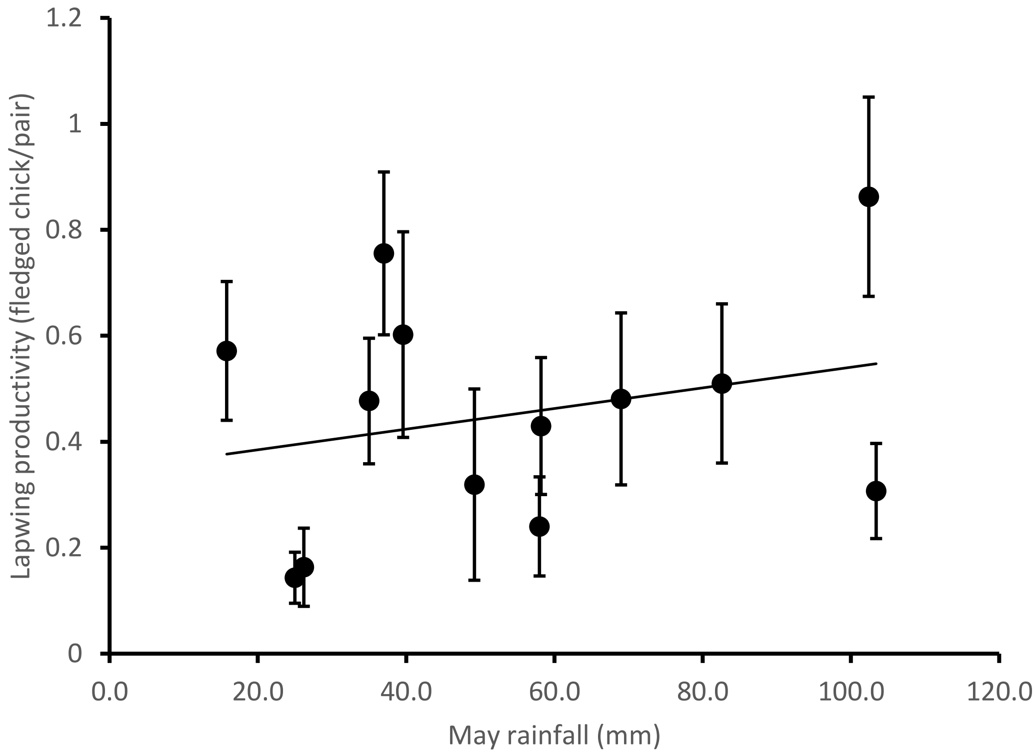


Figure 2. Estimated lapwing productivity (mean ± SE fledged chick/pair) in the Avon Valley during 2007-2019. Open bars represent control years and sites, black bars represent managed sites in 2016-2019.

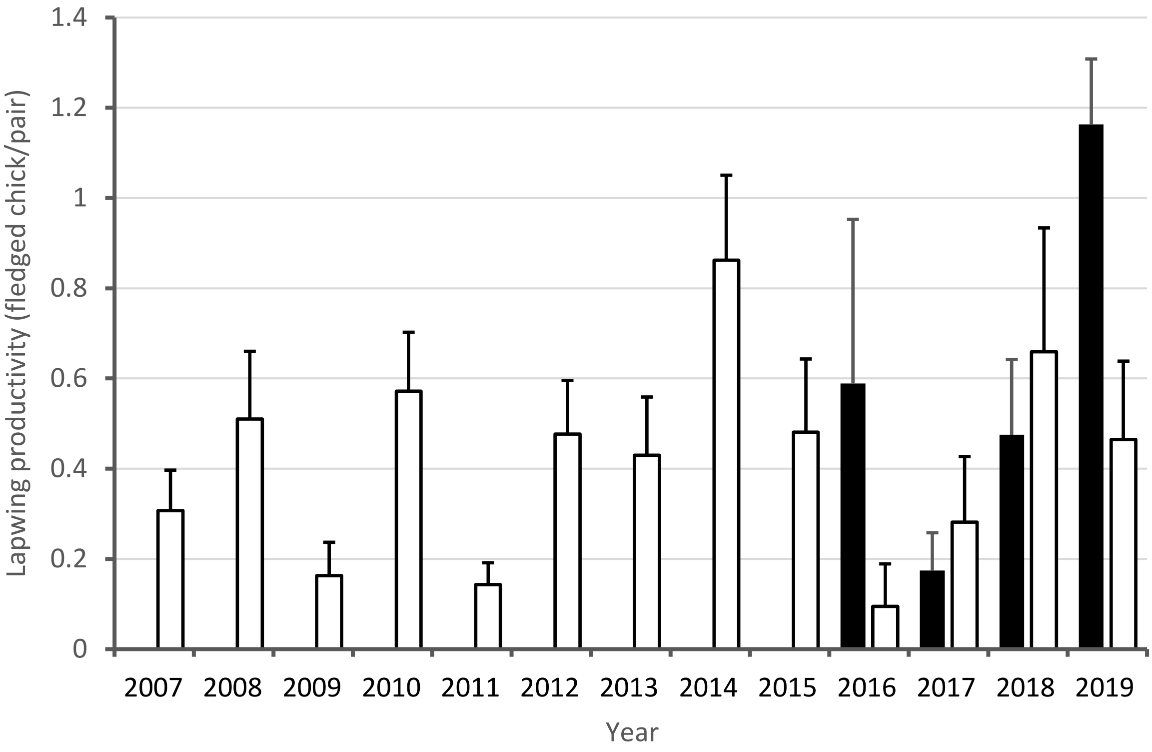


Figure 3. Number of lapwing pairs breeding in the Avon Valley between Downton and Christchurch, 2007-2019. Regression lines show the trends before the wader recovery project (2007-2015) and for the years of active management (2016-2019).

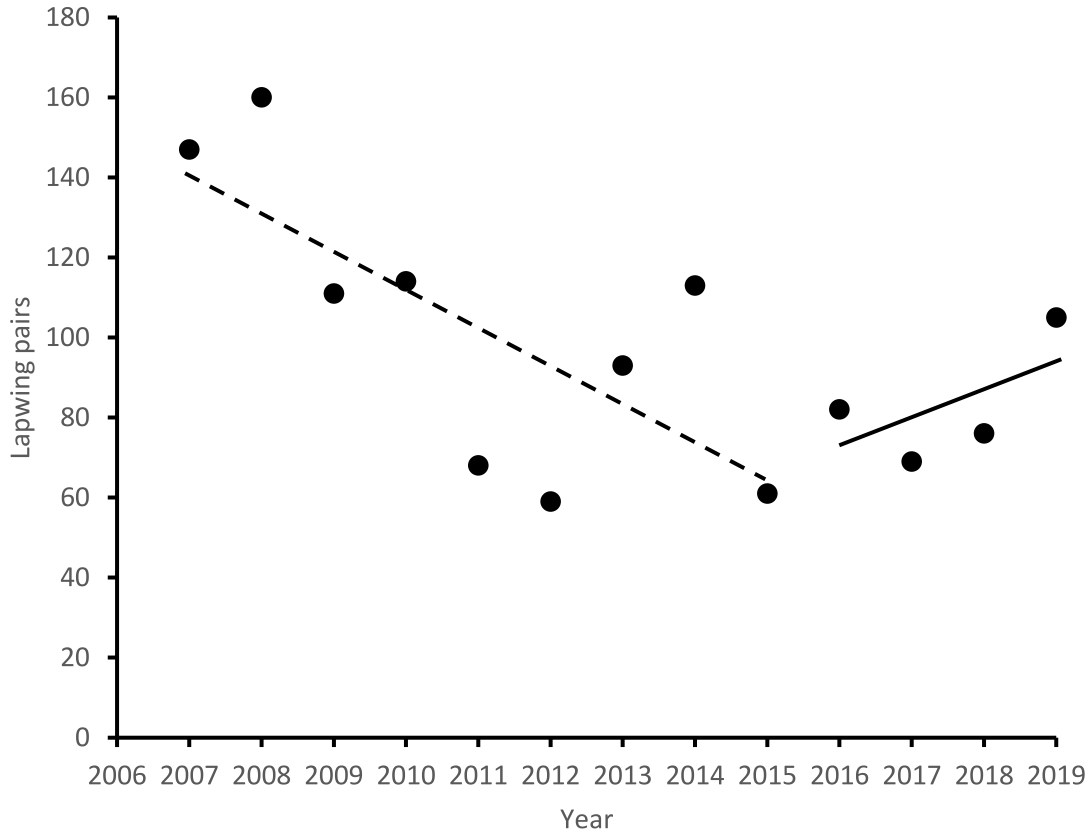


Figure 4. Relationship between the number of lapwing pairs breeding in the Avon Valley between Downton and Christchurch and rainfall the previous winter (November-March).