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REVIEW

Bird-mediated effects of pest control services on crop productivity: a global synthesis

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Abstract

Birds provide important ecosystem services in many ecosystems, including important pest control effects on productive systems. The typically low bird diversity observed in intensive agricultural landscapes renders them more susceptible to pests that cause important economic losses. Although these pests have traditionally been controlled using chemical methods, recent work suggests that bird-mediated biological control is an effective and environmentally friendly form of ecological intensification practice. We conducted a global meta-analysis to synthesize the effect of the exclusion of wild birds on crop damage, pest abundance, and crop yield in agroecosystems. We used 179 case studies from 55 articles, from which we found that wild birds reduced crop damage and pest abundance, but increased crop yield. The positive effect of birds as biological control agents was found to be significant on conventional farms using traditional chemical methods but not on organic farms. Our analysis shows that embracing ecological intensification practices such as using wild bird species as pest control represents a win–win strategy for agriculture and biodiversity.

Keywords Crop damage · Ecological intensification · Integrated pest management · Natural enemies · Pest abundance · Yield · Ecosystems services

Key message

- Wild birds play a major role in pest control services in the agroecosystems
- The presence of wild birds reduced crop damage, pest abundance, and increased crop yield
- Maintaining natural areas within productive lands enhance natural pest control services
- Ecological intensification practices are a win–win goal for farmers and the environment

Introduction

Pest control is one of the biggest challenges in modern agriculture (Tilman et al. 2002; Thrupp 2000; Manosathiyadevan et al. 2017; Isman 2019). Intensive agriculture, which typically harbors low biodiversity (Tilman et al. 2002), is highly vulnerable to animal pests attack (including vertebrates and invertebrates), leading to an average yield loss between 9 and 37% when crops are not protected (Oerke 2006; Culliney 2014). The dominant strategy for pest control in intensive agriculture relies on the application of chemical methods, a practice that is neither economically nor ecologically sustainable (Chaplin-Kramer et al. 2011; Pimentel 2005; Isman 2019). As a result, strategies based on sustainable pest control, which include biological control, the replacement of toxic pesticides by more environmentally

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friendly molecules, and the minimal application of chemical pesticide based on biological tolerance thresholds, have become increasingly important (Stenberg 2017; Dara 2019; Isman 2019). In this respect, recent ecological intensification practices have promoted the integration of ecosystem services mediated by biodiversity into agroecosystems in order to maintain crop productivity while minimizing negative environmental impacts (Kleijn et al. 2019). Within ecological intensification practices, the role of biodiversity and natural areas in agricultural landscapes has been highlighted for its value in sustaining insect and bird species that benefit crop production (Karp et al. 2013; Garibaldi et al. 2011).

Birds have important roles in different ecosystem functions (Şekercioğlu et al. 2016; Pejchar et al. 2018; Whelan et al. 2015). In this context, birds have been documented to induce strong cascading effects by suppressing herbivores, such as insects, mammals, or even other bird species in many natural and human-modified ecosystems (Kross et al. 2012; Karp et al. 2013; Labuschagne et al. 2016; Peisley et al. 2017; Chain-Guadarrama et al. 2019; Mooney et al. 2010; Mäntylä et al. 2011; Whelan et al. 2015; Mazía et al. 2009). There is increasing evidence highlighting the role of birds as biological control agents in agroecosystems, aiming to change the traditional biological control paradigm in agroecosystems, which have overlooked the potential contribution of vertebrate predators over parasitoids and predatory insects (see review of García et al. 2020).

At a global scale, it has been estimated that birds consume between 400 and 500 million tons of arthropods per year in many biomes, including croplands ecosystems, thus contributing in a significant way toward preventing crop damage and loss (Fig. 1) (Karp et al. 2013; Nyffeler et al. 2018; Johnson et al. 2010). However, the contribution of birds as biological pest control agents in agricultural landscapes has been largely underestimated (García et al. 2020). On the contrary, birds in agricultural landscapes are generally associated with environmental disservices by farmers (Lindell et al. 2012), since they can act as a pest in some cases, such as fruit-eating bird (Shave et al. 2018). For instance, bird damage to crops can cause losses of USD 189 million in five crops (e.g., Honeycrisp apples, wine grapes, blueberries, and sweet and tart cherries) (Anderson et al. 2013) and USD 1.3 million in corn (Klosterman et al. 2013) both in the USA; or they can have a neutral effect on yield, as arthropod suppression can equal the damage inflicted by birds (Gonthier et al. 2019). In addition, birds can suppress agricultural pest predators (i.e., intraguild predation; Rosenheim et al. 1993; Letourneau et al. 2009; Olimpi et al. 2020). For example, birds can prey on certain spider species, which are generalist predators that consume agricultural pests, thereby providing a disservice to farmers (Greenberg et al. 2000; Recher and Majer 2006; Grass et al. 2017).

Notwithstanding, several works and recent reviews have highlighted the importance of wild birds suppressing pests in agricultural landscapes, reducing crop damage (Greenberg et al. 2000; Pejchar et al. 2018; García et al. 2020; Boesing et al. 2017), consuming sentinel preys (Jedlicka et al. 2011; García et al. 2021), reducing pest abundance (Mols and Visser 2007; Karp et al. 2013), and increasing yield (Mols and Visser 2002; Gras et al. 2016). These studies have shown that the use of birds as biocontrol has positive impacts on herbivores abundances, crop damage and local economies. For instance, Shave et al. (2018) found that for every US dollar spent on a raptor's nest box to control birds, a loss of up to 220 US dollars in sweet cherry crops could be avoided. The nature of pest control and insect-insect interactions is highly context-dependent, and any conclusion must consider system-specific factors that may override any general benefits in ecosystem services (Karp et al. 2018).

Although, the ultimate goal of ecological intensification practices is to quantitatively evaluate the link between pest control and crop production. Despite being discussed in

Fig. 1 Graphical representation of bird-mediated pest suppression, and the effects of their exclusion on crop damage. Illustrations by ©Pen & Paper (https://en.penandpaper-sci.com/)

reviews and previous research, studies that have assessed quantitatively such a link are scarce (Karp et al. 2013). Thus, there is a clear knowledge gap to better understand and quantify the overall effect of bird-mediated pest control, as well as the effect on crop production, particularly under different agroecosystem managements and geographical zones. Furthermore, it is important to identify the main drivers that explain the positive, negative, or neutral effects of bird suppression in pest populations. Understanding the effects of wild bird species as biocontrol agents in agroecosystems represent vital information for landowners and farmers to effectively design and sustainably manage agroecosystems in the long term and contributes to helping improve farmers' perceptions of biodiversity (Jacobson et al. 2003; Kross et al. 2018). Therefore, we hypothesized that excluding wild birds would increase crop damage and pest abundance, as well as reduce crop yield. To test this hypothesis, we reviewed the scientific literature and conducted a formal meta-analysis to understand the net outcomes of bird-mediated biological control services on crop production, the effect on pest abundances, and production across different crop varieties, managements and ecosystems.

Materials and methods

Literature survey and data inclusion criteria

We searched the available literature on the Web of Science database (covering January 1977 to June 2020) using the following search strings: "bird" OR "avian" + "insectivory" OR "herbivory" OR "predation" OR "control" OR "reduction" OR "consumption" OR "suppression" + "insect" OR "arthropod" OR "plague" OR "larva*" OR "pest" OR "vertebrate" + "crop" OR "agr*" OR "field" OR "farm*" + "yield" OR "abundance" OR "herbivory" OR "damage" OR "production". We also incorporated the literature surveys used in previous meta-analyses and reviews (Van Bael et al. 2008; Lima 2009; Mäntylä et al. 2011; Labuschagne et al. 2016; Boesing et al. 2017; Lindell et al. 2018; Maas et al. 2019; Chain-Guadarrama et al. 2019; Marsden et al. 2020; Paiola et al. 2020; García et al. 2020) (the original database of the literature search is freely available from the *figshare* digital repository: https://doi.org/10.6084/m9.figshare.14307860). Our literature survey followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, which provides a standardized framework for meta-analyses and systematic reviews (Moher et al. 2009). Similarly, we followed the recommendations of Nakagawa et al. (2017) to obtain the informative results by taking into account data independence, publication bias, and the potential influence of outliers. To ensure a minimum quality standard for the data obtained and the study's replicability, we limited our search to peer-reviewed articles in English, excluding the gray literature and other databases. Our initial search provided 996 articles, which were limited to 70 after we filtered for off topic studies or the irrelevant results as described below (i.e., studies carried out in non-agricultural system, focused on another predator taxa, or reporting unrelated response variables; see Supplementary Material Fig. S1).

Each article was downloaded in full. We read every article to determine if they met the following criteria: (1) comparing a control situation (i.e., wild birds present) with an experimental situation (i.e., exclusion or attraction of wild birds) in different types of agricultural lands; (2) reporting either crop damage, pest abundance, or crop yield (or a combination of them) as response variables; (3) reporting the mean, sample size, and a dispersion measure (i.e., either standard error, standard deviation, or confidence intervals; transformed to standard deviation prior to perform effect size calculations) of the dependent variables. The article selection procedure was simultaneously performed by two researchers (PD-S and NO-M) to minimize reviewer bias. As a result of the selection process, we excluded 15 articles from the 70 articles initially chosen as they did not meet the inclusion criteria (see details on the *figshare* digital repository: https://doi.org/10.6084/m9.figshare.14307860). As a result, 55 articles were considered, which provided a total of 179 case studies: 57 of them were related to crop damage, 103 to pest abundance, and 19 to crop yield (Supplementary Material Fig. S1). Since some papers presented more than one case study, we considered the results from different locations as independent cases. However, we used the result with the largest effect size, following the criteria performed by Mäntylä et al. (2011), because it can be more critical to plants and to discarded temporal replicates (i.e., repeated measures) to avoid temporal pseudoreplication.

Model, effect size, and moderators

As we included studies reporting a variety of species, crop types, and geographic locations, there is unlikely to be a single common effect (Borenstein et al. 2009). Consequently, we used mixed-effects models to examine effects using moderator variables. To examine the overall heterogeneity, we used the Q_{total} statistic, and to examine heterogeneity among moderator levels, we estimated the between-group heterogeneity Q_{between} statistic. Q-statistics are heterogeneity measures that use a χ^2-distributed statistics to compare the variation among and within levels (Higgins et al. 2003). A significant Q_{between} value (i.e., with $P < 0.05$) indicates that there is significant variation among the effects among moderator levels (i.e., moderator levels do not share a common effect, having opposing trends). Thus, Q-statistics are more appropriate for random-effects models than other approaches (e.g., τ^2 or I^2), which are intended for fixed-effects models only (Borenstein et al. 2009).

We used Hedges' *d* unbiased standardized mean difference to measure the effect size of each case study (Hedges and Olkin 1985). This measurement is commonly used to estimate the magnitude of a particular situation's effect by comparing a control and an experimental group (Gurevitch et al. 2001). As most studies excluded wild birds, we considered the wild bird presence as a control and the exclusion of them as the experimental trial. However, a few case studies reported the results from attraction experiments (i.e., the opposite of excluding wild birds); in those cases, we used an inverse effect direction to make the effects comparable with those from the exclusion experiments. We conducted separate analyses for crop damage, pest abundance, and crop yield, estimating the overall effects of wild bird exclusion or attraction on these three response variables. To explore our results further, we used moderator variables, which are categorical variables contrasting two or more levels, to test if there are effect size differences among them and detect contrasting responses. We defined five moderator variables: (1) geographical zone (tropical or temperate); (2) crop type (i.e., brassica, cereals, coffee, cacao, macadamia, apple, vineyard, groundnut, alfalfa, palm, strawberry, or raps); (3) agriculture type (i.e., conventional, organic, agroforestry, or mixed when a study used more than 1 agriculture crop); (4) pest type (birds, arthropods, voles, or even sentinels as study models); and (5) experiment type (exclusion or attraction). There were sample size asymmetries among moderator levels, for which we excluded levels with $N < 4$ as we consider them non-informative. Finally, special care was taken when interpreting moderator levels $N < 10$.

Publication bias assessment

The meta-analysis results can be influenced by potential publication bias, as those articles reporting significant effects are more likely to be published than those reporting nonsignificant ones (Rosenberg 2005). To assess our results' robustness, first, we examined the relationship between effect and sample size using the funnel plot approach (Hedges and Vevea 1996) followed by an Egger's regression to test the statistical significance of potential funnel plot asymmetries (Egger et al. 1997). If significant asymmetries were detected, we conducted a sensitivity test recalculating the results after removing outlier points (as recommended by Nakagawa et al. 2017). We also examined the correlation between effect size and its variance using a Kendall correlation test with continuity correction, and then we used the Baujat plot (Baujat et al. 2002) to visually assess sources of heterogeneity. We then conducted a "trim and fill" analysis (Duval and Tweedie 2000a, b), which takes into account the asymmetry between positive and negative case distributions, which may be potentially biasing the results. This approach recalculates the mean effect and confidence intervals after balancing positive and negative cases (by trimming and filling cases on both sides of the funnel plot) to validate the results' robustness (Jennions and Møller 2002). All analyses were conducted using R 4.0.3 (R Development Core Team 2020) and the "*meta*" package (Balduzzi et al. 2019).

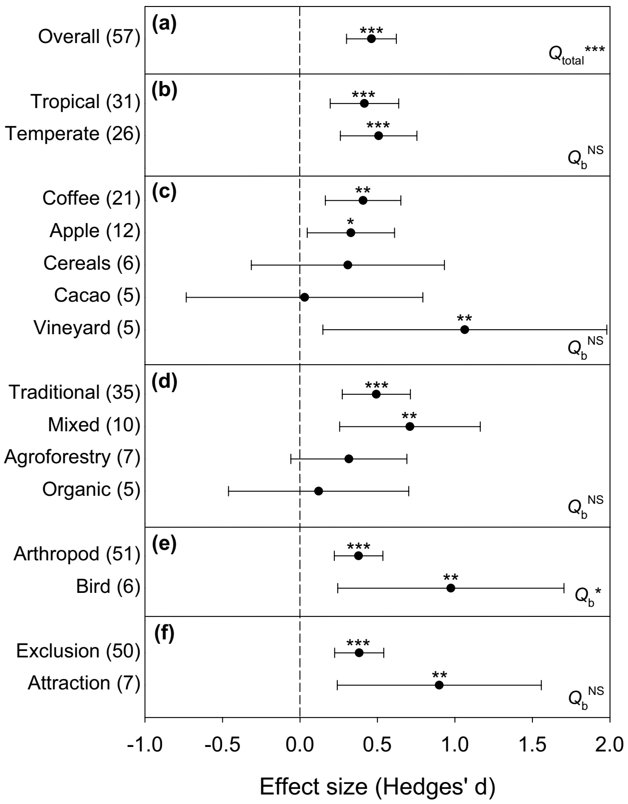

Fig. 2 Effects of bird exclusion on crop damage. We present the mean and the 95% confidence interval for **a** the overall effect, **b** geographical region, **c** crop type, **d** agriculture, **e** pest type, and **f** experiment type. $Q_B = Q_{\text{between}}$ statistics. Significance: $^{NS}P \geq 0.05$, $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$

Results

Effects on crop damage

Overall, we found that excluding wild birds significantly increased crop damage (Fig. 2a; $Q_{\text{total}} = 38.61$, P = 0.003). Our geographical zone analysis revealed that tropical and temperate zones showed the same trend as the overall result (Fig. 2b; $Q_{\text{between}} = 0.03$, $P = 0.568$), with a significant increase of crop damage when wild birds were absent. Our crop type analysis showed mixed responses (Fig. 2c; $Q_{\text{between}} = 6.21$, $P = 0.184$) with significant damage on coffee, apple, and vineyard crops when wild birds were absent.

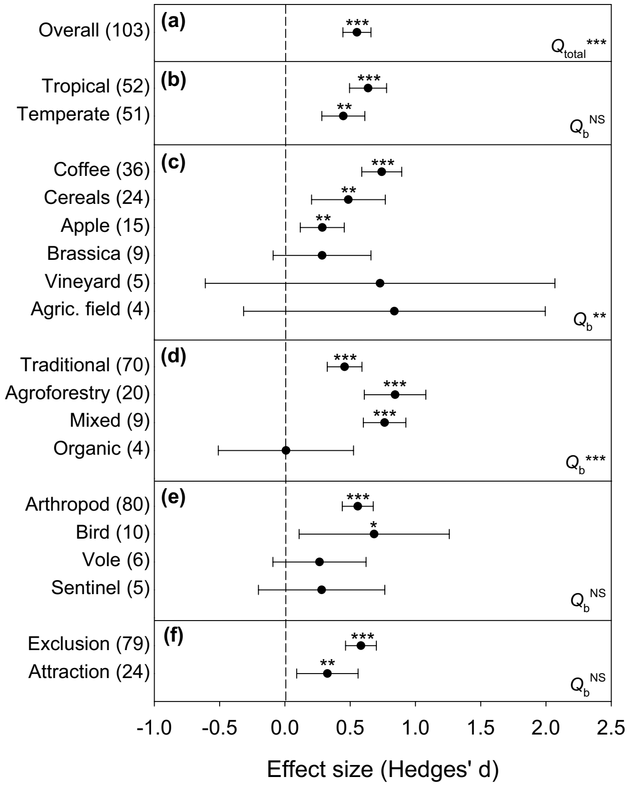

Fig. 3 Effects of bird exclusion on pest abundance. We present the mean and the 95% confidence interval for **a** the overall effect, **b** geographical region, **c** crop type, **d** agriculture, **e** pest type, and (**f**) experiment type. $Q_B = Q_{between}$ statistics. Significance: $^{NS}P \geq 0.05$, $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$

The results by agriculture type showed contrasting effects (Fig. 2d; $Q_{between} = 5.03$, $P = 0.169$), with significant crop damages on conventional and mixed fields, while there were nonsignificant effects of damage on agroforestry and organic fields when wild birds were absent. When examining our data by pest type, we found that wild birds reduced crop damage by both pest birds and arthropods (Fig. 2e; $Q_{between} = 4.09$, $P = 0.043$), but that the effects on pest birds were larger and more varied. Finally, when comparing experimental types, we found significant differences in crop damage at both exclusion and attraction experiments (Fig. 2f; $Q_{between} = 3.40$, $P = 0.065$). However, attraction experiments showed a larger variability than exclusion experiments.

Effects on pest abundance

Overall, we found that excluding wild birds causes a significant increase in pest abundance (Fig. 3a; $Q_{total} = 210.09$, $P < 0.001$). The results by geographic zone showed that tropical and temperate zones have a similar trend as the overall effect; however, birds reduced pest abundance more in tropical areas than in temperate areas (Fig. 3b; $Q_{between} = 3.07$, $P = 0.080$). Our crop type results showed heterogeneous responses (Fig. 3c; $Q_{between} = 20.60$, $P = 0.001$) with a significant increase in pest abundance for coffee, cereal, and apple crops when wild birds were absent. In relation to agriculture type, we found contrasting effects (Fig. 3d; $Q_{between} = 5.7.8603$, $P < 0.001$), as there was a significant increase in pest abundance in conventional fields, as well as in agroforestry and mixed land, but not in organic fields when wild birds were absent. The results of our pest type analysis showed that bird and arthropod pest abundance increased when wild birds were absent; this was not the case for the abundance of voles and sentinels, which did not change when wild birds were absent (Fig. 3e; $Q_{between} = 5.92$, $P = 0.115$). Finally, we found that exclusion experiments had a larger influence on pest abundance than those experiments that attracted birds (Fig. 3f; $Q_{between} = 4.01$, $P = 0.045$).

Effects on crop yield

Overall, we found that excluding wild birds significantly reduces crop yield (Fig. 4a; $Q_{total} = 38.61$, $P = 0.003$). Our analysis by geographic zone showed a significant reduction

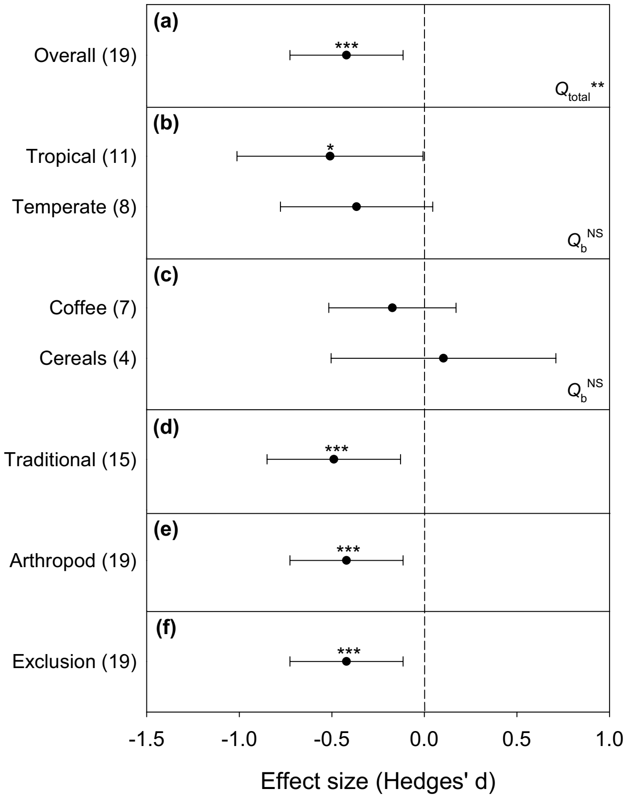

Fig. 4 Effects of bird exclusion on crop yield. We present the mean and the 95% confidence interval for **a** the overall effect, **b** geographical region, **c** crop type, **d** agriculture, **e** pest type, and **f** experiment type. $Q_B = Q_{between}$ statistics. Significance: $^{NS}P \geq 0.05$, $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$

in crop yield at tropical zones but not at temperate zones, when wild birds were absent (Fig. 4b; $Q_{\text{between}} = 0.25$, $P = 0.614$). However, when looking at our results by crop type, we found that excluding birds had no effects on yield in coffee and cereal crops (Fig. 4c; $Q_{\text{between}} = 1.35$, $P = 0.245$). We were unable to perform comparisons for agriculture type (Fig. 4d), pest type (Fig. 4e), and experiment type (Fig. 4f) because of low variability (i.e., only one level).

Publication bias

Our funnel plot analysis showed an even distribution of positive and negative cases for crop damage data (Fig. S2). Yet, it also revealed a significant general asymmetry ($t = 2.48$, df = 55, $P = 0.016$) between positive and negative cases. Although there were some outlier points for both pest abundance (Fig. S3) and crop yield (Fig. S4), we found no significant asymmetry for either (pest abundance: $t = 1.14$, df = 101, $P = 0.256$; crop yield: $t = 0.79$, df = 16, $P = 0.440$). We detected a significant correlation between effect size and its variance for crop damage data (Kendall's tau = 0.28, df = 54, $P = 0.002$), but no significant correlation was found for pest abundance (tau = 0.06, $P = 0.402$) or crop yield data (tau = 0.29, $P = 0.080$). Baujat plots (Figs. S4, S5, and S6) showed a regular pattern, in which most case studies have low contributions to heterogeneity and a few outlier points have large contributions.

We conducted a sensitivity analysis excluding outlier cases, but we found nonsignificant effects on our results' direction and significance (Table S1). Likewise, our results did not change in either significance or direction after performing the "trim and fill" procedure (Table S2). The latter indicates that our study results were robust and not influenced by publication bias in any case.

Discussion

Our study shows that the exclusion of the wild birds results in a significant increase in crop damage (Fig. 1) and pest abundances, as well as a significant reduction in crop yields. Given that wild birds can significantly decrease crop damage and pest abundance, it is essential to understand better their net impacts on crop production to inform policymakers and farm managers and achieve sustainable goals.

By highlighting the role of wild birds in agroecosystems, our results reinforce the importance of vertebrate predators as biological control agents. This contrasts with the traditional paradigms and perceptions of biological control centered on parasitoids and predatory insects. Our study supports the ecological intensification of farming practices, since birds' ecosystem contribution—as biological control agents—translates into increased productivity, which is the ultimate goal of ecological intensification (Tittonell 2014). Interestingly, we observed an important variation in our response variables (i.e., crop damage, pest abundance, and crop yield) across crop types, climatic regions, and agricultural management when wild birds were excluded. Pest-natural enemies' interaction is highly context-dependent (Karp et al. 2018). For instance, excluding wild birds in organic farms did not lead to a reduction in crop damage or pest abundance, while excluding them in conventional farms did have a significant effect. A similar result has been previously reported for organic apple farms by Mols and Visser (2007), with organic farming promoting a higher species diversity, particularly natural enemies, than conventional methods (Clough et al. 2007; Letourneau and Goldstein 2001). Hence, pests are diluted in the herbivore community and subject to a wider diversity of potential natural enemies (Letourneau and Goldstein 2001), which resulted in lower effect of wild birds on pests crop damage and lower pests abundances in organic farms (see Figs. 2 and 3; Muneret et al. 2018). Based on our results and previous work, there seems to be a clear link between the ecological context of agricultural land and its resilience to biodiversity loss (Muneret et al. 2018; Letourneau and Goldstein 2001).

Most studies on avian-mediated pest control have been conducted in tropical areas (49%) rather than in temperate (35%) or Mediterranean agroecosystems (16%) (Fig. S8). The predominance of tropical areas has been seen over time, although there has been an increase in the number of studies focused on other geographical areas (Boesing et al. 2017). Mediterranean regions are considered as global biodiversity hotspots for conservation (Myers et al. 2000). However, they also represent one of the most vulnerable ecosystems on the planet because of the negative effects of land-use change and the intensive establishment of forestry and agriculture (Sala et al. 2000; Armesto et al. 2010). Thus, identifying the contribution of biodiversity to crop production in Mediterranean regions is key to promoting sustainable land-use management and conservation of productive and natural areas (Cox and Underwood 2011). Conservation of natural areas near agricultural land can benefit pest-regulation services in agricultural landscapes (Tscharntke et al. 2012). A larger variety of wild bird-mediated pest control species have been frequently reported in woodland landscapes (Boesing et al. 2017; Sanz 2001).

It is important to acknowledge two important biases of the present study. First, 78% of the studies reviewed here were conducted in the Northern Hemisphere (Fig. S8). This knowledge gap results from a lack of data reported from the Southern Hemisphere in terms of research and monitoring of global ecosystems (Rozzi et al. 2012). This misrepresentation of the southern world is an important issue to take into account for agricultural and conservation management purposes. Second, most of the published studies included in our meta-analysis only considered coffee, cereal, and apple crops, all of which represent over 60% of the published research. The reduced variety of crops included in the international literature highlights an urgent need to expand research to other crops.

Previous work on the role of birds in agroecosystems showed that landscape structure has an important effect on species diversity (Boesing et al. 2017; Muñoz-Sáez et al. 2021). Birds and arthropods in agroecosystems interact in complex ways (Pejchar et al. 2018; García et al. 2020). Although previous studies have found that wild birds can have ecosystem disservice effects (Grass et al. 2017; Martin et al. 2013), our global meta-analysis highlights the importance of wild birds in increasing crop productivity through pest suppression. We emphasize that although there is the extensive literature on bird effect on pest abundance and crop damage, few studies (ca. 20%) have related these variables to productivity. Therefore, more research is needed to gain a better understanding of the relationship between wild birds and crop production.

Based on the available literature and our results, we recommend that wild birds be considered as effective biological control agents, and important components of sustainable pest management strategies (García et al. 2020). In this context, our review reveals that only 16% of our selected articles had increased bird diversity through ecological innovation practices (e.g., perches or nest boxes). We found that attracting wild birds, as an ecological intensification tools that is easily implemented by farmers, could significantly reduce crop damage and pest abundance (García et al. 2021). For instance, nest boxes for insectivorous birds or raptors provide a highly cost-effective ecosystem service to control fruit-eating birds or arthropods (Shave et al. 2018; García et al. 2021; Suhonen et al. 1994), and in-farm evaluation could be a way to improve farmer attitudes toward the conservation of biodiversity (Jacobson et al. 2003; Kross et al. 2018), and a bridge to advance toward other ecological intensification practices (Kleijn et al. 2019). In fact, as was proposed by García et al. (2021), attracting birds to farms by ecological innovations, farmers should receive direct benefit reported in this study, as well as indirect benefits through reduction of pesticide with the associated consequences of environmental damage. These innovations could be the focus on public subsidies from, (1) environmental policy focused on biodiversity conservation in rural landscapes, and (2) from agricultural policy focused to increase productivity in a sustainable way. Therefore, enhancing crops with ecological innovation practices can promote both biological control and biodiversity conservation within productive landscapes.

Finally, it is important to highlight that many studies have documented that most farmers associate birds with environmental disservices (e.g., damage to fruit crops) and that bird-friendly practices are not associated with economic incentives (Jacobson et al. 2003). However, our results support the idea that ecological intensification practices can complement and, in some cases, replace the use of pesticides or exotic enemy releases for biological control, with production-supporting ecological processes to sustain agricultural production (Bommarco et al. 2013; Kross et al. 2018; Smith et al. 2021).

Conclusion

Our global analysis showed that wild birds play a major role in pest control services in agroecosystems. In particular, wild birds in agroecosystems reduce crop damage and pest abundance, resulting in a significant increase in crop yield. We encourage farmers and land-use managers to embrace ecological intensification practices that represent a win–win strategy to benefit food production and the environment.

Author contributions

JLC-D conceived the ideas. PD-S, NO, and FEF designed the methodology. PD-S and NO collected and processed publication data. FEF analyzed data. PD-S and FEF led manuscript writing with contributions of BL, RAP, and JLC-D.

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Availability of data and material The original database and literature search and data used to perform this meta-analysis is freely available from the *figshare* digital repository: https://doi.org/10.6084/m9.figshare.14307860

Code availability Figshare digital repository: https://doi.org/10.6084/m9.figshare.14307860.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interest to disclose.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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