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**Conservation value of pome fruit orchards for overwintering birds  
in southeastern France**

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28 **Abstract**

29 Bird survival in winter relies on the availability of key population resources such as food, shelter  
30 and resting sites. In annual crops, intensive crop management has been shown to affect bird  
31 communities through a reduction in winter resources, but much less is known about perennial  
32 crops. In this study, we performed bird surveys in 30 orchards for two years to investigate how  
33 abundance, species richness and evenness in wintering bird communities were affected by the  
34 availability of unharvested fruits in pome fruit orchards and of fruiting ivy in surrounding  
35 hedgerows. We further investigated how these resources depend on orchard management. We  
36 observed 41 bird species overall, among which 13 were of conservation concern. Bird  
37 abundance was mainly driven by the number of unharvested fruits and to a lesser extent by the  
38 number of ivy bearing trees. Bird species richness was primarily driven by the number of ivy  
39 bearing trees. This result was consistent with analyses at the species level, indicating that the  
40 occurrence of seven species (*Sylvia atricapilla*, *Parus caeruleus*, *Parus major*, *Erithacus*  
41 *rubecula*, *Turdus iliacus*, *Turdus merula*, and *Turdus philomelos*) was significantly dependent  
42 on the number of ivy-bearing trees. Interestingly, compared to organic orchards, non-organic  
43 (conventional and integrated) orchards had significantly more unharvested apples because of  
44 the absence of prophylactic measures against pests, thus providing wintering birds with more  
45 available resources. Our study supports the conservation value of commercial pome fruit  
46 orchards for Palearctic bird species overwintering in Southern Europe.

47

48 **Key words:** Species richness, Bird community, Winter resource, Mediterranean, Hedgerow,  
49 Ivy

50

## 51 **Introduction**

52 Responses to increasing modern food demands across continents have involved drastic changes  
53 in land use through unprecedented conversions of natural ecosystems to simplified and  
54 intensively managed ones (Tscharntke et al. 2005). Agricultural intensification processes  
55 include a wide variety of components, e.g., increased mechanisation and chemical use,  
56 increased areas of monoculture, changes in areas of crop types, changes to sowing and  
57 harvesting practices, and suppression of non-farmed habitats such as hedgerows (see Stoate et  
58 al. 2001; Vickery et al. 2001; Robinson and Sutherland 2002; Newton 2004). Such processes  
59 are major drivers of global biodiversity losses across agricultural landscapes (Matson et al.  
60 1997; Tilman et al. 2001; Tscharntke et al. 2005), and the compatibility of agricultural land use  
61 and conservation has been traditionally questioned. In response, the development and  
62 implementation of agri-environmental schemes aim at counteracting the environmental impacts  
63 of modern agriculture on biodiversity (Stoate et al. 2009), as well as considering the potential  
64 for agricultural management to promote biodiversity and ecosystem functions through  
65 enhanced biomass productivity (Tscharntke et al. 2005).

66 Among the animal groups displaying landscape-wide biodiversity losses, populations of  
67 many farmland bird species have severely declined across Europe due to post-war agricultural  
68 intensification (Donald et al. 2001; Benton et al. 2003; Geiger et al. 2010; EBCC 2016). Links  
69 between agricultural intensification and avian biodiversity loss have also been reported at a  
70 global scale, with severe population declines in Africa (Söderström et al. 2003) and North  
71 America (Brennan and Kuvlesky 2005). Over several decades, modernisation of agriculture has  
72 led to drastic reductions in foraging resources in arable landscapes, which has strongly affected  
73 populations of seed-specialist farmland birds (Siriwardena et al. 2007). A large body of the  
74 literature has investigated bird responses to agricultural management in annual crops such as  
75 cereals and vegetables (e.g., Ponce et al. 2014; Navedo et al. 2015). Perennial crops such as

76 fruit orchards have been much less of a focus (Bruggisser et al. 2010; Rey 2011; Katayama  
77 2016). This is critical information that is lacking because crop management practices and  
78 habitat structures that strongly differentiate annual crop systems from perennial ones might  
79 influence bird responses to agri-environmental schemes (Bruggisser et al. 2010).

80 In this study, we aimed to fill these gaps by highlighting the capacity of fruit orchards to be  
81 used as habitat for farmland bird communities specifically during their wintering period. Avian  
82 communities and bird species requirements for feeding and habitat change throughout the year  
83 in agricultural landscapes as in any other environment, and evaluations of the role of agri-  
84 environmental schemes as food and habitat provision sites outside of the reproduction period  
85 have been increasingly needed (Marfil-Daza et al. 2013; Ponce et al. 2014; Redhead et al. 2018).  
86 The quality of winter habitats can affect bird lifetime reproductive success through influences  
87 on departure date from winter quarters and on condition during migration (Marra et al. 1998;  
88 Bearhop et al. 2004; Norris et al. 2004; Smith and Moore 2005). As perennial crops, fruit  
89 orchards constitute highly stable and predictable habitats for bird communities (Brown and  
90 Welker 1992), and their ability to provide quality resources and resting sites for birds is likely  
91 to vary with their size, plant diversity, surrounding land cover and management practices  
92 (Mangan et al. 2017). Orchards constitute intensively managed agroecosystems maximizing  
93 fruit production and subsequently affecting bird populations depending on the amount of  
94 chemicals sprayed for crop protection (Bishop et al. 2000; Bouvier et al. 2005; Genghini et al.  
95 2006; Bouvier et al. 2011). The influence of orchard management on farmland bird diversity at  
96 both local and landscape scales has been recognized during the reproductive season (Bouvier  
97 et al 2011; Belfrage et al. 2005), but their potential for bird conservation during winter is still  
98 poorly described globally (but see Myczko et al. 2013 in apple orchards of Central Europe).  
99 Fruit production seasons display sharp contrasts with winter seasons, during which  
100 anthropogenic disturbance becomes almost non-existent, making orchards substantially

101 beneficial for wintering farmland birds. Fruits can be left in orchards after harvest, the absence  
102 of chemical treatments favours survival and overwintering for many insect prey species (Skórka  
103 et al. 2006; Tryjanowski et al. 2011), and the occurrence of winter fruiting in the surrounding  
104 vegetation in orchard hedgerows can provide a high energy content food resource to many  
105 farmland birds (Metcalf 2005).

106 Here, we present the first study specifically investigating the response of wintering bird  
107 communities to winter resource availability in pome fruit orchards of Southern Europe. This  
108 study was conducted in southeastern France, which is at the crossroads of numerous migratory  
109 routes of Palearctic birds (Berthold 2001). The region includes natural landscapes (e.g.,  
110 grasslands and wetlands) of international importance that have long been the subject of wildlife  
111 protection measures and that face conservation and economic development issues (Beltrame et  
112 al. 2013). Pome fruit orchards currently cover an area of approximately 10,000 ha in this region,  
113 which corresponds to a quarter of the agricultural area dedicated to these fruits in France, the  
114 fourth largest apple producing country in Europe (Agreste 2014; Agreste 2019). However, the  
115 ability of such cultivated areas to provide refuge for migratory birds during winter, i.e., outside  
116 periods of high anthropogenic activities, has been largely understudied to date. We assessed  
117 various parameters of bird abundance and diversity in a network of thirty pome fruit orchards  
118 located in an area of key importance for overwintering Palearctic species (Berthold 2001). We  
119 tested how they were affected by the quantity of unharvested fruits and wild berries in  
120 hedgerows and how different orchard management strategies can influence the availability of  
121 these resources for overwintering birds.

122

## 123 **Materials and methods**

### 124 **Study sites**

125 Fieldwork was carried out in 30 commercial pome fruit orchards (15 apple and 15 pear) located  
126 in a 50 km<sup>2</sup> pome fruit production area ('Basse vallée de la Durance', central point: WGS84:  
127 43°8' N, 3°9' E) of southeastern France (Fig. 1). This area is a flat agricultural plain ranging  
128 from 40 to 60 m a.s.l. characterized by a dense network of ditches and hedgerows and by diverse  
129 farming systems. Fruit orchards are the dominant crop in a crop mosaic that also contains  
130 vineyards, vegetables, and cereal crops. Pome fruits, i.e., apple and pears together, represent  
131 87% of all fruit production in the study area. The studied orchards had an average area of 1.22  
132 ± 0.14 ha, a plantation density of approximately 1500 trees/ha distributed along an average of  
133 15.5 ± 1.5 rows and a grassy ground cover. The orchards had the following types of  
134 management: conventional, integrated pest management (IPM) or organic management (10  
135 orchards each). Disease and pest control treatment strategies in this study area correspond to  
136 those described by Bouvier et al. (2005, 2011, 2016). Treatments are carried out from March to  
137 October. Conventional orchards were managed with an average of 26.2 and 23.0 treatments in  
138 2009 and 2010, respectively. Treatments included chemical fungicides (13.1 and 13.7 in 2009  
139 and 2010, respectively) and broad-spectrum chemical insecticides (12.5 and 9.3 in 2009 and  
140 2010, respectively). IPM orchards were managed with chemical fungicides, insecticides and  
141 herbicides similar to those used in conventional orchards. The use of male mating disruption  
142 against the main Lepidopteran pest in these orchards resulted in chemical insecticide input  
143 reductions of 1.3 treatments in 2009 and 1.4 in 2010. The average number of annual treatments  
144 in the organic orchards was 29.7 and 27.0 in 2009 and 2010, respectively. These treatments  
145 included two mineral fungicides, copper and sulfur (2.5 and 8.1 in 2009 and 2010, respectively),  
146 a selective viral insecticide against codling moths (7.2 and 7.1 in 2009 and 2010, respectively)  
147 and mating disruption. All orchards were bordered by hedgerows (mainly poplar or cypress)  
148 for protection against the prevailing winds. Except for treatment strategies, orchards were



149 chosen for their similarity in structure and in local environmental features that might influence  
150 bird communities.

151

### 152 **Overwintering bird assemblages**

153 Two surveys were carried out in each orchard, one in January 2009 and one in December 2010,  
154 in days without heavy rain or wind and between 9.00 am and 2.30 pm to match bird foraging  
155 activity (Skorka et al. 2006; Myczko et al. 2013; Assandri et al. 2016). In two instances, two  
156 orchards were less than 300 m apart, and we took the precaution of not surveying them on the  
157 same day to avoid moving the birds from one orchard to the other. Birds heard and seen within  
158 orchards and their surrounding hedgerows were recorded using transect counts along the  
159 periphery and the central tree row of each orchard. Because the orchards had a small area and  
160 an elongated shape, this made it possible to cover the whole orchard. The length of the transects  
161 varied among the orchards with a mean  $\pm$  se of  $711 \pm 21$  m (range: [420, 1013]). This value was  
162 not correlated with orchard area (Pearson's  $r = 0.28$ ,  $P = 0.13$ ). The duration of each survey was  
163 approximately 20 min per ha. The similar and simple vegetation structure of the orchards, the  
164 similar climatic conditions when the surveys were conducted, and the performance of all  
165 surveys by the same experienced ornithologist (JCB) to exclude between-observer variation  
166 were meant to ensure that bird detectability did not vary among the orchards (Bibby et al. 2000).

167

### 168 **Food resource availability for overwintering birds in orchards**

169 The two main plant resources available for birds in winter are fruits remaining on the ground  
170 or in the pome fruit trees after harvest and the wild berries growing in hedgerows (Metcalf  
171 2005). In a preliminary approach, we investigated the floristic composition of the hedgerows in  
172 a random sample of 10 out of the 30 orchards to identify the plant species that produce berries  
173 during winter in the area. As ivy (*Hedera helix*) was by far the numerically dominant species

174 (Online Resource 1), we further focused on the abundance of this species throughout our  
175 experimental design.

176 Fruits laying on the ground or remaining in the trees were counted on 10 equidistant 5 m x  
177 3 m plots aligned along a diagonal of each orchard. Each plot included a 5 m length of one tree  
178 row and its adjacent alley. The counts were performed on the same day as the bird counts. The  
179 total number of fruits remaining in each orchard was estimated from its fruit counts in the 5 m  
180 x 3 m plots and its total area. This defined the *fruit* continuous independent variable for data  
181 analysis. The independent binary variable *presence of fruits* was further used to categorize  
182 orchards depending on whether fruits were absent (zero) or present (one).

183 We assessed the amount of available ivy berries in the orchard hedgerows by counting the  
184 number of trees carrying fruiting ivy in all hedgerows bordering each orchard. This defined the  
185 *ivy* independent variable for data analysis.

186

## 187 **Statistical analyses**

### 188 *Overwintering bird assemblages*

189 Data were analysed using R.3.5.1 software (R Core team 2018). We used the *vegan* R  
190 package (Oskasnen et al. 2019) to calculate estimates for richness, abundance, and evenness.  
191 These calculations were based either on all bird species when describing the data or excluding  
192 prey birds when assessing the effect of resources since this guild was not expected to directly  
193 benefit from the presence of fruits (Table 1). In three orchards in 2009, there were large flocks  
194 of *Sturnus vulgaris* and *Fringilla coelebs*; the presence of these two species was thus recorded,  
195 but these three orchards were removed from statistical analyses on abundance as species  
196 abundance was only roughly estimated. Correlations between bird abundance and species  
197 richness and between evenness and both bird abundance and species richness were first  
198 investigated with Spearman correlation tests.

199

200 Low species detectability may result in the underestimation of species richness, as some species  
201 may be undetected. We assessed the extent of this underestimation by also calculating the  
202 improved Chao1 index of species richness (Chao and Chiu 2016) using the SpadeR R package  
203 (Chao et al. 2016) for the whole dataset, as well as independently for orchards with and without  
204 remaining fruits and per year. We also calculated the Chao1 index for 57 out of the 60 orchard  
205 x year combinations, with the number of detected species being too low for its calculation for  
206 three of them. We further calculated the estimated community coverage, i.e., the estimated  
207 fraction of the entire population of individuals in the community that belonged to the detected  
208 species (SpadeR, Chao et al. 2016).

209

#### 210 *Effect of available resources on bird assemblages*

211 All statistical analyses were performed on the values of species richness and abundance  
212 calculated from detected species. The results based on improved Chao1 index estimations of  
213 species richness did not differ substantially (Online resource 2).

214

#### 215 Models

216 The effect of resources on bird abundance was analysed with linear mixed models including  
217 *year*, *orchard area*, *presence of fruits* and  $\log(\text{ivy} + 1)$  as independent variables. Only the  
218 interaction of  $\log(\text{ivy} + 1)$  with the *presence of fruits* was included. This effect was further  
219 analysed separately for orchards with and without remaining fruits, i.e., with linear mixed  
220 models including *year*, *orchard area* and  $\log(\text{ivy} + 1)$  as independent variables for both types of  
221 orchards and including the ' $\log(\text{fruits})$ ' variable for orchards with remaining fruits only. For  
222 these orchards, the interaction of  $\log(\text{ivy} + 1)$  with  $\log(\text{fruits})$  was also included. All quantitative  
223 independent variables were scaled. Orchard identity was included as a random effect in all

224 models to account for the fact that the same orchards were surveyed in 2009 and 2010. Variance  
225 inflation factors were below 3 for all models, indicating low levels of multicollinearity (Zuur et  
226 al. 2010). Model residuals were inspected for dispersion using a quantile-quantile (QQ) plot of  
227 standardized residuals and for uniformity and outliers using a plot of residual versus predicted  
228 values. Associated statistical tests were also performed with the DHARMA R package (Hartig  
229 2019). Following analyses of residuals, abundance values were square root transformed, and a  
230 Gaussian link function was chosen.

231 The effect of resource abundance on species richness was analysed with generalized linear  
232 mixed models including *year*, *orchard area*, *presence of fruits* and  $\log(\text{ivy} + 1)$  as independent  
233 variables assuming a Poisson distribution of the data (log link function). As for abundance, only  
234 the interaction of  $\log(\text{ivy} + 1)$  with the *presence of fruits* was included. The species richness was  
235 further analysed separately for orchards with and without remaining fruits. GLMMs included  
236 *year*, *orchard area* and  $\log(\text{ivy} + 1)$  as independent variables for both types of orchards and  
237 included the ' $\log(\text{fruits})$ ' variable for orchards with remaining fruits only. For these orchards,  
238 the interaction of  $\log(\text{ivy} + 1)$  with  $\log(\text{fruits})$  was also included. All quantitative independent  
239 variables were scaled. Orchard identity was included as a random effect in all models. Variance  
240 inflation factors were below 3 for all models. Model residuals were inspected as above using  
241 QQ plots and residuals versus predicted plots and tests for dispersion, uniformity and outliers.

242 Specific associations between the presence of individual bird species and the total number  
243 of fruits or of ivy-bearing trees were assessed for frequent species (i.e., species present in at  
244 least 10 year x orchard combinations) using generalized mixed linear models using *year*,  
245  $\log(\text{fruits} + 1)$  and  $\log(\text{ivy} + 1)$  with a binomial distribution of the data. As above, all quantitative  
246 independent variables were scaled and orchard identity was included as a random effect, and  
247 model residuals were inspected as above. Variance inflation factors were also below 3 for all  
248 models (Zuur et al. 2010).

249

250 Significance of independent variables

251 A multimodel inference approach was used to assess the significance of independent variables  
252 using the MuMIn R package (Barton, 2020). A model selection procedure using the corrected  
253 Akaike information criteria (AICc) was performed on the full models containing all  
254 independent variables. All models falling within a  $\Delta AICc < 4$  (Online resource 3) were then  
255 used in a model averaging procedure (Burnham and Anderson, 2002). This allowed the mean  
256 coefficient associated with each independent variable to be calculated, along with its confidence  
257 interval as well as each variable importance, i.e. the sum of the Akaike weights ( $\Sigma w$ ) of the  
258 models in which it appeared. The latter indicates the probability that the independent variable  
259 is a component of the best model (Burnham & Anderson, 2002). An independent variable was  
260 considered significant when the 95% confidence interval of its coefficient did not overlap 0.

261

262 *Effect of crop management on available resources*

263 To assess the effects of the crop treatment strategies on the resources available to the birds after  
264 harvest, the effects of crop treatment strategy on  $\log(\text{ivy} + 1)$  were analysed with a linear model  
265 including *year* and *crop management* (i.e., organic, IPM or conventional) as independent  
266 variables. The effects of the crop management strategies on the  $\log(\text{fruits} + 1)$  were analysed  
267 similarly in apple orchards only as there were no remaining fruits in the pear orchards (see  
268 Results). Model residuals were inspected as above. Pairwise comparisons between crop  
269 management strategies were carried out using post hoc Tukey tests (package multcomp,  
270 Hothorn et al. 2008).

271

272 **Results**

273 **Food resource availability for overwintering birds in orchards**

274 There were remaining fruits in 12 and 9 orchards in 2009 and 2010, respectively. The estimated  
275 number of fruits per orchard was higher in 2009 than in 2010 (mean  $\pm$  se: 2009: 10799 $\pm$ 1000,  
276 2010: 2533  $\pm$  177). The remaining fruit density per orchard was estimated to be 6.7  $10^{-2} \pm 3.9$   
277  $10^{-2}$  (mean $\pm$ se), 2.80  $\pm$  1.39 and 0.56  $\pm$  0.15 fruits.m<sup>-2</sup> in the organic, IPM and conventional  
278 orchards, respectively. These fruits were only apples, as pears were totally decayed at that time  
279 of year. Fruits mostly laid on the ground.

280 Fruiting trees with ivy were observed in 28 out of the 30 orchards with a mean number ( $\pm$   
281 se) of 51.75  $\pm$  10.19 (range [1, 207]) trees and was similar in orchards with and without  
282 remaining fruits (mean  $\pm$  se: 43.62  $\pm$  8.34 and 53.57  $\pm$  10.16 respectively). Of the two orchards  
283 without fruiting ivy, one had remaining fruits both years, and the other had no fruits.  
284 Considering only orchards with remaining fruits, the number of fruits and the number of trees  
285 with fruiting ivy were uncorrelated (2009: Spearman  $r=0.18$ ,  $p=0.55$ ; 2010:  $r=0.27$ ;  $p=0.47$ ).

286

### 287 **Overwintering bird assemblages in orchards**

288 We observed 1480 birds (excluding orchards with flocks) and identified 41 bird species overall,  
289 31 species during the 21 surveys in the orchards with fruits and 40 species during the 39 surveys  
290 in the orchards without fruits (Table 1). Overall, 93% of observed birds were common  
291 songbirds, representing a total of 35 species. Among these, 10 were granivores, 7 were  
292 insectivores and 18 fed on both arthropods and seeds or fruits during that period of the year  
293 (Table 1). The most frequent species were the black cap *Sylvia atricapilla*, the song thrush  
294 *Turdus philomelos*, the Great tit *Parus major*, the common chaffinch *Fringilla coelebs*, and the  
295 robin *Erithacus rubecula* (Table 1). Thirteen species were of conservation concern, being  
296 threatened either in France or with decreasing population trends at the global level (Table 1 and  
297 Online Resource 4).

298 The estimated coefficient of variation of species discovery probability was high (2.44). The  
299 improved Chao1 index was thus chosen to assess species richness because it does not assume  
300 similar species discovery (Chao and Chiu, 2016). The Chao1 index of species richness was  
301 slightly higher than the total raw number of species (mean [95% confidence interval], 53.9  
302 [42.9,125.5]) when considering orchards with fruits (32.4 [31.4, 35.5]) and when considering  
303 orchards without fruits (45.2 [41.7, 55.8]). The raw number of species was higher in 2009 than  
304 in 2010 (37 and 30, respectively), as was the Chao1 index of species richness (2009: 42.3 [40.1,  
305 49.2]; 2010: 31.9 [30.2, 52.1]). Consistent with the low estimated number of undetected species,  
306 the coverage estimate for the entire dataset was 0.99.

307 The number of birds per orchard ranged from 2 to 94 (excluding flocks), and there were on  
308 average (mean  $\pm$  se)  $25.9 \pm 2.7$  birds per orchard. Bird abundance per orchard was higher in  
309 2009 than in 2010 ( $32.2 \pm 4.2$  and  $20.3 \pm 3.1$ , respectively, Table 2). The raw number of species  
310 per orchard also varied widely from 1 to 16, with an average of  $7.4 \pm 0.4$ , and this number was  
311 also higher in 2009 than 2010 ( $8.3 \pm 0.7$  and  $6.6 \pm 0.4$ , respectively, Table 2). Bird abundance  
312 and bird species richness per orchard were highly positively correlated (Spearman  $r=0.7$ ,  $P=2.2$   
313  $10^{-9}$ ).

314 The evenness of the observed bird assemblages ranged from 0.25 to 1 (excluding flocks) and  
315 was (mean  $\pm$  se)  $0.82 \pm 0.01$  on average. It was highly negatively correlated with bird abundance  
316 ( $r=-0.65$ ,  $P=3.15 \cdot 10^{-8}$ ) but not with the observed bird species richness ( $r=-0.22$ ,  $P=0.09$ ).

317

## 318 **Effect of available resources on overwintering bird assemblages**

### 319 *Abundance*

320 Bird abundance was higher in orchards with fruits. Whatever the orchard type, it increased with  
321 an increasing number of trees with fruiting ivy (Table 2, Fig. 2). Bird abundance also increased  
322 with the number of remaining fruits in orchards with fruits (Table 2, Fig. 3).

323

324 *Species richness*

325 Bird species richness did not differ between orchards with or without remaining fruits, and it  
326 increased significantly with the number of trees with fruiting ivy in the hedgerows (Table 2,  
327 Fig. 4). Bird species richness also increased significantly with the amount of fruits in orchards  
328 with remaining fruits and with the number of trees with fruiting ivy in orchards without fruits  
329 (Table 2, Fig. 4).

330

331 *Occurrence of particular songbird species*

332 The 17 most frequent species (i.e., occurring in more than 10 year x orchard combinations)  
333 were *Carduelis carduelis*, *Carduelis chloris*, *Corvus corone*, *Erithacus rubecula*, *Fringilla*  
334 *coelebs*, *Garrulus glandarius*, *Parus caeruleus*, *Parus major*, *Phoenicurus ochruros*, *Pica pica*,  
335 *Picus viridis*, *Prunella modularis*, *Sylvia atricapilla*, *Sylvia melanocephala*, *Turdus iliacus*,  
336 *Turdus merula* and *Turdus philomelos* (Table 1). Analyses were carried out on all these species  
337 except *P. ochruros* and *S. melanocephala* due to incorrect model residuals in these two cases.  
338 The occurrence of seven songbird species (*S. atricapilla*, *P. caeruleus*, *P. major*, *E. rubecula*,  
339 *T. iliacus*, *T. merula* and *T. philomelos*) was significantly positively associated with the number  
340 of ivy-bearing trees (Table 3). These species were also those with the highest difference in  
341 occurrence between the 12 surveys in orchards with the most ivy bearing trees and the 12  
342 surveys in orchards with least ivy bearing trees (Table 1).

343

344 **Effect of crop management on available resources**

345 The number of trees with ivy did not depend on crop management strategy ( $P=0.18$ ). In contrast,  
346 the number of remaining fruits depended on crop management in apple orchards ( $P=2.7 \cdot 10^{-4}$ ).  
347 The number of remaining fruits was lower in the organic orchards than in the IPM (estimate -



348 6.69,  $P < 10^{-4}$ ) or in the conventional (estimate -5.31,  $P = 6.5 \cdot 10^{-4}$ ) orchards, and this value did not  
349 differ between the conventional and IPM apple orchards ( $p = 0.605$ ).

350

## 351 **Discussion**

352 As in other environments, avian species communities and their requirements for feeding and  
353 habitat change throughout the year in agricultural landscapes. There is an increasing need to  
354 evaluate the role of agri-environmental areas as food and habitat provision sites outside of the  
355 breeding season (Marfil-Daza et al. 2013; Ponce et al. 2014; Redhead et al. 2018). Efforts to  
356 conserve wintering bird communities in agricultural landscapes rely on improvements in winter  
357 habitat by increasing the availability of key resources such as food, shelter and resting sites  
358 (Hammers et al. 2015; Redhead et al. 2018). Research on the effectiveness of agri-  
359 environmental schemes has usually focused on the responses of a few species (Johnson et al.  
360 2006; Ponce 2014; Breeuwer et al. 2009; McHugh et al. 2017), although a large number of  
361 species or functional groups may respond (MacDonald et al. 2012; Ponce 2014; Henderson et  
362 al. 2000; Navedo et al. 2015; Bouam et al. 2017). Considering the whole bird community as a  
363 rule for biodiversity maintenance should thus be a priority (Ponce 2014; Ekroos et al. 2014).

364 Based on a 2-year community study in a local network of commercial pome fruit orchards,  
365 we showed that the amount of available fruits during winter, both on the ground or in  
366 surrounding vegetation, had a significant influence on the abundance and species richness of  
367 wintering bird populations in southeastern France. These orchards hosted no less than 15% of  
368 France's wintering avifauna (Issa and Muller 2015), which was predominantly composed of  
369 insectivorous and granivorous passerines. Thirteen of the recorded species were of conservation  
370 concern as either being threatened in France or having a decreasing population trend at the  
371 global level (Online Resource 4). This indicates that such perennial crops favouring the  
372 presence of fruits in winter are potentially important and relevant bird wintering areas, similar

373 to other apple orchards in Central Europe (Myczko et al. 2013) or olive groves in southern  
374 Spain (Rey 2011). This result is also in line with the provisioning of resources for wintering  
375 birds reported from other agricultural landscapes throughout Europe, such as improved  
376 grassland fields in Ireland (McMahon et al. 2013), rice fields on the western Iberian Peninsula  
377 (Navedo et al. 2015) and farmlands in the Netherlands (Hammers et al. 2015). Although this  
378 work was carried out at a local spatial scale, we posit that it sheds important light on the  
379 potential for perennial crops to provide sustainable, favourable habitats to overwintering bird  
380 populations in France and throughout Europe, where 473,000 ha of apple orchards and 100,000  
381 ha of pear orchards represented nearly 44 % of the total fruit cultivated area in 2017 (Eurostat  
382 2020. In the context of a large-scale decline in common farmland bird populations in Europe  
383 (Donald et al. 2006; EBCC 2016), our study thus supports orchards as one of the key favourable  
384 habitats for some Palearctic bird species during their wintering period (Rey 2011; Tryjanowski  
385 et al. 2011; Myczko et al. 2013), with potential beneficial effects for subsequent breeding  
386 seasons (Siriwardena et al. 2007).

387

### 388 **Factors affecting bird species richness and abundance in pome fruit orchards**

389 The availability of food resources is a key factor determining the selection of wintering sites by  
390 birds (Robinson and Sutherland 1999). One central finding of this study is that the presence of  
391 apples left on the ground after harvest and ivy berries in the surrounding hedgerows  
392 significantly influenced the use of cultivated area by wintering bird populations in southern  
393 France. Although orchards can also be used by birds for resources other than fruits or as a  
394 resting area, we suggest that there might be some complementarity between apples and ivy  
395 berries as food resources. In comparison to the number of apples, the number of trees bearing  
396 ivy berries in the surrounding windbreak hedgerows appeared to affect bird species richness  
397 more. Indeed, when the full set of orchards (i.e. with and without fruits) was considered, the

398 presence of fruits positively affected only bird abundance while the number of trees bearing  
399 ivy berries positively affected both bird abundance and bird species richness (Table 2, Figs. 2  
400 and 4). Further, the number of trees with ivy was also the only independent variable positively  
401 affecting Chao1 index estimations of species richness (Online resource 2). This relatively  
402 stronger effect of the number of trees with ivy on species richness was consistent with an  
403 increase in the occurrence of seven songbird frequent species (*E. rubecula*, *P. caeruleus*, *P.*  
404 *major*, *S. atricapilla*, *T. iliacus*, *T. merula* and *T. philomelos*) with the number of ivy bearing  
405 trees but not with that of apples (Table 3). A main difference between the effects of apples and  
406 ivy may rely on both the direct and indirect attractivity of apples for different diet guilds.  
407 Indeed, unharvested fruits may also host specialized arthropod pests (e.g., codling moth, *Cydia*  
408 *pomonella*, caterpillars) or fruit-decaying opportunistic species (e.g., *Drosophila* spp.) and thus  
409 attract a large range of birds. This has not been formally tested in the present study, but previous  
410 studies suggested that insect infestation can enhance the attractiveness of fruits to frugivorous  
411 bird species (Valburg 1992); however, some species may also avoid them (Traveset et al. 1995;  
412 Dixon et al 1997). In contrast, trees with ivy may have attracted species that preferentially  
413 forage in trees as opposed to on the ground or species that rely on ivy berries as a component  
414 of their diet. Four out of the seven species that responded positively to the number of trees with  
415 ivy are well known to feed on berries during winter (*S. atricapilla*, *T. iliacus*, *T. merula* and *T.*  
416 *philomelos*). On the other hand, the significant positive response of *E. rubecula*, *C. caeruleus*  
417 and *P. major* that are not known to feed on ivy berries may emphasize the beneficial role of ivy  
418 in microhabitat diversity in hedgerows, as interlacing ivy likely increases hedgerow structural  
419 complexity. Microhabitat diversity is a good predictor of bird diversity (Regnery et al. 2013).

420 Conversely, bird abundance was positively correlated with the number of available apples,  
421 i.e., the larger the number of apples was, the greater the number of birds (Fig. 3). Consistent  
422 with the results of Myczko et al. (2013) in Polish apple orchards, our study confirms the general

423 trend that birds forage preferentially on a food source when it is abundant (Ricklefs and Miller  
424 2005). In winter, the gregarious behaviour of particular species (e.g., Turdidae and Fringillidae  
425 species) can lead to large flocks of birds (>100 individuals) in a single site. Behavioural  
426 aggregation provides them with greater protection from predators and allows them to feed  
427 longer during the shorter days of the winter period (Pulliam 1973; Treisman 1975). We  
428 observed such flocks of *S. vulgaris* or *F. coelebs* in three orchards in 2009 and excluded these  
429 from our analyses as birds were difficult to estimate numerically, but importantly, flocks  
430 predominantly occurred in orchards in which apples were highly abundant on the ground (2 out  
431 of 3 orchards). Interestingly, the number of trees with ivy was also positively associated with  
432 bird abundance in orchards with remaining fruits on the ground (Fig. 2). This may have resulted  
433 from an increase in the number of species that responded to the complementarity of these  
434 resources, as discussed above.

435 Overall, our results suggest that the presence of hedgerows is likely favourable to the bird  
436 communities that use pome fruit orchards during winter. Hedgerows have been acknowledged  
437 for their positive influence on local bird abundance and species richness in agricultural  
438 landscapes, meadows, and wheat and alfalfa fields (Hinsley and Bellamy 2000; Batáry et al.  
439 2010; Kross et al. 2016). In addition, a multi-species composition of vegetal hedgerows can  
440 provide short-range shelter to many species, including those that do not forage on berries, which  
441 may facilitate resource exploitation in areas that might otherwise be too risky to use (Suhonen  
442 1993; Andrews and Rebane 1994). In southern France, hedgerows are mostly planted as a  
443 barrier against strong prevailing winds, but a trend in orchard farming consists of removing  
444 hedgerows and taking advantage of the wind-breaking efficiency of insect pest exclusion nets  
445 that cover trees (Middleton and McWaters 2002; Iglesias and Alegre 2006). Our results,  
446 however, showed the likely important role of hedgerows when vegetally diversified in  
447 overwintering bird conservation. Additionally, fruits on the ground are food sources that cannot

448 be replenished during winter because they are gradually depleted through bird consumption,  
449 decomposition and incorporation into the soil. The presence of hedgerows with tree species that  
450 produce berries all winter may provide some bird species with an additional sustainable food  
451 supply. In terms of bird population conservation, we suggest that management  
452 recommendations include the maintenance of hedgerows concomitantly with the use of insect  
453 pest exclusion nets. In addition to maintaining a diversity of hedgerow structures (i.e., in  
454 density, width and height) that are generally attractive for numerous bird species (Duckworth  
455 1994), diversifying hedgerow composition with different plant species fruiting in winter and  
456 reducing hedgerow pruning intensity may also strengthen sustainability in fruit provision to  
457 overwintering birds (Hinsley and Bellamy 2000). Given the importance of landscape  
458 composition for overwintering birds (Geiger et al. 2010), the maintenance of hedgerow  
459 diversity should also be managed at the landscape scale based on good coordination between  
460 farmers. Although landscape management is frequently advocated as part of biodiversity  
461 conservation, it causes specific challenges in agricultural landscapes due to the spatial scale  
462 mismatch between ecological processes and agricultural farm management, and to the strong  
463 economic constraints that farmers are facing (Pelosi et al. 2010; Kremen and Merenlender  
464 2018). Its implementation is still rare (but see, e.g., Bretagnolle et al 2011). In the study area,  
465 collective management could be supported by current French incentives for groups of farmers  
466 that want to act collectively to increase the durability of their farming systems (GIEE :  
467 Groupements d'intérêt économique et environnemental).

468 Notably, the present study did not consider the presence of seeds from the herbaceous  
469 stratum, which were also likely abundant on the ground. Herbaceous seeds may constitute an  
470 additional attractive food for birds in orchards (Myczko et al. 2013) and farmlands (Wilson et  
471 al. 1999; Newton 2004; Stoate et al. 2009). However, as all orchards were grassed, a common

472 practice in the study area to facilitate the use of agricultural machinery, this is unlikely to affect  
473 our conclusions.

474

#### 475 **Effects of farming practices on fruit resource availability**

476 In agroecosystems, the resources available for birds are often dependent on farmers' practices.  
477 The number of surrounding trees with ivy around orchards varied among orchards but did not  
478 depend on the orchard management strategy. This lack of correlation to management strategy  
479 may be explained by the orchards' past history. All plots were initially planted similarly and  
480 were managed as conventional orchards, and some of them were later converted to IPM and  
481 organic farming without changes in their surrounding environment. In contrast, the quantity of  
482 apples left on the ground strongly depended on the type of orchard management. Myczko et al.  
483 (2013) found that abandoned or traditionally managed apple orchards increased food and shelter  
484 opportunities to birds than intensively managed ones in Poland. In contrast, we found that  
485 available apples in winter were significantly more abundant in both conventional and IPM  
486 orchards than in organic orchards, which resulted from a substantial divergence in the  
487 management of unharvested apples during winter. Post-harvest apple grinding is a prophylactic  
488 method for controlling insect pests in organic orchards, where spring pest control strategies are  
489 generally less effective in maintaining insect populations at low risk levels than those used in  
490 conventional or IPM orchards. Apple grinding aims to kill insect larvae that develop in apples  
491 after they have fallen to the ground, thereby reducing the size of overwintering pest populations.  
492 Conversely, higher pesticide pressure in both conventional and IPM orchards during the apple-  
493 growing season causes growers to neglect overwintering insect populations that may have  
494 escaped treatments and to not manage uncollected fruits. The positive impact of this latter  
495 practice on overwintering bird abundance in conventional and IPM orchards occurred in  
496 contrast to the adverse effects of phytosanitary treatments (in particular synthetic insecticides)

497 on the reproductive success of passerines and on bird abundance and species richness reported  
498 during the breeding season (Bouvier et al. 2005; Bouvier et al. 2011; Katayama 2016; Kajtoch  
499 2017). Our results thus suggest that how agricultural management strategies affect bird  
500 communities in orchards may change over the course of a year, supporting the claim that  
501 environmental impacts of farming practices should be considered not only at the seasonal scale  
502 but also at the annual scale. Further work on the impacts of annual farming practices on  
503 overwintering insect communities might complement approaches that enable orchards to  
504 provide wintering birds with resources.

505

## 506 **Conclusion**

507 This study highlighted that pome fruit orchards likely serve as habitats for overwintering birds  
508 due to the presence of unharvested fruits and hedgerows with ivy. Modifications of agricultural  
509 practices at local and regional scales can improve the suitability of agroecosystems to a greater  
510 number of bird species by incorporating vegetation elements that favour bird species less  
511 adapted to croplands (Benton et al. 2003). This scenario is still poorly documented in pome  
512 fruit landscapes (Garcia et al. 2018), and our work provides additional support for the potential  
513 benefit of hedges in orchards for wintering bird populations.

514 Finally, our results also emphasized the positive effect that the presence of apples had on bird  
515 abundance during winter, which suggests that late season practices allowing the persistence of  
516 non-harvested fruits in orchards may be beneficial to overwintering bird populations. In the  
517 context where leaving unharvested fruits on the ground occurs with the cost of an increased risk  
518 for pests in organic orchards, supporting growers with effective pest management tools that are  
519 alternatives to pesticides (e.g., pest exclusion nets) could be a means of increasing the surface  
520 area favourable to wintering birds in agricultural landscapes.

521

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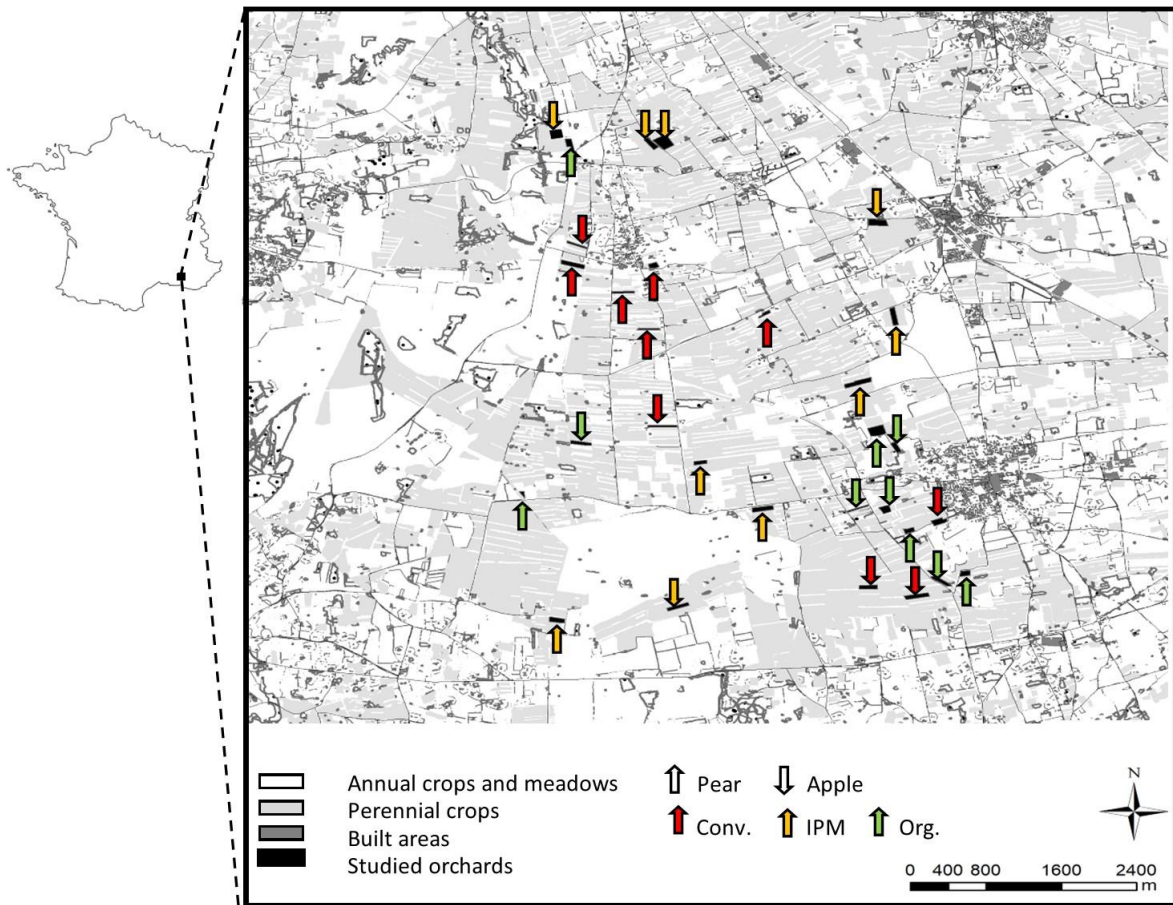
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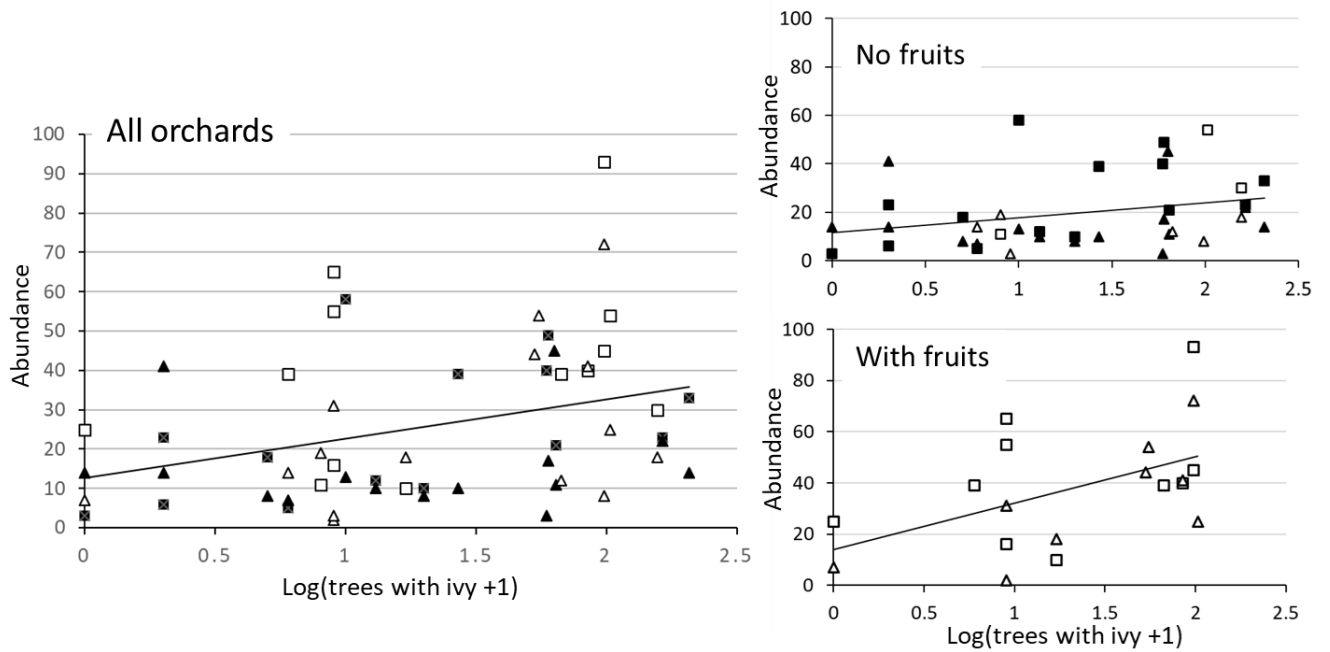


728 Fig. 1 Colour for online version  
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731 **Figure 1:** Map of the study area. Arrows point to the 30 sampled orchards. The orientation of  
732 the arrows differentiates pear and apple orchards, the colour of the arrow indicates the  
733 management strategy (Org.: Organic, IPM : Integrated pest management, Conv.: Conventional).  
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736 Fig. 2



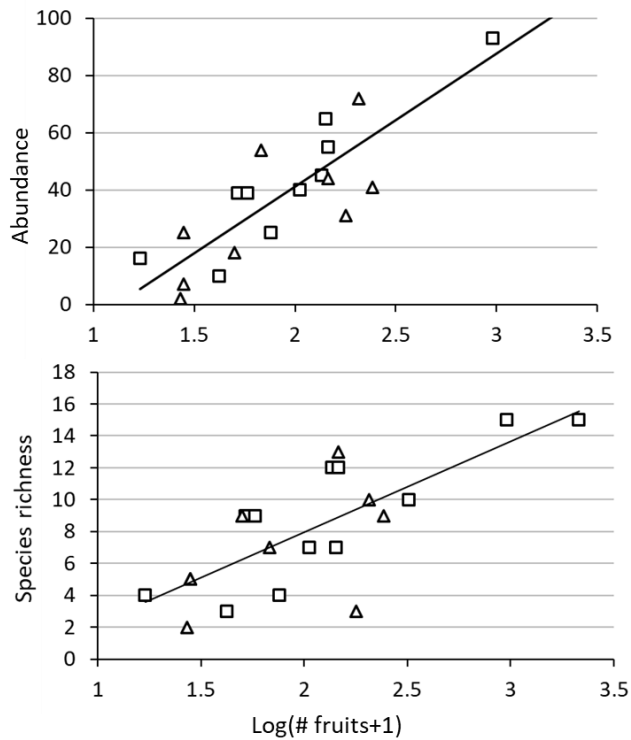
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**Figure 2:** Observed bird abundance as a function of the log-transformed number of ivy bearing trees in hedgerows considering either all orchards or considering separately orchards with and without remaining fruits on the ground. Abundance was assessed in 2009 and 2010 in pome fruit orchards in southeastern France. Filled symbols: pear orchards; open symbols: apple orchards; Squares 2009; triangles 2010.

746

747 Fig. 3

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750 **Figure 3:** Bird abundance and species richness per orchard as a function of the log-transformed  
751 number of remaining fruits per orchard. Abundance and species richness were assessed in 2009  
752 and 2010 in pome fruit orchards in southeastern France. Regression lines are presented for these  
753 two significant ( $p < 0.05$ ) relationships. Squares 2009; triangles 2010.

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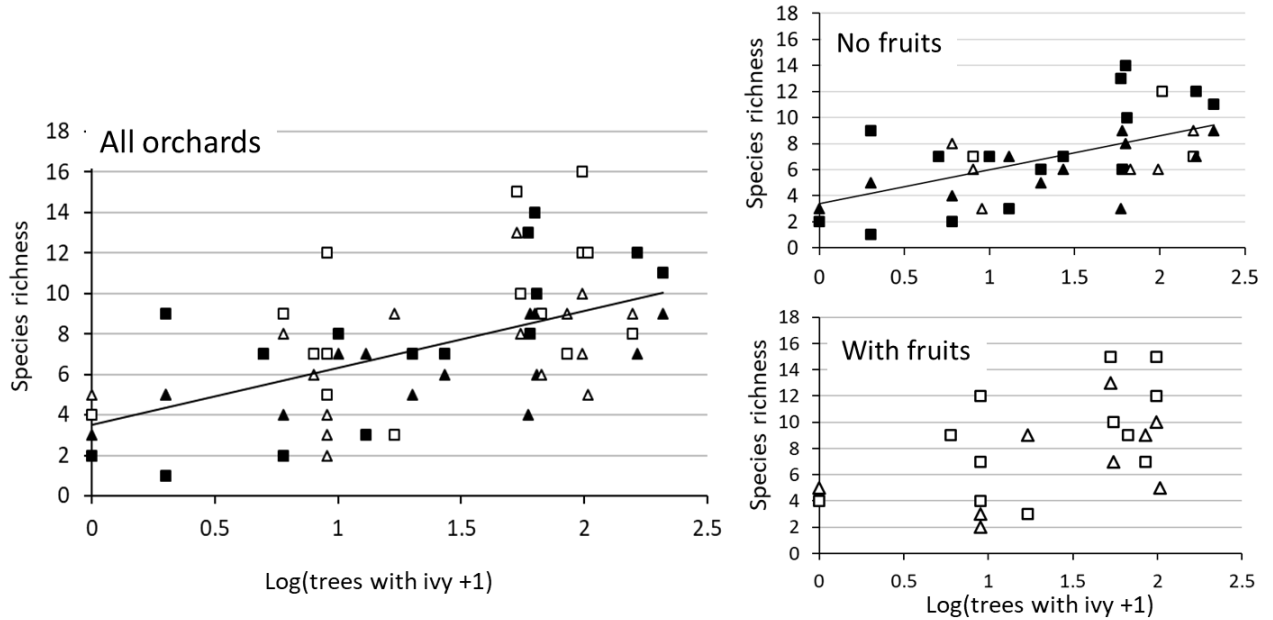
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756 Fig. 4

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761 **Figure 4:** Bird species richness as a function of the log-transformed number of ivy-bearing trees

762 in hedgerows considering either all orchards or considering separately orchards with or without

763 remaining fruits on the ground. Species richness was assessed in 2009 and 2010 in pome fruit

764 orchards in southeastern France. Regression lines are presented for significant ( $p < 0.05$ )

765 relationships. Filled symbols: pear orchards; open symbols: apple orchards; squares 2009;

766 triangles 2010.

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**Table 1:** Frequency of occurrence of bird species in orchards in southeastern France. The table provides the frequency of occurrence of bird species in orchards with and without remaining fruits after harvest in 2009 and 2010, the number of orchards in which they occurred among the 12 orchards with the most (ivy +) or less (ivy -) ivy bearing trees and their overall frequency of occurrence.

Year		Without fruits		With fruits		Ivy +	Ivy -	Total
		2009	2010	2009	2010			
# Orchards		18	21	12	9	12	12	60
Species name	Winter diet							
<i>Aegithalos caudatus</i>	I; Gr	0.06	0.00	0.00	0.00	0	0	0.02
<i>Anthus pratensis</i> *	I	0.11	0.05	0.17	0.11	2	1	0.10
<i>Buteo buteo</i>	P	0.28	0.19	0.08	0.11	1	2	0.18
<i>Carduelis cannabina</i> *	Gr	0.00	0.05	0.17	0.00	1	1	0.05
<i>Carduelis carduelis</i> *	Gr	0.28	0.14	0.50	0.33	3	5	0.28
<i>Carduelis chloris</i> *	Gr	0.00	0.19	0.25	0.33	3	1	0.17
<i>Certhia brachydactyla</i>	I	0.00	0.19	0.00	0.11	1	0	0.08
<i>Cettia cetti</i>	I	0.00	0.05	0.00	0.00	0	0	0.02
<i>Coccothraustes coccothraustes</i>	Gr	0.06	0.00	0.00	0.00	0	0	0.02
<i>Corvus corone</i>	O	0.28	0.24	0.50	0.56	1	3	0.35
<i>Corvus monedula</i>	O	0.11	0.05	0.00	0.00	0	0	0.05
<i>Dendrocopos major</i>	I; Gr	0.06	0.00	0.00	0.00	1	0	0.02
<i>Emberiza cia</i>	I; Gr	0.06	0.00	0.00	0.00	0	1	0.02
<i>Emberiza cirulus</i>	I; Gr	0.06	0.00	0.33	0.00	2	0	0.08
<i>Emberiza schoeniclus</i> *	I; Gr	0.17	0.05	0.08	0.11	0	1	0.10
<i>Erithacus rubecula</i>	I; Gr	0.33	0.67	0.50	0.67	7	3	0.53
<i>Falco tinnunculus</i> *	P	0.06	0.00	0.00	0.00	0	0	0.02
<i>Fringilla coelebs</i>	Gr	0.89	0.81	1.00	0.89	11	11	0.88
<i>Fringilla montifringilla</i> *	Gr	0.11	0.00	0.33	0.11	0	1	0.12
<i>Garrulus glandarius</i>	O	0.11	0.19	0.58	0.11	4	2	0.23
<i>Motacilla alba</i>	I	0.00	0.00	0.08	0.00	1	0	0.02
<i>Parus caeruleus</i>	I; Gr	0.33	0.24	0.17	0.33	6	1	0.27
<i>Parus major</i>	I; Gr	0.44	0.57	0.58	0.67	9	4	0.55
<i>Passer montanus</i> *	Gr	0.17	0.05	0.00	0.00	1	1	0.07
<i>Phasianus colchicus</i> *	Gr	0.06	0.00	0.00	0.00	1	0	0.02
<i>Phoenicurus ochruros</i>	I; Gr	0.17	0.24	0.17	0.11	1	3	0.18
<i>Phylloscopus collybita</i>	I	0.06	0.14	0.08	0.11	1	1	0.10
<i>Pica pica</i>	O	0.56	0.29	0.25	0.33	3	4	0.37
<i>Picus viridis</i>	I	0.17	0.14	0.33	0.00	5	1	0.17
<i>Prunella modularis</i> *	I; Gr	0.28	0.10	0.08	0.11	1	0	0.15
<i>Regulus ignicapillus</i>	I	0.11	0.00	0.17	0.00	2	2	0.07
<i>Serinus serinus</i> *	Gr	0.00	0.05	0.08	0.00	1	0	0.03
<i>Streptopelia decaocto</i>	Gr	0.06	0.00	0.08	0.00	1	1	0.03
<i>Sturnus vulgaris</i>	I; Gr	0.17	0.00	0.25	0.00	1	0	0.10
<i>Sylvia atricapilla</i>	I; Gr	0.67	0.52	0.42	0.67	11	3	0.57
<i>Sylvia melanocephala</i>	I; Gr	0.22	0.05	0.00	0.22	4	1	0.12
<i>Troglodytes troglodytes</i>	I; Gr	0.17	0.19	0.00	0.00	2	0	0.12
<i>Turdus iliacus</i> *	I; Gr	0.11	0.24	0.33	0.22	6	0	0.22
<i>Turdus merula</i>	I; Gr	0.44	0.10	0.50	0.44	8	2	0.33
<i>Turdus philomelos</i>	I; Gr	0.67	0.29	0.75	0.44	10	3	0.52
<i>Turdus pilaris</i>	I; Gr	0.00	0.10	0.25	0.11	3	0	0.10

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Gr: granivores, I: insectivores; O: omnivores; P: birds of prey; \* bird species of conservation concern.

773 **Table 2:** Multimodel analysis of the variation in bird abundance and species richness. Average parameter estimates ( $\pm$  standard error), associated  
774 95% confidence intervals and variable importance (I) are provided for the subset of models with  $\Delta AIC < 4$  as compared to the best model. ‘-’  
775 indicates that the variable was not retained in the subset of models. ‘/’ indicates that the variable was not included in the analysis. Parameter  
776 values for which the confidence intervals does not overlap 0 are in bold.

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	All orchards			With fruits			Without fruits		
	Estimate $\pm$ se	C95%	I	Estimate $\pm$ se	C95%	I	Estimate $\pm$ se	C95%	I
<b>Abundance</b>									
Year (2010)	<b>-0.299 <math>\pm</math> 0.1102</b>	<b>[-0.515; -0.083]</b>	1	-0.262 $\pm$ 0.141	[-0.539; 0.014]	0.53	<b>-0.341 <math>\pm</math> 0.159</b>	<b>[-0.651; -0.030]</b>	0.85
Transect	-0.010 $\pm$ 0.146	[-0.296; 0.277]	0.12	-	-	-	0.159 $\pm$ 0.197	[-0.229; 0.546]	0.17
Area	0.215 $\pm$ 0.114	[-0.008; 0.438]	0.45	-0.101 $\pm$ 0.182	[-0.458; 0.256]	0.04	[0.120 $\pm$ 0.160	[-0.193; 0.546]	0.12
Log(ivy +1)	<b>0.323 <math>\pm</math> 0.136</b>	<b>[0.057; 0.589]</b>	1	<b>0.300 <math>\pm</math> 0.147</b>	<b>[0.012; 0.588]</b>	0.46	<b>0.320 <math>\pm</math> 0.163</b>	<b>[0.001; 0.639]</b>	0.55
Log(fruits)	/	/	/	<b>0.758 <math>\pm</math> 0.160</b>	<b>[0.444; 1.072]</b>	1	/	/	/
Log(fruits) x Log(ivy+1)	/	/	/	-	-	-	/	/	/
Presence fruits	<b>0.357 <math>\pm</math> 0.116</b>	<b>[0.130; 0.583]</b>	1	/	/	/	/	/	/
Presence fruits x Log(ivy+1)	0.193 $\pm$ 0.131	[-0.063; 0.449]	0.46	/	/	/	/	/	/
<b>Richness</b>									
Year (2010)	<b>-0.034 <math>\pm</math> 0.015</b>	<b>[-0.063; -0.005]</b>	0.9	-0.019 $\pm$ 0.023	[-0.064; 0.027]	0.13	-0.033 $\pm$ 0.021	[-0.074; 0.009]	0.5
Transect	7.5 $10^{-5}$ $\pm$ 0.018	[-0.034; 0.035]	0.15	0.002 $\pm$ 0.023	[-0.042; 0.047]	0.09	-0.010 $\pm$ 0.028	[-0.066; 0.045]	0.19
Area	0.006 $\pm$ 0.015	[-0.024; 0.035]	0.17	-0.031 $\pm$ 0.024	[-0.078; 0.015]	0.26	-0.002 $\pm$ 0.022	[-0.045; 0.042]	0.18
Log(ivy +1)	<b>0.081 <math>\pm</math> 0.016</b>	<b>[0.049; 0.113]</b>	1	0.046 $\pm$ 0.027	[-0.007; 0.098]	0.56	<b>0.091 <math>\pm</math> 0.023</b>	<b>[0.045; 0.137]</b>	1
Log(fruits)	/	/	/	<b>0.071 <math>\pm</math> 0.024</b>	<b>[0.023; 0.118]</b>	1	/	/	/
Log(fruits) x Log(ivy+1)	/	/	/	-4.6 $10^{-4}$ $\pm$ 0.028	[-0.055; 0.054]	0.05	/	/	/
Presence fruits	0.019 $\pm$ 0.014	[-0.009; 0.048]	0.49	/	/	/	/	/	/
Presence fruits x Log(fruits)	0.007 $\pm$ 0.019	[-0.029; 0.044]	0.07	/	/	/	/	/	/

778

779 **Table 3**

780 Multimodel analysis of the variation in the presence of individual species as a function of study year, transect length, presence of fruits and  
 781 number of ivy bearing trees. Values provided are average parameter estimates ( $\pm$  standard error), associated 95% confidence intervals and  
 782 variable importance (I) in the subset of models with  $\Delta AIC < 4$  as compared to the best model. Values are highlighted in bold when 95%  
 783 confidence intervals do not overlap value 0.

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	<i>Year (2010)</i>		<i>Transect</i>		<i>Fruits</i>		<i>Log(ivy+1)</i>	
	Estimate $\pm$ se	C95%	Estimate $\pm$ se	C95%	Estimate $\pm$ se	C95%	Estimate $\pm$ se	C95%
<i>Carduelis carduelis</i>	-1.002 $\pm$ 0.710	[-2.426; 0.421]	-0.13 $\pm$ 0.878	[-1.888; 1.628]	1.264 $\pm$ 0.792	[-0.321; 2.851]	-0.392 $\pm$ 0.843	[-2.082; 1.297]
<i>Carduelis chloris</i>	1.595 $\pm$ 1.062	[-0.532; 3.722]	-0.086 $\pm$ 1.209	[-2.504; 2.332]	1.763 $\pm$ 0.964	[-0.168; 3.694]	1.685 $\pm$ 1.192	[-0.702; 4.073]
<i>Corvus corone</i>	-0.123 $\pm$ 0.653	[-1.432; 1.186]	<b>2.490 <math>\pm</math> 0.853</b>	<b>[0.784; 4.197]</b>	1.185 $\pm$ 0.640	[-0.098; 2.468]	-1.207 $\pm$ 0.788	[-2.787; 0.373]
<i>Erithacus rubecula</i>	<b>1.211 <math>\pm</math> 0.572</b>	<b>[0.064; 2.358]</b>	-0.526 $\pm$ 0.659	[-1.849; 0.795]	0.367 $\pm$ 0.575	[-0.786; 1.521]	<b>1.336 <math>\pm</math> 0.631</b>	<b>[0.071; 2.601]</b>
<i>Fringilla coelebs</i>	-1.628 $\pm$ 1.410	[-4.453; 1.195]	-1.062 $\pm$ 1.465	[-3.994; 1.870]	1.928 $\pm$ 1.770	[-1.617; 5.474]	0.976 $\pm$ 1.493	[-2.012; 3.965]
<i>Garrulus glandarius</i>	-0.837 $\pm$ 0.770	[-2.381; 0.705]	0.274 $\pm$ 0.865	[-1.459; 2.007]	1.416 $\pm$ 0.762	[-0.110; 2.944]	0.846 $\pm$ 0.853	[-0.864; 2.556]
<i>Parus caeruleus</i>	-3 $10^{-12}$ $\pm$ 0.729	[-1.460; 1.460]	1.024 $\pm$ 0.917	[-0.813; 2.863]	-0.329 $\pm$ 0.732	[-1.797; 1.138]	<b>2.587 <math>\pm</math> 1.017</b>	<b>[0.551; 4.623]</b>
<i>Parus major</i>	0.478 $\pm$ 0.564	[-0.651; 1.609]	-0.505 $\pm$ 0.651	[-1.809; 0.798]	0.418 $\pm$ 0.567	[-0.717; 1.554]	<b>1.593 <math>\pm</math> 0.638</b>	<b>[0.315; 2.871]</b>
<i>Pica pica</i>	-0.621 $\pm$ 0.567	[-1.756; 0.514]	-0.033 $\pm$ 0.559	[-1.154; 1.087]	-0.573 $\pm$ 0.583	[-1.741; 0.594]	0.123 $\pm$ 0.561	[-1.001; 1.248]
<i>Picus viridis</i>	-1.419 $\pm$ 1.028	[-3.480; 0.641]	1.602 $\pm$ 1.135	[-0.670; 3.875]	0.245 $\pm$ 0.944	[-1.646; 2.136]	1.797 $\pm$ 1.222	[-0.649; 4.244]
<i>Prunella modularis</i>	-1.166 $\pm$ 1.070	[-3.311; 0.978]	0.721 $\pm$ 1.048	[-1.377; 2.820]	-1.032 $\pm$ 1.146	[-3.328; 1.264]	-0.015 $\pm$ 1.043	[-2.105; 2.074]
<i>Sylvia atricapilla</i>	1 $10^{-12}$ $\pm$ 0.627	[-1.256; 1.256]	-0.352 $\pm$ 0.891	[-2.139; 1.434]	-0.430 $\pm$ 0.750	[-1.932; 1.072]	<b>2.493 <math>\pm</math> 0.881</b>	<b>[0.728; 4.259]</b>
<i>Turdus iliacus</i>	0.364 $\pm$ 0.877	[-1.395; 2.123]	<b>-3.594 <math>\pm</math> 1.580</b>	<b>[-6.762; -0.427]</b>	1.011 $\pm$ 0.879	[-0.752; 2.774]	<b>4.791 <math>\pm</math> 1.670</b>	<b>[1.443; 8.138]</b>
<i>Turdus merula</i>	<b>-1.780 <math>\pm</math> 0.775</b>	<b>[-3.335; -0.226]</b>	<b>-3.687 <math>\pm</math> 1.363</b>	<b>[-6.418; -0.956]</b>	1.512 $\pm$ 0.796	[-0.083; 3.108]	<b>4.226 <math>\pm</math> 1.366</b>	<b>[1.488; 6.963]</b>
<i>Turdus philomelos</i>	<b>-2.061 <math>\pm</math> 0.702</b>	<b>[-3.468; -0.655]</b>	1.264 $\pm$ 0.838	[-0.412; 2.942]	0.501 $\pm$ 0.675	[-0.853; 1.855]	<b>2.113 <math>\pm</math> 0.843</b>	<b>[0.426; 3.800]</b>

