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HABITAT PREFERENCE AND PREY SELECTION OF MARSH HARRIER (*CIRCUS AERUGINOSUS*) IN OVERWINTERING AREA OF SOUTHEAST CHINA

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Marsh harrier (*Circus aeruginosus*) populations have declined dramatically in China for a variety of reasons, in particular habitat destruction. In order to better understand this key protected species in its overwintering area, we conducted a-four-year investigation of marsh harrier habitat preference and prey selection in the Shahu Nature Reserve, an area of low human population density. Of the four habitats monitored, grassland was the first choice for marsh harrier despite the presence of grazing cattle, with both the highest mean rank and lowest coefficient of variation. The abundances of the two prey types (common pheasant and passerine birds) varied significantly in different habitats, and the regression relationships between marsh harrier and the two prey types in different habitats were completely independent of each other. The habitat preference of the marsh harrier associated with both prey types was influenced not only by habitat type, but also by habitat structure. The type and abundance of prey varied with different habitat types and structures, but the abundance of marsh harrier did not change accordingly.

Key words: habitat preference, prey selection, marsh harrier, key protected species, overwintering area, SE China

INTRODUCTION

Predators play an important role in ecosystems because they can determine, to some extent, the community structure patterns of their prey (MENGE *et al.* 1994). Additionally, population decline of some raptor species may indicate dysfunctional ecosystems because population dynamics of top-order predators often reflect the nature of the ecosystems they inhabit (NEWTON 1979, OLENDORFF *et al.* 1989). In addition, predators are often used as "umbrella" species in conservation strategies because their protection may facilitate the conservation of unaltered habitats (SIMBERLOFF 1987). Predators are especially vulnerable because they are at the top of food webs and need large home ranges. Thus, it has been recommended that raptors should be included in the management and conservation plans of any region, especially for threatened habitats (THIRGOOD *et al.* 2002, THIOLLAY

2006). Ecological data and clear understanding of population trends are crucial for effective conservation management and for the development of conservation strategies (e.g. GREEN 2002, UNDERHILL & GIBBONS 2002, WHITTINGHAM *et al.* 2005). The marsh harrier (*Circus aeruginosus*), a diurnal raptor, is listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, Appendix II), as well as in the China Red Data Book for Endangered Animals (Grade II, WANG 1998). Threats to marsh harrier include poor land management, persecution and habitat destruction, which have resulted in a worldwide decline in number (LI 2004). In China, main threats include drainage of wetlands, direct persecution (especially shooting), poisoning by pesticides (applied to wetlands and nearby crop fields), and generalized poisoning by heavy metals (LI 2004).

Knowledge on marsh harrier in China is scant: only one study, looking at the migration and overwintering habits of this species, has been published (GUAN *et al.* 1997). Because the species does not breed in our study area (XIAO *et al.* 1996), it may not have received appropriate attention from conservation biologists. In our field investigations, we found that abundance of marsh harrier differed in the four habitats available, and that the main prey was common pheasant (*Phasianus colchicus*) especially in grassland. We also found some remains of passerines. Based on these initial findings, the current study explores habitat preference of the marsh harrier in relation to prey abundance. In particular, we focus on habitat preferences among the four habitats in the overwintering area, the effects of habitat type and structure on marsh harrier abundance, and finally, relationships between marsh harrier and the two prey types (passerines and common pheasant).

MATERIALS AND METHODS

Study area

Shahu Nature Reserve (hereafter SNR, 29°58'–30°07'N, 113°39´–113°58´E, Fig. 1), lies 23 km northeast of Honghu Nation-Class Wetland Nature Reserve and 9 km southwest of Chenhu Province-Class Nature Reserve, and is located in the east of Xiantao municipality in Hubei province, China. The total area of SNR, which is encircled by dikes of the Yangtze Rive, is 66 km^2. Eighty-five to ninety percent of SNR is submerged by water from late April to middle October annually, varying in depth with the rhythm of Yangtze Rive tides. After the water ebbs in middle October, the nature reserve provides four types of habitat. The proportions of the habitats are reed 59.8 km^2 (90.6%), grassland 1.32 km^2 (2%), farmland 0.96 km^2 (1.46%) and water area 3.92 km^2 (5.94%). Farmland and scattered dikes are the areas of highest elevation in SNR. The main water systems are the Dongjing River, Nanwu Lake, Beiwu Lake, and Daocao Lake. The Dongjing River is joined to the Yangtze River's biggest branch, the Han River, on the west and pours into Yangtze River on the East, running through the whole nature reserve. The SNR has a subtropical monsoon climate. The extreme highest air temperature is 38.8 °C, the lowest –14.2 °C and the mean 16.6 °C. The mean sunlight time is

2002.6 h/yr, and the annual frost-free period is 256d. The SNR is notorious for schistosome (*Schistosoma japonicum katsurada*, LIU *et al*. 2006, WU *et al*. 2007), which may account for the low human population density.

Outdoor survey

We surveyed SNR during autumn (Oct. and Nov.) and winter (Dec. and Jan.) in 2001, 2003, 2004 and 2006, with each survey lasting 15d. We selected sunny days to count birds. Habitats were classified as reed, grassland, farmland and water area. In the four years, we surveyed 186 line transects altogether, including 47 reed transects, 47 grassland transects, 46 farmland transects and 46 water area transects. Between five and seven transects were surveyed in each type of habitat per season, and each transect was surveyed once. Usually we surveyed different habitats with equal numbers of transects during the same season. A binocular telescope (Type: BD42 Series Kowa 10×) was used when counting birds within 0.1 km on both sides in reed, and a monocular telescope (Type: Diascope 85 T*FL Carl Zeiss 20–60×) was used to count birds within 0.2 km unilateral in the other three habitats. All the line transects were 2 km in length. We counted birds, walking along each line transect at the speed of 1 km/h, and completing two line transects respectively in the morning and in the afternoon. When we surveyed water habitat, we counted birds including both those appeared in water area transects and those appeared in the sites within three metres to water.

Bird counts

We counted marsh harriers that flew out of (but not those flying into) line transects as well as birds hovering over line transects for more than one minute. For the common pheasant (*Phasianus*

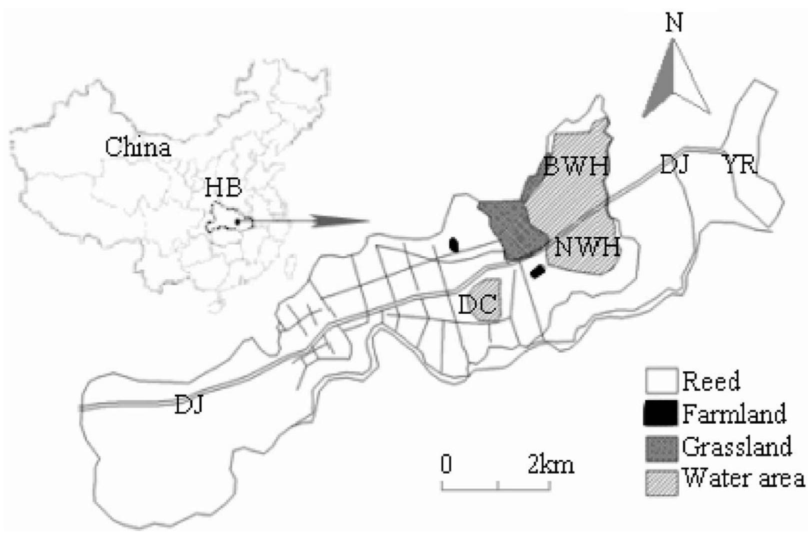

Fig. 1. Shahu Nature Reserve (SNR, autumn and winter). The up left shows the location of SNR; HB, Hubei Province; BWH, Beiwu Lake; NWH, Nanwu Lake; DC, Daocao Lake; DJ, Dongji River; YR, Yangtze River

colchicus, hereafter pheasant), we counted flying individuals flushed out the line transect as well as those standing or moving within line transect, using standard analytical methods to obtain total count of birds for each transect (JENKINS *et al*. 1963). Lastly for passerines, we counted the number of individuals (by species) found on transects.

Classification of grassland

After the water ebbs in middle October every year, cattle were grazed in the grassland area. The grass is 40–80 cm high in autumn. Generally, the grass is consumed within only 6–10d, and then trampled but not necessarily consumed. The abundance of cattle (ignoring their age) was 18, 30, 27 and 32 respectively in 2001, 2003, 2004 and 2006. Grassland was separated into four classes (quartiles) based on the proportion of untrampled grass.

Data analysis

No pheasant was found in the water area habitat in any of the four years; for this reason pheasant is not represented in figures depicting this habitat. When we calculated the prey abundance and analysed the relationships between marsh harrier and prey, we summed all passerine species in a given habitat as a single species, following ARIM and JAKSIC (2005). All these passerine species are known to be prey of the marsh harrier (REDPATH & THIRGOOD 2002, KOKS *et al*. 2007).

We used the Kruskal-Wallis nonparametric ANOVA, which is the appropriate test to compare goup medians when variance is inhomogeneous. T-test was used for pairwise comparisons. When we detected the relationships between marsh harrier and the two prey types, a multiple regression model was used with marsh harrier abundance as dependent variable and abundance of the two prey types as independent variables. The variables that do not fit to normality distribution (Shapiro-Wilk test) were cube (x^3) transformed. Since each transect census was not repeated thus season as case was independent, we treated birds in seasons as cases when we calculated the multiple regressions. All statistical analyses were carried out in SPSS version 13.0 (SPSS Inc.).

RESULTS

No significant difference in marsh harrier abundance was detected between years ($F = 0.085$, $n = 186$, $P = 0.986$, ANOVA), but abundances in autumn were significantly higher than those in winter ($t = 2.059$, $n = 186$, $P = 0.041$, Independent Samples T-test).

Distribution of marsh harrier in the different habitats

The abundance of marsh harriers differed statistically according to habitats ($\chi^2_3 = 39.57$, $P < 0.001$, Kruskal-Wallis test), with grassland containing more birds than reed, and reed containing more birds than the water area and farmland (Fig. 2). Conversely, the coefficient of variation of abundance of marsh harrier in each hab-

Table 1. Degree of variation of wintering marsh harrier abundance in the four habitats in Shahu Nature Reserve, China.

Habitat	n	mean	S.D.	C.V.
Reed	47	0.60	0.54	89.67%
Grassland	47	0.98	0.79	81.02%
Farmland	46	0.22	0.42	189.55%
Water area	46	0.24	0.43	179.58%

n = numbers of line transect; S.D. = standard deviation; C.V. = coefficient of variation (= 100*S.D. / mean)

itat was ranked in reverse order (Table 1), indicating that the abundance of marsh harrier in grassland was both highest and least variable.

Abundance of passerines and pheasant in the different habitats

Passerines and pheasant abundances in the different seasons and the different habitats are shown in Appendix 1. Passerine abundance varied significantly with habitat (χ^2_3 = 26.24, P < 0.001, Kruskal-Wallis test), with abundance decreasing from farmland to water area, reed and grassland. In contrast pheasant abundance, which also varied significantly (χ^2_3 = 19.39, P < 0.001), had highest abundance in grassland, and then farmland, reed and water area.

Relationships between marsh harrier and the two prey types

The relationship between the abundances of the marsh harrier, pheasants and passerines in the different habitats was complex (Fig. 3). A multiple regression

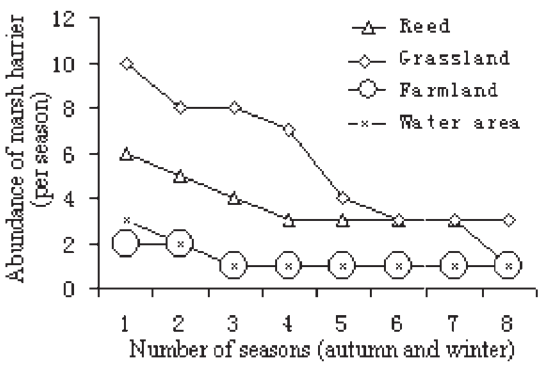

Fig. 2. Wintering marsh harrier's abundance in different habitats in Shahu Nature Reserve, China in autumn and winter of 2001, 2003, 2004 and 2006

Table 2. Multiple regression models (Enter) for wintering marsh harrier abundance (as dependent variable) and the abundance of two prey types (as independent variables) in the four habitats of the Shahu Nature Reserve, China.

Habitat	Sum of seasons	R	ANOVA P	Variable	Partial correlations	B	S.E.
Reed	8	0.982	**< 0.001**	Constant		- 1.363	0.569
				Passerines	0.951	0.011	0.002
				Pheasant	- 0.275	- 4.0E – 006	0.000
Grassland	8	0.881	**0.024**	Constant		5.973	1.445
				Passerines	- 0.624	- 1.5E–005	0.000
				Pheasant	0.877	6.87E – 006	0.000
Farmland	8	0.238	0.865	Constant		0.929	0.665
				Passerines	0.032	1.34E – 005	0.001
				Pheasant	0.117	0.007	0.026
Water area	8	0.398	0.328	Constant		- 0.035	1.352
				Passerines	0.398	3.06E – 008	0.000

Significant P given in bold. B-values of constant are intercepts. B-values of passerines and pheasant are regression coefficients.

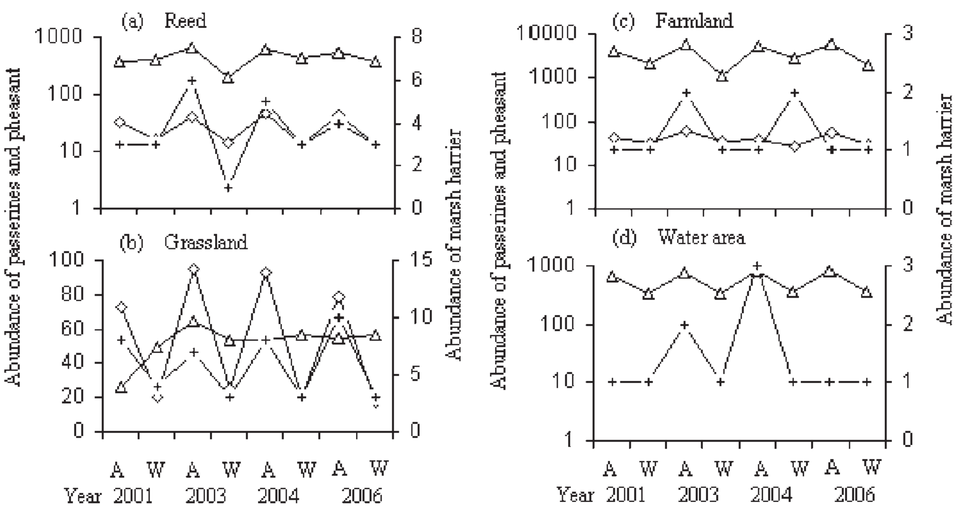

Fig. 3. Abundances of passerines (△), pheasant (◇) and marsh harrier (+) of the four years in the four habitats in Shahu Nature Reserve, China, with line transects 2000 m × 200 m (A, autumn; W, winter)

Table 3. ANOVA of marsh harrier abundance among different grassland habitats.

Test resource	Sum of squares	df	Mean square	F	P
Between grades	9.66	3	3.22	6.73	**0.002**
Within grades	11.01	23	0.48		
Total	20.67	26			

Grades are the quartiles based on the proportion of untrampled grass by cattle; Grades in Tables 4, 5 and 6 are the same meaning.

Table 4. Multiple comparisons of harrier abundance between different grassland habitats (LSD).

Grades (S)	n	Mean	Mean–0.20	Mean–0.83	Mean–1.63
$0.75 \leq S \leq 1$	8	1.75	1.55**	0.92*	0.12
$0.5 \leq S < 0.75$	8	1.63	1.43**	0.79*	
$0.25 \leq S < 0.5$	6	0.83	0.63		
$0 \leq S < 0.25$	5	0.20			

*Significant at the 0.05 level and ** 0.01 level.

Table 5. ANOVA of passerines abundance among different grassland habitats.

Test resource	Sum of squares	df	Mean square	F	P
Between grades	393.69	3	131.23	32.51	**< 0.001**
Within grades	92.83	23	4.04		
Total	486.52	26			

model (Enter) indicated that harrier abundance was significantly and positively correlated with prey abundance in reed ($R = 0.982$, $P < 0.001$, Table 2) and in grassland ($R = 0.881$, $P = 0.024$), but not in farmland ($R = 0.238$, $P = 0.865$) or in water area ($R = 0.398$, $P = 0.328$). A multiple regression model (Stepwise) indicated that in reed habitat, marsh harrier was related only to passerines ($R^2 = 0.962$), while in grassland, only pheasant entered the model ($R^2 = 0.633$).

Impact of interference to birds in grassland

Harrier abundance differed significantly according to grassland types ($P = 0.002$, ANOVA, Table 3), with decreasing abundance with increasing quartile of grazed and trampled grassland (Table 4). Conversely, passerine abundance increased with increasing trampled proportion within grassland ($P < 0.001$, ANOVA, Table 5 and 6). Abundance of pheasant according to trampled areas significantly varied ($\chi^2_3 = 13.11$, $P = 0.004$, Kruskal-Wallis test), but nonlinearly:

Table 6. Multiple comparisons of passerines abundance between different grassland habitats (LSD).

Grades (S)	n	Mean	Mean–3.25	Mean–6.00	Mean–9.33
$0.75 \le S \le 1$	5	14.00	10.75**	8.00**	4.67**
$0.5 \le S < 0.75$	6	9.33	6.08**	3.33**	
$0.25 \le S < 0.5$	8	6.00	2.75*		
$0 \le S < 0.25$	8	3.25			

*Significant at the 0.05 level and ** 0.01 level.

highest abundance was observed in the second quartile. With the proportion of trampled grassland considered, harrier numbers negatively correlated with passerines by simple linear regression analysis (slope = –0.141, intercept = 2.264, R = 0.683, n = 27, P < 0.001), and positively correlated with pheasant (slope = 0.095, intercept = 0.024, R = 0.645, n = 27, P < 0.001).

DISCUSSION

In a previous study, voles have been shown to form a minor component of harrier diet during winter (e.g. MARQUISS 1980). Such prey could be eliminated from marsh harrier diet in our study, because 85–90% of the SNR was flooded by water from late April to middle October every year, vole populations are precluded from establishing within the SNR (LUO *et al*. 2009). Additionally, farmlands are cultivated with short crops every year, an environment that is not favored by common voles in other regions such as Europe (BUTET & LEROUX 1989, KOKS 2007).

Habitat preferences of harriers

The marsh harrier was more abundant and showed less variation in numbers in grassland than in any other habitat. This is probably a consequence of high abundance of pheasant in grassland (31.5±S.E. 2.9 ind/km^2, while pheasant's abundance was possible determined by available food (YIN & LIU 1995). Passerines, however, showed a low density in grassland, with 18.5±S.E. 2.1 ind/km^2. Passerines are known to reduce predation risk by avoiding habitat where they were susceptible to attack (NORRDAHL & KORPIMÄKI 1998, PATRICK *et al*. 2008). Previous work has revealed that generalist predators take a variety of prey but can be sustained at high densities by consuming one prey type (ANDERSSON & ERLINGE 1977, THIRGOOD *et al*. 2000), which may apply to our study in which major prey was pheasant in grassland.

Farmland habitat harbored abundant passerines and pheasant (Fig. 3), possibly because of the availability of residual unspoiled winter wheat seed (providing pheasant with food) and of insects such as tipulids, coleoptera and diptera (an important food source for passerines) (COULSON & WHITTAKER 1978, WALTON 1979). Surprisingly, farmland supported very few harriers (Fig. 2). We suggest that despite their abundance in the farmland, prey accessibility to harriers was limited. Perhaps preys are abundant in a certain habitat, less available to hunting harriers result in fewer harriers occurrence in this habitat (AMAR & REDPATH 2005, AMAR *et al.* 2008).

In reed habitat, harrier abundance was strongly positively correlated to passerines, but not to pheasant (Table 2), presumably as a consequence of reed height (around 1.8 m in average). Most of time pheasants are active at the bottom of reed habitat, and such high plants can protect pheasants from predation (e.g. SIMMONS 2000, VULINK 2001). In water area habitat, there was no significant linear relationship between marsh harrier and passerines (pheasant lacked from water habitat) because marsh harrier may also hunt water birds (GUAN *et al.* 1997).

Grassland quality, prey and predator abundance

We found that prey species reacted differently to grazing and trampling. In particular, pheasant abundance was reduced in grassland with increasing trampling, and thus marsh harrier abundance decreased (Table 3 and 4) because of strong correlation between this prey and the predator. The alternative prey hypothesis predicts that the diet of generalist predators changes with abundance of the main prey (KEITH *et al.* 1977, KORPIMÄKI *et al.* 1990, KURKI *et al.* 1997). With grassland quality decreasing, the abundances of marsh harrier and pheasant decreased, but the abundance of passerines increased (Table 5 and 6). The relationship between marsh harrier and passerines showed therefore negative correlation. Grazing can affect foraging efficiency and food availability (BAKER *et al.* 2009), particularly for ground-foraging granivorous and insectivorous passerines (MARON & LILL 2005, MARTIN & POSSINGHAM 2005, DENNIS *et al.* 2008). Reduction of grazing pressure may lead to decrease passerines, such as meadow pipits (e.g. SIMON *et al.* 2000).

Light grazing increases biodiversity (e.g. EYRE *et al.* 2009). For instance, prey in tall and dense vegetation are less available to hunting harriers (SIMMONS 2000, VULINK 2001). Prey availability to harriers may be increased through appropriate mowing management. Mowing does not in itself lower prey survival significantly, but by reducing cover, it makes the prey more vulnerable to predators (JACOB 2003). However, the grassland was overgrazed in our study area. Conversely, overgrazing destroys habitats, which can impact bird populations (AMAR *et al.* 2008). We found that reduced grassland habitat area or quality resulted in a strong reduction of marsh harrier abundance (Table 3 and 4).

Many studies have previously analysed relationships between harrier species and their diet, relying on vomited pellets that can only be gathered on roost site, therefore most studies on this aspect are conducted during the breeding season (e.g. MILLON *et al.* 2002, REDPATH *et al.* 2002, GARCIA & ARROYO 2005, KOKS *et al.* 2007). It would therefore be important in the future that we are able to assess marsh harrier diet quantitatively and accurately throughout its overwintering period.

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Appendix 1. Abundances (shown by mean±1S.E.) of passerines (by species) and pheasant in different habitats in Shahu Nature Reserve, China in autumns (A) and winters (W) of 2001, 2003, 2004 and 2006, measured by line transects in the size of 2000 m × 200 m.

	2001(A)	2001(W)	2003(A)	2003(W)	2004(A)	2004(W)	2006(A)	2006(W)
Line transects	6	5	7	5	7	5	7	5
Reed								
Pheasant	5.5±0.7	3.2±0.4	5.9±0.9	2.8±0.6	6.4±1.0	2.6±0.4	6.0±0.5	2.6±0.5
Oriental skylark	48.0±6.6	45.2±10.8	72.9±9.0	23.6±4.0	69.7±7.0	49.6±8.6	60.3±8.7	46.8±12.1
Eurasian skylark	8.8±1.5	17.2±2.8	11.0±2.1	8.6±1.3	10.4±2.3	18.4±2.1	9.0±2.3	14.2±2.4
Water pipit	0.3±0.3	0.4±0.2	0.3±0.2	0.4±0.4	0.9±0.6	2.0±1.3	0.1±0.1	0.4±0.4
White wagtail	0.5±0.3	1.4±0.4	0.6±0.3	1.0±0.3	0.9±0.3	0.8±0.4	0.4±0.3	1.0±0.3
Meadow bunting	5.8±2.6	11.6±2.7	6.7±3.0	6.8±1.2	6.7±1.9	11.0±2.3	6.1±3.1	11.4±2.6
Rustic bunting	0.3±0.2	4.8±1.0	0.4±0.3	1.0±0.5	1.1±0.5	2.6±0.9	0.1±0.1	3.0±1.3
Line transects	6	5	7	5	7	5	7	5
Grassland								
Pheasant	12.2±1.7	4.0±1.0	13.6±2.7	5.0±0.9	13.3±2.7	4.0±0.5	11.3±2.3	3.4±0.8
Oriental skylark	2.0±0.3	3.4±0.4	6.1±0.9	3.8±1.0	5.1±1.4	4.4±0.5	5.3±1.1	4.6±0.7
Eurasian skylark	1.8±0.7	4.0±0.3	1.6±0.5	4.4±0.5	1.9±0.6	4.4±1.0	1.9±0.6	4.2±0.7
Water pipit	0	1.2±0.5	0.3±0.2	0.6±0.2	0.1±0.1	1.0±0.6	0.1±0.1	1.0±0.6
White wagtail	0.3±0.2	0.8±0.4	1.0±0.4	1.0±0.5	0.3±0.2	0.8±0.4	0.4±0.2	0.6±0.4
Meadow bunting	0	0	0	0	0	0	0	0
Rustic bunting	0.2±0.2	0.6±0.2	0.3±0.2	1.0±0.3	0.3±0.2	0.8±0.2	0.1±0.1	1.0±0.6

Appendix 1 (continued)

	2001(A)	2001(W)	2003(A)	2003(W)	2004(A)	2004(W)	2006(A)	2006(W)
Line transects	5	5	7	5	7	5	7	5
Farmland								
Pheasant	8.2±0.7	6.4±1.2	9.0±1.1	6.8±1.5	5.6±1.0	5.4±0.7	8.0±1.0	5.6±1.4
Oriental skylark	653.2±111.4	284.2±96.2	682.0±71.3	106.2±38.5	650.9±72.6	388.4±91.5	697.0±97.1	264.8±92.4
Eurasian skylark	117.4±25.2	121.4±16.4	100.7±21.5	100.4±11.9	98.7±21.8	152.2±30.2	98.0±23.8	130.6±22.3
Water pipit	0.4±0.4	0.4±0.2	0.3±0.2	0.2±0.2	0.3±0.2	0.2±0.2	0.4±0.2	0.2±0.2
White wagtail	3.2±0.2	3.0±0.6	2.4±0.9	3.4±0.6	1.4±0.4	3.8±0.9	2.7±0.6	3.2±0.4
Meadow bunting	0	0	0	0	0	0	0	0
Rustic bunting	4.2±1.0	3.4±0.6	4.4±0.9	4.2±0.8	4.9±0.9	4.0±0.9	5.0±1.8	4.0±0.71
Line transects	5	5	7	5	7	5	7	5
Water area								
Pheasant	0	0	0	0	0	0	0	0
Oriental skylark	36.4±10.9	49.4±17.6	28.6±10.6	51.2±17.9	30.7±7.9	56.0±15.9	28.3±9.1	56.6±20.2
Eurasian skylark	89.6±21.7	7.6±2.0	75.9±16.0	8±0.8	79.3±17.1	9.2±2.7	83.4±20.3	8.4±1.4
Water pipit	3.4±0.8	4.6±1.2	2.9±1.0	4.8±1.2	3.9±1.1	4.8±0.7	3.4±1.3	4.2±1.3
White wagtail	4.6±0.5	4.6±1.0	3.71±0.8	4.2±0.7	3.4±0.7	3.6±1.2	4.1±0.9	4.0±1.1
Meadow bunting	0	0	0	0	0	0	0	0
Rustic bunting	0.4±0.2	0.2±0.2	0.1±0.1	0.2±0.2	0.1±0.1	0.4±0.2	0.3±0.3	0.2±0.2

Latin name of birds: oriental skylark (*Alauda gulgula*), Eurasian skylark (*Alauda arvensis*), water pipit (*Anthus spinoletta*), white wagtail (*Motacilla alba*), meadow bunting (*Emberiza cioides*), rustic bunting (*Emberiza rustica*), common pheasant (*Phasianus colchicus*).