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RESEARCH ARTICLE

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Typha-based paludiculture offers potential for greater bird species abundance and diversity than drained agricultural grassland

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Abstract

1. Agriculture on drained lowland peat, though very productive, contributes significantly to greenhouse gas (GHG) emissions. One potential solution is to implement paludiculture: an agricultural system of cropping with raised water tables. Despite the potential for reducing GHG emissions, little is known about the impact of paludiculture on biodiversity.
2. We carried out breeding bird surveys using point counts to investigate bird habitat associations in cattail (*Typha* spp.) paludiculture at 10 trial sites in the Netherlands. We also performed point counts at nine nearby natural wetland sites and nine agricultural grassland sites for comparison. We modelled the results using generalised linear mixed model and analysis of similarities to understand differences in bird abundance and community composition between these land uses.
3. Paludiculture hosted a range of generalist and wetland specialist bird species, including several that are considered of European or global conservation concern. Predicted bird abundance in paludiculture was comparable to natural wetland (30.8 birds per ha; standard error: ±7.85; and 31.5 ± 10.5, respectively) and significantly higher than on grasslands (10.5 ± 3.23, $p < 0.01$).
4. Community composition in paludiculture was between that of wetlands and grasslands. While some wetland specialists were recorded in paludiculture, they were at lower abundance than in wetlands, and not all wetland specialists were present in paludiculture. The only species present in both paludiculture and grassland were those which forage in both habitats and are considered generalists.
5. *Practical implication*. Our study shows that paludiculture can support overall bird abundance on par with wetlands, and function as a habitat bridging agricultural and wetland species assemblages by providing resources for both generalist

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and wetland-associated species. These results suggest that paludiculture can be a multifunctional land use, enhancing biodiversity in addition to other known benefits.

KEYWORDS
biodiversity, breeding birds, ecological monitoring, ecosystem service, land use, sustainable agriculture

1 | INTRODUCTION

Peatlands play a disproportionate role in the carbon cycle, covering only 3% of Earth's terrestrial surface yet storing 30% of its carbon (Joosten, 2015; Yu et al., 2010). However, through degradation from drainage for agriculture, forestry and peat extraction, drained peatlands currently emit an estimated 5% of anthropogenic greenhouse gas (GHG) emissions (Nichols & Peteet, 2019; Strack et al., 2022). By 2050, this figure is predicted to rise to 8%, and 25% of Earth's peatlands will likely be in a degraded state (Urák et al., 2017). The continued practice of draining and use of drained peatlands poses significant threats; therefore, halting and reversing this degradation through protecting and restoring peatlands is key to reducing GHG emissions and mitigating the climate crisis (Barbier & Burgess, 2021; Glenk et al., 2021; Zou et al., 2022). Immediate action is essential, and in 2024, the EU wrote into law that member states must restore at least 30% of drained peatlands by 2030 and 50% by 2050 (European Parliament, 2024). However, while restoring drained peatlands back to a more natural state can be a fast way to reduce agricultural emissions (Niemi et al., 2024; Zou et al., 2022), this blanket approach may not be the most effective strategy, not least in the context of the high productivity and significant agricultural output from lowland peatlands (see NFU, 2019). An integrated land use approach, combining restoration with paludiculture, may offer a viable alternative whereby both climate goals and the often-overlooked socio-economic resilience can be achieved, aligning with the principles of sustainable peatland management.

Paludiculture, an agricultural system of cropping with raised water tables, can facilitate the continued productive use of land while reducing GHG emissions in the long term (Geurts et al., 2019; Geurts & Fritz, 2018; Lahtinen et al., 2022). First described by Joosten (1998), the concept has evolved over the past two decades (see Wichtmann et al., 2016) with a range of crops being cultivated for food, fodder, fibre and fuel. Research trials of different crops and management styles across northern Europe, particularly in Germany (Ross, 2025; Wichtmann et al., 2016), the Netherlands (Geurts & Fritz, 2018) and the United Kingdom (Mulholland et al., 2020), indicate that paludiculture can improve water quality (Vroom et al., 2018), reduce GHG emissions (Vroom et al., 2018) and maintain economic productivity (Wichtmann et al., 2016). Among these, *Typha* spp. (bulrush/cattail) has emerged as one of the most widely cultivated paludiculture crops due to its fast growth and tolerance of permanently waterlogged conditions (Geurts & Fritz, 2018). *Typha* provides versatile biomass for a range of applications, and while paludiculture itself is still limited to trials, *Typha* is the crop most commonly and extensively cultivated within these projects in northern Europe, reflecting both its economic value and ease of establishment. Harvest typically occurs in late winter for fibre and insulation products, or in spring if used as livestock fodder (Wichtmann et al., 2016). While *Typha* paludiculture remains largely limited to pilot projects, interest is growing and emerging markets for renewable construction and insulation materials suggest potential economic viability (de Jong et al., 2021). Recent policy analyses have also identified potential markets for paludiculture crops in the United Kingdom (Ross, 2025), highlighting increasing attention from government and industry.

The impact on biodiversity of changing land use from drained peatland to paludiculture has been little studied, but is essential to understand, in conjunction with GHG flux and profitability assessments, to determine whether paludiculture is a viable alternative to wetland habitat creation. Martens et al. (2023) show paludiculture can offer biodiversity benefits across a range of taxa, but this study had a limited sample size with no comparison to a counterfactual. Some insights can be gained from wider evidence of wetland management, as outlined by Wichtmann et al. (2016). Water table depth is one of the factors determining floral diversity in fenlands (Kreyling et al., 2021), suggesting it is likely that raising the water table for paludiculture may be beneficial, though management of the water table regime, water quality and harvest of standing crop will also affect the floral diversity. A range of studies document faunal responses to habitat restoration. Van Duinen et al. (2007) demonstrate that biodiversity development varies considerably depending on former land use, proximity to source populations and the trajectory of succession under prevailing environmental stressors, influencing factors and management. Beadle et al. (2023) observed increased invertebrate diversity and abundance following the re-wetting of blanket peatlands. Similarly, Görn et al. (2015) found that re-wetting intensively managed grassland can enhance species richness and diversity among wetland bird species (see also Fraixedas et al., 2020; Robledano et al., 2010). However, further evidence is needed to assess the relative biodiversity value of paludiculture.

Though they are not perfect indicators of all biodiversity, birds are often used to indicate ecosystem health (i.e. Fraixedas et al., 2020; Robledano et al., 2010) as they depend on lower trophic levels, may exhibit strong habitat preferences and can be quick to respond to environmental change. Here, we carry out an assessment of bird abundance and species assemblages in *Typha* spp.-based paludiculture in the Netherlands. *Typha* was chosen because it is one of the most widely cultivated paludiculture crops in Europe, with an increasing number of experimental and commercial trial sites. This made it both representative of current paludiculture practice and practical for study, as the availability of multiple sites allowed a robust assessment of its value as a habitat for birds. We compare bird species abundance and assemblage in *Typha* to both established natural wetland sites dominated by reed (*Phragmites*) and improved agricultural grassland to determine: (i) whether there are differences in abundance and community composition of bird species between these different land uses; and (ii) how far paludiculture could provide a valuable habitat for birds.

2 | MATERIALS AND METHODS

2.1 | Site selection

Our study focused on *Typha*-based paludiculture trials in the Netherlands, with comparison to natural wetland and agricultural grassland (Figure 1). Sites were purposively selected based on established paludiculture trials with several years of growth, geographical spread across the Netherlands, and accessibility. Reference wetland and grassland sites were chosen based on proximity to paludiculture sites, sufficient size and established condition, allowing meaningful comparisons while controlling for climate, elevation and soil.

In total, 28 plots were surveyed (10 paludiculture, 9 grassland and 9 wetland; Figure 2), across nine sites, with some sites containing multiple survey plots. Paludiculture plots varied in size from 0.2 to 0.8 ha (median = 0.2 ha) and age (3– 7 years since establishment) and had been harvested in the previous winter. Grassland plots were intensively managed agricultural grasslands, typically improved and managed for grazing or silage production, and dominated by perennial ryegrass (*Lolium perenne*) with a short sward height at the time of surveys due to recent cutting or grazing. These varied in size from 0.4 to 4.8 ha (median = 2.2 ha). Natural wetland plots varied from 0.4 to 2.2 ha (median = 0.6 ha) and were comprised of established wetland habitat dominated by reed (*Phragmites*) and containing *Typha*. Reference plots were a median distance of 711 m from paludiculture sites (range: 150 m to 5 km); the median distance from paludiculture to grassland plots was 550 m, and to wetland plots was 2000 m. The minimum distance between areas of the same habitat was over 1 km. Uneven plot areas reflect trial sizes and natural boundaries such as fences, ditches or roads. Plot boundaries were delineated using high-resolution satellite imagery within GIS software. This allowed us to calculate the precise area of each plot and provided spatial reference for locating and navigating during field surveys.

2.2 | Bird surveys

Bird surveys were carried out between the 11th and 19th of May 2024, to coincide with peak breeding season, and during the first 2 h after sunrise to align with peak bird activity. We used 10-min point counts to record the number of individuals of each species detected by sight or sound within each survey plot (paludiculture, grassland or wetland). Fixed-radius point counts were not used due to the small and irregularly shaped paludiculture plots (0.2–0.6 ha). Instead, surveys covered the entire plot area, delineated by boundary ditches, fences or roads, and were mapped using high-resolution satellite imagery to calculate precise plot area for density-based analyses. A single observation point was located within each plot. Flying individuals not associated with the habitat were excluded, and juvenile and immature birds were omitted to focus on breeding habitat associations. Surveys were not conducted in heavy rain, poor visibility or strong winds due to reduced detectability.

Although only a single visit was conducted at each plot, this approach aligns with established methodologies for assessing habitat associations and relative species abundance (Bibby, 2000).

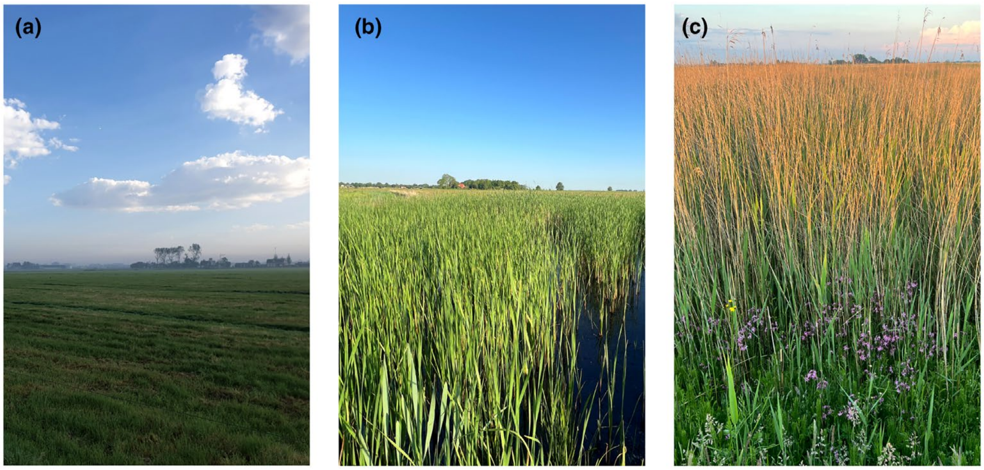

FIGURE 1 Examples of the three habitat types surveyed: (a) Intensively managed agricultural grassland, dominated by perennial ryegrass; (b) *Typha*-based paludiculture; (c) Natural wetland, dominated by *Phragmites*.

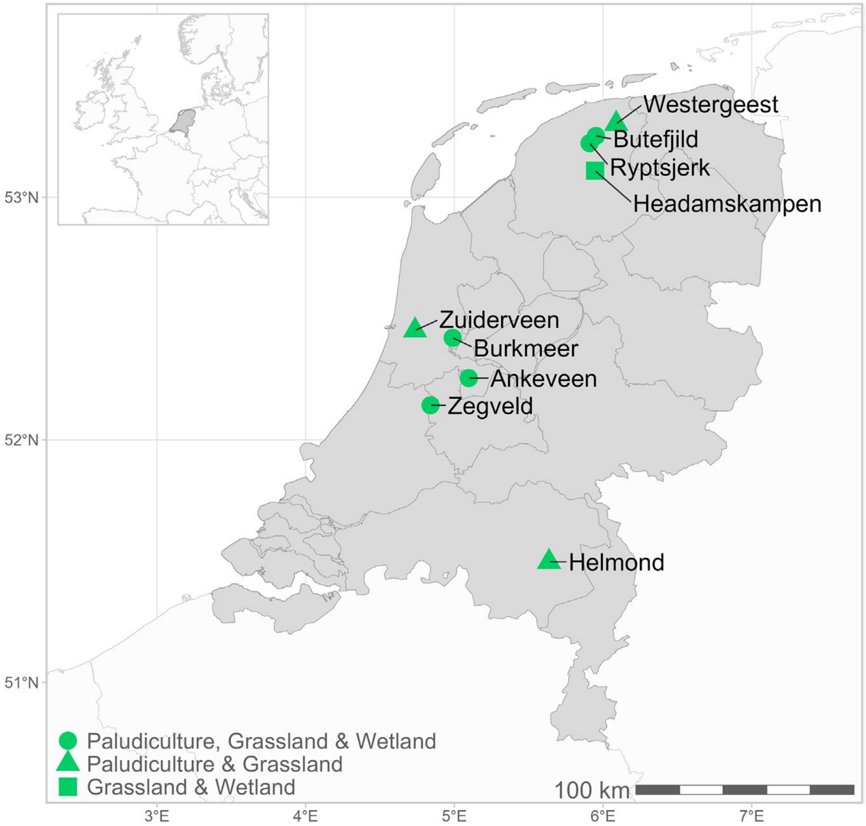

FIGURE 2 Map of The Netherlands with sites included in this study. Circle points indicate where paludiculture, grassland and wetland habitats were surveyed ($n=5$); triangle points indicate only paludiculture and grassland habitats were surveyed in these sites ($n=3$); square points indicate only grassland and wetland habitats were surveyed ($n=1$). Some sites contained multiple survey plots for a given habitat.

Single-visit point counts have been widely and successfully applied in bird surveys (Morrison & Peitz, 2025) and for other taxa (Stolen et al., 2024), and Klingbeil and Willig (2015) show that for single-site visits, point counts provide a reliable estimate in bird biodiversity assessments. Sequential analysis of species density across plots indicated that estimates were robust despite single-visit sampling. We acknowledge that this study represents a preliminary assessment, and additional visits would help capture rarer or cryptic species and refine abundance estimates. However, the current dataset provides reliable insights into primary bird community patterns in *Typha*-based paludiculture. No permits or licences were required for the field surveys conducted in this study. Landowner permission was obtained where necessary prior to accessing private land. All fieldwork was carried out in accordance with relevant ethical guidelines.

2.3 | Data analysis and modelling

Where relevant, we first assigned species to groups: (i) Grassland birds or wetland birds according to categories in the European Breeding Bird Atlas (Keller et al., 2020); and (ii) Species of European Conservation Concern category (SPEC; BirdLife International, 2017). Species not classified as wetland or grassland specialists were included in the all-species group; specialist groupings were selected based on relevance to our study objectives and established reference sources, rather than being assigned by the authors. For SPEC, we focused on three categories: SPEC 1 includes European species of global conservation concern, classified as Critically Endangered, Endangered, Vulnerable or Near Threatened at the global level; SPEC 2 includes species whose global population is concentrated in Europe and which are classified as Regionally Extinct, Critically Endangered, Endangered, Vulnerable, Near Threatened, Declining, Depleted or Rare at the European level; and SPEC 3 includes species whose global population is not concentrated in Europe but which are classified as Regionally Extinct, Critically Endangered, Endangered, Vulnerable, Near Threatened, Declining, Depleted or Rare at the European level. See Table S1 for a full list of species recorded, their habitat association and SPEC category.

To explore each group's response to habitat type and predict summed abundance at the 1 ha scale, we fitted generalised linear mixed models (GLMMs; Bolker et al., 2009) with a negative binomial error structure. Summed abundance was calculated as the total number of individuals per species group (all species, wetland birds, grassland birds or SPEC categories) within each plot. Summed abundance was used as the dependent variable and fixed effects included in the model were: (i) plot habitat: a 3-level categorical factor (paludiculture, grassland and wetland) representing the focal survey plot; and (ii) landscape habitat composition, expressed as the total area (ha) of wetland, grassland and other habitat types within a 1 km radius buffer around each survey plot. Site was included as a random intercept with nine levels, and an offset term accounted for the effective sampling area. Effective area was calculated as the product of survey area (accounting for unequal plot sizes) and the weighted average detection probability of species, per group and plot. Species detection probability values were taken from Johnston et al. (2014); although these values were derived from UK data, they are appropriate for our study area because the United Kingdom and the Netherlands share similar latitudes, temperate climates, habitat types and land-use practices, suggesting minimal differences in species detectability.

We used R^2 to assess model performance, where marginal R^2 describes the variance explained by the fixed effects, and conditional R^2 describes the variance explained by the combination of both fixed and random effects (Nakagawa et al., 2013). Model statistics and performance are provided in Tables S2 and S3. Fitted abundance was predicted and is presented for each group in the three habitat categories for a 1 ha area. We evaluated spatial autocorrelation to ensure that individual observations could be considered independent. Using the Moran's *I* statistic on model residuals revealed no significant spatial autocorrelation (for details, see Table S4). We also calculated the mean density (count per ha) of each species in each habitat and corrected this using species' detection probability.

Differences in community composition between habitats were then examined using Analysis of Similarities (ANOSIM; Clarke, 1993). We used the Bray–Curtis dissimilarity coefficient, with the output (*R*-value) indicating the degree of separation between groups, where an *R*-value of 0 indicates complete similarity and 1 indicates complete dissimilarity. We determined which bird species were strongly associated with each habitat type using Indicator Species Analysis (Dufrêne & Legendre, 1997). An indicator value of 0.3 with a $p \leq 0.05$ was used as the threshold to identify indicator species. All analyses were carried out in R version 4.1.

3 | RESULTS

In total, across 28 plot counts, we recorded 213 individuals from 33 species. Greylag Goose (*Anser anser*) was the most common, with 32 individuals counted across grasslands, followed by Sedge Warbler (*Acrocephalus schoenobaenus*) with 26 individuals recorded at both paludiculture and wetland plots. No species was present across all three habitat types. Seven species were considered SPEC, accounting for 21% of the species and 18% of the individuals recorded. SPEC species recorded were: Eurasian Oystercatcher (*Haematopus ostralegus*) and Meadow Pipit (*Anthus pratensis*), classed as SPEC 1: Species of global conservation concern; and Eurasian Bittern (*Botaurus stellaris*), Eurasian Coot (*Fulica atra*), Common Kestrel (*Falco tinnunculus*), Common Starling (*Sturnus vulgaris*) and Willow Warbler (*Phylloscopus trochilus*), classed as SPEC 3: Species of European conservation concern not concentrated in Europe. We recorded 25 species in only one habitat type, five in both paludiculture and wetland, two in paludiculture and grassland, and one in grassland and wetland (Figure 3). Mean density was highest in

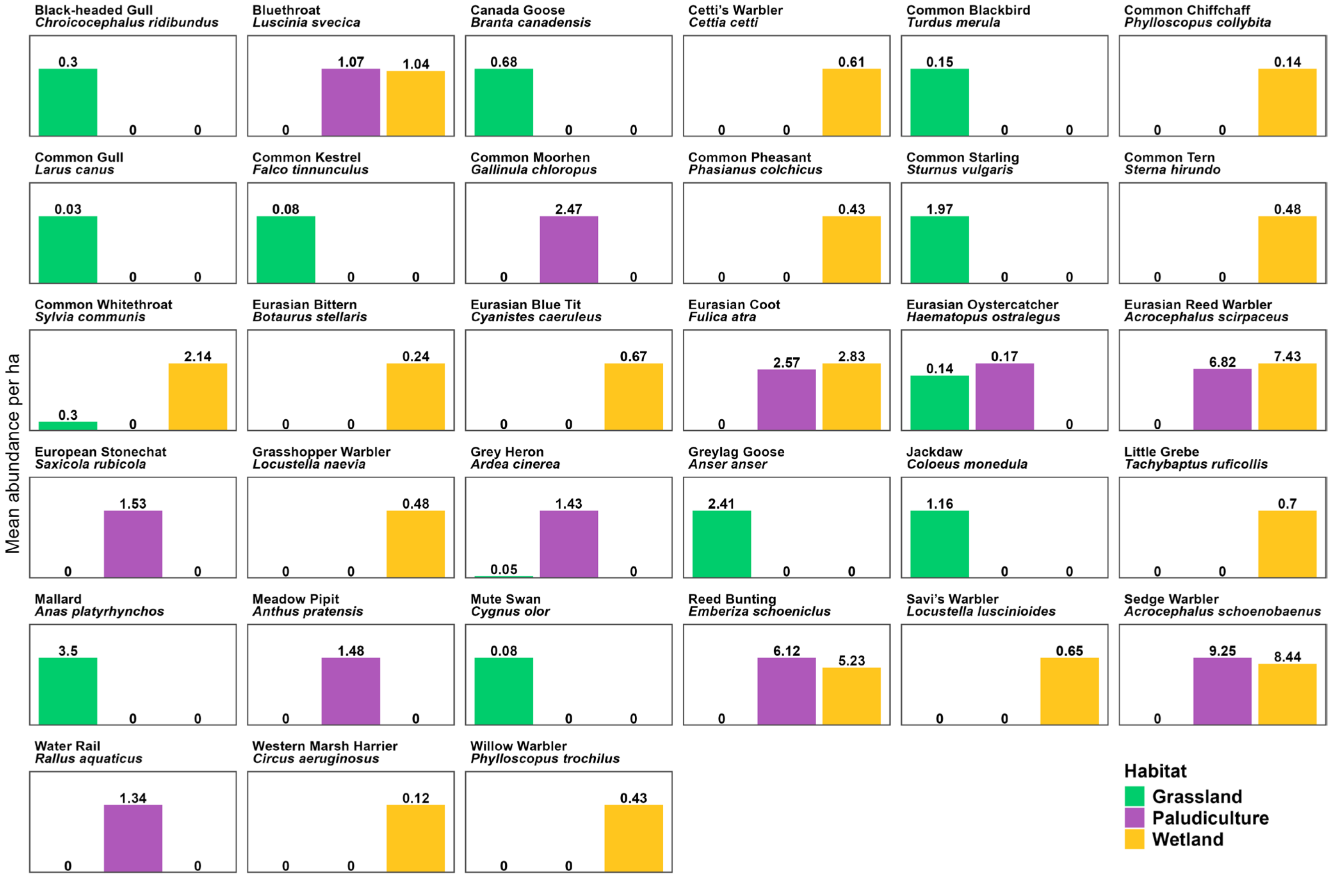

FIGURE 3 Mean density (species abundance per ha) for each individual species recorded across the three different habitat classifications. *Y*-axis scale is variable per species plot.

wetlands for 14 of the total 33 species, compared to 10 on grasslands and nine in paludiculture. To assess the adequacy of sampling, we examined species accumulation curves and sequential estimates of species density across sites (Figure S1). While the accumulation curves did not reach a full asymptote, our sequential calculations of total species density and associated standard errors, based on progressively larger numbers of sites, showed that standard errors decreased and eventually stabilised. This demonstrates that our estimates of species density were robust despite the continued accumulation of species richness. Our use of standardised point count methodology, consistent with established bird monitoring protocols, provides reliable comparative data across habitats. While no survey can achieve perfect detectability, particularly for cryptic species, additional sampling would have been unlikely to substantially alter the patterns observed.

Summed all-species model-fitted predicted abundance was significantly higher in paludiculture (Figure 4; mean: 30.8 birds per ha; standard error: ±7.85; $p<0.01$; Table S2) than in grassland (10.5 ± 3.23) and comparable to that in natural wetlands (31.5 ± 10.5; $p=0.13$). For the wetland bird group, predicted abundance was significantly higher in paludiculture (28.8 ± 10.2; $p<0.01$) than in grasslands (6.99 ± 2.42), and natural wetlands had a similarly high predicted abundance (26.9 ± 7.5), but was not significantly different from grasslands ($p=0.07$). Differences in predicted abundance across habitats for the grassland bird group were small and not significant (2.64 ± 1.71, 2.39 ± 1.49 and 2.06 ± 1.98 for paludiculture, grassland and wetland, respectively; $p>0.05$). Similarly, predicted abundance of SPEC species showed no significant differences among habitats, with 3.76 (±1.99) birds per ha in paludiculture, 3.38 (±1.56) in wetlands and 2.29 (±1.23) in grasslands. See Table S2 for full model statistics and Table S3 for model performance.

When comparing wetland and grassland habitats, there was little overlap in community composition. In fact, Whitethroat (*Sylvia communis*) was the only species present in both habitats, which resulted in ANOSIM results showing dissimilarity between sites (*R*-value: 0.42, $p<0.01$; Figure 5). However, when the test was run again with the addition of paludiculture habitat, results showed less dissimilarity (*R*-value: 0.17, $p<0.01$), owing to the similarities in species presence and abundance between paludiculture and grassland, and between paludiculture and wetland sites.

The species driving the differences and similarities between habitats were revealed using Indicator Species Analysis. There was no single species associated as an indicator for paludiculture (Figure S2; Table S5), but Reed Warbler (*Acrocephalus scirpaceus*) and Sedge Warbler were indicators of both paludiculture and wetland, found only in these habitat types and present in over half the sites ($\text{stat}=0.83$, $p<0.01$ and $\text{stat}=0.73$, $p<0.05$, respectively). Wetland also had Savi's Warbler (*Locustella luscinioides*) as an indicator, present only on wetlands and found in a third of those we surveyed ($\text{stat}=0.57$, $p<0.5$). For grassland, Mallard (*Anas platyrhynchos*) and Jackdaw (*Coloeus monedula*) were associated indicators, present only in this habitat type and found in over 40% of grassland sites ($\text{stat}=0.75$, $p<0.01$; $\text{stat}=0.67$, $p<0.05$, respectively), but no species were identified as indicators in common with paludiculture. Full Indicator Species Analysis results can be seen in Figure S2 and Table S5.

4 | DISCUSSION

This study represents one of the first in-depth assessments of breeding bird associations of *Typha*-based paludiculture. Our findings

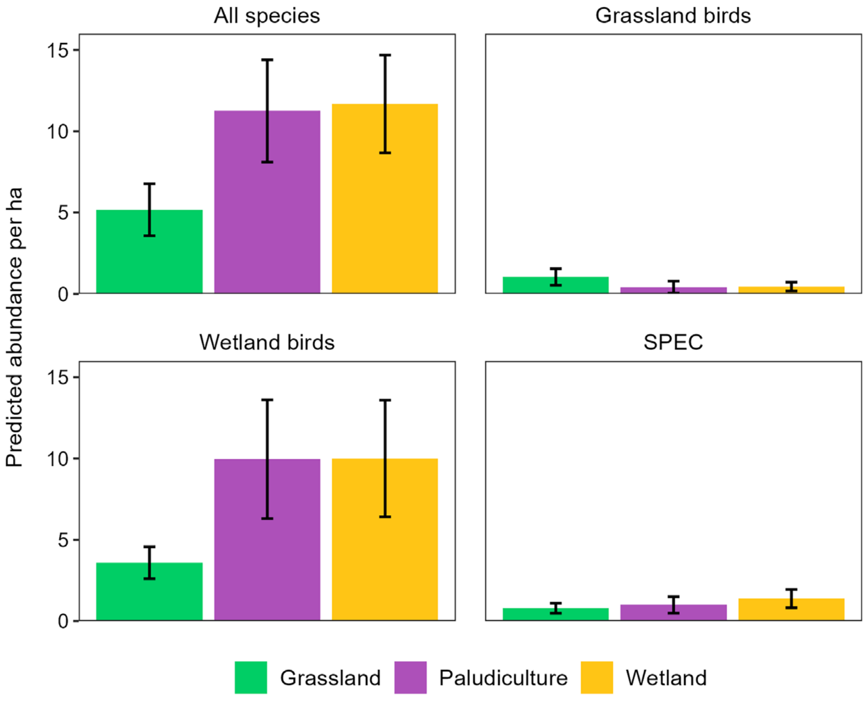

FIGURE 4 Predicted abundance and ±SE per ha for all species, grassland birds, wetland birds and Species of European Conservation Concern across the three different land use classifications.

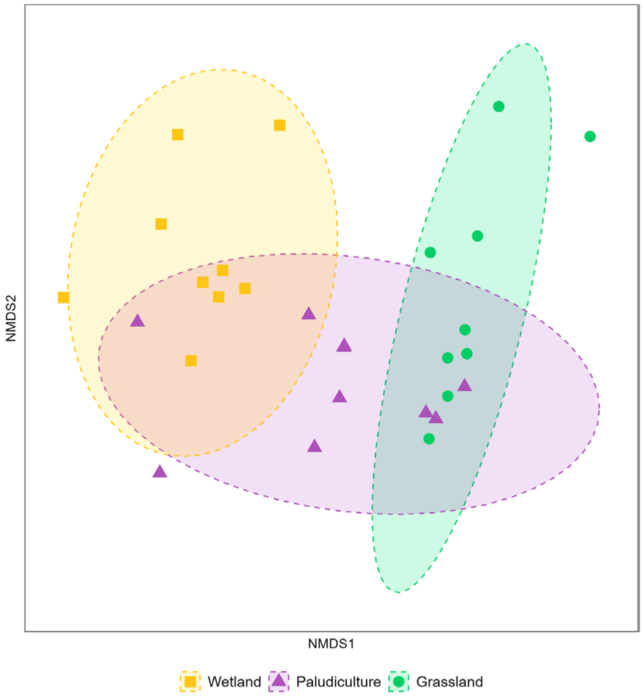

FIGURE 5 Non-metric multidimensional scaling ordination showing similarity in community composition between habitat types. Yellow square points represent wetland sites, green circular points represent grassland sites and purple triangular points represent paludiculture sites, with associated coloured ellipses for each habitat based on 95% confidence intervals. Analysis of Similarities statistic $= 0.17$, $p < 0.01$.

indicate that such systems can support diverse and abundant bird communities, including wetland specialist species and those considered at risk (listed as Species of European Conservation Concern), with population densities of many species comparable to those observed in natural wetland reference sites. Our results align with those of Martens et al. (2023), who recorded threatened flora and fauna in German *Typha* cultivations, even at sites that were intensively managed.

Insights from the wider wetland management literature suggest cultivated systems can offer meaningful habitat for specialised species under certain conditions. For example, Tanneberger et al. (2008) found that commercially cut reed (*Phragmites australis*) provided habitat for the threatened Aquatic Warbler (*Acrocephalus paludicola*) due to its association with sparse, low height reedbeds in Europe. However, the effects of harvesting on bird communities remain complex: Vadász et al. (2008) show that cutting of reeds may decrease the abundance and richness of warbler species, while Schmidt et al. (2005) provide a more nuanced view, suggesting that while mechanised reed cutting at a large scale may negatively impact passerines through lack of prey abundance, reed cutting on a small scale may have the opposite effect by increasing habitat heterogeneity. Additionally, the frequency of cutting has been shown to be a major contributor to the abundance of breeding birds, with less frequent cutting regimes hosting more breeding territories for a range of wetland specialist species (Antoniazza et al., 2018).

In our study, the presence of wetland passerines during the breeding season in *Typha* cultivations suggests habitat suitability for breeding, though the timing of harvest is likely a key determinant of breeding success. Encouragingly, the optimal harvest window for *Typha* used in construction and insulation is in winter (Wichtmann et al., 2016), falling outside the bird breeding season, potentially reducing disturbance. However, for other uses such as fodder, where *Typha* is cut before the development of seed heads, the harvest window tends to occur in spring and may overlap with the sensitive breeding period (Pijlman et al., 2019), highlighting the need for tailored management practices to avoid potential ecological traps.

While paludiculture sites supported high bird abundance with a community composition broadly similar to wetlands, there were differences. This was not unexpected, as re-wetting peatlands after drainage for agriculture does not often result in the same ecosystem functionality as an undrained natural wetland (Kreyling et al., 2021; Loisel & Gallego-Sala, 2022), and all paludiculture sites surveyed here were most recently agricultural grasslands. Some of the rarer wetland specialists such as the Eurasian Bittern, Savi's Warbler and Western Marsh Harrier (*Circus aeruginosus*) were only recorded in wetlands. This probably reflects their preference for large, structurally complex habitats (Cramp & Brooks, 1992; Gilbert et al., 2005), which small, isolated paludiculture trial sites are currently unable to provide. These differences between habitats also inherently capture contrasts in vegetation structure: tall, dense *Typha* in paludiculture, mosaics of *Typha* and *Phragmites* in wetlands, and short, ryegrass-dominated swards in intensively managed grasslands. Because these features are inseparable from the habitat types themselves, we interpret bird community differences at the habitat level rather than discussing vegetation characteristics separately.

As *Typha* paludiculture scales up and is implemented in mosaics with natural wetlands, it may offer increasing value to more specialised species, although further evidence and the upscaling of paludiculture are needed to confirm this potential. Importantly, our results highlight the functional overlaps between habitats, indicating that paludiculture functions as an ecological ‘bridge’ between grassland and wetland habitats: species typical of both habitat types were present in paludiculture sites, leading to intermediate community composition (Figure 5). In addition, paludiculture may act as a wetland surrogate or buffer ecosystem. By providing structurally complex, raised water table habitat in landscapes where natural wetlands are limited, degraded or fragmented, paludiculture can support wetland-associated species, facilitate ecological connectivity and maintain key ecosystem functions. While *Typha* paludiculture does not fully replicate natural wetlands, even small sites may help mitigate biodiversity loss, enhance landscape heterogeneity and buffer adjacent ecosystems against environmental change or habitat loss. For example, species such as Eurasian Oystercatcher and Greylag Goose, commonly observed in grasslands, were also present in paludiculture sites, possibly due to shared foraging opportunities, particularly when substrate is exposed. While our data are limited to single-season surveys at small experimental sites, the observed pattern highlights the potential ecological significance of paludiculture in linking and supporting biodiversity across adjacent habitat types. Importantly, our research advances the understanding of bird species' habitat associations with paludiculture beyond previous studies (e.g. Martens et al., 2023), and confirms some of the biodiversity benefits suggested in the broader literature (Tanneberger et al., 2022).

Although only a single visit was conducted at each site (see Section 2), sequential analysis of species density across sites indicated that estimates were sufficiently robust to capture main patterns in abundance and community composition. While some rarer or cryptic species may have been undetected, additional surveys would be unlikely to substantially alter these patterns. These results appear transferable to similar contexts—namely sites with comparable management, *Typha* growth stages, sizes and landscape settings. Nonetheless, extrapolation beyond the sampled sites should be made with caution. Long-term studies are necessary to assess how bird use varies across different crop stages, management regimes and throughout the full annual cycle. Crucially, our data are based on a single visit during the peak breeding season in May, at sites that had been harvested the previous winter, which limits inference on intra-annual dynamics and the full range of potential habitat use.

While the climate-related benefits of paludiculture are increasingly recognised and economic assessments are ongoing (de Jong et al., 2021; Tanneberger et al., 2022; Wichtmann et al., 2016), potential trade-offs with food production must not be overlooked. Despite the potential for paludiculture to produce an income for farmers, this is likely to involve growing crops for fibre. At present, *Typha*-based paludiculture is still in the trial stage across northern Europe, but recent demand for sustainable building materials has created emerging markets that may support wider adoption (Ross, 2025; Tanneberger et al., 2022). In addition, *Typha* fibres are being developed into novel textiles and used as a sustainable insulation material for clothing, highlighting broader opportunities for climate-friendly paludiculture products (Ponda, 2025). While fibre crops are currently the main focus, there have been several trials of food crops under paludiculture (Mulholland et al., 2020), but in these cases edible yields are typically lower than in conventional arable rotations. Therefore, conversion of high-grade arable land to paludiculture could lower food production and can be expected to lead to potentially damaging impacts elsewhere; these leakage effects must be considered in assessing the overall impacts of adopting paludiculture (Balmford et al., 2025; Phalan et al., 2016). Our results specifically address *Typha*-based paludiculture; systems based on other crop types, particularly food crops with different structures, may not provide comparable outcomes for bird communities. As such, caution is needed in generalising these results across all paludiculture systems.

Overall, our findings suggest that *Typha*-based paludiculture on re-wetted lowland peat can contribute meaningfully to biodiversity conservation while providing climate change mitigation. While paludiculture does not replicate natural wetland habitats, alongside greatly reducing GHG emissions, it offers clear ecological advantages over drained agricultural land, particularly by providing habitat for wetland bird species, including some of conservation concern. However, to ensure that paludiculture fulfills its ecological and climate potential without compromising food security or causing unintended land use displacement, policy development must be both evidence-based and context-sensitive. This could include incentivising site selection that avoids full re-wetting on the most agriculturally productive land and promoting biodiversity-friendly management practices. Long-term ecological monitoring and adaptive management will be essential to assess trade-offs, refine best practices and ensure resilience. Integrating paludiculture into broader agricultural and climate strategies offers a promising pathway to reconcile productive land use with ecological restoration and climate mitigation, helping to deliver long-term benefits for both people and nature across peatland landscapes.

AUTHOR CONTRIBUTIONS

Joshua P. Copping, Catherine E. Waite, Andrew Balmford, Richard B. Bradbury, Gert-Jan van Duinen, Tom Finch, Ivan S. Mettrop and Rob H. Field conceived the ideas and designed methodology; Joshua P. Copping and Catherine E. Waite collected and analysed the data; Joshua P. Copping led the writing of the manuscript; all authors contributed to the editing and review of the manuscript and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

PEER REVIEW

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Data are available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.fbg79cp8s (Copping et al., 2025).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Bird species included in this study, whether they are associated with wetland or grassland based on the European Breeding Bird Atlas 2, and their Species of European Conservation Concern category.

Table S2. Fixed effects table for the generalised linear mixed model (GLMM) fitted to bird abundance for species groups (all species; wetland birds; grassland birds; and Species of European Conservation Concern, SPEC).

Table S3. Model performance (conditional and marginal *R*-squared values) for each generalised linear mixed model (GLMM) by species grouping.

Table S4. Moran's *I* results.

Table S5. Indicator species analysis.

Figure S1. Assessment of sampling adequacy across habitats.

Figure S2. Indicator species analysis plot.

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