Effectiveness of providing in-field wet features at increasing lapwing chick survival in a non-reserve situation

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ABSTRACT

INTRODUCTION

Lapwing *Vanellus vanellus* have suffered a decline in breeding population of 65% since 2013 (Rspb, 2015), leading to them being put on the UK red list of birds of conservation concern (Eaton *et al.*, 2015). Declines in the breeding population of lapwing in the UK have mainly been driven by loss of their breeding habitat; areas of wet grassland have been destroyed by land drainage and associated intensification of grassland management (Newton, 2004). Lapwing declines have been seen nationally and the evidence suggests that the main driver is high chick mortality, changes in nest survival and adult survival cannot explain the decline alone (Sharpe *et al.*, 2008). However, the reason for this low chick survival will differ between sites.

Although poor chick survival may be an important factor limiting productivity and therefore lapwing population recovery (Peach *et al.*, 1994; Sharpe *et al.*, 2008), many studies have focused on lapwing nest survival rather than chick survival and fledging success. Monitoring chick survival is potentially harder than nest survival because chicks are mobile, and their fates are more difficult to establish.

To increase lapwing chick survival, we need to better understand what habitat features are most important for chicks, for example what features are used by chicks when foraging. Wet features have been linked to higher lapwing densities and chicks are more likely to forage near them (Eglington *et al.*, 2008). In-field shallow wet features provide high invertebrate prey densities and better foraging conditions for lapwing chicks (Eglington *et al.*, 2010). However, we do not know if this translates to higher chick survival rates, and therefore fledging success, in areas with increased amounts of wet features. The wet meadow grassland habitat associated with the river Avon, which flows through Wiltshire, Hampshire and Dorset in the southern UK, has experienced typical changes in lapwing populations and land management and therefore provides an appropriate study system for addressing this question. Lapwing numbers in the Avon Valley decreased by 64% from 1982-2003 and the population fell to around 60 pairs in 2011-2015 (Grayshon and Hoodless, 2017). The Avon Valley has a relatively high nest survival rate averaging 46.4% before 2015 and 51.5% 2015-2018. Therefore, it seems likely that poor chick survival could be limiting lapwing numbers in this habitat.

Since 2014, an EU Life+ project; 'Waders for Real', which is a collaborative project between farmers, keepers, landowners and conservation organisations, has aimed to facilitate lapwing population recovery in the Avon Valley. The project approach was to create strategic hotspots of optimum habitat with reduced predation pressure, where the birds are able to fledge sufficient chicks to increase recruitment to the population and where higher breeding densities enable the birds to better fend off predators (Berg *et al.*, 1992) . This approach involved several management interventions designed to increase lapwing chick survival. These have included habitat management and restoration strategies aiming to increase the density of wet features, such as adding scrapes to the middle of fields, re-digging ditches and removing scrub along ditch lines and predation mitigation strategies such as removing dead trees and old fence lines which can act as perching posts for avian predators.

This project therefore provides a useful opportunity to examine the factors effecting lapwing chick survival in wet grassland habitat. By intensively monitoring lapwing breeding success, and in particular chicks, over the course of the project we could explore how different habitat factors influence chick survival. By radio-tagging a sample of lapwing chicks and tracking their movements we could investigate their habitat use and foraging activity in relation to wet features, for example.

The high levels of wet features implemented on a reserve scenario can be unrealistic for a farming situation. This study explored whether implementation of a smaller number of scrapes and ditches in key lapwing nesting fields on wet grassland within a non-reserve river valley landscape is sufficient to improve lapwing chick survival and productivity. This could illustrate potential management strategies that are economically workable alongside low intensity farming in wet meadows.

METHODS

Study site – The Avon Valley

The Avon Valley is a typical river valley system with varied ownership and management. The water meadows run in a linear system alongside the river, the study area stretches over 25km, with the widest section of water meadows at around 1km. The study area consists of 18 different sites, average site area is 77.8 ha. Due to the linear layout of the sites, sites fit together at northern and southern ends however, east and west sides are neighboured by arable land, woodland or urban areas.

Most farms within the Avon Valley are enrolled onto higher level stewardship schemes and now beginning to enter into countryside stewardship (Natural England, 2015). These higher-level schemes alongside the SSSI designation allow for low intensive farming practices which work alongside conservation measures. Farms either manage fields with low intensive grazing, or for hay, often with aftermath grazing.

Lapwing breeding success

Lapwing chick survival in the Avon Valley was monitored using a number of methods between 2015 and 2018.

Breeding wader surveys

Breeding wader surveys were conducted every two weeks, surveys commenced in late March and span the lapwing breeding season. On each visit, the total number of adult lapwings, number of sitting adults, number of alarm-calling females and numbers of young according to age class were recorded. The surveys yield information on site occupancy and overall productivity per site and were used to inform our assessment of brood survival.

Lapwing chick survival

Ideally chicks were caught on day of hatching while still in the nest. Once caught, chicks were fitted with a metal BTO ring with a unique code. Biometrics were taken - bill and tarsus length (to 0.1 mm), weight to 0.1g. One chick per brood was randomly selected to be fitted with a 0.4g, 30-day life, Pip Ag379 VHF tag, glue mounted to the chicks back (chicks could be radio-tagged from day 1 providing they weighed at least 16g). In cases when chick age was not known (when chicks were not found on day of hatching) bill length was used to calculate chick age (Beintema and Visser, 1989).

At each capture location environmental variables which might affect chick condition were measured. Measures of factors which might affect foraging conditions were taken (n = 169). Specifically, percentage cover of bare ground, soil penetration resistance and vegetation height. Distance to nearest wet feature was also calculated (n = 238).

Other factors that might affect chick condition were also measured. The presence of con-specifics could influence the levels of harassment from predators, for example. We measured this by counting the number of females alarming in the field in which the chick was captured.

Chicks were radio-tracked twice a week where possible by triangulation from field edges and will only be approached closely where death is suspected (tags indicating a static signal or no movement or a very large movement since the previous day). Fixes recorded on 1:10,000 scale maps with the time of the fix and information on whether the chick was seen or assumed alive by adult behaviour.

Chicks were classified as fledged once they reached 35 days of age. If a radio tagged chick could not be re-located, the search area was expanded. If the rest of the brood appeared to still be alive, we attempted to recapture another chick from the brood. If the signal from a tagged chick was coming from an area unlikely to be used by Lapwing e.g. woodland or an unsuitable field, this was investigated further and if possible, the tag retrieved. Survival outcomes were made on a case by case basis. In some cases when remains were recovered an assessment of cause could be made; for example if a tag was high in a tree avian predation was assumed and if a tag was buried mammalian predation was assumed. Exact predator identity could only be assigned in a few cases.

Lapwing habitat use

Brood foraging locations

Firstly, we attempted to gain insight into the habitat preferences of the lapwing chicks; at each catching occasion, environmental measurements were taken where chicks had been observed foraging. Environmental variables (soil penetration resistance, vegetation height and percentage cover of bare ground, of grass and of dicots) were measured at 119 brood foraging locations and paired random locations. This could indicate how chick foraging preferences related to wet features.

Chick condition and chick survival

Secondly, we examined habitat factors, particularly with relation to wet features, likely to affect chick survival and chick condition.

Distance to nearest wet feature was measured for each location at which an individual chick was radio-tracked and averaged across locations. Wet features were mapped using OS vector data, and satellite imagery (Contains Ordnance Survey data © Crown copyright and database right 2014). New features added in the last four years were mapped using handheld GPS units. Maps were created for each year to allow for new features being added each year.

In each year of data collection vegetation height and soil penetration resistance were systematically sampled across fields used by lapwing in the study area. The vegetation heights and soil penetration resistance measures from the fields in which chicks were radio-tracked were extracted from this dataset.

There was variation in the frequency of vegetation height and soil penetration resistance sampling between fields. To get summary measures for each chick, vegetation height and soil resistance measures taken in the year the chick was radio-tracked were averaged across all fields the chick was located in.

To assess the impact of the presence of conspecifics the number of females calling in the fields the chicks were radio-tracked in was counted. This measure was also averaged across all the fields a given chick was located in.

Daily weather data were sourced from the nearest Met Office Land Surface Stations to the study area; Hurn (50.78°N, 1.83°W) for temperature data (Met Office, 2006b) and Bisterne (50.81°N, 1.78°W) for rainfall data (Met Office, 2006a). These were used to calculate winter (November-March) rainfall totals and temperature and rainfall variables for the seven days prior to chick capture.

Statistical analysis

Brood foraging locations

To determine whether brood foraging locations differed from random locations, we used MANOVA (Multiple Analysis of Variance) with the difference values between paired locations for each of the five field variables as the dependent variables and year as a factor. We checked for significance in this multivariate test first, to reduce the possibility of type 1 error, before examining differences in individual field variables. We used paired t-tests to assess differences between brood and random locations for individual variables. All variables were checked for normality and homogeneity of variance (using Bartlett's test) before inclusion in analysis. MANOVAs were carried out using the *car* package (Fox and Weisberg, 2011).

Chick condition

Chick condition was examined by fitting a Gompertz growth curve (Ricklefs, 1967, 1968; Fletcher *et al.*, 2010) of chick weights (g) for all years on chick age (days). The curve was described by the equation: weight = 205.36 x exp(-2.8113) x exp(-0.07234 x age). Recapture rates of chicks were low and so for chicks measured more than once data from one capture was randomly selected. Growth curve residuals were then used as a measure of the relative condition of chicks.

These residuals comprised the response variable in a general linear mixed model (GLMM) examining factors influencing chick condition. Independent environmental variables considered likely to affect chick condition and included in the model were: cover of bare ground (%), soil penetration resistance (kg), vegetation height (cm) and distance to the nearest wet feature (m) ($n = 238$). The number of alarm-calling females in the field in which chicks were located was fitted as a three-level categorical predictor ($n = 233$). Total rainfall (mm) and average minimum temperature (°C) in the seven days preceding chick capture were included. To account for the possibility that amount of rainfall in the previous seven days could affect other environmental variables first order interaction terms between rainfall and soil penetration resistance and rainfall and distance to wet features were also fitted. We accounted for any effects of sampling strategy by fitting chick age at capture and sampling year as fixed effects, and brood identity and farm as random effects.

Chick survival

Chick survival was analysed using a generalised linear mixed model with a binomial error distribution and logit link function (Aebischer, 1999). The response variable was days survived/days exposed – days survived. The mean distance to a wet feature (m), vegetation height (cm) and soil penetration resistance (kg) in the field in which the chick was reared and the mean number of alarm-calling females in the field were fitted as predictors. As with the chick condition model, year and chick age at tagging (days) were fitted as fixed effects, and brood identity and farm were fitted as random effects. In this case, brood identity was included because in a few instances two chicks from the same brood were radio-tracked.

Wald tests were used to examine the influence of fixed effects in GLMMs (Aebischer *et al.*, 2014). All fixed effects were included in minimal models, but we removed non-significant first-order interactions to assess the significance of main effects (Crawley, 2012; Fox *et al.*, 2013). We used diagnostic plots to evaluate GLMM assumptions (Thomas *et al.*, 2015). All analyses were carried out in R v3.5.1 (R Core Team, 2018). GLMMs were built using the lme4 package (Bates *et al.*, 2014).

RESULTS

The survival and condition of lapwing chicks monitored in the Avon Valley were influenced by the habitat conditions they experienced. Although conditions which can be influenced by management, including those associated with wet features and sward height, did affect chicks, large annual differences in external environmental factors were also influential in determining chick condition and chick survival.

Brood foraging locations

There was an overall difference in the values of field variables measured at brood and random locations (MANOVA Wilk's Λ = 0.687, df = 1,115, P<0.001) and variation in this difference between years (MANOVA Wilk's Λ = 0.554, df = 3,115, P<0.001). Differences between brood and random locations across the five variables were significantly different from zero in each year (2015: Λ = 0.530, df = 5, P <0.001; 2016: Λ = 0.529, df = 5, P = 0.005; 2017: Λ = 0.310, df = 5, P <0.001; 2018: Λ = 0.280, df = 5, P<0.001). Despite the variation in magnitude of overall effects between years, the results of paired t-tests on each of the five variables for each year were broadly consistent. There was with little difference in vegetation height, or sward composition between brood and random locations (Table 1, supplementary material). However, there was more bare ground and the soil was more penetrable at brood locations in all four years (bare ground: year P = xx, location P = xx, year x location P = 0.xx, date P = 0.xx; soil penetration resistance: year P ≤ 0.01, location P ≤ 0.01, year x location P = 0.312, date P = 0.949).

Chick condition

Chick condition was affected by the combination of rainfall during the seven days preceding capture and soil penetration resistance at the capture location. Consequently, chicks in locations where soils were harder (higher soil penetration resistance) were in better than average condition with more rainfall, but those feeding where the soil was softer had reduced condition following higher rainfall (Table 1, Figure 2). Higher amounts of rainfall in the previous week was associated with higher chick condition at sites where chicks could not easily penetrate the soil.

Mean chick condition varied between years, being significantly higher in 2016 and 2018 than in 2015 and 2017. Examination of annual differences in the seven continuous independent variables included in the chick condition model, and winter (November-March) rainfall, indicated that winter rainfall and soil penetration resistance differed significantly between years (ANOVA F = xx, P = xx and F= xx, P = xx respectively) and correlated broadly with annual differences in lapwing chick condition (Figure 3). Fitting winter rainfall to the minimal GLMM instead of year indicated that chick condition was higher following wetter winters (Wald's t-test = 2.46, df = 51.59, p=0.017).

Survival of radio-tracked chicks

Of the radio-tracked lapwing chicks whose fate was known (n = 81), 28 (35%) survived until fledging. Of the chicks which did not survive to fledging, 20 (38%) were known to be predated and a further 22 (42%) were assumed to be predated. Of those known to be predated 35% were taken by avian predators. In a further 4% of cases other causes of death were attributed; 1 chick was trampled, and 1 chick drowned in a ditch. For the nine remaining chicks cause of death could not be determined (See Table 2).

Significant difference in daily chick survival rate between years ($F_{3,95}$ = 3.62, P = 0.016) with no significant effect of age of tagging ($F_{1,95}$ =2.78, P = 0.098). Daily survival rates were 2015 0.9061 ± 0.02865, 2016 0.9795 ± 0.00936, 2017 0.9247 ± 0.02563, 2018 0.9635 ± 0.01532.

Chick survival was affected by environmental variables (Table 3); survival was lower for chicks that spent time in fields in which vegetation height was higher. Chick survival also differed significantly between years, being higher in 2018.

DISCUSSION

Improving lapwing chick survival is likely to be critical in achieving reversal in the current population decline observed across many wet grassland sites (Newton, 2004). Identifying habitats factors which influence this survival is therefore of critical conservation importance. In this study we identified environmental and habitat factors which affected lapwing chick survival and condition.

Availability of chick foraging habitat

Although we did not find a direct relationship between the proximity of wet features and lapwing chick condition or survival, we did find indications that wet features are important to lapwing chicks in the Avon Valley.

Lapwing chicks preferred to forage in area with more exposed bare ground and in areas with softer soil, these conditions are likely to facilitate feeding (Eglington *et al.*, 2008). In the wet grassland habitat of our study site it is likely that these conditions were associated with wet features.

The importance of penetrable soils to lapwing was further evidenced by the observation that higher amounts of rainfall in the previous week was associated with higher chick condition at sites where chicks could not easily penetrate the soil, however if chicks were feeding in soft soil areas, higher rainfall can reduce chick condition.

This suggests that chick condition can be improved when soils are more penetrable. The creation of wet features is one way to produce areas of more penetrable soil in a farmed environment. However, other external factors are also likely to affect the availability of this preferred chick foraging habitat. Lapwing chick condition was higher in years following a wetter winter. Overwinter flooding is likely to be associated with a higher water table in the breeding season and possibly with the availability of improved foraging habitat (Bellebaum and Bock, 2009).

It was not just the penetrability of soil that could influence the suitability of habitat for foraging. Chicks in fields where vegetation was shorter had higher survival. This could be because shorter vegetation makes prey more accessible to chicks and facilitates chick mobility (Kentie *et al.*, 2013).

Other causes of chick mortality

It is worth noting that, although not directly examined here, variation in these habitat attributes (and associated foraging habitats) are likely to interact with other causes of chick mortality (Whittingham and Evans, 2004). Predation was the largest cause of chick mortality in this study and it is likely that chick risk of predation is related to the availability of suitable foraging habitats. When foraging habitat is scarce chicks may have to move further to forage increasing their exposure to predators (Durant *et al.*, 2008). Overwinter flooding could also affect predation rates. If sites are flooded overwinter mammalian predators may be slow to re-colonise in spring (Bellebaum and Bock, 2009). In addition, vegetation heights may influence the ability of chicks to perceive approaching predators and their ability to escape (Kentie *et al.*, 2013).

Management implications

This research highlights the importance of creating suitable habitat in improving lapwing chick survival and condition. However, it also illustrates some of the challenges of achieving this habitat in practice, particularly in a non-reserve situation.

Most sites within the study were managed by different farms, this difference in management can lead to large site and year effects. The Avon Valley is a floodplain and is prone to both winter and summer flooding, these flooding events have a large effect on management, especially summer flooding events. Although the LIFE Waders for Real project aimed to influence management on some sites, it was not possible to standardise management across sites. In addition, on these sites it is not possible to regulate water levels, this means that external factors such as overwinter flooding and breeding season rainfall are likely to have a large influence on lapwing breeding success. Creation of lapwing chick rearing habitat reliably year on year is likely to be critical in reversing long term population declines.

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TABLES

*Table 1: Relative influence of field variables and year on lapwing chick condition, measured as residual from a growth curve estimated for all chicks in all years. Reference levels were Year – 2015, Number of broods in field – 1. * p<0.05.*

Fixed effects		Estimate	Std. Error	df	Wald	P
Distance to wet feature (m)		-0.007	0.005	64.288	-1.418	0.161
Total rainfall in 7 days preceding capture (mm)		-0.051	0.023	116.792	-2.268	0.025*
Soil penetration resistance (kg) at capture location		0.005	0.069	120.798	0.065	0.948
Average minimum temperature in 7 days preceding capture (°C)		0.012	0.046	49.432	0.251	0.803
Vegetation height (cm) at capture location		0.015	0.016	65.741	0.936	0.353
Area of bare ground at capture location (%)		-0.006	0.006	57.784	-1.034	0.305
Age at tagging (days)		0.004	0.015	123.890	0.256	0.799
Year	2016	1.347	0.461	41.623	2.922	0.006*
	2017	0.524	0.508	46.434	1.032	0.307
	2018	1.037	0.453	43.818	2.289	0.027*
Number of broods in field	2	0.206	0.317	61.865	0.651	0.517
	3+	0.339	0.335	52.166	1.011	0.317
Total rainfall in 7 days preceding capture*Soil penetration resistance (kg) at capture location		0.012	0.005	117.205	2.518	0.013*

Table 2: The fate of ninety-eight chicks radio-tracked over four years (24 in 2015; 31 in 2016; 19 in 2017; 24 in 2018).

Outcome	Cause	Number of chicks
Fledged		28
Failed	Assumed predated	22
	Known predated	20
	Trampled	1
	Drowned	1
	Unknown	9
Unknown		17

*Table 3: Influence of field variables and year on daily lapwing chick survival rate. Reference levels were Year – 2015. * p<0.05.*

Predictor		Estimate	Std. Error	Z-value	P
Year	2016	1.261	0.977	1.290	0.197
	2017	-0.004	0.683	-0.005	0.996
	2018	2.523	0.786	3.212	0.001*
Vegetation height in field		-5.802	2.062	-2.814	0.005*
Distance to wet feature		-4.115	10.334	-0.398	0.690
Age at tagging		0.087	0.036	2.386	0.017*
Number of broods in field		-0.107	0.220	-0.484	0.628
Soil penetrability in field		-13.431	21.666	-0.620	0.535

FIGURES

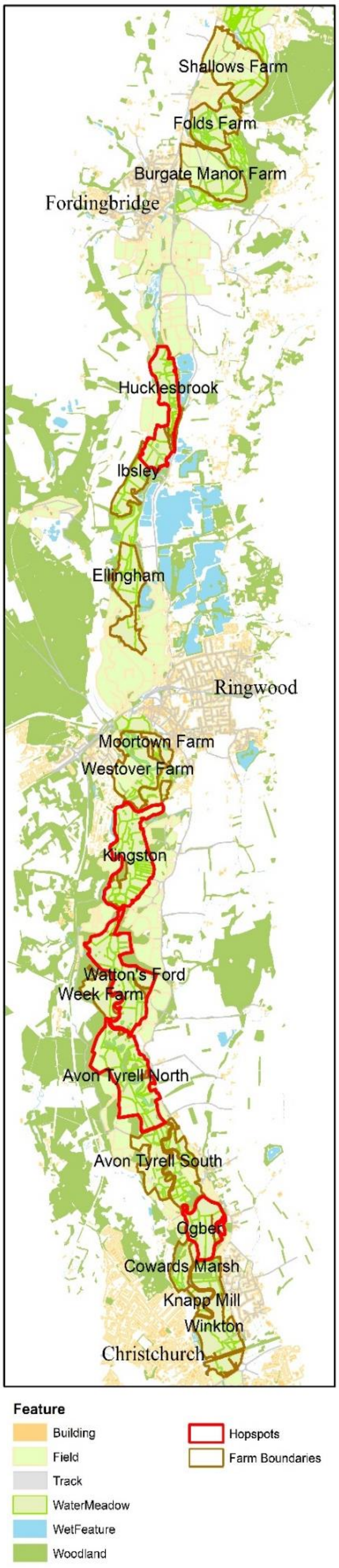

Figure 1: Map of the Avon Valley showing different habitat types

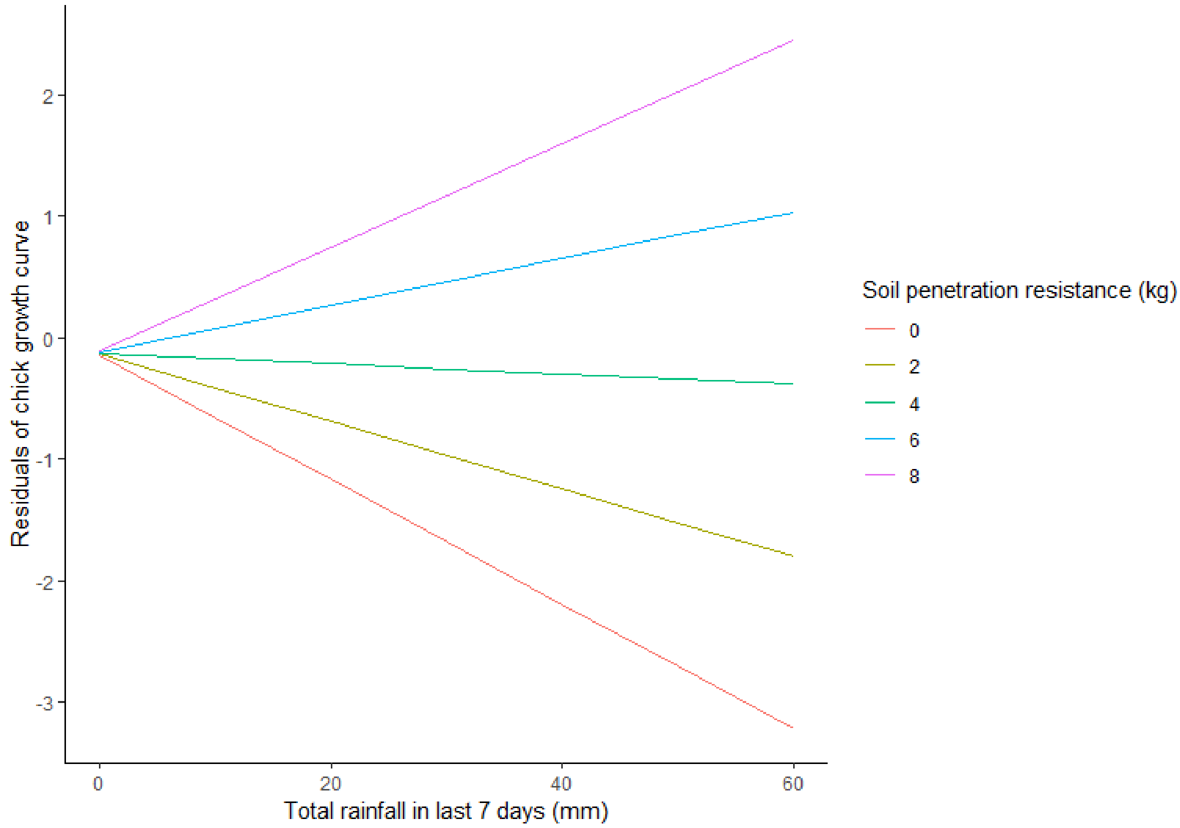

Figure 2: Relationship between relative difference in chick condition (residuals of chick growth curve – more positive values indicate better condition) and rainfall during the preceding seven days. Displayed for soil penetration resistance of 0kg, 2kg, 4kg, 6kg and 8kg.

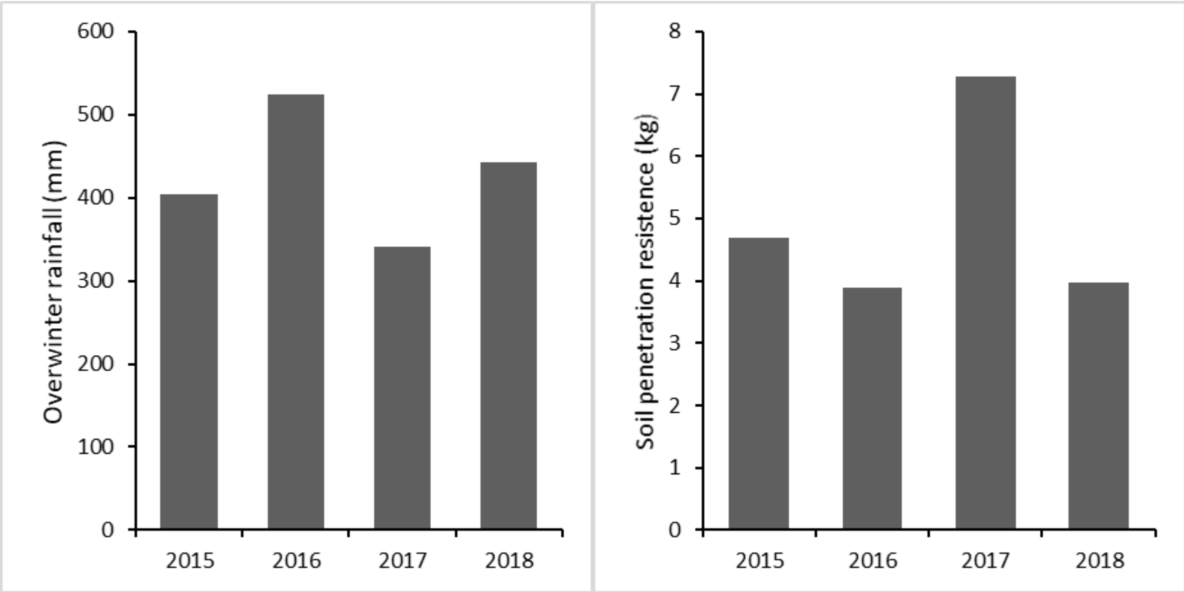

Figure 3: Annual differences in factors influencing chick condition; overwinter rainfall (left) and soil penetration resistance (right)

SUPPLEMENTARY MATERIAL

Table S1. Differences in field variables between brood foraging locations and paired random locations in each sampling year.

Year	Response	Mean ± SE		t	P
		Brood	Random		
2015	Soil penetration resistance (kg)	4.87 ± 0.50	7.55 ± 0.24	t_{44}=-5.14	<0.001*
	Vegetation height (cm)	14.4 ± 1.4	13.7 ± 1.3	t_{38}= 0.33	0.743
	Cover of bare ground (%)	30.6 ± 5.3	5.4 ± 2.6	t_{38}= 4.71	<0.001*
	Cover of grass (%)	52.0 ± 4.6	67.2 ± 3.5	t_{38}=-2.77	0.009*
	Cover of dicots (%)	23.3 ± 2.7	23.8 ± 3.0	t_{38}=-0.13	0.894
2016	Soil penetration resistance (kg)	3.81 ± 0.32	5.11 ± 0.34	t_{20}=-3.52	0.002*
	Vegetation height (cm)	24.3 ± 2.7	18.3 ± 2.7	t_{20}= 2.09	0.049*
	Cover of bare ground (%)	21.0 ± 4.5	6.9 ± 2.4	t_{20}= 3.03	0.007*
	Cover of grass (%)	53.3 ± 6.4	56.9 ± 4.8	t_{20}=-0.71	0.487
	Cover of dicots (%)	22.4 ± 4.8	20.0 ± 3.0	t_{20}= 0.48	0.639
2017	Soil penetration resistance (kg)	6.42 ± 0.55	8.41 ± 0.42	t_{20}=-3.47	0.002*
	Vegetation height (cm)	9.9 ± 1.0	10.0 ± 0.8	t_{20}= 2.09	0.888
	Cover of bare ground (%)	47.9 ± 7.7	1.5 ± 0.9	t_{20}= 5.62	<0.001*
	Cover of grass (%)	49.6 ± 6.3	50.5 ± 6.3	t_{20}=-0.09	0.929
	Cover of dicots (%)	20.7 ± 4.5	33.4 ± 5.9	t_{20}=-1.80	0.087
2018	Soil penetration resistance (kg)	4.51 ± 0.31	5.72 ± 0.40	t_{35}=-4.59	<0.001*
	Vegetation height (cm)	16.2 ± 1.3	28.8 ± 2.3	t_{37}=-5.09	<0.001*
	Cover of bare ground (%)	57.9 ± 4.7	6.4 ± 1.8	t_{37}= 9.46	<0.001*
	Cover of grass (%)	43.3 ± 4.9	44.0 ± 3.8	t_{37}=-0.12	0.902
	Cover of dicots (%)	13.0 ± 2.5	30.3 ± 3.0	t_{20}=-1.80	0.087