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The environmental impacts of biomass crops: use by birds of miscanthus in summer and winter in southwestern England

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We compared birds in a group of established and well-managed miscanthus (*Miscanthus x giganteus*) fields in Somerset and East Devon, southwestern England, with plots of short rotation coppice (SRC) willow, arable crops and grassland in two winters and one summer. Following early spring cutting, 19 miscanthus fields grew taller, initially produced greater cover and were less weedy than SRC. As stubble in May, the miscanthus contained broadly similar species at similar densities to arable and grassland comparison plots. By July, at 2-m-tall, miscanthus held higher densities of birds but of fewer species, most of them characteristic of woodland and scrub. SRC, previously identified as being a beneficial crop for many birds, always contained more species and individuals than miscanthus. Throughout each of two winters, 15 miscanthus plots remained unharvested and contained more wood/scrub species such as Blackbirds *Turdus merula*, tits, Reed Buntings *Emberiza schoeniclus* and Woodcock *Scolopax rusticola* than the comparison plots, which held more corvids and Skylarks *Alauda arvensis* amongst others. Similar overall mean densities of birds in the miscanthus and the comparison plots masked relatively low density variance in miscanthus and very high variance in the comparison plots. Unharvested miscanthus crops grown in place of habitat types supporting flocks of wintering birds would displace these flocks. Miscanthus plantations with open patches attracted more finches and waders in winter. The two previous studies of birds in miscanthus in the UK found more species and more individuals than we did in summer and winter. Both these studies documented high levels of weediness and patchy crop growth. In the context of this previous work our data suggest that bird use of miscanthus in summer and winter is likely to be variable, affected by region, weediness, crop structure and patchiness. While large-scale cropping of SRC in England is likely to have a positive overall impact on a suite of common farmland and woodland birds, our data suggest that miscanthus in the southwest of England may have an approximately neutral effect. However, some open farmland specialist species may be lost when planting either crop.

Keywords: arable, bioenergy crop, farmland, grassland, short-rotation coppice, willow.

Giant Miscanthus *Miscanthus x giganteus* is a sterile hybrid perennial grass that undergoes C4 photosynthesis (Lewandowski *et al.* 2003, Clifton-Brown *et al.* 2004). When grown as a biomass crop in temperate climates, it is established from rhizomes in the spring and harvested in subsequent springs every year, producing typically over 10 and up to 20 dry tonnes of biomass per hectare (Schwarz & Greef 1996, Bullard 2000, Clifton-Brown *et al.* 2000). Following planting or harvesting, miscanthus produces new shoots which emerge during April once mean daytime temperatures exceed around 10 °C (Farrell *et al.* 2006). Over the

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summer it can grow to 3 m tall in the UK, before senescing over the winter months. As the leaves start to senesce during the autumn, nutrients return to the rhizomes (Mutoh & Nakamura 1978), so fertilizer requirements are low (Defra 2007a). Weed control when establishing the crop is essential but once established, weed growth is suppressed in a vigorous crop by the closure of the canopy and the accumulated leaf litter layer (Bullard 2000). It can be harvested annually for up to 20 years (Defra 2007a). Short rotation coppice willow (SRC) is currently the main alternative biomass crop to miscanthus in the UK. It is planted as cuttings and, once established, produces numerous woody shoots from a basal stool before harvesting every 2 or 3 years. For more information on SRC see Defra (2007a) or Sage *et al.* (2006).

The UK Government's Biomass Strategy (Defra 2007b) predicts that bioenergy crops, including dedicated biomass crops, could occupy some 1.1 million ha by 2020. While the scale of planting to achieve this has not yet materialized [in 2008, biomass crops, mostly miscanthus, planted under the Energy Crops Scheme (Natural England 2009) covered around 7500 ha in England], the RELU-Biomass project (http://www.relu-biomass.org.uk) aims to inform the bio-energy debate and future land-use planning processes about the impacts of the large scale introduction of miscanthus and SRC willow (*Salix* spp.) (Haughton *et al.* 2009). It uses an integrated approach to assess the social, economic and environmental implications of changing rural land use and focuses on the maintenance or enhancement of biodiversity. To provide the necessary information, data have been collected on plants and insects in SRC and miscanthus using the Farm Scale Evaluation (FSE) methodology (Firbank *et al.* 2003), plus bird counts in miscanthus only. Studies of birds in SRC show that SRC willow will bring new bird communities to farmland and provide opportunities for many existing farmland species while displacing relatively few (Sage & Robertson 1996, Sage *et al.* 2006). In this study, we count birds in miscanthus and compare these counts with those in nearby arable and grass fields, and in a sample of cut SRC willow fields. This provides the basis for comparisons between miscanthus and the types of fields miscanthus is likely to replace, as well as with SRC willow, the main alternative biomass crop in the UK.

The RELU-Biomass data collection programme ran between 2005 and 2008, inclusive, and coincided with the establishment phase of the first generation of commercial miscanthus crops grown in the UK. Previous work on birds in early miscanthus plantings in the UK suggested that these crops can attract a variety of birds in summer and winter at relatively high densities (Semere & Slater 2007, Bellamy *et al.* 2009). Both these studies used count data from an early generation of non-commercial miscanthus plantations, most of which were poorly established, with patchy growth across fields and generally high weed cover. Semere and Slater (2007) used only two sites, both of which held poorly established crops that were essentially weedy fields with a relatively small amount of miscanthus growth. The more recent study by Bellamy *et al.* (2009) was undertaken in six better established miscanthus crops, but these still recorded mean weed cover of 60%. Both papers suggested that the birds recorded may, at least partly, be a response to this poor crop growth and weediness. The questions this poses are first, will commercial miscanthus crops continue to be patchy and have high weed cover and secondly, if not, will birds still use the crop?

The bird surveys reported here were undertaken in commercial miscanthus fields. Comparing these new data with those collected by previous studies provides the first insight into the likely impacts of large-scale cropping of miscanthus grass in the UK on birds. It also provides some clues as to the factors that are likely to influence the crop's value to birds and hence where crop management protocols may provide the scope for stewardship options in the future which maximize bird use and minimize unwanted impacts.

METHODS

Study sites

Surveys were carried out in two winters (2006/07 and 2007/08) on 15 miscanthus and 15 comparison plots, and in one summer (2008) on 19 miscanthus plots and 20 comparison plots (arable, grassland and SRC willow) in Somerset and East Devon, southwestern England. All miscanthus plots were managed by the leading UK grower of these crops (Bical). We selected miscanthus fields by visiting potentially suitable sites for which Bical had provided details and from which a final sample was defined. Small fields (< 2 ha) were excluded and the largest selected was 9 ha. Where arable or grass comparison plots were greater than about 10 ha, a 10-ha portion of the field was surveyed. The sites used in the study were a mix of cane crops, used for producing biomass over many years, and rhizome crops, used for producing miscanthus propagation material. Rhizome crops are often destroyed after 2 or 3 years when the rhizomes are harvested. All miscanthus crops were grown commercially and most were agronomically well managed, although some fields had open patches.

Comparison fields were usually on the same farm as a miscanthus plot, although at two sites in winter and four in summer, suitable fields were located on other holdings nearby. The arable and grass field types were chosen in discussion with Bical with regard to the typical previous land use of miscanthus plots. The aim was to use grass or arable comparison plots on grade 2 or 3 land in winter and summer, as this is the type of land on which miscanthus is usually planted (T. Cox pers. comm.). Arable plots were predominantly winter wheat but included several oilseed rape fields. In summer only, we also included a sample of cut SRC plots. Unlike miscanthus, which is harvested every year, SRC is harvested every second or third year. Cut SRC describes a crop harvested in the previous winter. In the spring, cut SRC appears as a field of small coppice stools from which the new leaf and shoots grow over the following months. We did not count birds in SRC plots in winter because of limited resources.

Crop characteristics

In both June and July, crop canopy cover and crop height were measured in each plot of miscanthus or cut SRC. Crop canopy cover was estimated as a percentage of leaf or stem area in a 2 × 2-m quadrat at each of 10 locations. In May, June and July, the cover of weeds on the soil surface, excluding the biomass crop itself, was estimated using the DAFOR scale (Dominant > 50%, Abundant 25–50%, Frequent 10–25%, Occasional 1–10%, Rare < 1%) in 10 10 × 1-m quadrats. Mean values for each plot were estimated for each of these 3 months before comparing overall means for each crop type each month using *t*-tests. In winter, the standing miscanthus crops were categorized as either open or closed, as several sites had a number of significant open patches within them in both years, while others had a continuous uniform stem structure.

Summer bird surveys

In summer 2008 we recorded birds in a total of 19 miscanthus plots, eight wheat fields, six grassland fields and six recently cut SRC plots. Fifteen of the miscanthus fields had been established for at least 3 years; the remaining four were planted in 2007 and cut (but not harvested) prior to the study. At the start of the summer surveys the established miscanthus plots had recently been harvested, with the exception of three sites that were not harvested until June and were therefore not surveyed during May. Bird surveys were undertaken in all plots once each in May, June and July. The aim of all surveys in miscanthus, cut SRC, and arable and grass comparison plots was to cover a discrete area, usually but not always a whole field, and to record, usually by flushing, all birds in that area. In all plot types, birds were recorded in the crop itself, but not those in field boundary features.

In May and June, the crop height in the miscanthus and cut SRC plots was low enough to allow birds to be surveyed by systematically walking transects through the crop until the entire area of the field was covered. Transects were never more than 50 m apart or crop edges < 25 m away. The arable and grassland plots were monitored in this way throughout the study. By July, the typical height of the miscanthus was 2 m (with SRC slightly shorter) and different methods were employed. This involved the use of two surveyors, one watching from a high vantage point (usually a deer seat located strategically within the field) whilst the other walked through the crop along transects 10 m apart to cover an area of 2 ha around the vantage point. Birds were flushed from the crop by the walker and recorded by the observer.

Winter bird surveys

A total of 15 miscanthus plots and 15 arable and grassland comparison plots were monitored three times during the winter (mid-November/December, January and February) over two consecutive years (2006/07 and 2007/08).

The miscanthus plots were monitored by two field surveyors, one watching the plot from a high vantage point, as in the July surveys, whilst the other walked through the crop to flush birds. The entire area that was visible from the vantage point was walked for a time period ranging from 45 to 75 min depending on the size of the plot. The size of the visible area covered in this way was estimated so that the number of birds recorded per hectare could be calculated. A similar time was spent walking the comparison plots.

Data analysis

Summer counts were converted to densities for each species by dividing by plot area, and then log-transformed prior to analysis. Log-transformed densities were normally distributed and significant overall effects of crop type on mean bird numbers were identified using ANOVA for each of the three survey months in turn. Contrast analysis was then used to identify significant differences between two crop types, in particular between biomass crops or between miscanthus and the arable and grass comparison plots. This ANOVA-based approach was used in an analysis of similar bird count data from commercial willow SRC (Sage *et al*. 2006), and is used again here to permit easier comparison between the two studies and hence crop types.

The winter counts, for both the comparison and the miscanthus plots could not be normalized with transformations, so non-parametric tests were used to compare mean bird densities between plots. First, we compared densities of individual or groups of species in winter between open or closed miscanthus fields, by month, using Kruskal–Wallis tests. Secondly, because of the tendency of birds to group in winter, we tested for differences in the frequency of occurrence of species on plots using Pearson's Chi-square tests. Lastly, we tested for differences in the overall distribution functions of birds (densities of all species summed) between miscanthus and comparison plots that contained birds (assessing whether flocks of birds were more likely on arable or grass than miscanthus) using a Kolmogorov–Smirnov test. We treated each plot/visit combination as a separate data point for these comparisons if there was no consistent pattern (of, for example, flocking) across visits at certain sites (i.e. if, in a Kruskal–Wallis test, bird densities did not vary significantly between plots per visit).

RESULTS

Crop characteristics

All plots in both our samples of miscanthus and SRC were cut near to the ground in late winter or spring, usually before our surveys. Miscanthus then grew more quickly and became significantly taller than the SRC by visit 3 (July, $t_{23} = 2.92$, $P = 0.008$). In June only, miscanthus also had significantly greater canopy cover ($t_{23} = 2.47$, $P = 0.021$) (Fig. 1). Weediness was much greater in SRC fields than miscanthus fields throughout the summer (e.g. July, $t_{23} = 3.21$, $P = 0.004$) (Fig. 1). In the winter, all miscanthus plots remained unharvested throughout the survey period (until at least the end of February).

Summer birds

Fourteen bird species were recorded in the 19 miscanthus plots during the summer, 12 in the eight wheat fields, 10 in the six grass fields and 21 in the six cut SRC plots (see Appendix 1 for list). Only Chaffinch *Fringilla coelebs*, Greenfinch

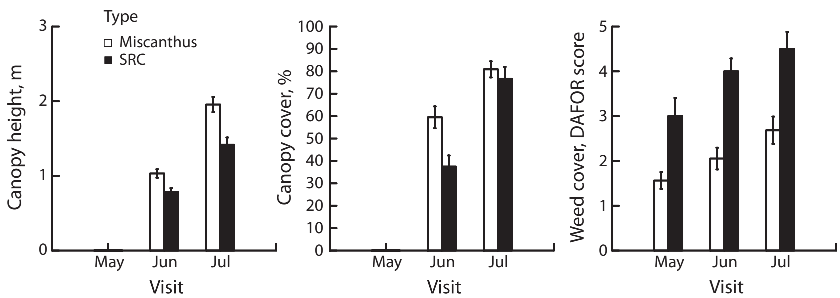

Figure 1. Changing characteristics of miscanthus and cut-back willow SRC during the summer (crop height and cover not measured in visit 1, May). Miscanthus was taller, denser and less weedy than SRC in some or all months. Mean values ± 1 se. A DAFOR score of 2 is equivalent to 5–10% weed cover, 3 is 10–25% and 4 is 25–50%.

Carduelis chloris and Reed Warbler *Acrocephalus scirpaceus* were recorded in the miscanthus but not in the wheat or grass. Species only found in the SRC included certain warblers, Linnet *Carduelis cannabina* and Goldfinch *Carduelis carduelis* and, early in the summer, Northern Lapwing *Vanellus vanellus*. A European Nightjar *Caprimulgus europaeus* was also flushed from one SRC plot in July and a Green Woodpecker *Picus viridis* from another in June.

There was no difference in the mean density of all birds across the four plot types in May (Table 1). Skylarks *Alauda arvensis* were more common in the arable and SRC than in the miscanthus and corvids were more common in the grass than in the miscanthus, wheat or SRC.

Table 1. Densities of birds recorded in miscanthus (MC), short rotation coppice willow (SRC), wheat and grass. W+G is mean of wheat and grass comparison plots combined.

	Bird density (no./ha, mean ±1se)				ANOVA	Contrasts $F_{1,32}$		
Group	MC	SRC	Wheat	Grass	$F_{3,32}$	MC vs. SRC	MC vs. W+G	SRC vs. W+G
a. May, when biomass crops are typically below knee height (Fig. 1)								
Total Birds	0.35 + 0.23	0.46 + 0.10	0.27 + 0.10	0.49 + 0.35	ns			
Thrushes	0.03 + 0.02	0	0.02 + 0.02	0.01 + 0.01	ns			
Finch & Buntings	0.03 + 0.03	0.04 + 0.03	0.02 + 0.01	0	ns			
Pipits & Wagtails	0.26 + 0.23	0.02 + 0.02	0	0	ns			
						MC vs. SRC	MC vs. W	SRC vs. W
Skylark	0	0.12 + 0.06	0.10 + 0.03	0	6.02**	10.6***	6.02**	ns
						MC vs. SRC	MC vs. G	SRC vs. G
Corvids	0.01 + 0.01	0	0.03 + 0.03	0.40 + 0.28	3.97*	ns	10.6**	7.7*

	Bird density (no./ha, mean ±1se)				ANOVA	Contrasts $F_{1,36}$		
	MC	SRC	Wheat	Grass	$F_{3,36}$	MC vs. SRC	MC vs. W+G	SRC vs. W+G
b. June, when biomass crops are typically around waist height (Fig. 1).								
Total Birds	0.22 + 0.05	1.99 + 0.78	0.28 + 0.11	0.96 + 0.83	7.68***	21.8***	ns	15.6***
Thrushes	0.05 + 0.02	0.14 + 0.12	0.05 + 0.03	0.01 + 0.01	ns			
Finch & Buntings	0.07 + 0.03	0.91 + 0.71	0.03 + 0.03	0	4.15*	9.46**	ns	10.8**
Warblers	0	0.07 + 0.06	0	0	ns			
Robin & Dunnock	0	0.02 + 0.02	0.03 + 0.03	0	ns			
						MC vs. SRC	MC vs. W	SRC vs. W
Skylark	0.06 + 0.03	0.31 + 0.12	0.10 + 0.04	0	5.01**	11.7**	ns	4.98*
						MC vs. SRC	MC vs. G	SRC vs. G
Corvids	0.04 + 0.02	0	0.02 + 0.02	0.89 + 0.78	3.06*	ns	7.76*	6.06*

	Bird density (no./ha, mean ±1se)				ANOVA	Contrasts $F_{1,35}$		
	MC	SRC	Wheat	Grass	$F_{3,35}$	MC vs. SRC	MC vs. W+G	SRC vs. W+G
c. July, when biomass crops are typically around or above (for miscanthus) head height (Fig. 1)								
Total Birds	1.35 + 0.23	3.20 + 0.83	0.38 + 0.10	0.21 + 0.12	11.9***	9.34**	23.1**	34.9***
Thrushes	0.45 + 0.16	0.99 + 0.20	0.12 + 0.09	0	5.21**	6.33*	7.68**	15.6***
Finch & Buntings	0.42 + 0.13	0.93 + 0.45	0.03 + 0.02	0	3.89*	ns	8.05*	11.2**
Warblers	0.08 + 0.06	0.73 + 0.36	0	0	7.51***	17.6***	ns	ns
Robin & Dunnock	0.01 + 0.01	0.22 + 0.10	0.04 + 0.04	0	6.85***	14.3***	ns	ns
Pipits & Wagtails	0	0	0.02 + 0.02	0.05 + 0.03	ns			
Skylark	0.12 + 0.07	0.14 + 0.09	0.13 + 0.07	0	ns			
						MC vs. SRC	MC vs. G	SRC vs. G
Corvids	0	0	0	0.08 + 0.05	6.41**	ns	17.3***	11.4**

ns $P > 0.05$, *$P < 0.05$, **$P < 0.005$, ***$P < 0.0005$.

In June, the mean density of birds in the miscanthus plots was similar to that in the wheat and grass but there were higher densities in the SRC (Table 1b). The miscanthus contained the occasional Skylark, Reed Bunting *Emberiza schoeniclus*, Yellowhammer *Emberiza citrinella* and Chaffinch. The SRC had relatively high numbers of Blackbirds, Chaffinches, Goldfinches, Linnets, Reed Buntings, Skylarks, Reed Warblers and Yellowhammers.

By July, the miscanthus plots contained more birds than the arable and grassland (Table 1c). This was due to an increase in the numbers of birds attracted to dense cover, especially Blackbirds, Reed Buntings (recorded in half of all plots) plus the occasional Reed Warbler. There were still higher densities of birds in the recently cut SRC plots than the miscanthus, with more thrushes, finches and buntings as in June, plus European Robins *Erithacus rubecula*, Dunnocks *Prunella modularis*, Common Whitethroats *Sylvia communis* and Willow Warblers *Phylloscopus trochilus*. In June and July, corvids were the only group more common in the grass than the biomass crops and the occasional House Sparrow *Passer domesticus* only occurred in the wheat fields.

Winter birds

Over both years, 20 species were recorded in the miscanthus in winter compared with 26 in the comparison plots (Appendix 2). More species were found in the miscanthus on a regular basis than the grass or arable plots, with nine species recorded from at least four miscanthus plots in one or other year compared with only one, the Carrion Crow *Corvus corone*, from the grass plots. Fourteen of the 26 species recorded in comparison plots did not occur in miscanthus at all, whereas 8 of 20 species occurring in the miscanthus did not occur in the comparison plots.

There was no significant difference in the total number of birds using the arable or grass comparison plots in either year for each month (Kruskal–Wallis tests, $P > 0.1$ in all cases). Data from these plots were combined for further statistical comparisons with miscanthus. The average density of birds (all species combined) recorded in miscanthus plots was not significantly different from the comparison plots (Table 2). There were, however, more thrushes, Robins, Dunnocks and tits (Paridae) in miscanthus fields in one or more months/years, whereas there were consistently more corvids in the comparison plots than in the miscanthus.

Neither the presence nor the numbers of birds varied significantly between plots per visit for either the comparison plots (e.g. total birds, year 1: Kruskal–Wallis $(KW)_{14} = 18.1$, $P = 0.22$; year 2: $KW_{14} = 18.8$, $P = 0.17$) or the miscanthus plots (total birds, year 1: $KW_{14} = 21.9$, $P = 0.10$; year 2: $KW_{14} = 16.1$, $P = 0.32$). This indicates no consistent pattern across visits at certain sites for either plot type in winter. In year 1, the likelihood of a comparison plot having no birds when visited was 0.36 (16/45) and 0.29 (13/45) for the miscanthus plots (no difference, $\chi^2 = 0.46$, $P = 0.5$) but in year 2 was 0.47 (21/45) for comparison plots and 0.24 (11/45) for miscanthus plots (significant difference, $\chi^2 = 4.85$, $P = 0.028$). For sites with birds, the difference in probability distributions in a Kolmorgorov–Smirnov two-sample test was 0.370 ($P = 0.031$) in year 2, indicating that the frequency

Table 2. Average densities for species groups in miscanthus plots and comparison plots in winter by month (December, January, February).

	Year 1			Year 2		
	December	January	February	December	January	February
Total Birds						
Thrushes	M**			M*	M*	M*
Finch & Buntings						
Robin & Dunnock			M*	M*		M*
Tits			M**			
Pipits & Wagtails						
Skylark						
Waders						
Corvids	C**	C*		C*	C*	C*

Kruskal–Wallis test with 1 df in all cases. *$P < 0.05$, **$P < 0.005$. M – more in miscanthus, C – more in comparison plot.

distributions (Fig. 2) differed significantly between miscanthus and comparison plots. The arable and grass plots were more likely to contain flocks of birds (Fig. 2) such as Fieldfares *Turdus pilaris*, Common Starlings *Sturnus vulgaris*, Skylarks and Lapwings, all of which were absent from miscanthus plots in both winters.

Miscanthus fields that had uniform dense cover tended to have fewer birds overall, and fewer finches and buntings, and fewer waders (e.g. Common Snipe *Gallinago gallinago* and Eurasian Woodcock *Scolopax rusticola*) than miscanthus fields that had open patches (Fig. 3, Table 3).

DISCUSSION

Summer bird use

Previous studies of birds in large commercial, uncut SRC plantations in summer recorded two or three individual birds per hectare of crop (Sage *et al.* 2006), with five or six or sometimes even more in the edge zone (Göransson 1994, Sage & Robertson 1996, Sage & Tucker 1997), to reach levels comparable with traditional woodland coppice habitats (Fuller & Henderson 1992). In our cut SRC (normally cut every third year), we still found two or three birds per hectare in June and July, respectively. This was significantly higher than in the miscanthus plots, particularly in June, when very few birds were recorded. Species composition in the miscanthus was broadly similar to the SRC, albeit at lower densities (Sage *et al.* 2006). The main difference was that warbler and certain finch species were relatively less common in the miscanthus fields. We know little about how birds use either of these crops, although some of the birds recorded in SRC are known to nest in the crop or nearby and forage there (Sharples 1997, Sage *et al.* 2006).

While we attempted to see all birds in survey areas of all crop types, we need to be aware of

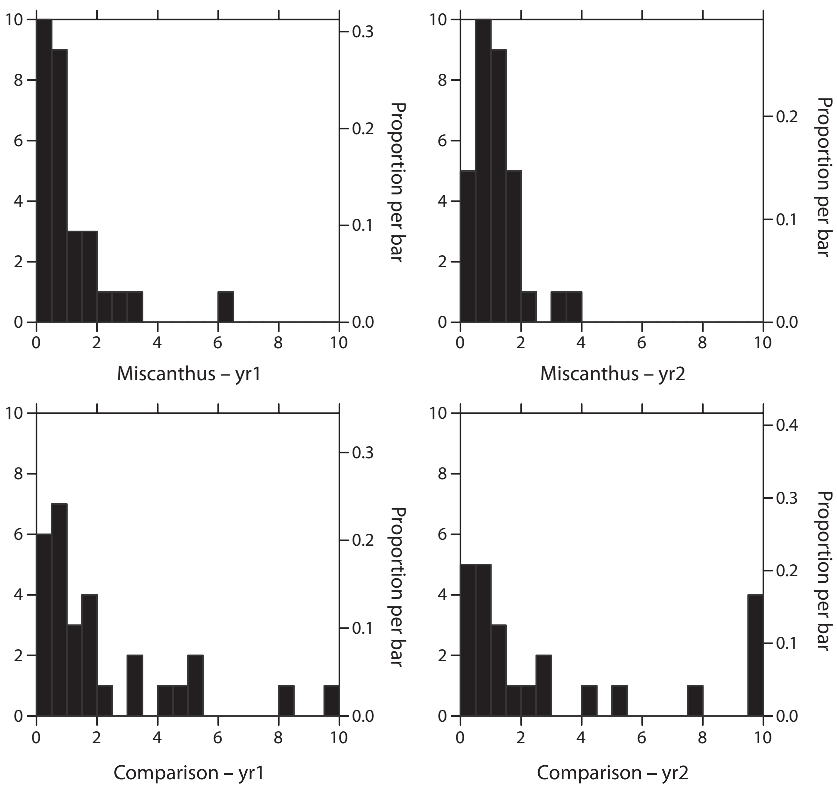

Figure 2. Histograms showing the number (left *y*-axis) and proportion (right *y*-axis) of sites when visited at which different numbers of total birds per hectare were recorded in winter counts (*x*-axis, birds per hectare) each year. In year 2, these frequency distributions were different for the miscanthus plots compared with the comparison plots (see Results) – the surveyor did not record more than four birds per hectare in any miscanthus field but did on seven occasions in a comparison plot.

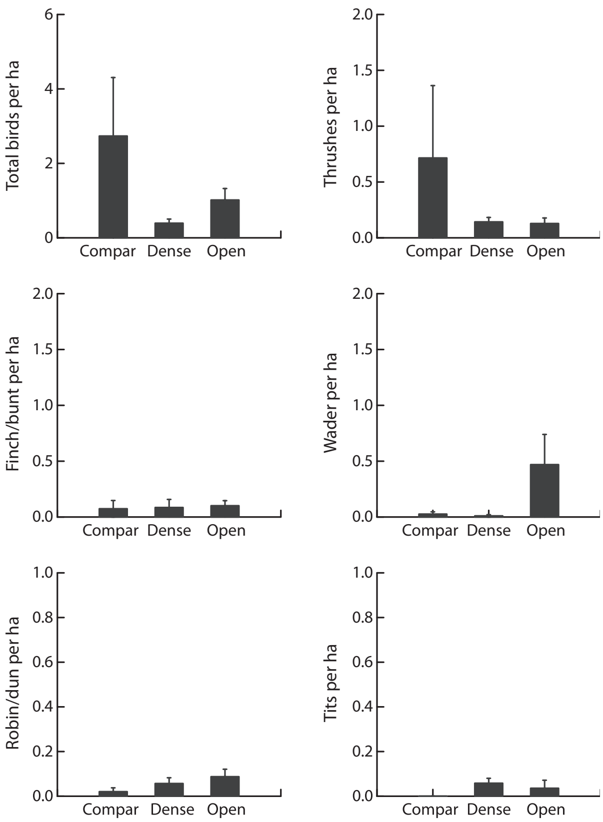

Figure 3. Mean winter numbers of key bird groups (± 1 se) in comparison plots and in dense and open miscanthus plots in year 2 for all months combined. Data for year 1 were similar. In some months, differences between comparison and miscanthus plots (Table 2), and between open and dense miscanthus were significant (Table 3).

possible differences in detectability, and changes in these differences with different crop phases, between in particular miscanthus and the arable and grass comparison crops. In early summer, the recently cut-back miscanthus stubble plots contained broadly similar species to the arable and grass fields (the crops most likely to be replaced by miscanthus on grade 2 or 3 land). Although Skylarks were common in miscanthus plots in June and July, they were absent in May. This may be due to the late harvesting of miscanthus plots (April), after Skylarks had already established territories. Corvids were much more common in grassland fields so that, overall, bird densities were similar in miscanthus to the grass comparison plots during May and June. Taking account of recent declines of some species (Gregory *et al.* 2004), our data from the arable fields are consistent with those of Arnold (1983) who found on average 0.5 songbird territories per hectare of arable land.

In July, however, a switch in species use was recorded in the miscanthus with the arrival of Blackbirds and Reed Buntings. Overall densities of birds in miscanthus increased, too, while densities in the arable and grass fields did not. It is possible that this difference is a function of the change in survey method in miscanthus in July. It is likely that by July the birds were responding to the changing structure of the miscanthus in conjunction with their changing needs during the breeding season but we cannot test this because changes in structure are confounded with month. In SRC, which is not cut back every year, breeding birds have been found to use different age classes of the crop, which have differing structures (Sage & Robertson 1996). Similarly, the age-class-based structural changes of traditional coppice habitats have been shown to influence bird use heavily (Fuller & Henderson 1992). Because the structure of miscanthus crops changes so rapidly, it is conceivable that the immediate environment and

Table 3. Average densities for species groups between dense and open miscanthus plots in winter by month (December, January, February).

	Year 1			Year 2		
	December	January	February	December	January	February
Total Birds					O*	
Thrushes						
Finch & Buntings		O*				
Robin & Dunnock						
Tits			D*			
Waders		O*				

Kruskal–Wallis test with 1 df in all cases. **P* < 0.05. D – more in dense miscanthus, O – more in open. See also Figure 3.

microclimate in which nesting birds find themselves becomes inhospitable and it is possible that the potential of some breeding birds to hatch and fledge young is compromised.

Bellamy *et al.* (2009) recorded 24 bird species in six miscanthus fields in Cambridgeshire, twice as many as in six arable plots, at a mean density of 1.8 + 0.12 birds/ha, three times the density recorded in wheat. They recorded more warblers, Skylarks, finches and buntings in miscanthus than we did in our study in southwest England. Notwithstanding the slightly higher bird density in their arable plots, there is a substantial disparity between Bellamy's findings and ours. Notable was the presence of 0.4 breeding warblers (mostly Reed Warblers) per hectare in Bellamy's miscanthus. Breeding *Acrocephalus* warblers favour shrubby habitats including SRC and traditional willow coppice, but only when it is weedy (Price 1969, Sage 1995). Bellamy *et al.* recorded mean weed cover of 59% in their miscanthus fields, whereas at our sites mean weed cover peaked at between 10 and 20%. While the studies were undertaken in different regions of southern England, it is possible that weediness explains at least some of the difference in bird species composition and densities recorded in the two studies.

The availability of insects in these biomass crops may also be a key factor in their value to breeding birds. In general the decline in the insect resource in intensively managed arable crops is thought to have contributed to the decline of many farmland birds (Fuller 2000, Gregory *et al.* 2004). A notable feature of SRC is its rich invertebrate resource in the canopy of the crop itself (Sage & Tucker 1997), which is available to foraging birds (Sharples 1997). SRC contains these insects even if it is not weedy (Sage 1995), although the crop has a high tolerance for weeds (Sage 1999). Bellamy *et al.* (2009) sampled insects and found many more in the cereal crop samples than in the miscanthus crop. Currently unpublished detailed data on insects from a large number of SRC and miscanthus sites from the RELU-Biomass programme indicate that insects occur in miscanthus on the soil and, where weeds are present, that the crop canopy supports relatively few insects.

Winter bird use

In winter, the habitat structure presented by miscanthus was relatively stable, as the crop remained unharvested throughout our winter survey period at all sites in both years. There is a relatively subtle structural change (not quantified here) as most lower leaves drop and the crop, while still standing, thins out, leaving a mass of bamboo-like canes. While overall mean densities of birds in winter were similar in miscanthus and in arable and grass comparison plots, there were significant differences in densities of some species groups. Miscanthus held more thrushes (mostly Blackbirds), tits, Robins, Winter Wrens *Troglodytes troglodytes* and Dunnocks in one or more months/years. Comparison plots had consistently higher densities of corvids throughout. Species associated with open habitats such as Skylark and Lapwing were not found in miscanthus in winter. Some of the miscanthus sites provided good overwintering habitat for Snipe and Woodcock, especially when the crop had open patches. Overall, the two crop types had an overlapping but different species composition (see Appendix 2), with 14 of the 26 species recorded in comparison plots not occurring in miscanthus and eight of the 20 species occurring in the miscanthus not found in the arable or grass.

As in the summer, Bellamy *et al.* (2009) found more bird species, and at higher densities, than we did in our study. In Cambridgeshire, there were 24 species at a mean density of 5.0 + 1.8 per hectare in winter in six miscanthus fields, twice as many species as found in six arable plots. In particular, Bellamy *et al.* found many more seed-eating passerines than our study did in southwest England. Again, region may explain part of this difference but the seed resource and cover associated with the very high weediness recorded in Bellamy *et al.*'s fields may also be important. Our finding in relation to crop patchiness also reinforces the idea that patchy growth in miscanthus improves opportunities for birds. Although not quantified, it appears that at some sites, weeds cause patchy growth and at others it is likely that weeds take advantage of areas where crop establishment is poor. Patchy crop growth and weediness may work together to attract birds in this otherwise dense crop.

The overall similarity in winter bird densities between miscanthus and comparison plots masks a very different overall pattern of use. First, the open arable and grass fields were more likely to contain flocks of certain species than the miscanthus plots (e.g. Fieldfare, Linnet, Skylark, Starling), some of which were entirely absent from miscanthus (Appendix 2). Secondly, the comparison plots also had a higher proportion of sites in which no birds were recorded (Table 1). Thirdly, no species other than Carrion Crow were recorded at more than three comparison plots, whereas many more species occurred at four or more miscanthus sites. In these respects, miscanthus contains bird assemblages more like those found in SRC, scrub or shrub habitats but with some species missing or at lower densities (Fuller & Henderson 1992, Sage & Robertson 1996).

This fundamentally different distribution and species composition of birds in winter in the miscanthus compared with the crops it is likely to replace (grade 2 and 3 arable and grass) is significant because widespread plantings of miscanthus in areas could displace flocks of species that use open field habitats. This could have a significant negative impact on overwinter habitat availability for these birds in these regions where cropping was widespread. Currently, miscanthus crops are cut in late winter or early spring so we do not know whether cut miscanthus fields would be attractive to open farmland birds at this time. It is possible that they are and it may be that early cutting could be good practice for birds. However, it is currently not seen by the industry as a practical option because the moisture content of miscanthus declines during the winter and minimizing it is a key quality objective (Defra 2007a, Bical pers. comm.)

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

Overall, our data suggest that the numbers of species and densities of birds using miscanthus fields in Somerset/East Devon in summer and winter were comparable with those in other crops. Species composition changed from open field species to scrub/woodland species during the summer as the crop structure underwent considerable change. In winter, the miscanthus remained unharvested and contained a different community of birds from the comparison plots but with similar mean densities. This, however, masked a more complex picture of relatively low density variance in miscanthus (always a few birds in each plot) and very high variance in the comparison plots with several species that formed flocks at some sites and others containing no birds at all. The availability of suitable winter sites for these flocks could be reduced by widespread plantings of miscanthus.

Previous work (e.g. Sage *et al.* 2006) suggests that SRC willow planted as a biomass crop could have a positive overall impact on both the Farmland Bird Indicator (FBI) and Woodland Bird Indicator (WBI) species lists [which include 19 and 33 common birds that best indicate the state of the farmland and woodland environment in England (British Trust for Ornithology 2009)]. Our data suggest that miscanthus biomass crops may have an approximately neutral overall impact, with perhaps four FBI species benefitting (Woodpigeon *Columba palumbus*, Skylark, Reed Bunting and Yellowhammer), six adversely affected and with not enough information on about nine, plus four of the generalist WBI species benefitting (Blackbird, Chaffinch, Dunnock, Robin, but this could rise with more information).

Large-scale but sympathetic cropping of SRC is therefore likely to have a positive overall impact on common farmland and woodland birds in this country and, potentially, elsewhere in Europe. However, a number of scarce or declining farmland species (e.g. Grey Partridge *Perdix perdix* or Stone Curlew *Burhinus oedicnemus* in England) would be negatively affected by large-scale SRC cropping and most woodland specialists will not use this crop (Sage *et al.* 2006). Miscanthus may have a roughly neutral overall impact on common farmland and woodland generalists in the southwest of England but there is possibly an even greater need to identify and avoid conflicts with open farmland specialists. This is currently a tentative conclusion, partly because we found fewer bird species and individuals than in the other two main published sources of information on birds in miscanthus in a European context (Semere & Slater 2007, Bellamy *et al.* 2009). We also need to be aware that our data were collected from a regionally confined group of sites. We would expect to see differences in bird use in different regions. In summer 2009, bird surveys were undertaken in miscanthus sites in the southwest and east Midlands of England by the RSPB and Game and Wildlife Conservation Trust. These provisionally suggest that Lapwing and Skylark were more common in miscanthus fields in early summer in Lincolnshire than in Somerset (G. Anderson pers. comm.).

Comparison of our data from this latest generation of well-maintained miscanthus fields together with the findings of previous studies in less well-managed crops (especially Bellamy *et al.* 2009) suggests that there may be a significant crop management impact on bird use. In particular, weediness and crop patchiness may be decisive factors for many birds, and there may be potential to manipulate miscanthus crops for birds by developing plantation design and management options within agri-environment schemes. We suggest further work, possibly focused on individual species, to improve understanding of bird exploitation of these crops, the effects of changing crop structure on these activities and, in the winter, the potential effects of earlier harvesting.

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APPENDIX 1

Summer birds. Species recorded from miscanthus, SRC and from arable and grass comparison plots by month in summer 2008 and their mean density within the crop.

	Miscanthus			SRC			Wheat			Grass		
	May	June	July	May	June	July	May	June	July	May	June	July
Blackbird *Turdus merula*	*	**	****		***	****	*	*	**	*	*	
Carrion Crow *Corvus corone corone*	*	*					*	*		*	*	*
Chaffinch *Fringella coelebs*		*		*	***	***						
Dunnock *Prunella modularis*			*		*	*		*	*			
Goldfinch *Carduelis carduelis*					****	**						
Greenfinch *Carduelis chloris*	*					*						
Green Woodpecker *Picus viridis*					*							
House Sparrow *Passer domesticus*							*	*	*			
Jackdaw *Corvus monedula*		*								***	*	
Northern Lapwing *Vanellus vanellus*				***	*							
Linnet *Carduelis cannabina*				*	****	***						
Magpie *Pica pica*										*		**
Mallard *Anas platyrhynchos*				*								
Mistle Thrush *Turdus viscivorus*												
Meadow Pipit *Anthus pratensis*	***								*			*
European Nightjar *Caprimulgus europaeus*						*						
Pheasant *Phasianus colchicus*				*			**		*	**		
Pied Wagtail *Motacilla alba yarrellii*												*
Red-legged Partridge *Alectoris rufa*	*	*	**	*	**			*				
Reed Bunting *Emberiza schoeniclus*	*	*	****	*	***	****	*	*	*			
Reed Warbler *Acrocephalus scirpaceus*			**									
European Robin *Ericathus rubecula*						**						
Rook *Corvus frugilegus*										**	****	
Sedge Warbler *Acro. schoenobaenus*					*							
Skylark *Aluada arvensis*		**	***	***	****	***	***	***	***			
Barn Swallow *Hirundo rustica*												*
Common Whitethroat *Sylvia communis*					*	****						
Willow Warbler *Phylloscopus trochilus*						***						
Woodpigeon *Columba palumbus*			***	***	***	**		*			**	**
Yellowhammer *Emberiza citrinella*		*	**		**		*		*			
Yellow Wagtail *Motacilla flava*	*			*					*			

*Mean density < 0.05 birds per hectare.
**0.05–0.1 birds per hectare.
***0.1–0.3 birds per hectare.
****> 0.3 birds per hectare.

APPENDIX 2

Winter birds. Total number of each species recorded over three separate visits (November/December, January and February) in miscanthus and comparison plots in each of two winters with the number of sites present also shown.

	Miscanthus				Comparison plot			
	Winter 2006/07		Winter 2007/08		Winter 2006/07		Winter 2007/08	
Species	Total no.	Sites present	Total no.	Sites present	Total no.	Sites present	Total no.	Sites present
Blackbird *Turdus merula*	22	12	37	12	1	1	1	1
Black-headed Gull *Larus ridibundus*							40	2
Blue Tit *Cyanistes caeruleus*	7	6	3	2				
Common Buzzard *Buteo buteo*					4	2	8	2
Carrion Crow *Corvus corone corone*					25	9	19	8
Chaffinch *Fringella coelebs*	6	3	4	2	39	2	16	2
Dunnock *Prunella modularis*	5	2	5	5	2	2		
Fieldfare *Turdus pilaris*					175	1	52	2
European Goldfinch *Carduelis carduelis*	1	1	2	1				
Grey Heron *Ardea cinerea*					1	1		
Herring Gull *Larus argentatus*							4	1
Jackdaw *Corvus monedula*					15	1	4	1
Northern Lapwing *Vanellus vanellus*							58	1
Linnet *Carduelis cannabina*	5	1	5	1	20	1	32	2
Long-tailed Tit *Aegithalos caudatus*	4	1	7	3				
Magpie *Pica pica*					1	1	1	1
Meadow Pipit *Anthus pratensis*	11	3	2	1	55	3	34	3
Mistle Thrush *Turdus viscivorus*					2	1	2	1
Pheasant *Phasianus colchicus*	75	7	76	10	10	3	5	3
Pied Wagtail *Motacilla alba yarrellii*	2	1			4	2	13	3
Red-legged Partridge *Alectoris rufa*			1	1			38	2
Reed Bunting *Emberiza schoeniclus*	6	1	2	1	10	1	24	2
Reed Warbler *Acrocephalus scirpaceus*	6	4	10	7				
European Robin *Ericathus rubecula*	4	4	6	2	1	1		
Rook *Corvus frugilegus*					11	1	3	1
Skylark *Aluada arvensis*					26	2	61	2
Common Snipe *Gallinago gallinago*	36	4	10	2	6	1	1	1
Eurasian Stonechat *Saxicola torquatus*	2	1						
Song Thrush *Turdus philomenos*			1	1				
Common Starling *Sturnus vulgaris*					255	2	5	1
Eurasian Woodcock *Scolopax rusticola*	11	5	4	3				
Woodpigeon *Columba palumbus*					17	3	9	1
Winter Wren *Troglodytes troglodytes*	3	3	5	4				
Yellowhammer *Emberiza citrinella*	4	1					12	1