

The breeding ecology of Reed Buntings *Emberiza schoeniclus* in farmland and wetland habitats in lowland England

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We studied the nesting and feeding ecology of Reed Buntings *Emberiza schoeniclus* breeding on farmland and wetland habitats along the Trent Valley in Nottinghamshire, England. Rank and emergent vegetation accounted for most nests and most foraging by provisioning adults. Caterpillars and spiders accounted for 70% of chick invertebrate prey and all broods were fed cereal grain or other vegetable matter. Variation in the abundance of key invertebrate prey across habitats accounted for the foraging preferences of adult buntings. Depredation was the main cause of nest failure, and survival of nests at the egg stage was positively related to the extent of nest concealment. A measure of total brood biomass was positively related to the abundance of key invertebrate prey within 100 m of nests. Rank and emergent vegetation provided Reed Buntings with greater nest concealment and a richer source of invertebrate prey than agricultural habitats such as set-aside, cereals and oilseed rape. The provision of rank and emergent vegetation on farmland is likely to increase the nesting opportunities and productivity of Reed Buntings in agricultural landscapes.

Large declines in breeding populations of Reed Buntings *Emberiza schoeniclus* in both farmland and wetland habitats have resulted in the inclusion of this species on the UK 'red list' of birds of conservation concern (Gregory *et al.* 2002). Most of the population decline occurred between 1975 and 1983 when numbers fell by 66% along linear waterways and by 58% on farmland (Peach *et al.* 1999). Following a modest recovery during the late 1980s, further significant declines in abundance were recorded in England (though not in other parts of the UK) during the 1990s (Baillie *et al.* 2001). Extensive demographic data suggest the decline of the late 1970s was driven by a reduction in overwinter survival, possibly linked to the loss of winter seed resources as a consequence of the intensification of agricultural practices. Although overwinter survival improved during the 1990s, breeding densities in England continued to decline and it is possible that reduced nesting success since the mid-1980s might now be limiting population recovery (Peach *et al.* 1999).

Breeding Reed Buntings are strongly associated with wetland habitats, including recently excavated mineral workings (Cramp & Perrins 1994), but their widespread utilization of arable farmland has been recognized for some time (Kent 1964, Williamson 1968) and approximately half of all British Reed Buntings now breed on farmland (Gregory & Baillie 1998). At the scale of a Reed Bunting territory, the distinction between wetland and farmland habitats is often unclear with most wetland sites being surrounded by farmland, and with ponds, ditches and streams being scattered across farmland.

In this study, we investigate factors affecting the breeding ecology of Reed Buntings across a variety of 'farmland' and 'wetland' settings. Rather than comparing breeding performance between these two heterogeneous categories, we consider relationships between various measures of nesting success, habitat availability and invertebrate abundance within the vicinity of the nest. Reed Buntings feed their chicks a largely invertebrate diet, and reduced availability of invertebrate prey for chicks has been implicated in the declines of Grey Partridge *Perdix perdix* (Potts 1986), Skylark *Alauda arvensis* (Poulsen *et al.* 1998) and Corn Buntings *Miliaria calandra* (Brickle *et al.* 2000).

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METHODS

Study area

Reed Buntings were studied in six areas along the Trent Valley and Vale of Belvoir, Nottinghamshire, during 2000 and 2001. Three study areas in 'wetland' landscapes were comprised mainly of rank grassland and herbaceous vegetation around open water (mainly gravel pits) with emergent marginal vegetation and patches of willow carr. Three 'farmland' areas were comprised mainly of mixed and arable farmland dominated by cereal rotations. 'Wetland' areas frequently contained, and were surrounded by, farmland while 'farmland' areas contained wetland features such as ponds, ditches, canals and rivers. The six study areas were considered typical of the Trent Valley.

Nest monitoring

Territories of singing males were mapped across all study areas. Each territory was then systematically watched for periods of at least 1 h, at intervals of no more than 3 days, from early April until mid-August. Nests were found by watching the behaviour of the adults. Nests were visited as little as possible (never on successive days) and care was taken when approaching nests to leave no obvious trail. Daily nest survival probabilities were used to compare breeding success between subsamples of nests. Nests were considered to have been successful at the incubation stage if one or more eggs hatched, and at the nestling stage if one or more chicks fledged. About 5–7 days after hatching, chicks were weighed to the nearest 0.1 g using a spring balance (Salter Super Samson, 50 g) and their maximum tarsus length measured to the nearest 0.1 mm using dial callipers.

First egg date (FED) was calculated either from direct observation or by extrapolation. If hatching date was known, extrapolation assumed that eggs were laid daily and incubation lasted 12 days (Cramp & Perrins 1994, our pers. obs.). In other cases, FED was estimated as the mid-point of the range of possible dates, although nests for which FED could not be estimated to within 2 days were excluded from analyses. Seasonal (or 'monthly') changes in nesting parameters were considered by grouping nests into three time periods according to FED: 26 April (earliest FED)–20 May, 21 May–20 June and 21 June–16 July (latest FED). A total of 152 Reed Bunting nests were studied (104 in 2000, 48 in 2001).

Foraging trips

Foraging locations and flight distances of provisioning adults were determined by direct observation 1–6 days after hatching between 08:00 and 15:00 h. Foraging distance was recorded as the maximum straight-line distance from the nest reached on a foraging trip, measured from 1 : 5000 digitized maps. Mean foraging distances were calculated for each nest. Because it was not always possible to distinguish male and female foraging buntings, analyses are based on pooled data for each nest.

Habitat use

For each nest located, we recorded the habitat in which the nest was built and nest cover as the percentage of the nest that was visible when viewed from directly above. Habitat availability was mapped within a 100-m-radius circle centred on the nest. The maximum observed foraging distance was 288 m but the 100-m radii included 87% of all foraging observations. Nine habitat types were recognized: winter-sown cereals, improved grass, rank vegetation (rank grassland/rank herbaceous vegetation including nettles, willowherbs, umbellifers and brambles), emergent vegetation (reeds and rushes), oilseed rape, set-aside (all rotational), woodland and hedges, open water (rivers, streams, ponds, lakes), and 'miscellaneous' (all other habitats including peas, beans, tracks, farm buildings and bare ground).

Nestling diet

Remains of dietary items in faecal samples were used to evaluate nestling diet. Faecal samples were collected from chicks aged 5–7 days old, and stored individually in industrial methylated spirits. Laboratory analysis followed Brickle and Harper (1999) and Moreby (1988). Each faecal sac was gently washed through a 210- μ m sieve and the contents examined under a binocular microscope (6–50 \times magnification). Invertebrates were identified using Moreby (1988) and a reference collection of invertebrate specimens from the study area. We counted key body parts to estimate the minimum number of individuals, taking account of variation in the size and shape of body parts. The proportions of invertebrate prey falling into the following taxonomic categories were calculated for each brood: spiders, caterpillars, beetles, Diptera and 'other'. For plant material, we estimated the percentage by volume (to the nearest 5%) of the

sieved contents, and this was averaged across samples from the same brood. This was not a comparable measure to the invertebrates so the two were analysed separately.

Invertebrate abundance

In 2001, sweep-netting was used to provide a crude estimate of the relative abundance of key chick invertebrate prey in different habitats. Sweep-netting has been widely used in dietary studies of farmland and grassland birds (Robel *et al.* 1995, Brickle *et al.* 2000). As grasses or low herbaceous vegetation dominated most of the sampled habitats, most between-habitat variation in the efficiency of sweep netting was probably minor. The one exception to this was oilseed rape, in which sweep netting was less efficient and invertebrate densities were probably underestimated. Because the vertical distribution of invertebrates varies diurnally and according to weather conditions (Southwood 1978), sampling was restricted to dry mornings.

Three sets of invertebrate samples were collected during the last weeks of May, June and July. All discrete habitat blocks within 100 m of all nests were sampled. These habitat blocks were determined by their apparent uniformity and the geography of the study area, and included fields, grass margins, tracks and areas of rank grass. Where more than one block of a particular habitat was within 100 m of a nest, each individual block was sampled separately. A single habitat block was sampled with five sets of 20 sweeps, with each of the five sets being started at a random location within the habitat block. Samples were transferred to plastic bags and stored in a freezer. Invertebrates were later identified to order (or family) using a binocular microscope and standard reference guides. All invertebrate groups found in chick diet samples were counted, excluding small linyphiid spiders and small (< 2 mm) Diptera, which were occasionally numerous in sweep-net samples but were never found in chick faecal samples (which contained only large spiders and large Diptera). For each habitat block, we calculated the mean count of all invertebrates found in the diet of Reed bunting chicks (see below) across the five sets of sweeps. This value was then assigned to that particular habitat block for subsequent analysis. Where neighbouring bunting pairs foraged in the same habitat block, the same estimate of invertebrate abundance was used. Any hedgerows or wood-lots were assigned a zero invertebrate score as provisioning Reed buntings were never seen to forage in trees or bushes.

To investigate relationships between foraging location and food availability, the abundance of invertebrates (weighted by the area of each habitat block) was compared between foraging and non-foraging areas within 100 m of each nest. When comparing invertebrate abundance with breeding success, we used the weighted density of invertebrates in foraging areas only, as we were primarily interested in the total availability of invertebrate prey rather than their overall abundance. In both cases, invertebrate samples collected closest to the period when the nest was active with chicks were used in analyses. No invertebrate data were collected in 2000.

Statistics

The intensity of usage of different foraging habitats by provisioning adult buntings was assessed using log linear models following the methods of Green *et al.* (2000). This flexible approach allows the testing of covariates (in this case 'month' and 'year') on the pattern of habitat selection, and quantifies the relative intensity of usage of each habitat type. The statistical significance of covariates and of variation in the intensity of habitat usage was assessed using Green *et al.*'s (2000) randomization tests (based on 1000 replicates), in which the individual nest is the unit of replication. The analysis was based on 417 foraging observations from 72 different nests.

We tested for differences in the composition of chick invertebrate diet between years, months and in relation to the proportion of all foraging visits to emergent and rank vegetation, using compositional analysis (Aebischer *et al.* 1993). Proportions of different dietary items were converted to log ratios (using brood as the unit of analysis) and explanatory variables were then tested using multivariate analysis of variance (Brickle & Harper 1999).

Relationships between daily whole nest survival probabilities and nest cover were explored using binomial trials logistic regression, which amounts to an extension of the Mayfield method (Mayfield 1961, Hensler & Nichols 1981, Aebischer 1999). Only nests visited at least twice were included, and when the exact date of failure was unknown, the mid-point between possible dates was used.

Generalized linear models were used to investigate relationships between food availability and an integrated measure of brood size and chick body condition. This 'standardized brood size' (SBS) was developed as an index of the total amount of chick biomass present in the nest at 5–7 days after hatching.

Table 1. Composition and usage of habitats within 100 m of 152 Reed Bunting nests.

Habitat	Habitat composition of all territories combined (%)	% of territories in which habitat was present	Distribution of nesting sites (%)	Mean % cover of nests	% utilization by foraging adults	Mean count of chick food inverts ^a (\pm se)	Relative intensity of habitat selection ^b
Rank grassland/ herbaceous vegetation	30	95	58	66	62	9.6 (0.9)	8.1
Open water	18	82	0	–	0	–	–
Set-aside	15	30	14	38	6	2.9 (0.4)	0.31
Cereals	14	34	3	40	7	3.0 (0.6)	0.39
Oilseed rape	9	12	10	50	9	4.3 (1.9)	1.0
Improved, grazed grass	6	36	0	–	0	–	–
Woods and hedges	5	97	0	–	0	–	–
Miscellaneous	2	11	0	–	0	–	–
Emergent vegetation	2	42	15	65	16	10.0 (0.6)	22.0

^aIncludes all large invertebrates found in the chick diet (see Methods).

^bIndices of the intensity of habitat usage (derived from a log linear model) are expressed on an absolute scale and are relative to an arbitrary intensity of 1 in oilseed rape.

This reflects the possibility that a given amount of food might sustain one to two chicks in good condition or four to five in poorer condition. SBS was therefore the summed observed weights of all chicks in each nest (adding the mean weight for any chicks that were present but for some reason not weighed) divided by the predicted weight of a chick that age (derived from a regression of mean weights against age for all broods). If the chicks in a nest were all above average weight for their age, then the SBS will exceed the raw brood count, and if the chicks were under weight then the SBS will be less than the raw brood count.

Unless stated otherwise, means are expressed \pm se. All analyses were conducted using SAS version 8.02 (SAS Institute Inc. 2001).

RESULTS

Nesting habitats

Rank vegetation and open water were the commonest and most ubiquitous habitats within 100 m of nests, whereas farmed habitats (cereals, set-aside, oilseed rape, improved grassland and 'miscellaneous') accounted for 46% of the area within 100 m of all nests (Table 1). Territory habitat composition differed significantly between nests in wetland and farmland landscapes (Wilk's $\Lambda = 0.233$, $F_{8,143} = 58.68$, $P < 0.001$), with rank vegetation being commoner in the former and agricultural habitats commoner in the latter (Fig. 1). A few nests were found in bramble but none in hedges or scrub.

Most (73%) nests were located in rank or emergent vegetation, with fewer in farmed habitats (27%

in cereal crops, oilseed rape or set-aside) (Table 1). Reed Buntings did not use nesting habitat randomly with respect to availability ($\chi^2_8 = 261.91$; $P < 0.001$), preferring to nest in rank and emergent vegetation and avoiding cereals (Table 1).

The average height of nests above ground or water level was 25 cm (± 0.04 , range 0–170 cm) and the mean percentage nest cover was 61% ($\pm 2\%$, range 20–90%). Nest cover varied significantly between habitats (ANOVA: $F_{4,98} = 7.03$, $P < 0.001$) but not between years or months ($F_{1,98} = 0.13$, $P = 0.724$ and $F_{2,98} = 0.27$, $P = 0.763$, respectively). Nests were most concealed in emergent and rank vegetation, whereas those in set-aside and cereals were most exposed (Table 1).

Foraging habitats

The foraging locations of birds feeding nestlings were observed for 92 nests (59 in 2000, 33 in 2001). The mean number of foraging visits observed per nest was 5.96 ± 0.30 (range 1–11) and the average foraging distance was 58 ± 4.98 m (range 12–288 m). The distribution of foraging distances was heavily skewed, with most (87%) sorties being within 100 m of the nest and only 2% more than 200 m away.

Nearly 80% of all foraging by provisioning adult Buntings was in rank or emergent vegetation, with much lower utilization of oilseed rape, cereals and set-aside (Table 1). The relative intensity of habitat usage for foraging did not differ significantly between years (randomization $P > 0.5$) or months (randomization $P > 0.9$). Although there were large differences in the relative intensity of usage of the five recognized foraging habitats (e.g. emergent vegetation was

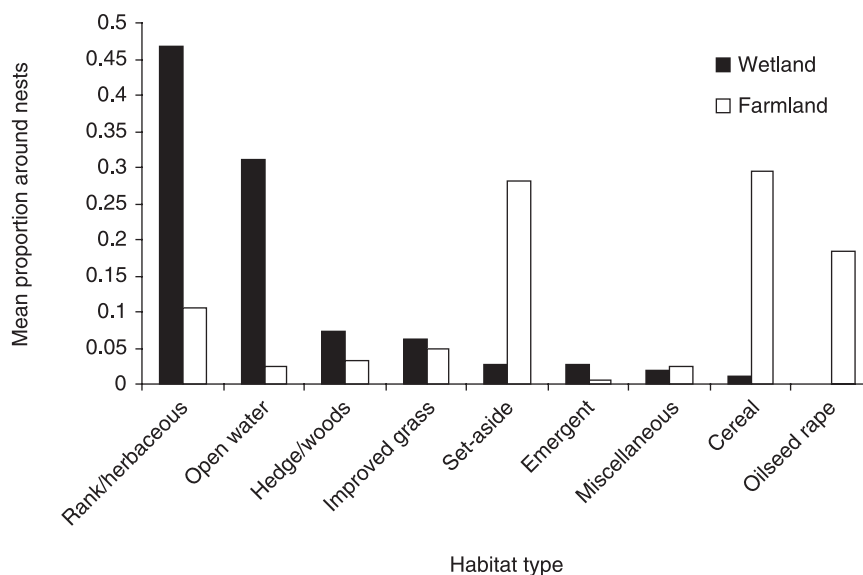


Figure 1. Mean proportional habitat composition within 100 m of 152 Reed Bunting nests in 'farmland' and 'wetland' settings. 'Wetland' includes several unmanaged former gravel pit sites in the Trent Valley (see text).

Table 2. Invertebrate composition of chick diet as derived from prey fragments in faecal samples.

Order (family)	Proportion of all prey items summed across broods	Proportion of broods known to have eaten each invertebrate group
Araneae	0.29	94
Lepidoptera larvae	0.33	78
Hymenoptera (Symphyta larvae)	0.08	47
Coleoptera (Elateridae)	0.07	33
Diptera (other)	0.07	41
Diptera (Nematocera)	0.05	22
Coleoptera (unknown)	0.05	29
Coleoptera (Staphilinidae)	0.02	12
Coleoptera (Chrysomelidae)	0.01	12
Opiliones	0.01	10
Homoptera (Aphididae)	0.01	4
Hymenoptera (Formicidae)	< 0.01	2
Coleoptera larvae	< 0.01	2
Coleoptera (Carabidae)	< 0.01	4
Odonata	< 0.01	2
Orthoptera	< 0.01	2

used 22 times as intensively as oilseed rape, Table 1), the pattern of habitat selection did not differ significantly from random (randomization $P = 0.10$). Emergent and rank vegetation were the most intensively used habitats, and set-aside and cereals were the least intensively used habitats (Table 1).

Chick diet

We collected 144 faecal samples from 49 broods, finding at least 466 invertebrates (mean = $3.31 \pm$

0.14 per faecal sac, range 1–10). More than 40% of invertebrate remains were caterpillars (Lepidoptera and Symphyta larvae, Table 2) and these were fed to 90% of broods. Spiders constituted 29% of all invertebrate prey items and were found in 94% of broods. Beetles accounted for 15% of all prey items and were fed to 67% of broods (Table 2). About 10% of the sieved faecal contents consisted of plant material (mean proportion = 0.092 ± 0.006), mainly cereal grains or tiny fragments. Samples from all broods contained some plant material. The composition of

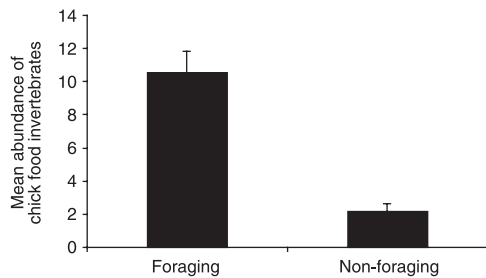


Figure 2. Mean weighted density (\pm se) of chick food invertebrates (see Table 2) in foraging and non-foraging areas within 100 m of nests ($n = 33$).

invertebrates in faecal samples did not vary significantly between years, months or according to the proportion of all foraging visits in emergent or rank vegetation (Year: Wilk's $\Lambda = 0.877$, $F_{4,39} = 1.37$, $P = 0.263$; month: Wilk's $\Lambda = 0.833$, $F_{8,78} = 0.93$, $P = 0.497$; foraging habitat: Wilk's $\Lambda = 0.970$, $F_{4,39} = 0.30$, $P = 0.874$).

Foraging habitats and invertebrate abundance

The density of all chick invertebrate prey differed significantly between habitats but not between months or study sites (Table 1; ANOVA based on 65 home ranges: habitat, $F_{4,56} = 8.57$, $P < 0.001$; month, $F_{2,56} = 1.67$, $P = 0.198$; site, $F_{3,56} = 0.16$, $P = 0.921$). The highest invertebrate densities were found in emergent and rank vegetation, and the lowest in set-aside and cereals. The rank order of the intensity of habitat usage was identical to the rank order of the density of key invertebrates therein (Table 1). The four commonest chick prey types (combined) were significantly more abundant in sweep-net samples from foraging areas than in those from non-foraging areas within 100 m of the nest (paired t -test: $t_{32} = 6.04$, $P < 0.001$; Fig. 2).

Clutch and brood sizes

Mean maximum clutch size was 4.59 ± 0.07 eggs ($n = 74$, range 3–5) and mean maximum brood size was 3.91 ± 0.11 chicks ($n = 86$, range 1–5). Partial losses were common, with $84 \pm 2.6\%$ of eggs producing chicks ($n = 60$ nests for which maximum clutch and subsequent brood size were known). The remainder were either lost or did not hatch. Twenty-eight of these 60 nests suffered partial losses (one egg failed in 16 broods, two in nine broods, three in two broods and four in one brood).

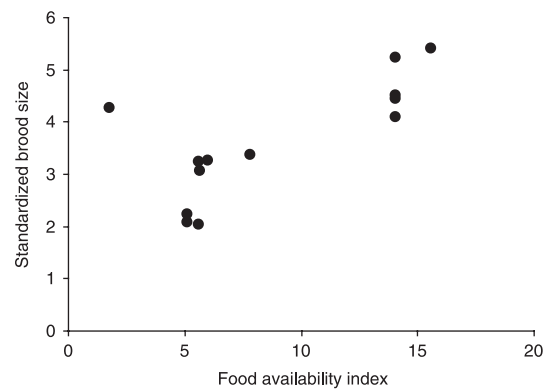


Figure 3. Standardized brood size at 5–7 days after hatching (see text) in relation to the availability of chick food invertebrates in foraging habitats within 100 m of nests ($n = 13$ nests). The index of food availability is the number of individual chick prey invertebrates in sweep-net samples weighted by the area of each habitat within 100 m of the nest.

Standardized brood size

Brood sizes adjusted for chick weight (or SBS) varied between 1.35 and 5.55 (mean = 3.69 ± 0.16). SBS increased significantly with the abundance of chick food invertebrates in foraging areas within 100 m of the nest, and did not vary through the breeding season (overall model, $F_{5,7} = 6.74$, $P = 0.013$; food availability, $F_{1,7} = 22.01$, $P = 0.002$; month, $F_{2,7} = 3.23$, $P = 0.101$; interaction, $F_{2,7} = 2.61$, $P = 0.142$; Fig. 3).

Nest survival and productivity

Of the 152 nests found, 57% were known to be successful and 35% unsuccessful as a result of depredation (21% of all nests at the egg stage and 10% at the nestling stage). Daily whole-nest survival probability averaged 0.981 ± 0.005 during incubation and 0.976 ± 0.006 during the nestling period ($n = 76$ and 96 nests, respectively). Daily whole-nest survival rates did not differ between years at either the egg or the chick stages (egg stage: $n = 74$, $\chi^2_1 = 0.37$, $P = 0.54$; chick stage: $n = 96$, $\chi^2_1 < 0.01$, $P = 0.91$), but declined significantly through the breeding season at the chick stage (egg stage: $\chi^2_2 = 3.4$, $P = 0.18$; chick stage: $\chi^2_2 = 6.7$, $P = 0.035$). Whole-nest survival increased significantly with nest cover at the egg stage ($\chi^2_1 = 5.15$, $P = 0.023$; Fig. 4) though not at the chick stage ($\chi^2_1 = 2.05$, $P = 0.15$). There was no relationship between whole-nest survival at the chick stage and food availability within 100 m of the nest ($n = 29$ nests, $\chi^2_1 = 0.68$, $P = 0.41$).

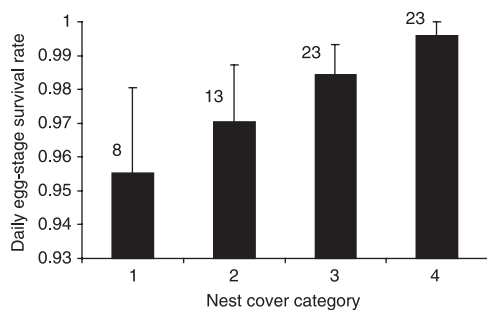


Figure 4. Daily whole-nest survival rates at the egg stage (\pm se) in relation to nest cover category (where 1 = 0–25% cover, 2 = 26–50%, 3 = 51–75%, 4 = 76–100%). Numbers above histograms indicate sample sizes.

Discussion

Key nesting and foraging habitats

This study emphasizes the importance of rank and emergent vegetation as both nesting and foraging habitat for Reed Buntings. These habitats together accounted for 32% of territories, 73% of nest-sites and 78% of foraging (Table 1). Much rank and all emergent vegetation is associated with wetland features such as gravel pits, ponds and streams, and it was notable that Reed Bunting territories and foraging were strongly associated with rank vegetation even on farmland where it was relatively scarce. Both of these habitats provided relatively high levels of concealment for nests and this reduced the likelihood of depredation. Both habitats were also relatively rich in key chick invertebrate prey and were heavily utilized by foraging adults during chick provisioning (Table 1).

The preference of Reed Buntings for wetland habitats and features is well documented (Cramp & Perrins 1994, Gregory & Baillie 1998, Surmacki 2001). Less well understood is their use of arable crops. Cereals and set-aside fields are used for nesting and foraging by Corn Buntings (Brickle & Harper 2000) and Yellowhammers *Emberiza citrinella* (Stoate *et al.* 1998, Morris *et al.* 2001), and evidence highlighting the value of oilseed rape for farmland birds is accumulating (Burton *et al.* 1999, Moorcroft *et al.* 1997, Holland *et al.* 2002). More than a quarter of nests in our study were from arable fields (Table 1) but this certainly underestimates the importance of oilseed rape as a nesting habitat because nests in this crop were difficult to locate. A recent survey of a random sample of arable fields from the same study area found densities of breeding Reed Buntings to be four times greater in oilseed rape than in cereals or

set-aside (Gruar *et al.* in press). Our data suggest that oilseed rape provides greater nest concealment, and therefore higher nest survival rates, and higher densities of key invertebrate prey than either cereals or set-aside. Oilseed rape appears therefore to constitute a lower quality breeding habitat than rank and emergent vegetation, but a higher quality habitat than cereals or set-aside. Although our use of sweep-netting may have underestimated invertebrate densities in oilseed rape, other studies using suction sampling also report higher densities of invertebrates in oilseed rape than in cereals (Holland *et al.* 2002, J. Bright pers. comm.). Gruar *et al.* (in press) found that cereal and set-aside fields were only likely to be occupied by breeding Reed Buntings if they were close to wet features such as streams and ditches. However, oilseed rape fields were often occupied in the absence of nearby wet features, suggesting that rape might provide some of the key nesting or foraging resources otherwise provided by wetland habitats. The spraying of rotational set-aside with broad-spectrum herbicides during late April or May (a practice that aims to control grass weeds) is likely to have reduced the value of these fields as both nesting and foraging habitats for Reed Buntings.

Diet and invertebrate abundance

Our data highlight the importance of spiders, caterpillars (Symphyta and Lepidoptera) and beetles to Reed Bunting chicks. Previous studies have indicated these and other insect groups to be important components of chick diet, particularly adult Tipulids and aquatic groups such as Ephemeroptera (mayflies) and Odonata (dragonflies and damselflies) (Cramp & Perrins 1994). The lack of Tipulids fed to chicks in our study may reflect a general lack of permanent grassland in the study area, whereas the lack of aquatic insects is more difficult to explain as many nests were close to freshwater habitats. Previous studies of chick diet in Reed Bunting (above) and other buntings (Evans *et al.* 1997, Brickle & Harper 1999) have highlighted seasonal and habitat differences in chick diet, and our failure to measure such variation may reflect our relatively modest sample sizes.

Habitat utilization and selection closely reflected the relative abundance of key invertebrate prey, with rank and emergent vegetation being relatively food-rich and heavily utilized, and cereals and set-aside being relatively food-poor and little utilized (Table 1). We also demonstrated that Reed Buntings selected

relatively food-rich patches of habitat in which to forage (Fig. 2).

Breeding performance and nest survival

Our study has identified two factors that may limit breeding productivity on farmland: ground vegetation providing concealment from nest predators and the abundance of invertebrate prey that appear to limit the number and condition of chicks raised and fledged. Whole-nest survival during the egg stage was positively related to nest concealment (Fig. 4), with rank and emergent vegetation providing better concealment than set-aside or cereals (Table 1). Average nest cover score was also positively correlated with the density of nests across habitats ($r_s = 0.96$, $P < 0.05$, Table 1), suggesting that nesting habitat selection may be influenced by structural suitability. Several previous studies of open-nesting passerines have reported higher nest predation rates for relatively exposed nests (e.g. Hatchwell *et al.* 1996, Weidinger 2002). Our data highlight nest concealment as a potentially limiting factor for farmland Reed Buntings, although formal testing of this would require some assessment of the availability of concealed suitable nesting locations.

The clear relationship between invertebrate availability and standardized brood size (albeit on a relatively small sample of nests; Fig. 3) suggests that chick condition, a probable predictor of subsequent survival probability (Perrins & Moss 1974, Mock & Parker 1998), is sensitive to the local abundance of key chick invertebrate prey. Similar relationships between the number and/or condition of chicks of farmland birds and their invertebrate food supply have been demonstrated for Grey Partridge (Potts 1986), Skylark (Poulsen *et al.* 1998) and Corn Bunting (Brickle *et al.* 2000), suggesting that lack of invertebrate prey for chicks may be a general phenomenon limiting reproduction by farmland birds.

One issue that merits further study is the utility and importance of oilseed rape to farmland Reed Buntings. Oilseed rape was preferred to cereals and set-aside as both a nesting (Gruar *et al.* in press) and a foraging habitat providing more nesting cover and key invertebrate prey (Table 1). Nests in oilseed rape fields are difficult to locate and monitor mainly due to the tall, impenetrable nature of the crop, but we suspect that breeding performance may be high in this crop at least until swathing destroys any active nests (Burton *et al.* 1999).

Conservation implications

The results of this and other studies (e.g. Burton *et al.* 1999, Surmacki 2001) highlight the importance of wet features and non-cropped habitats as feeding and nesting habitats for breeding Reed Buntings. Thus, the loss of small wet features such as ponds, and the dredging and straightening of rivers and streams is likely to have reduced the suitability of large areas of farmland as a breeding habitat for Reed Buntings (Smith 1975, Campbell 1988). Furthermore, the widespread installation of under-field drainage particularly during the 1970s (Robinson & Armstrong 1988) will have increased the dryness of farmland, including ditches and wet features (Peach *et al.* 2004). Production subsidies during the 1970s and 1980s encouraged farmers to crop previously uncropped marginal land with the consequent loss of rank vegetation often around the edges of fields (O'Connor & Shrubbs 1986), and increased use of herbicides and insecticides will have reduced weed and invertebrate densities on most farmland (Campbell *et al.* 1997).

Of the measures available under the UK Government's Countryside Stewardship Scheme (CSS) (Defra 2001) and the new Entry Level Pilot Scheme (ELS) (Defra 2003) for England, the establishment of uncropped, tussocky grass field margins and wildlife strips, pollen and nectar mixes and uncropped field corners should all increase nesting and feeding opportunities for farmland Reed Buntings. Pond creation, ditch restoration and the various waterside land management options should also be beneficial as long as emergent vegetation is provided along the edges of water bodies. The sensitive management of rush pastures (under the ELS) should promote nesting and feeding opportunities on damp grassland.

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