

# Habitat preferences of breeding Yellow Buntings *Emberiza sulphurata* in hilly rural areas following rice field abandonment in northern Japan

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## Summary

We studied the habitat preferences of breeding Yellow Buntings *Emberiza sulphurata*, taking into account the effects of paddyfield abandonment in hilly rural areas within the heavy snow region of northern Japan. Across 30 transects located in valley bottoms, we investigated the relationship between Yellow Bunting abundance and landscape characteristics. The results of generalized linear mixed models showed that forest edge density and landslide sites positively affected Yellow Bunting abundance. These habitats were associated with bush vegetation (forest edge, shrub land, and tall grassland) and were adjacent to the forest. Paddyfield abandonment showed a hump-shaped effect with a peak at the middle succession stage, which was covered primarily with tall grass and some shrubs, but the effect on Yellow Bunting abundance was not statistically significant. To conserve Yellow Bunting habitats in hilly rural areas, it is necessary to protect the forest edge and landslide sites from urbanisation and exploitation. It is also necessary to continue crop cultivation in such areas, to maintain the edges between open land and forest. If cultivation can no longer be continued, the abandoned paddyfields should be kept bushy, using reed beds and shrubs, by active management.

## Introduction

The Yellow Bunting *Emberiza sulphurata* is an endangered migratory passerine found in the East Asian flyway (Yong *et al.* 2015). Although it has a few wintering sites across East Asia (e.g. Philippines, Taiwan, and southern China), the breeding sites are exclusively restricted to the northern part of Honshu Island, Japan (Ministry of the Environment 2004, Byers *et al.* 2013). The total number of Yellow Buntings has been estimated at approximately 3,500–15,000 (IUCN 2014). Owing to significant habitat loss, it is listed as globally 'Vulnerable' on the IUCN Red List (IUCN 2014) and 'Near-Threatened' at the national level in Japan (Ministry of the Environment 2014). Although it is known to be associated with forest edge, shrubs, and thickets (del Hoyo *et al.* 2011), the detailed habitat requirements have not been elucidated (IUCN 2014, Japan Ministry of the Environment 2014). Niigata Prefecture, which is located in the northern part of Honshu Island, is one of the regions where Yellow Buntings breed at a high density (Ministry of the Environment 2004). Within the Niigata Prefecture, they breed in hilly agricultural landscapes (Kaneko 1979), akin to the traditional "yatsu" landscape in Japan, which is characterized by hills, with paddyfields in the valley bottom and secondary forests on the valley slopes (Takeuchi *et al.* 2002).

In Japan, the abandonment of paddyfields has increased since the 1980s, owing to socioeconomic changes (Katayama *et al.* 2015a). Abandonment has occurred primarily in the hilly and mountainous

areas (Katayama *et al.* 2015a) owing to factors such as depopulation, aging farmers and lower productivity compared with plains areas (Katayama *et al.* 2015b). Field abandonment accompanied by vegetation succession alters the habitats for birds, consequently affecting diversity within bird communities in the agricultural landscape (Suárez-Seoane *et al.* 2002, Sirami *et al.* 2007, 2008, Nikolov 2010, Ambarlı and Bilgin 2014, Zakkak *et al.* 2014). Threatened bird species in Europe, such as the Corn Bunting *Emberiza calandra* (Zakkak *et al.* 2014) and Golden Eagle *Aquila chrysaetos* (Pedrini and Sergio 2001) have lost areas of habitat due to similar instances of abandonment. Negative impacts of paddy abandonment on Grey-faced Buzzard *Butastur indicus* have been found in Japan (Ueta *et al.* 2006, Kadowaki *et al.* 2007). However, field abandonment could also serve as an opportunity for birds to recover their native habitats (Queiroz *et al.* 2014).

Yellow Buntings, which inhabit hilly rural areas, might be affected by paddyfield abandonment in these regions. Furthermore, the growing tendency towards field abandonment means the trend is likely to continue in such areas (Ichinose 2007, Katayama *et al.* 2015a). Therefore, to conserve the Yellow Bunting, understanding its habitat requirements and the effects of changes in its habitat, caused by paddy abandonment, is extremely important. The goal of this study was to document the habitat selection by Yellow Buntings and to determine the effects of paddyfield abandonment on habitat suitability.

## Methods

### Study area

The study was conducted in hilly rural areas akin to the “yatsu” landscape, in the Koshiji (37°23'N, 138°47'E) and Oguni (37°18'N, 138°42'E) regions (c.14.4 ha) of Nagaoka City, within the Niigata Prefecture in northern Japan (Figure 1). The study area comprised hills of sedimentary rocks and numerous mountain streams flowing into the Shibumi River. The mean annual temperature in Nagaoka City (37°27'N, 138°49'E) is 12.9°C, with a minimum monthly average of 1.3°C in January and a maximum of 26.0°C in August, and the mean annual precipitation is 2,324.8 mm. These mean values were based on observed values over 30 years, 1981–2010 (Japan Meteorological Agency 2015). In addition, the study area is located in a heavy snow region, where small avalanches occur every year (Kaneko 1979, 2012). The snow starts falling in late December and often accumulates to over 100 cm every year. Small-scale avalanches and landslides often lead to the development of ‘avalanche vegetation’, which is unique to heavy snow regions and consists mostly of dwarf trees or tall grasses such as *Alnus pendula*, *Weigela hortensis*, and *Miscanthus sinensis* (Kaneko 1979, Kikuchi 2001). We use a few terms associated with vegetation types in this paper with the following meanings, bush: middle stages of succession, such as shrubland and tall grassland, including forest edge; woodland: small range, such as abandoned paddyfields covered with tall trees; forest: wide range, covered with tall trees on hill and valley slopes. The vegetation in our study area mainly comprised plantations of *Cryptomeria japonica* and secondary forests dominated by *Quercus serrata*, *Acer amoenum* var. *matsumurae*, and *Magnolia obovata* (Kaneko 2012). Furthermore, there were grasslands dominated by *M. sinensis* at the avalanche sites (Kaneko 2012). The valley bottoms were mainly covered with rice paddy, as well as croplands, ginkgo *Ginkgo biloba* orchards, and ponds for breeding coloured carp *cyprinus carpio* or irrigation of smaller areas. Paddyfield abandonment occurred in the 1970s in this area (Kaneko 1979). Vegetation in the abandoned paddyfields is mentioned below in the section ‘Landscape characteristics’. We randomly selected 30 points across the valleys in the study area (58–75 m asl). At each of these points, we established a transect (321–683 m long, c.100 m wide), to quantify the abundance and landscape characteristics. In this region, Yellow Buntings are found only from breeding to the autumn migration period (April–October), and are absent during the winter (Kaneko 1981, Deguchi *et al.* unpublished data). Yellow Bunting is one of the dominant bird species in this region during their breeding season (Kaneko 1981).

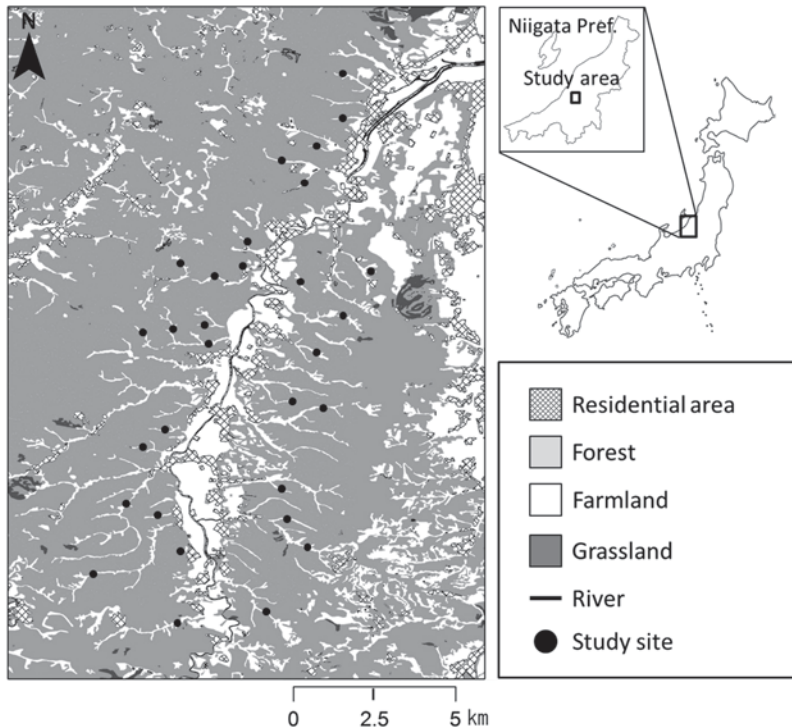


Figure 1. Map of the study area. Closed circles indicate the 30 transects (321–683 m long, ca. 50 m wide).

### *Bird data*

We counted the number of singing males as an estimate of abundance along the line transects. One observer walked along the transect and counted the number of birds within a 50-m band on either side of the line. The duration of surveys was 10 min and they were conducted twice each in May and June 2014 during the four hours following dawn on calm days, along all transects. To avoid recording the same bird more than once, efforts were made to record synchronously singing males. We used the maximum number of birds detected at a given transect as an estimate of abundance.

### *Landscape characteristics*

In order to examine the habitat requirements of Yellow Buntings, edge density (EDG\_D) for each transect was calculated by dividing the sum of perimeters of valley bottoms, that is, the total length of edge between open land and forest, by the area of valley bottom ( $\text{m}/\text{m}^2$ ). Furthermore, distances in metres from the central points of each transect to the nearest residential area (DNR) were measured. DNR indicated whether a transect was in the upper or the lower reach of the valley as residential areas are usually found in the lowest reaches of the valley. We also measured the area affected by landslides adjoining each transect because it and small avalanches together can establish avalanche vegetation which could be associated with the distribution of Yellow Buntings (Kaneko 1979, Nakamura 1994). In comparison to vegetation on abandoned paddy, avalanche vegetation tends to persist because regular disturbance such as small avalanches and landslides prevents vegetation succession. We used the values of landslide area per length of transect ( $\text{m}^2/\text{m}$ , LSLIDE)

in the analysis. To evaluate the effects of paddyfield abandonment on Yellow Buntings, we measured the proportion of land cover (%) of cultivated (CU) and abandoned paddies on each transect. We categorised the abandoned paddyfields into three types according to their successional stages: (1) the early stage, with short grasses (< 50 cm), where *Equisetum arvense* and *Polygonum thunbergii* were predominant (AB\_E); (2) the middle stage, covered primarily with *Phragmites australis*, *Miscanthus sacchariflorus*, or *M. sinensis*, and some shrubs such as *Weigela hortensis* or *Lespedeza bicolor* (AB\_M), and (3) the late stage, where trees such as *Alnus fauriei* or *Salix* sp. were found (AB\_L). We also quantified the land cover heterogeneity (L\_HTR) using Shannon's Diversity Index,  $H' = -\sum p_i \times \ln p_i$ , where  $p_i$  is the proportion of land cover  $i$  (Katayama *et al.* 2015b) because some species use different habitat types (Dunning *et al.* 1992, Brotons *et al.* 2005). However, land cover heterogeneity was not applicable to our analysis because of high inter-correlation with the area of abandoned paddyfields at the middle stage ( $r = 0.7$ ; Table 1). We used Arc Map 10.2 (ESRI 2013) along with geographically referenced topographical maps at 1:2,500 scale and aerial photographs taken in 2014 by Digital Globe ([www.digitalglobe.com](http://www.digitalglobe.com)) and ZENRIN ([www.zenrin.co.jp](http://www.zenrin.co.jp)) for all measurements of landscape characteristics, except the landslide areas. The landslide areas were determined using landslide GIS data (National Research Institute for Earth Science and Disaster Prevention 2000).

### Statistical analyses

We analysed the relationships between bird abundance and landscape variables using the generalized linear mixed model (GLMM) with a Poisson distribution and a log link function, using the R package 'lme4'. Valley bottom identities (ID) were fitted as random effects and the areas of valley bottoms (ha) were used as offset terms because transects were of different sizes (1.22–6.39 ha). We used abundance of singing birds as the response variable and landscape characteristics as the explanatory variables. All of the explanatory variables were standardized to make the regression coefficients comparable. Since we obtained multiple candidate models, including the null model, with  $\Delta AIC < 2.0$  (Burnham and Anderson 2002), model selection using AIC was not performed. We evaluated the significance of variables using 95% confidence intervals. To evaluate goodness-of-fit of the full model, we used the coefficient of determination ( $R^2$ ) for GLMM using the 'MuMIn' package in R, following Nakagawa and Schielzeth (2013). We calculated the marginal  $R^2$  ( $R^2_m$ ), which examines the variance explained by only the fixed effects, and conditional  $R^2$  ( $R^2_c$ ), which examines the variance explained by both fixed and random effects (Nakagawa and Schielzeth 2013). These analyses were conducted using R ver. 3.2.0 (R Development Core Team 2015).

Table 1. Pearson's correlation coefficients among the candidate explanatory variables.

	LSLIDE	DNR	CU	AB_E	AB_M	AB_L	L_DIV
EDG_D	0.22	-0.07	-0.35	0.10	0.26	-0.03	0.22
LSLIDE		0.23	0.14	0.20	-0.07	-0.16	0.06
DNR			0.11	-0.20	-0.10	-0.28	-0.17
CU				-0.01	-0.53	-0.49	-0.59
AB_E					0.13	-0.15	0.45
AB_M						0.42	0.70
AB_L							0.45

Abbreviations: EDG\_D: edge density calculated by dividing the sum of perimeters of valley bottoms and forest edges by the area of valley bottom. Land cover heterogeneity was calculated using the Shannon's Diversity Index ( $H'$ ). LSLIDE: landslide area per transect ( $m^2/m^2$ ), DNR: Distance from nearest residence area (m), L\_HTR: land cover heterogeneity calculated with Shannon's Diversity Index ( $H'$ ). Following variables indicate land cover proportions: CU: cultivated paddy (%), AB\_E: abandoned paddy at the early succession stage (%), AB\_M: abandoned paddy at the middle succession stage (%), AB\_L: abandoned paddy at the late succession stage (%). L\_HTR was removed from the analysis due to its high correlation with variable AB\_M (-0.59).

## Results

### *Occurrence patterns of Yellow Buntings*

Of the 30 transects investigated, Yellow Buntings occurred in 19 and 26 transects in May and June, respectively (Table 2). There was negligible difference in the mean densities of Yellow Bunting between May ( $0.4 \text{ ha}^{-1}$ ) and June ( $0.5 \text{ ha}^{-1}$ ) (Table 2).

### *Relationship between Yellow Bunting abundance and landscape characteristics*

Values of all landscape characteristics varied among the transects (Table 3). The proportion of cultivated paddyfield was higher than that of the three types of abandoned paddyfield (Table 3). The landscape characteristics used in the GLMM analysis as explanatory variables were not strongly correlated (Table 1). The full model had an  $R^2_m$  value of 0.55 and an  $R^2_c$  value of 0.77. Abundance of Yellow Bunting was correlated significantly and positively to edge density and landslide area (Figures 2 and 3). DNR and abandoned paddyfields with progressed succession (middle and late) had a positive effect on Yellow Bunting abundance, although the effects were not significant (Figures 2 and 3). Edge density showed a higher coefficient value ( $0.73 \pm 0.19$ ) compared with the other variables, for which it ranged between  $-0.21$  and  $0.48$  (Figure 2; Appendix S1 in the online supplementary material). On the other hand, cultivated and early abandoned paddyfields had a negative effect on Yellow Bunting abundance, although not significant (Figures 2 and 3). Paddyfield abandonment showed a hump shaped effect with a peak at the middle succession stage (Figure 2).

## Discussion

Yellow Bunting density was stable through May ( $0.4 \text{ ha}^{-1}$ ) and June ( $0.5 \text{ ha}^{-1}$ ). Kaneko (1981) investigated this study area in 1977 and reported a similar trend (May:  $0.3 \text{ ha}^{-1}$ , June:  $0.28 \text{ ha}^{-1}$ ). The current density has not changed significantly compared with that recorded about 40 years ago (Kaneko 1981). We show that edge density, and as Nakamura (1994) stated, landslide areas have a positive effect on Yellow Bunting abundance. Greater edge density is associated with the availability of forest-edge habitat. Landslide sites are usually dominated by shrub species with several sprouting shoots (Kikuchi 2001). These bushy habitats, which are favoured by the Yellow Buntings (Nakamura and Nakamura 1995), were consistently found adjacent to forests. Hence, Yellow Buntings need not only bush, but also habitats consisting both bush and forests. DNR was not significant, which means that there was no relationship found between the location of transects (upper or lower reach of the valley) and Yellow Bunting abundance. It is possible that the environment of valleys did not vary drastically between the upper and lower reaches because of the very small scale of the mountain streams.

Paddyfield abandonment showed a hump-shaped effect. Mid-abandoned paddyfields could be better suited than cultivated ones for Yellow Buntings because the former are similar to edge or landslide habitats, which develop bushy cover. In hilly rural areas of Japan, Yellow Buntings use the abandoned paddyfields occupied by reeds both as nesting sites during the breeding season (Kaneko 1979) and as stopover sites during their autumn migration (Yoshida 2007, S. Deguchi

Table 2. The number of transects where Yellow Buntings occurred and their density (buntings  $\text{ha}^{-1}$ ) in May and June 2014.

Month	The number of occurred sites	Density (buntings/ ha)			
		Minimum	Maximum	Mean	SD
May	19	0	1.0	0.4	0.3
June	26	0	1.7	0.5	0.4

Table 3. Summary of landscape characteristics of the 30 transects in the study area. Each value is calculated using the total value of each landscape feature for the 30 transects.

Variables	Abbreviation	Minimum	Maximum	Mean	SD
Site area (ha)	Non-assigned	1.2	6.4	3.2	1.4
Edge density (m/m <sup>2</sup> )	EDG_D	131.3	818.4	484.8	145.8
Landslide area per transect (m <sup>2</sup> /m)	LSLIDE	0.0	197.2	39.0	51.9
Distance from nearest residence area (m)	DNR	1569	2636	1940	245.6
Cultivated paddy	CU	0.0	77.5	34.5	23.0
Abandoned paddy Early	AB_E	0.0	27.9	6.4	6.7
Abandoned paddy Middle	AB_M	0.0	29.7	7.4	8.2
Abandoned paddy Late	AB_L	0.0	58.7	9.2	14.7
Land cover heterogeneity (H)	L_DIV	0.2	1.2	0.8	0.3

unpubl. data), or as shelter from predators (Maeda 2001). Previous studies have revealed that cultivated paddy can have a negative effect on species (Maeda 2001, Amano *et al.* 2008) such as the Meadow Bunting *Emberiza cioides* (Katayama *et al.* 2015b). However, the effect of paddyfield abandonment was not significant in our study. Therefore, it is possible that abandoned paddyfields are just an accidental habitat for the Yellow Buntings, in contrast to the forest edge, and they share no special relationship with paddy cultivation, with respect to habitat selection. Levees surrounding the cultivated paddyfields are favoured by many passerines (Maeda 2001), and we also observed Yellow Bunting forage on a levee once. However, herbicides are often sprayed on the levees in the study area. High levels of chemical agents such as pesticides are also one of the major threats to the Yellow Bunting (del Hoyo *et al.* 2011, IUCN 2014).

Conservation implications

We found that forest edges and landslide sites are the most important habitats for Yellow bunting. These habitats are composed of bush and forest cover. Paddyfield abandonment was found to have no effect on Yellow Buntings, although it could provide them with marginal habitats.

To conserve Yellow Bunting habitats in rural hilly areas, we should first protect the forest edge and landslide sites, which seemed to be original Yellow Bunting habitats, from urbanisation and exploitation. Development should be undertaken with care, as suggested by Kaneko (2012),

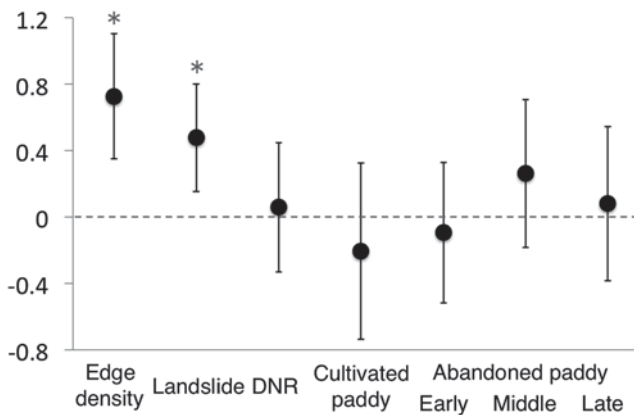


Figure 2. Regression coefficients [mean ± 95% confidence interval (CI)] estimated using generalized linear mixed model (GLMM) for Yellow Bunting abundance. Asterisks signify factors for which the 95% CI did not include zero.

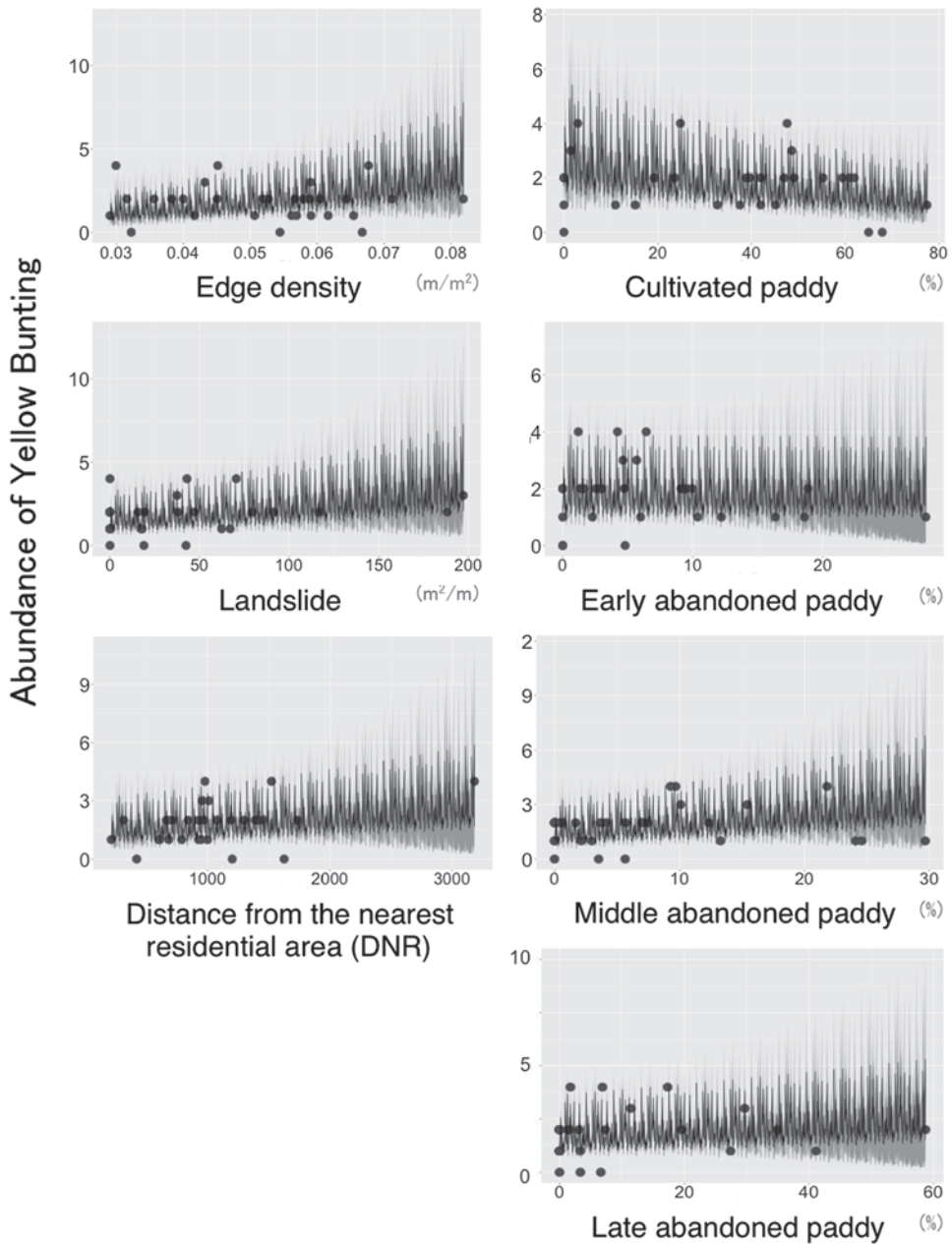


Figure 3. Response curves of Yellow Bunting abundance with respect to the landscape characteristics.

who implied that excessive sand mining in the pits had reduced Yellow Bunting abundance. In addition, we should continue cultivation practices, as open lands such as arable paddyfields contribute toward shaping forest edges in the hilly rural landscape. Habitat supplementation by paddyfield abandonment can be temporary because Yellow buntings rarely use the interior of the forests (Katou 1990, Nakamura 1994). Therefore, dense woodlands caused by the progression of vegetation succession could have negative effects. To maintain the reed beds in

abandoned paddyfields, we should maintain a high ground water level (Ikegami *et al.* 2011). We should also determine the suitable tree density or vegetation cover for Yellow Buntings, as done for the congeneric Black-faced Bunting *Emberiza spodocephala* (Fujimaki 1986, Deguchi *et al.* 2015), in preparation for succession toward dense forests in the abandoned fields. In addition, we must pay attention to not only habitat loss but also the threat of trapping (IUCN 2014) as another species, Yellow-breasted Bunting *Emberiza aureolai*, has recently seen a major decline in its populations due to illegal trapping (Kamp *et al.* 2015).

## Supplementary Material

To view supplementary material for this article, please visit <https://doi.org/10.1017/S0959270916000435>

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