

Higher nestling food biomass in organic than conventional soybean fields in eastern Ontario, Canada



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ABSTRACT

Intensive farming methods have been linked to population declines of farmland birds. One possible mechanism for these declines is a reduction in the biomass of small invertebrates, necessary for growth and survival of the young of many songbirds (nestling food). We predicted that organic farming, with its avoidance of synthetic pesticides and longer more diverse crop rotations, supports higher nestling food biomass than conventional farming. Pitfall traps were used to test this prediction in nine organic and nine conventional soybean fields in eastern Ontario, while controlling for landscape level crop cover. Weed cover, tillage (measured as cover of crop residue) and hedgerow plant species richness were tested as possible factors explaining patterns of nestling food biomass. Overall nestling food biomass was significantly greater on organic fields than conventional fields in both June (43% greater in organic than conventional) and July (35%). When habitats were examined separately, this difference was marginally significant in crop fields, and not significant in field edges or hedgerows. Weed cover and hedgerow plant species richness did not significantly predict nestling food biomass, but there was weak evidence that cover of crop residue predicted nestling food biomass in hedgerows only. The greater nestling food biomass in organic fields may be a result of longer, more diverse crop rotations compared to conventional fields.

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1. Introduction

Intensive farming practices, such as use of pesticides and artificial fertilizers, simplification of crop rotations, and reductions in semi-natural habitat in farmed areas have been linked to declines in abundance and richness of many taxa, especially birds (Donald et al., 2001; Geiger et al., 2010). One possible mechanism for reduced abundance and richness of birds in intensively managed agriculture is inadequate biomass of small invertebrates (Campbell and Cooke, 1997; Wilson et al., 1999; Piha et al., 2007). Small invertebrates (hereafter nestling food) are required for survival and growth of the young of many bird species, and farmland birds breeding at nest sites with lower nestling food abundance, or higher insecticide applications can show reduced nestling mass, nestling survival, fledging success and nest survival (Potts, 1986; Boatman et al., 2004; Dunn et al., 2010 but see Bradbury et al., 2003; Zalik and Strong, 2008).

Many studies have suggested that organic farming methods, which do not use synthetic pesticides or fertilizers and tend to use more varied crop rotations than conventional farming methods, might support higher abundances of invertebrates (reviewed by Hole et al., 2005). However results differ widely among and within taxa (e.g. Bengtsson et al., 2005; Kragten et al., 2011) and with landscape context (Rundlöf and Smith, 2006; Diekötter et al., 2010) and most previous studies have focused on abundance of invertebrates, rather than biomass. Invertebrate abundance and biomass are not interchangeable, and can show different patterns in response to environmental variables (Saint-Germain et al., 2007). Previous studies on nestling food in organic farmland have found mixed results; Moreby et al. (1994) found no difference in abundance of nestling food items in organic and conventional wheat fields in England. Reddersen (1997), working in Denmark, found that densities of bird food items were significantly greater in the midfield of organic cereal than in conventional fields, but not in field margins. Finally, Kragten et al. (2011) found that earthworms and aerial invertebrates were more abundant on organic farms in the Netherlands across a range of crop types, but that abundance of ground invertebrates was not significantly different between organic and conventional farms.

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Possible mechanisms for differences in invertebrate biomass or abundance between organic and conventional management systems include differences in pesticide use, tillage and plant species richness. Insecticides, by design, have a direct negative effect on invertebrates, whereas herbicides have an indirect effect on invertebrates, by reducing weed cover and diversity (Boatman et al., 2004). Weeds affect invertebrates by providing food, altering microclimate and providing shelter from predators (Diehl et al., 2012). However, relationships between weed cover and invertebrate abundance are not straightforward. For example, Buckelew et al. (2000) found both positive and negative relationships between weed cover and different pest species in soybean. Activity density of ground beetles (Carabidae) is typically found to decrease with decreasing weed cover (reviewed by Diehl et al., 2012), but the response of ground beetles to weeds can vary by species (Pavuk et al., 1997).

Organic farms typically support higher species richness of plants than conventional farms (reviewed by Bengtsson et al., 2005; but see Weibull et al., 2003). Higher species richness of plants has been linked to increased invertebrate abundance (Asteraki et al., 2004; Hyvönen and Huusela-Veistola, 2011) and size (Woodcock et al., 2005). However, Perner et al. (2005) showed that plant richness was not correlated with invertebrate abundance when additional factors such as soil, plant species composition and productivity were accounted for.

The aim of this study was to test (a) whether nestling food biomass is higher in organic than conventional soybean fields and (b) whether local variables related to farm type (weed cover, tillage, measured as cover of crop residue, and hedgerow plant species richness) help explain variation in nestling food biomass in soybean fields. These relationships were examined for total nestling food biomass, and for biomass in crop fields, field edges and hedgerows separately, because use of these foraging habitats differs among bird species (Boutin et al., 1999), and because Reddersen (1997) showed that densities of bird food items between organic and conventional fields were stronger within fields than at field edges. We predicted that nestling food biomass would be higher in organic than in conventional fields, and that weed cover, cover of crop residue and species richness of hedgerow plants would all be positively related to nestling food biomass.

2. Materials and methods

The study was carried out in eastern Ontario, to the northwest and southeast of Ottawa. This area is part of the St Lawrence lowlands ecodistrict; mean annual temperature is approximately 5 °C and mean summer temperature approximately 16.5 °C (Ecological Stratification Working Group, 1995). Mean length of growing season is 205–230 days (Crins et al., 2009). Approximately 25% of eastern Ontario is farmed; the three dominant crops in the region are hay (approx. 275,000 ha, 37% of farmed land), corn (*Zea mays*, approx. 111,000 ha, 15%) and soybean (*Glycine max*, approx. 84,000 ha, 12%, Ontario Ministry of Agriculture Food and Rural Affairs, 2011).

2.1. Study sites

Soybean was selected as the focal crop, because it is widely grown by both organic and conventional farms in the study region. To find organic farms, we used local directories of organic growers and contacted local sellers of organic seed, resulting in nine organic farms growing soybeans and willing to participate in the study, spread over an area of approximately 100 km × 25 km between Fitzroy Harbour (45°28'12.12"N, 76°12'48.76"W) and Iroquois, Ontario (44°50'58.74"N, 75°18'58.90"W). One soybean field

and adjacent hedgerow were selected for sampling on each farm. To control for changes in physiographic features and species assemblages over the study area, each organic field was paired with a nearby conventional soybean field. Paired fields were between 2.8 and 6.4 km apart, and all fields were at least 2 km apart. Wherever possible the conventional hedgerow was selected to have similar structure to the organic hedgerow (e.g. presence of ditch, similar cover of shrubs and trees). We therefore had a total of nine organic and nine conventional soybean fields.

2.2. Model species

To aid in the study design, song sparrows (*Melospiza melodia*) were used as a model farmland bird species. Song sparrows are common and abundant in farm fields (Boutin et al., 1999; Jobin et al., 2001). They forage most often on the ground, and during the breeding season feed primarily on small invertebrates (Arcese et al., 2002).

2.3. Invertebrate trapping

Pitfall traps were used to sample invertebrates active on the soil surface, and therefore accessible to ground-foraging birds. Pitfall traps consisted of plastic cups, placed in holes in the ground, so that the top of the cup was level with the ground surface. Traps were one-third filled with water, with a drop of soap added to break the water tension, and were in place for three days.

To insure that invertebrate trapping locations reflected potential breeding locations and thus food abundance relevant to breeding birds, locations of singing song sparrows were mapped on two visits to each field (organic and conventional) in May. In each field, two consistent singing locations at least 95 m apart on the same hedgerow were selected as the centers of two 60 m long invertebrate sampling transects. Each transect consisted of 12 pitfall traps, four each in the soybean field, in the field edge and in the hedgerow (Fig. S1). Trapping was carried out twice in each field, once between 31 May and 8 June 2009 (hereafter June), and once between 14 and 30 July 2009 (hereafter July). These time periods were chosen to approximate peak nestling-feeding times of song sparrows (J. Girard, unpublished data). Each pair of fields was sampled on the same days.

The contents of each trap was collected separately, cleaned, and stored in denatured ethanol until the sample could be counted. Invertebrates were identified to order or family (Table S1), counted, and measured in 2 mm intervals. To calculate biomass of invertebrates important in song sparrow nestling diet (hereafter nestling food biomass), invertebrates not important in nestling diet because they are noxious or difficult for nestlings to handle (Hymenoptera, Sternorrhyncha, Acari, Gastropoda, Oligochaeta) and invertebrates that live primarily in aquatic habitats (Dytiscidae) were excluded. Equations created from invertebrate captures in pitfall traps from the same habitat and study region (Girard, 2012) were used to convert counts of invertebrates in each taxonomic class to dry nestling food biomass (mg) for each trap.

Not all traps were recovered from the field sites, due to occasional destruction by animals, flooding, or farm machinery. The number of traps included in the analysis is shown in Table S2.

2.4. Farm management

Farmers were contacted between 28 November 2009 and 26 February 2010, to assess how field management differed between organic and conventional farms. A standardized questionnaire was used (Table S3) and interviews were conducted either in person or over the telephone. Seven conventional farmers and eight organic farmers provided information about farm management (Table S4).

Planting dates in organic had a smaller range than in conventional fields, and started and ended later (organic range: 18 May–7 June, conventional range: 9 May–4 June). Synthetic fertilizer was applied at one conventional site and manure at two organic sites. The number of spring tillage passes in organic was higher than the number of passes on conventional fields (organic: mean 2.9 ± 1.8 SD, conventional: 1.0 ± 0.6). All the conventional soybean fields were sprayed with herbicide at least once, but only one field was sprayed with insecticide, after invertebrate trapping was completed. Four conventional fields were planted with treated seeds; two were treated with fungicides, and two with fungicides and insecticides. Two organic fields had inoculate seed treatments added to promote nitrogen fixing. Of the six conventional fields for which we had information, the previous year's crop was corn in five and soybean in one field. Of the eight organic fields for which we had information, the previous year's crop was much more varied; two were grown in wheat the previous year, two in corn, one each in rye, hay and soybean, and one was planted in wheat and then seeded in clover after harvest. All the conventional fields used only two crops in the standard crop rotation (corn and soybean) whereas all the organic fields used at least three crops (3.8 ± 0.8).

2.5. Cover of weeds and crop residue

At each sampling time, percent cover of weeds and crop residue were recorded in four 1 m^2 quadrats, within each invertebrate trapping transect. Two quadrats were placed in the field, and two at the field edge (Fig. S1).

2.6. Hedgerow plants

Between August 12 and 14, 2009 hedgerow vegetation in each field was surveyed to assess plant species richness and diversity. Plants were surveyed along the 60 m long invertebrate trapping transects (Fig. S1). All plants in the grass/forb layer between the edge of the crop and the center of the hedgerow were identified, and total percent cover of each species along the whole transect in three categories; <10, 10–50 and >50% was estimated. Species richness and Shannon–Weiner diversity index of plants was calculated in each transect. These were highly correlated ($t = 6.95$, $df = 14$, $P < 0.01$, $r = 0.88$), so only species richness was used for analyses.

2.7. Landscape data

To control for landscape complexity, percent crop cover was included in analyses and differences in landscape structure were tested for between organic and conventional sites. Land use data was obtained from a 1 km radius around each field from aerial photographs taken in 2008 (OMNR, 2010). Using ArcMap™ v 10.0 (ESRI, 2011), the following land uses were digitized: forest, hay fields, hedgerows, other (includes successional or abandoned land and other unmanaged habitats), pasture, crop fields, riparian/wetland, unknown and verge (roadside vegetation).

To compare the pattern of land uses surrounding the organic and conventional sites, the following landscape metrics were calculated within a 500 m radius of each site, approximating average farm size in the study area: percent area of crop fields (hereafter crop cover), percent area of open semi-natural habitats (includes hay fields, hedgerows, other, pasture, riparian/wetland and verge), mean field area (calculated across crop fields, hayfields and pasture) and the Shannon–Weiner diversity index of all land uses. None of the metrics was significantly different between organic and conventional sites (paired t -test, Table S5).

To select a scale at which percent crop cover should be included in the nestling food biomass models, crop cover was calculated at multiple radii around each crop field (100–1000 m at 100 m

intervals) and used to create models predicting nestling food biomass at each scale. For all habitats combined, and for crop fields, models including crop cover at 1000 m had the lowest AICc, while for edge the most important scale was 500 m and for hedgerows 400 m (Fig. S2).

2.8. Statistical analysis

To account for the hierarchical study design, linear mixed effects models were used to investigate the effect of management type (organic vs. conventional) on nestling food biomass per trap (Zuur et al., 2009). Nestling food biomass was log transformed to improve normality. Fixed effects were management type (organic vs. continuous), month (June vs. July) and percent crop cover (continuous). Month was included as a fixed effect to allow us to examine whether patterns in nestling food biomass changed with time. Since previous studies have shown that the effect of management type can vary with crop cover (see Section 2.7) an interaction between crop cover and management type was included in preliminary models, but was later excluded because it was never significant. To account for the hierarchical study design, the random effects of habitat (field, edge, hedgerow), nested in month, nested in site needed to be included in the model. Habitat was included as a random effect because we were interested in the variation among habitats, rather than the specific effects of each habitat (Zuur et al., 2009). Possible additional random effects were pair and transect. We tested whether these variables needed to be included as random effects by creating a global model, including all predictor variables and using AICc to select the most parsimonious combination of random effects (Zuur et al., 2009). Neither improved the global model, and were therefore excluded from the analysis. Nestling food biomass was first analyzed across all habitats (total nestling food biomass). Each habitat (field, edge and hedgerow) was then analyzed separately, to see whether the effect of management on nestling food biomass differed among habitats.

The three local variables (weed cover, cover of crop residue and hedgerow plant species richness) were averaged across transects at each site for analysis. Weed cover and cover of crop residue were arcsine transformed to improve normality. The first step was to test the effect of management type and month and their interaction on each variable, using an ANOVA. If there was no effect of management type and month, we then proceeded to use an ANCOVA, with a random effect of site, to test for the effect of the local variable on nestling food biomass, while controlling for management type and month. If there was an effect of management type, we tested the effect of the local variable on nestling food biomass within month, using a linear mixed model with site as the random variable. If there was an effect of both management type and month, we tested the effect of the local variable on nestling food biomass within each management type by month combination, using linear regression, as appropriate. All analyses were carried out in R (v 2.14.1, R Development Core Team, 2011). Mixed effects models were run using the nlme package (Pinheiro et al., 2009). Results are reported as mean \pm 1 SD.

3. Results

Ground beetles dominated pitfall trap captures, comprising on average 30% of dry biomass/trap ($0.09\text{ mg} \pm 0.18$), followed by millipedes (Diplopoda, 20%, $0.03\text{ mg} \pm 0.07$) and true spiders (15%, $0.02\text{ mg} \pm 0.02$).

3.1. Management type

Both management type and month significantly affected total nestling food biomass; as predicted, the overall biomass of nestling food invertebrates was higher in organic than in conventional fields in both June and July (Fig. 1, Table 1). For an average site, the mixed model predicted that nestling food biomass per trap was 43% higher in organic than conventional fields in June, and 35% higher in organic than

Table 1
Results of linear mixed models predicting chick food biomass in soybean fields from farm management type, month and crop cover.

Habitat	Management type ^a				Month ^b				Crop cover			
	β (SE)	F	df	p	β (SE)	F	df	p	β (SE)	F	df	p
All habitats ^c	0.37 (0.17)	5.11	1,15	0.04	0.47 (0.14)	12.17	1,17	0.003	0.79 (0.50)	2.45	1,15	0.14
Crop ^d	0.54 (0.23)	4.55	1,15	0.05	0.81 (0.26)	10.03	1,16	0.006	1.09 (0.77)	2.00	1,15	0.18
Edge ^d	0.31 (0.19)	2.54	1,15	0.13	0.59 (0.16)	13.00	1,16	0.002	0.66 (0.57)	1.35	1,15	0.26
Hedge ^d	0.26 (0.16)	2.60	1,15	0.13	-0.06 (0.12)	0.23	1,16	0.62	0.96 (0.45)	4.59	1,15	0.05

^a Conventional or organic.

^b June or July.

^c Random effects are habitat type, nested in month, nested in site.

^d The random effects are month, nested in site.

conventional fields in July. Nestling food biomass was also significantly greater in July than in June (organic, 57% increase between June and July, conventional 70%). The proportion of the surrounding landscape in crop fields did not significantly affect total nestling food biomass (Table 1).

When the three habitats were examined separately, nestling food biomass in crop fields and field edges showed the same pattern of greater nestling food biomass in organic than conventional fields, and greater nestling food biomass in June than in July (Fig. 1), but the effects of management in crop fields were only marginally significant, and in field edges were non-significant (Table 1). In hedgerows, the pattern was also similar to overall nestling food biomass, but neither management type nor month significantly predicted nestling food biomass; however, there was a marginally significant positive effect of crop cover in a 400 m radius (Table 1).

3.2. Weed cover

When weed cover was modeled based on management type and month, there was a significant interaction (management type: $F_{1,16} = 6.42$, $p = 0.02$, month: $F_{1,16} = 48.23$, $p < 0.001$, type \times month: $F_{1,16} = 12.92$, $p = 0.002$), so the effect of management type on weed cover was tested separately in each month. There was no significant difference between weed cover in organic and conventional fields in June, but in July, weed cover was significantly higher in organic than in conventional fields (June organic: 1.53 ± 1.36 , June conventional: 3.63 ± 5.48 , $F_{1,16} = 0.48$, $p = 0.50$, July organic: 36.12 ± 18.74 , July conventional: 12.03 ± 12.11 , $F_{1,16} = 11.86$, $p = 0.003$).

In crop fields and in hedgerows, weed cover did not significantly predict nestling food biomass in either organic or conventional fields in June or July (Table 2). In field edges, weed cover did negatively predict nestling food biomass in organic fields in June, but did not significantly predict nestling food biomass in organic fields in July or in conventional fields in either month (Table 2, Fig. S3). The negative

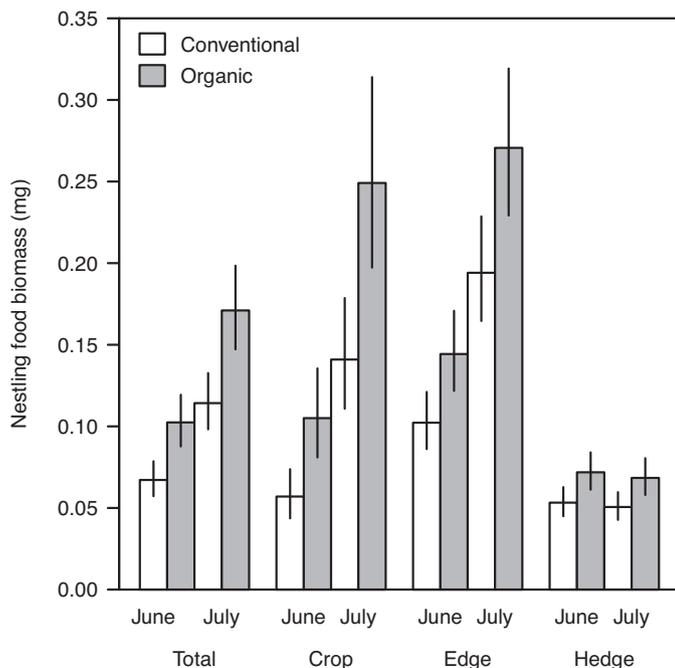


Fig. 1. Effect of management type (conventional or organic) and month on nestling food biomass in 18 soybean fields (mean \pm SE, conditional on random effects).

relationship in June was driven by one site, without which the relationship was non-significant.

3.3. Cover of crop residue

There was no significant effect of management type on cover of crop residue in either month, but residue cover was greater in June than in July (June organic: 25.49 ± 26.41 , July organic: 19.95 ± 28.39 , June conventional: 35.11 ± 27.86 , July conventional: 27.68 ± 24.34 , management type: $F_{1,16} = 0.74$, $p = 0.40$, month: $F_{1,16} = 14.86$, $p = 0.001$, type \times month: $F_{1,16} = 1.34$, $p = 0.26$).

In crop fields and in field edges, cover of crop residue did not significantly predict nestling food biomass in either month (Table 3). However, for nestling food biomass in hedgerows, cover of crop residue in the field was a significant positive predictor in July (Table 3, Fig. 2).

3.4. Hedgerow plant species richness

Mean hedgerow plant species richness/site ranged from 15 to 36.5 species (25.5 ± 6.0). Hedgerow species richness was not significantly different between organic and conventional hedgerows (organic: 27.17 ± 5.66 , conventional 23.83 ± 6.26 , $F_{1,16} = 1.40$, $p = 0.25$), and did not significantly predict nestling food biomass in any habitat (crop fields: $F_{1,15} = 1.70$, $p = 0.21$, field edge: $F_{1,15} = 0.19$, $p = 0.67$, hedgerow: $F_{1,15} = 2.09$, $p = 0.17$).

4. Discussion

As predicted, nestling food biomass was higher in organic than in conventional soybean fields despite the low level of insecticide use in the conventional fields. This difference was strongest within the crop field which is presumably where the difference in management between organic and conventional fields is greatest. This suggests that the birds that benefit most from organic farming

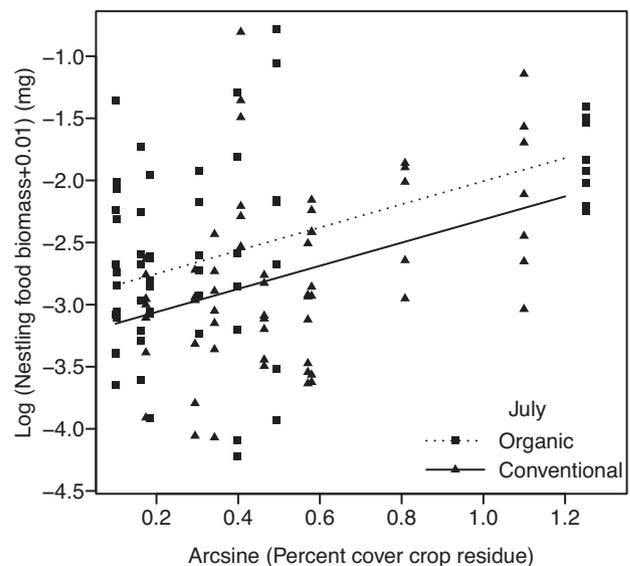


Fig. 2. Predicted nestling food biomass in July based on hedgerows adjacent to 18 soybean fields.

Table 2
Results of mixed models predicting chick food biomass from mean percent weed cover in soybean fields. The random effect is site.

Habitat	Organic								Conventional							
	June				July				June				July			
	β (SE)	F	df	p	β (SE)	F	df	p	β (SE)	F	df	p	β (SE)	F	df	p
Crop	-0.42 (4.04)	0.01	6	0.92	-1.23 (1.05)	1.37	7	0.28	2.33 (2.51)	0.86	7	0.38	1.33 (1.34)	0.99	7	0.35
Edge	-4.64 (0.91)	26.08	7	0.001	-0.17 (0.79)	0.05	6	0.84	-0.01 (1.71)	0.00	7	0.99	-0.43 (1.19)	0.13	7	0.73
Hedge	-2.05 (2.73)	0.56	7	0.48	-0.40 (0.67)	0.36	6	0.57	-0.69 (1.09)	0.40	7	0.56	1.07 (0.92)	1.35	7	0.28

will be those that are most dependent on crop fields for foraging. For example [Piha et al. \(2007\)](#), comparing the effects of landscape structure and organic farming on farmland bird assemblages, found that the bird species that showed increases in population densities in organic fields (lapwing, *Vanellus vanellus*, and skylark, *Alauda arvensis*) were those most strictly associated with agricultural fields.

Invertebrate trapping was carried out in approximate song sparrow territory locations to control for the possibility that birds could be selecting territories with increased food abundance compared to random locations ([Burke and Nol, 1998](#)). If transects were located at random locations and no effect of farm management was found, we could not have rejected the possibility that invertebrate abundance was different between organic and conventional fields within bird territories. However, locating transects within song sparrow territories may limit the generality of our results to other breeding birds.

Studies comparing nest success on organic and conventional farms have typically found few differences ([Lokemoen and Beiser, 1997](#); [Wilson et al., 1997](#); [Bradbury et al., 2000](#); [Kragten and de Snoo, 2007](#)). However, three of these studies examined nests within the crop fields where the largest source of nest failure was destruction by farm machinery, so the role of food in driving reproductive success may be less important in these cases. In our eastern Ontario study region, chick mass and number of fledglings for song sparrows nesting in hedgerows adjacent to conventional farmland, was not affected by variability in nestling food biomass similar in magnitude to the differences in nestling food biomass reported here ([Girard, 2012](#)). This suggests that at least for song sparrows, either the difference in invertebrate biomass between organic and conventional soybean fields in our study area is not large enough to produce a measurable difference in nestling mass or number of fledglings, or the food availability between organic and conventional fields is not altered, despite the difference in food abundance. Nevertheless, even if increased nestling food biomass does not directly affect nestling or even nest survival, it may still benefit birds nesting in organic farmland by allowing breeding to start earlier in the season ([Bradbury et al., 2000](#)) or possibly though increased fledgling or chick survival.

Our results suggest that weed cover and hedgerow plant species richness were not important in explaining the difference in nestling food biomass between organic and conventional fields. The more diverse crop rotations found in organic compared to conventional

fields, may provide an alternate explanation. Diverse crop rotations, together with absence of herbicide, often increase biomass of soil organisms (bacteria, fungi and micro and macro invertebrates, [Altieri, 1999](#)), which can in turn support larger populations of surface-active invertebrates captured in pitfall traps (e.g. [Salamon et al., 2011](#)). Use of manure in place of synthetic fertilizers will enhance this relationship ([Altieri, 1999](#)), but we do not have data on long-term fertilizer use in our study fields. Diverse crop rotations will also act to increase crop diversity in the landscape, which can further increase invertebrate abundance (e.g. [Thorbeck and Topping, 2005](#)).

There was little evidence that weed cover was driving the difference in nestling food biomass between organic and conventional fields, despite the wide variability in weed cover among our sites (Fig. S3). While many previous studies have shown positive effects of weed cover on invertebrate abundance, the effects of weed cover do vary among invertebrate taxa ([Pavuk et al., 1997](#); [Buckelew et al., 2000](#)), so differing responses among taxa may result in a lack of overall effect of weed cover on nestling food biomass. There was also no evidence of an effect of cover of crop residue, a measure of tillage, on nestling food biomass in crop fields or field edges. Tillage passes in many fields occurred in the two weeks prior to the June invertebrate sampling, so if there was a negative effect of tillage, we should have been able to detect it. However, different responses to tillage among invertebrate taxa might again obscure the effect of tillage ([Shearin et al., 2007](#)). Weed cover has generally been shown to have positive effects on non-pest invertebrate abundance (reviewed in [Marshall et al., 2003](#)), whereas tillage has often been shown to have negative effects on ground invertebrate abundance ([Stinner and House, 1990](#)).

We did find evidence of a positive effect of crop residue (i.e. a negative effect of tillage) on biomass of nestling food in hedgerows (Fig. 2). It is difficult to say why tillage should have a negative effect on nestling food biomass in hedgerows, but not in crop fields or field edges. Undisturbed habitats, such as hedgerows can act as a source of colonizers after disturbance by agricultural management ([Thomas et al., 1990](#); [Alvarez et al., 2000](#)), so it is possible that hedgerows adjacent to fields with high tillage have lower nestling food biomass due to invertebrates leaving the hedgerow to recolonize the adjacent fields.

There was no effect of hedgerow plant species richness on nestling food biomass. This is in contrast to previous studies which have often found that invertebrate abundance is correlated with

Table 3
Results of mixed models predicting chick food biomass from mean percent cover of crop residue in soybean fields. The random effect is site.

Habitat	June								July							
	Management type				Crop residue				Management type				Crop residue			
	β (SE)	F	df	p	β (SE)	F	df	p	β (SE)	F	df	p	β (SE)	F	df	p
Crop	0.52 (0.44)	1.40	14	0.26	0.43 (0.70)	0.22	14	0.65	0.71 (0.32)	4.96	15	0.04	0.78 (0.51)	1.12	15	0.31
Edge	0.19 (0.26)	0.54	15	0.47	-0.20 (0.43)	0.31	15	0.58	0.51 (0.25)	4.14	14	0.06	0.49 (0.39)	0.70	14	0.42
Hedge	0.40 (0.21)	3.75	15	0.07	0.53 (0.35)	1.51	15	0.24	0.31 (0.17)	3.37	14	0.09	0.63 (0.31)	10.74	14	0.006

plant species richness in farmland (Asteraki et al., 2004; Hyvönen and Huusela-Veistola, 2011). This difference might be because we measured biomass of ground invertebrates rather than biomass of invertebrates living in the vegetation, which might be more affected by plant species richness (Thomas and Marshall, 1999). In addition, we did not measure species richness of weeds within the crop fields, which may be more important than species richness of hedgerow plants, for invertebrates living in the crop field.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.agee.2014.03.033>.

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