1 Criteria for effective fallow field eco schemes for farmland

2 birds during non-breeding

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13

14 **Abstract**

15 1. Farmland eco schemes implemented under the current Common Agricultural Policy
16 (CAP) of the European Union are often considered ineffective in halting farmland bird
17 declines. Fallow fields, often seeded with dedicated seed mixtures, rate among the more
18 beneficial eco scheme types. Yet, the CAP currently defines no minimum criteria for
19 fallow fields to qualify as eco scheme, likely jeopardizing their potential biodiversity
20 benefits.

21 2. We investigated the attractiveness of four fallow field types established under CAP eco
22 schemes and dedicated bird conservation programs in Southern Germany. Our 2-year
23 surveys on > 100 fields focused on the non-breeding season, where food limitation can
24 become particularly problematic. We modelled bird incidences also in response to
25 vegetation structure and adjacent landscape features to derive minimum criteria for
26 effective fallow field eco schemes.

27 3. Fallow field types varied only mildly in overall species richness but showed striking
28 differences in the attracted species. Finches in particular tended to preferentially visit 1-
29 year fallow fields, while buntings tended towards 2-year and older field types. 1-year CAP
30 fallows, however, are typically removed before mid-winter, and thus potentially act as a
31 trap to farmland birds and other wildlife.

32 4. The investigated species consistently preferred larger fallow fields with a more
33 differentiated vegetation structure. Placement close to woods and hedgerows positively
34 affected birds inhabiting woodland ecotones, while classic farmland species showed
35 higher incidences on fallow fields embedded in open landscapes.

36 5. '*Policy implications*' Our findings call for the ongoing CAP revisions to specify minimum
37 requirements that qualify fallow fields as eco schemes. These should include an at least
38 biennial cycle, a diversification of seed mixtures, standards for fallow field size, and
39 criteria for their placement in the landscape matrix.

40 Keywords: wild bird mixtures, wildflower plots, set aside, Common Agricultural Policy,
41 farmland eco schemes, winter food gap, farmland birds

43 1 Introduction

44 The diversity and abundance of farmland birds across most of Central and Western
 45 Europe has severely declined. The European common farmland bird indicator decreased
 46 by 57 percent between 1980 and 2016 (EBCC & Birdlife International 2020). This decline
 47 has been linked to the ongoing intensification of farming practices under the Common
 48 Agricultural Policy (CAP) of the European Union, whose subsidies primarily scale with farm
 49 size and productivity (Donald et al. 2002, Pe'er et al. 2014). While CAP payments also
 50 require farmers to implement dedicated eco schemes, their effectiveness to halt or even
 51 reverse farmland biodiversity declines has been questioned (Pe'er et al. 2014, 2017).

52 Current CAP eco schemes rest on three components. First, 'Greening' measures in CAP
 53 pillar I make 30 % of the direct cross compliance payments to farmers dependent on the
 54 assignment of Ecological Focus Areas (EFA) on $\geq 5\%$ of their arable land. Second, agri-
 55 environment-climate schemes (AECS) offer complementary CAP pillar II funding to
 56 member states for farmland-related rural development programs to which farmers can
 57 voluntarily subscribe. Third, targeted species protection measures through contractual
 58 conservation agreements have been developed by most European countries, again co-
 59 funded through CAP pillar II. The third component typically includes highly efficient
 60 conservation measures but is implemented on small land fractions, only. In Germany, for
 61 example, these measures covered approx. 4,000 km² or 2.4 % of the agricultural area in
 62 2013 (Grajewski & Schmidt 2015). In contrast, the first two components receive
 63 substantial funding (approx. 27 % of the annual EU agricultural budget, Pe'er et al. 2020)
 64 and affect > 10 % of the agricultural area in Germany (Zinngrebe et al. 2017), thus offering
 65 a potential to support biodiversity at relevant spatial scales. Recent work, however,
 66 suggests that 75 % of the eco scheme area implemented under current Greening and
 67 AECS regulations employs options such as catch crops, green cover, or nitrogen fixing
 68 crops that are considered ineffective for biodiversity support (Nitsch et al. 2017,
 69 Zinngrebe et al. 2017, Pe'er et al. 2017).

70 One eco scheme considered generally effective for farmland bird conservation is the
 71 designation of fallow fields (here broadly including uncultivated set-aside cropland as well
 72 as fields seeded with dedicated 'wild bird' or wildflower seed mixtures). Yet, since

73 farmland bird species differ in food preferences and the habitat structures they prefer for
 74 shelter, plant species composition and the resultant food supply on different fallow field
 75 categories can be expected to differently attract or deter particular bird species (e.g.
 76 Perkins et al. 2008). Hence, the conservation value of fallow field eco schemes likely
 77 varies with the chosen seed mixtures, age since establishment, vegetation structure, and
 78 the composition of the adjacent landscape matrix. This perception contrasts to current
 79 CAP eco scheme regulations, which offer only a narrow set of prescribed seed mixtures
 80 with (mostly short-term) fallow durations and lack minimum quality requirements with
 81 respect to size or placement. To enable a target-oriented revision of CAP eco schemes,
 82 our study quantified how fallow field type as well as structure and placement
 83 characteristics affect farmland bird incidences.

84 Our surveys focussed on the non-breeding season, when energy demands to maintain
 85 body temperature and metabolism are particularly high. Food limitation in late autumn
 86 and winter can thus substantially affect farmland bird condition and survival (Newton
 87 2004, Siriwardena et al. 2008, Siriwardena 2010). The severity of this ‘winter food gap’
 88 further increased with recent agricultural intensification. For example, enhanced
 89 harvesting efficiency and the replacement of seed rich winter stubble fields by winter
 90 crops and green manure reduce the availability of leftover cereal grains (Atkinson et al.
 91 2002, Moorcroft et al. 2002, Newton 2017). Moreover, the widespread application of
 92 herbicides combined with the abolishment of set-aside requirements in the CAP 2008
 93 reform reduced the availability of fields rich in weed seeds, and thus a prime foraging
 94 resource for granivorous birds (Marshall et al. 2003, Gillings et al. 2010).

95 In winter, fallow fields are well known to meet foraging and shelter requirements of many
 96 farmland birds (Gillings et al. 2010, Kasprzykowski & Goławski 2012, Joest et al. 2016,
 97 Dellwisch et al. 2019). Yet, only few studies to date differentiated bird habitat use within
 98 the ‘fallow’ category, i.e. among different types and ages of fallow fields (e.g. Buckingham
 99 et al. 1999, Orłowski 2006, Perkins et al. 2008, Birrer et al. 2018). Their findings varied
 100 substantially, likely because of differences in the investigated fallow field types, seed
 101 mixtures and surveyed regions, calling for further studies to better substantiate decisions
 102 about management strategies. Likewise, only few earlier studies investigated effects of

103 fallow field vegetation structure and placement on bird abundance (e.g., Henderson et al.
104 2004, Stoate et al. 2004).

105 We investigated habitat use across fallow field types of different age and origin in an
106 agricultural landscape of SW Germany. Our findings can inform the ongoing reform of
107 CAP eco schemes for the upcoming funding period, and help conservation practitioners to
108 select particularly suitable fallow land schemes to support their respective core target
109 species.

110

111 **2 Methods**

112 We studied habitat use by 17 bird species known to use fallows for foraging or shelter
113 (Tab. 2). These fall into two guilds containing typical inhabitants of woodland ecotones
114 and of semi-open to open farmlands, respectively (Tab. 2). All species except chaffinch,
115 great tit, and blue tit experienced significant population declines in Europe (EBCC &
116 Birdlife International 2020) and / or Germany (Gerlach et al. 2019) over the past three
117 decades, and nine species are integrated into the European farmland bird index (Tab. 2).

118

119 **2.1 Study area**

120 We surveyed nine study areas (A to H in Fig. 1) at 330–400 m a.s.l. in an agricultural
121 landscape in the centre of the SW German federal state of Baden-Württemberg. The
122 study region includes floodplain soils in the valleys of the Neckar and Ammer rivers, and
123 highly fertile loess soils on the adjacent plateaus. Most study areas are under intense
124 agriculture, but study areas D, E and I (in Fig. 1) share exceptionally high baseline
125 proportions of organic farming. All areas have seen an increasing establishment of annual
126 fallows under EU CAP regulations, and perennial fallows in the context of governmental
127 grey partridge and corn bunting conservation projects since 2014.

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131 **Figure 1.** Localisation of the nine study areas and all fallow fields investigated in at least one season (sample
132 sizes in Table 1). A – Ammerbuch, B – Oberndorf, C – Ammer Valley, D – Heuberg North, E – Heuberg South,
133 F – Weiler, G – Hirrlingen North, H – Hirrlingen South, I – Neckar Valley. Map source: OpenStreetMap.

134 2.2 Fallow field types and their characteristics

135 We distinguished four fallow field types based on seed mixture (details in Online
136 Supplement A) and fallow age, with sample sizes given in Table 1.

137 (i) **'1yr-FAKT'** subsumes spring-sown annual fallows that qualify as ecological focus areas
138 (EFA) under EU greening regulations, or as a regional eco scheme under the federal
139 government's AECS-program 'FAKT' (BMEL 2015, MLR 2017). Seed mixtures have high
140 shares of annual plants such as sunflower *Helianthus annuus*, blue tansy *Phacelia*
141 *tanacetifolia*, and ramtil *Guizotia abyssinica* (Fig. 2a). 1yr-FAKT fallows are often removed
142 in September or November (LTZ 2020) to prepare the field for the subsequent winter
143 culture.

144 (ii + iii) **'GM'** subsumes fallow fields sown with the so-called Göttingen mixture (GM), a
145 perennial seed mix optimized for grey partridge conservation (Gottschalk & Beeke 2014).
146 It has a rather balanced mix of annual and perennial plants, usually resulting in
147 structurally rich fields. Yet, dominance may occur by mallow *Malva sylvestris* and
148 sunflower in year 1, or yellow sweet clover *Melilotus officinalis* in year 2. GM fallows are
149 implemented via contractual species conservation agreements under the regional
150 Landscape Conservation Directive (Landschaftspflegeberichtlinie, Az.: 73-8872.00). In a
151 biennial alternated rotation, half the field is ploughed in winter and newly sown in spring,
152 the other half left untouched until the subsequent winter. Hence, at any time, half the
153 field is in its first year since sowing (**1yr-GM**, Fig. 2b), the other half in its second year
154 (**2yr-GM**, Fig. 2c).

155 (iv) **'3+yr'** subsumes perennial fallows established under a diverse range of conservation
156 activities (Fig. 2d) that were sown at least three years prior to our surveys. Seed mixtures
157 cannot be reconstructed for all those sites, but about half were initially sown with
158 'Lebensraum-I-Tübingen' (Online Supplement A). 3+yr fallows vary in structure and plant
159 composition, but often show high coverage of grasses, teasel *Dipsacus fullonum*, wild
160 carrot *Daucus carota*, tansy *Tanacetum vulgare* and upcoming shrubs.

Figure 2. Examples of the four surveyed fallow field types: (a) 1yr-FAKT (25 Sep 2019), (b) 1yr-GM (27 Aug 2019), (c) 2yr-GM (30 Aug 2019), (d) 3+yr (11 Sep 2019). Photo © Sarah Mailänder.

Table 1. Survey periods, the number of replicate surveys, and the number of fields surveyed per fallow field type and investigated season.

	Autumn 2018	Winter 2018/19	Autumn 2019	Winter 2019/20
	21 Aug–25 Sep	03 Jan–16 Feb	26 Sep–12 Nov	02 Dec–30 Jan
Field type	7 surveys	8 surveys	6 surveys	6 surveys
1yr-FAKT	12	10	37	27
1yr-GM	54	42	65	65
2yr-GM	26	6	47	43
3+yr	17	17	19	19
Σ	109	75	168	154

To understand how bird incidence varies with characteristics beyond fallow field type, we recorded the following covariates for each surveyed fallow field:

- i. *Fallow field size* (in ha, range 0.06-0.70 ha, with extremes reaching 2.80 ha).
- ii. *Vegetation height* (in 10 cm steps, measuring the dominant vegetation layer).
- iii. *Secondary plant layer* (presence/absence), as generated by exposed bud stands of perennials such as sunflower, fennel *Foeniculum vulgare* or wild teasel, indicating structural diversity.
- iv. *Dominant plant species* (presence/absence, with at least 1 species reaching a minimum coverage of 30%).

- 177 v. *Bare ground* coverage (3 categories: 0-10%, 10-30%, and >30% of accessible soil
- 178 representing potential foraging habitat).
- 179 vi. *Farm track* (presence/absence) along the longer edge of the fallow field,
- 180 potentially disturbing roosting birds.

181 Finally, we predicted bird presence to vary with landscape features directly adjacent to a
 182 fallow field. We quantified coverage of alternative roosting and foraging structures within
 183 a 100 m buffer around each surveyed fallow field from aerial images (Bing maps) using
 184 QGIS version 3.2. From this we derived proportional area coverages for other fallow fields
 185 (*Fallow coverage*) and for hedges, tree clusters and orchards (*Hedge and grove coverage*).

186

187 **2.3 Bird surveys**

188 Surveys covered autumn and mid-winter periods, each replicated twice in the seasons
 189 2018/19 and 2019/20 (Table 1). We recorded the presence and individual numbers of
 190 each target species per survey round and fallow field (overpasses ignored). To exclude
 191 confounding sequence effects, we randomized starting time, walking direction and the
 192 order in which fallow fields were visited across consecutive surveys in a given study area.
 193 We spread surveys roughly uniformly across daytimes between 30 min after sunrise and
 194 30 min before sunset and excluded periods with continuous rainfall or winds exceeding
 195 40 km/h. We slowly passed along the long edge of each fallow field, entering it
 196 occasionally to also detect birds hiding in the vegetation. To avoid double-counts we
 197 visually traced flushed birds to their new location, recording only the fallow field of first
 198 encounter. Fields that were mulched or ploughed within a given survey period were
 199 excluded when only a single survey had been possible.

200

201 **2.4 Statistical analysis**

202 Statistical analyses for species-specific habitat use per season included all species with >
 203 10 sightings that spread across at least 15 percent of the visited fallow fields (Table 2).

Table 2. Number of sites with sightings (# fields) and total number of sightings (# obs.) per species per season. Species in bold face were used for a species-level statistical analysis.

Species	Autumn		Winter		Autumn		Winter	
	2018	2018/19	2018/19	2019	2019	2019/20	2019/20	2019/20
	# fields	# obs.	# fields	# obs.	# fields	# obs.	# fields	# obs.
(a) Forest ecotone guild								
Blue tit <i>Cyanistes caeruleus</i>	-	-	4	4	64	97	29	33
Great tit <i>Parus major</i>	-	-	4	4	66	111	23	32
Brambling ^b <i>Fringilla montifringilla</i>	-	-	-	-	27	37	4	5
Chaffinch <i>Fringilla coelebs</i>	-	-	22	43	81	153	25	35
Tree sparrow ^a <i>Passer montanus</i>	48	107	10	22	67	123	15	23
(b) Semi-open to open farmland guild								
Whitethroat <i>Sylvia communis</i>	22	29	-	-	-	-	-	-
Yellowhammer ^a <i>Emberiza citrinella</i>	76	184	21	39	81	113	49	66
Reed bunting <i>Emberiza schoeniclus</i>	29	44	14	36	36	54	25	33
Greenfinch <i>Chloris chloris</i>	48	107	8	12	60	78	14	19
Linnet ^a <i>Linaria cannabina</i>	18	28	10	29	37	42	6	7
Goldfinch <i>Carduelis carduelis</i>	62	148	25	57	78	134	29	34
Whinchat ^a <i>Saxicola rubetra</i>	30	40	-	-	6	6	-	-
Stonechat ^{a,b} <i>Saxicola rubicola</i>	22	32	1	2	15	18	2	2
Skylark ^{a,b} <i>Alauda arvensis</i>	33	69	8	11	10	10	2	4
Corn bunting ^a <i>Emberiza calandra</i>	8	13	1	1	5	7	-	-
Grey partridge ^a <i>Perdix perdix</i>	-	-	8	10	-	-	-	-
Meadow pipit ^a <i>Anthus pratensis</i>	-	-	11	12	7	8	5	5

^a species is part of the European farmland bird index (EBCC & International 2020).

^b species-level statistical analysis only for autumn.

Separately for each bird species, but combined across years for autumn and winter season (Table 1), we modelled bird occurrences using generalized linear mixed models (GLMM). Bayesian estimation procedures used the Stan C++ library as implemented in the rstanarm package version 2.19.2 (Goodrich et al. 2020) for R version 3.6.2 (R Core Team 2017). The response variable in species-level models was derived from the number of surveys with and without recordings (= successes and failures) using the binomial family and a logit-link, resulting in 'bird incidence' as the probability to encounter a species on a

217 given fallow field. We separately calculated models with the number of sighted species
218 ('species number') as our response variable, now using the Poisson family and a log-link.

219 In all models, *fallow field type* served as our key predictor variable, with four levels as
220 defined above. The models further contained fixed covariates to account for variation
221 associated with fallow field characteristics beyond field type, as specified in section 2.2.
222 Continuous covariates included *fallow field size*, *fallow coverage*, *hedge and grove*
223 *coverage*, and *vegetation height*. The first three of these were $\log_{10}(x + 0.01)$ -transformed
224 to approach normality, and all four z-transformed prior to analysis. Categorical covariates
225 included *farm track* presence, *secondary plant layer* presence, and *survey year* (2018/19,
226 2019/20). The analysis of winter species numbers further contained *survey completeness*
227 (0/1) as a covariate, where '0' identifies 1yr-FAKT and 2yr-GM fallow fields that were
228 ploughed already before the end of our successive surveys. We excluded the covariates
229 *bare ground* and *dominant plant species* because of strong covariation with fallow field
230 type.

231 While the combined surveys on a given fallow field per season and year represent our raw
232 data points, these suffer from some degree of spatial non-independence, where fields
233 from the same study area are more likely to be visited by the same local bird population.
234 We therefore added *study area ID* (Fig. 1) as a random intercept to each model. Study
235 areas without any record of a given species during a particular season were excluded
236 from the analysis. We further included an observation-level random intercept,
237 successfully treating overdispersion (Harrison 2014).

238 We initiated Bayesian models with weakly informative prior distributions (means $\pm$ SD for
239 intercepts 0 ± 10 and for coefficients 0 ± 2.5 , respectively) and used posterior predictive
240 model checking to assess model fit and an adequate representation of observed zero
241 counts. For each model, we ran 10 MCMC chains from which we retained 3000 post-
242 warm-up samples. We then derived covariate coefficient estimates (means $\pm$ 95% credible
243 intervals, CrI) from the combined 30,000 posterior samples. From these, we also derived
244 posterior probabilities (so-called Bayes *P*) that coefficient estimates – as well as pairwise
245 differences between our four fallow field type levels – exceed 0. The explanatory power
246 of a given model covariate increases when its posterior probability approaches 0 or 1.
247 Most covariate estimates achieved reliable conversion indicators (Korner-Nievergelt et al.

248 2015), namely 5000 effective posterior samples (observed min 4344), Rhat values ≤ 1.02
 249 (max 1.002) (Brooks & Gelman 1998), and Monte Carlo standard errors (MCSE) $\leq 2\%$ of
 250 the standard deviation (max 1.5%). For graphical displays, we extracted model
 251 predictions and their CrI of the predictor of interest for defined values of the remaining
 252 model predictors, i.e. continuous covariates set to their sample mean, and factors set to a
 253 single level when predicting for covariates (Korner-Nievergelt et al. 2015).

254 3 Results

255 Out of 17 target species, 16 and 15 were recorded at least once during the autumn and
256 winter season, respectively (Table 2), with clearly higher average species numbers per
257 fallow field in autumn (Fig 3).

258

259 3.1 Fallow field types

260 Average species numbers varied only little between fallow field types. In autumn, even
261 the strongest contrasts yielded differences in mean species numbers of only 0.7 to 1.3
262 between 1yr-FAKT and 1yr-GM fields versus 2yr-GM and 3+yr fields, with substantial
263 overlap in credible intervals (Fig 3a, full statistical detail in Online Supplements B and C).
264 Mean species numbers were clearly lower in winter, and very similar in all four fallow
265 field types (Fig 3b, Online Supplements B and C).

266 **Figure 3.** Observed variation in species number in (a) autumn and (b) winter between fallow field types.
267 Grey dots show raw data and scale with the number of fallow fields. Black dots and flags show model-
268 predicted means and their 95% CrI for the following co-variate levels: survey completeness = yes, year =
269 2019/20, farm track = no, secondary plant layer = yes. For detailed statistical results, see Online
270 Supplements B and C.
271

272

Individual species exhibited more differentiated patterns in their use of fallow field types. We found a particularly consistent contrast in the usage of 1-year fallow fields (1yr-FAKT and 1yr-GM) compared to later successional stages (2yr-GM and 3+yr), but no further differentiation within each of these two groups. All five surveyed finch species, great tit and tree sparrow – at least in autumn and then coupled with an undifferentiated pattern in winter – showed higher incidences in 1-year compared to older fallow fields, as exemplified in Fig 4a-c (full statistical detail and graphical displays for all study species in Online Supplements B, C, D). The reverse pattern consistently occurred in yellowhammer, reed bunting or whinchat, all showing higher incidences in older fallow fields compared to their first year counterparts (Fig 4d-f, full statistical detail in Online Supplements B, C, D).

Figure 4. Variation in bird incidences between fallow field types. Examples illustrate strong (goldfinch, a chaffinch, b) and weak (linnet, c) preferences for 1-st year fallows, and strong (yellowhammer, d, reed bunting, e), and weak (whinchat, f) preferences for later successional stages. Grey dots show raw data and

scale with the number of fallow fields. Black dots and flags show model-predicted means and their 95% CrI for the following co-variate levels: year = 2019/20, farm track = no, secondary plant layer = yes. Detailed results and displays for all study species in Online Supplements B, C, and D.

3.2 Fallow field characteristics

Several fallow field characteristics exhibited rather universal co-variation with the total number of recorded species per site as well as species-specific bird incidence. Fallow field size showed a consistent positive, and often strong, relationship with both response measures (Fig 5a). We found similar but slightly more variable positive relationships for fallow fields with taller vegetation (Fig 5b) and – in particular during winter – for the presence of a secondary plant layer (Fig 5e), indicating benefits to a structurally diverse fallow field vegetation.

Contrary to these consistent patterns, species varied strikingly in their predicted response to the availability of hedges and groves nearby fallow fields (Fig 5c). While inhabitants of woodland ecotones such as great tit, chaffinch or blue tit tended towards positive responses, farmland birds such as goldfinch, linnet, skylark or stonechat showed higher incidences on fallow fields with little or no hedges and groves nearby, indicating avoidance reactions. Given these differential species responses, overall species richness varied largely independent of this covariate (Fig. 5c).

In the majority of cases, the availability of other fallow fields in the near surroundings unfolded no striking correlations with species presence (Fig 5d). Similarly, the presence or absence of a farm track along the long side of a fallow field yielded no consistent patterns with respect to bird presence or species richness (Fig 5f).

310
311

312 **Figure 5.** Covariates estimates with their 95% Crl for each species, separated by autumn (black circles) and
313 winter (grey triangles) surveys, and grouped by woodland ecotone versus farmland inhabitants. Full
314 coefficient estimates are given in Online Supplement B.

315

316 **4 Discussion**

317 Our study illustrates how fallow field eco schemes differentially support Central European
318 farmland birds. This differentiation did not manifest at the level of overall species
319 richness, which distributed rather uniformly across fallow field types. Instead, we
320 document substantial variation in the degree to which individual species made use of the
321 four investigated fallow field types. The attractiveness of fallow fields further varied
322 strongly with several field characteristics, in particular their size, vegetation structure, and
323 integration into the landscape matrix.

324

325 **4.1 Fallow field types**

326 A major shift in the supported bird community occurred between 1-year and 2-year and
327 older fallow field types. 1-year fallow fields primarily attracted granivorous birds foraging
328 on large seeds picked from the exposed buds of e.g. sunflowers or bare ground
329 (Henderson et al. 2004), with finches as prime representatives of this guild. 2-year and
330 older fallow fields rather attracted granivores foraging well hidden in the dense and
331 highly structured vegetation on smaller seeds, with buntings as prime representatives.

332 We interpret this pattern to arise from three interacting factors. First, the seed mixtures
333 used in the majority of our investigated fallow fields (Online Supplement A) contain large
334 fractions of – mostly cultivated – annuals that provide many large seeds from, for
335 example, sunflower, borage *Borago officinalis* or linseed *Linum usitatissimum*. In their
336 second year, these fields tend to develop clearly lower flowering densities, resulting in
337 lower seedset, with the latter more dominated by perennials such as yellow clover,
338 yellow chamomile *Anthemis tinctoria* or tansy with rather small seeds. Second, our 1-year
339 fallow fields tended to produce tall stands with little differentiation in vegetation heights
340 and hardly any ground cover by segetal flora or grasses, thus offering only limited shelter
341 for species that preferentially forage in the ground vegetation. This differentiation
342 increases from 2-year onwards, providing suitable habitat structure for a wider range of
343 bird species. Finally, immigrating weeds such as goosefoot *Chenopodium album*, mugwort
344 *Artemisia vulgaris*, red-root amaranth *Amaranthus retroflexus* or thistle *Cirsium arvense*

345 increase vegetation differentiation in 2-year and older fallows, and enhance the
346 availability of small seeds.

347 Earlier studies also found diverging winter bird communities between younger and older
348 fallow fields, but differences in the investigated plant compositions and age-classes make
349 comparisons difficult. In Poland, for example, *Cirsium*-rich young fallows (< 3 years) were
350 preferred by granivores and *Tanacetum*-rich permanent fallows (> 3 years) by insectivores
351 (Orłowski 2006). In Great Britain, skylark, finches and yellowhammer showed more
352 consistent preferences for 1-year than to $\geq$ 2-year fallows when compared to other
353 cropland types (Buckingham et al. 1999). In Switzerland, meadow pipit and goldfinch
354 preferred $\leq$ 2-year wildflower strips rich in wild teasel and wild carrot, whereas
355 yellowhammer preferred perennial (14-year on average) fallow fields rich in *Rubus* shrubs
356 (Birrer et al. 2018).

357 While our data may seem to suggest that 1-year fallows generally represent attractive
358 foraging habitats and thus high quality eco schemes for farmland birds, only 1yr-GM-
359 types – in stark contrast to 1yr-FAKT-types – can reliably unfold their ecological service.
360 This contrast is rooted in current CAP regulations, which allow 1yr-FAKT type eco schemes
361 to be mown and ploughed already between September and November of the year of
362 sowing (e.g. LTZ 2020). As a consequence, these fallow fields are not available as foraging
363 habitat or shelter during mid and late winter when food restriction culminates
364 (Siriwardena et al. 2008). Such eco schemes may therefore act as a trap for overwintering
365 birds, in particular in arable landscapes that lack local escape options at the time of
366 ploughing. In contrast, GM-type eco schemes are maintained into at least their second
367 year before ploughing, and are then adjacent to a 1-year field section that can act as a
368 local refuge into spring (Gottschalk & Beeke 2014). This failure of 1yr-FAKT type eco
369 schemes unfolds large scale consequences: Compared to more targeted (and then
370 typically more effective) contractual conservation programs, this scheme alone covers a
371 substantially larger land fraction, in Germany alone approx. 2330 km² or 1.4 % of the
372 agricultural area in 2019 (DBV 2019).

373

374 4.2 Fallow field characteristics

375 Beyond fallow field type, we found higher overall species richness and incidences of
 376 individual bird species on large fields with a tall and structurally diverse vegetation. This
 377 implies that eco schemes should prioritize large fallow patches, and seed those with
 378 mixtures that develop into structurally diverse and seed rich fallows (see section 4.3). We
 379 propose to derive minimum size standards from earlier suggestions that the width of
 380 fallow fields should exceed 12-20 m to minimize predation risks on breeding farmland
 381 birds such as Grey Partridge (Bro et al. 2004, Gottschalk & Beeke 2014). For a field of 150
 382 m length, this results in minimum fallow field sizes of 0.15-0.3 ha.

383 The placement of fallow fields within the landscape matrix exhibited species-specific links
 384 with bird incidence. Inhabitants of woodland ecotones (Table 2) preferentially visited
 385 fallow fields adjacent to (tall) hedges, orchards or groves. This is consistent with earlier
 386 findings that many granivores preferentially forage on arable fields along hedgerows,
 387 where seed availability is enhanced and shelter nearby (e.g. Robinson & Sutherland 1999,
 388 Stoate et al. 2004, Dellwisch et al. 2019). In contrast, classic farmland birds tended to
 389 show higher incidences on fallow fields embedded in a rather open landscape matrix.
 390 Avoidance reactions towards woodland-type habitats are well-known for skylark, but
 391 have occasionally been documented also for other farmland birds such as goldfinch,
 392 linnet and buntings (Parish et al. 1995, Robinson & Sutherland 1999, Donald et al. 2001).
 393 We cannot differentiate whether our observed patterns arise from avoidance reactions or
 394 a lower likelihood to observe birds in a given fallow field when they may also just roost in
 395 a nearby grove. The latter appears plausible for yellowhammer, greenfinch, and goldfinch,
 396 which show lower incidences on fallow fields close to groves in the current study, but
 397 have been found to frequently roost in tall hedges in an earlier survey in the same study
 398 area (Dellwisch et al. 2019). In summary, fallow fields seem to represent attractive winter
 399 foraging habitat irrespective of their placement relative to hedges and groves, but with
 400 differences in the supported bird communities. Hence, to serve both requirements,
 401 effective eco schemes should assure that fallow fields are not placed solely at marginal
 402 yield locations close to forests or tall hedgerows, but also integrated into the widely open
 403 agricultural landscape.

404

405 **4.3 Seed availability, winter food gap and seed mixtures**

406 We did not quantify seasonal variation in seed availability in flower heads or soil samples
 407 on our study sites. Yet, haphazard surveys of seed loads in sunflowers or teasel imply
 408 substantial depletion towards mid-winter, consistent with previous research (e.g.
 409 Boatman et al. 2003, Henderson et al. 2004, Perkins et al. 2008, Geiger et al. 2014).
 410 Fallow field eco schemes may therefore fail on winter food provision as one of their key
 411 goals, with established negative effects on buntings, sparrows, or skylark (Peach et al.
 412 1999, Siriwardena et al. 2008). Mitigation can pursue three approaches. First, fallow field
 413 eco schemes should explicitly integrate seed mixtures sown in late summer instead of
 414 spring, then enhancing chances that annuals set seed late and maintain seed provisioning
 415 until late winter.

416 Second, seed mixtures should increase the share of plants that retain seed into late
 417 winter. Promising candidate species include kale *Brassica oleracea*, quinoa *Chenopodium*
 418 *quinoa*, linseed, triticale *Triticum secale* or millet, while sunflower, borage, oat *Avena sativa*
 419 or barley *Hordeum vulgare* deplete seeds already in autumn (Boatman et al. 2003,
 420 Henderson et al. 2004, Perkins et al. 2008). This coincides with studies identifying kale,
 421 quinoa, linseed and several cereals as particularly relevant food sources for granivorous
 422 buntings and finches (Stoate et al. 2003, Henderson et al. 2004, Stoate et al. 2004, Perkins
 423 et al. 2008). We propose that these species should partially replace the substantial seed
 424 mixture shares of plants with minimal role for foraging farmland birds, such as phacelia,
 425 buckwheat or yellow sweet clover (Marshall et al. 2003, Henderson et al. 2004, Perkins et
 426 al. 2007), consistent with their representation in wild bird mixtures for the British
 427 environmental stewardship program (Boatman et al. 2003).

428 Third, we propose to enhance regional AECS-based funding for unharvested cereal crops
 429 (so-called 'seeding cereals' in Henderson et al. 2004), which represent a prime winter
 430 food for many granivorous birds. Such cereal-biased options are central to the British
 431 environmental stewardship program (e.g. Natural England 2013) and available also in
 432 some German Federal States (e.g. Joest et al. 2016), but insufficiently attractive to
 433 farmers under the current subsidy system in Baden-Württemberg. Buntings and sparrows
 434 in particular profit from the high abundance of cereals, for example on unharvested crop
 435 mixtures (Holland et al. 2006, Joest et al. 2016, Perkins et al. 2008).

436

437 **4.4 Conclusions**

438 This study supports the hypothesis that farmland birds substantially vary in habitat use
 439 among available fallow field types, both between species but also between seasons
 440 within single species. We suggest that the ongoing CAP reform formulates explicit
 441 minimum standards to qualify fallow fields as effective eco scheme options. A large-scale
 442 application of just a few types of fallow field seed mixtures and age as supported under
 443 current CAP regulations clearly fails to support the full diversity and demands of farmland
 444 birds in winter (Hinsley et al. 2010, Redhead et al. 2018). CAP eco schemes should
 445 therefore integrate diversification of seed mixtures (in particular to include plants
 446 retaining seed into late winter) and successional stages (e.g., 2-year-rotational and
 447 perennial) within a local context. While 1-year fallow fields provide attractive foraging
 448 habitat, CAP eco schemes need to integrate a biennial cycle as a minimal requirement,
 449 with no ploughing before April of year 2 (Siriwardena 2010). Finally, CAP eco schemes
 450 need to define minimum standards for fallow field size and criteria for their placement in
 451 the landscape matrix.

452

453 **Authors' contributions statement**

454 NA and JS conceived the study, and jointly with LS, MR and SM designed its methodology;
 455 MR, SM and LS collected the data; MR, SM and NA analysed the data; MR, SM and NA led
 456 manuscript drafting. All authors contributed critically to the drafts and gave final approval
 457 for publication.

458

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467

468 **Online supplements**

469 **Online Supplement A.** Seed mixtures.

470 **Online Supplement B.** Bayesian model coefficients.

471 **Online Supplement C.** Pairwise comparisons between fallow field types.

472 **Online Supplement D.** Covariate raw data plots for all investigated species.

473 **Data available via the Dryad Digital Repository:**

474 DOI <https://doi.org/10.5061/dryad.1rn8pk0rt>

475

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