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IMPACTS OF INTENSIVE AGRICULTURE ON BIRDS: A REVIEW

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ABSTRACT

Intensive agriculture has had a negative impact on biodiversity and human health across the world. Specifically, bird populations have declined for many years due to soil degradation and agrochemical pollution. This review, which draws on 890 sources, including research articles and literature reviews, examines the interaction between birds and intensive agriculture to better understand its effects and conservation implications. Intensive agricultural activities have resulted in significant population declines among insectivorous and carnivorous birds, while generalist bird populations have increased. The heavy use of pesticides in intensive agriculture affects food availability for birds by reducing invertebrate and vertebrate populations as well as natural vegetation cover, which has a significant impact on bird diversity. Additionally, the accumulation of toxic compounds reduces bird reproductive success. In general, intensive agroecosystems have consistently had lower avian diversity than forest habitats and even lower-impact agricultural systems. However, some agroecosystems, such as rice fields, agricultural drainages, and canal systems, create alternative habitats that can benefit waterfowl. Future work should consider strategies such as restoring and enhancing vegetation edges, preserving natural vegetation, implementing organic farming practices, maintaining water bodies, and providing economic incentives for landowners to conserve biodiversity on their land to promote bird diversity conservation.

Keywords: agricultural intensification, avifauna, biodiversity, land use change, pesticides.

INTRODUCTION

One of the primary factors contributing to climate change worldwide is the conversion of natural ecosystems into cropland and pastureland. Agricultural areas currently occupy about 12 % of the Earth's surface, and their expansion is responsible for 80 % of global forest loss (FAO, 2022). Large-scale commercial agriculture, particularly intensive farming, has caused 40 % of natural vegetation loss, while subsistence farming has contributed 33 % (Song *et al*., 2018).

In the 1960s, developing countries saw the introduction of intensive agriculture through the "Green Revolution." This system involves using machinery to increase production per surface unit, higher planting density, deeper plowing, more fertilizers and pesticides, and high-yield seeds (Reif and Hanzelka, 2020). Most of the expansion of intensive agriculture has occurred in tropical and subtropical regions due to population growth and the resulting demand for food, which leads farmers from traditional and subsistence systems to specialize in fewer products. This has worsened the problem of biodiversity loss, resulting in a shift from heterogeneous areas to large monocultures. As a result, the landscape has become simplified and homogenized, making resources less available for the biota (Šálek *et al*., 2021).

The loss and degradation of natural ecosystems caused by agricultural practices and their intensification have had a significant impact on birds. In fact, agricultural expansion affects 73 % of globally threatened birds (BirdLife International, 2022). Rosenberg *et al*. (2019) reported a net loss of 3000 million individual birds over a period of 48 years. Grassland birds showed the greatest population decline—more than 700 million individuals of 31 species—representing declines in 74 % of the species in this biome, with temperate region species experiencing the greatest decline in abundance (~1.4 billion individuals).

Population decline has not been limited to birds that are sensitive to disturbance or have limited distributions (i.e., endemic), but has also affected species with a wide range of distribution. Bird populations are declining more rapidly in countries with intensive agricultural activities, particularly in Europe and North America (Quinn *et al.*, 2017). In addition to land-use change, several aspects of intensive agriculture have an impact on bird communities, including the use of pesticides, which can be fatal to birds if they come into direct or indirect contact with them (Mineau and Whiteside, 2013).

Until now, numerous ecological studies have provided insights into the interactions between birds and agricultural agroecosystems. These studies have investigated a variety of topics, including the composition of bird communities, their reproduction, survival, and persistent population decline. Despite the availability of such information, there have been limited efforts to utilize it for developing conservation plans in this agroecosystem or to suggest ways of preserving the non-arable surrounding areas and maintaining the diversity of the landscape. These applied studies are particularly scarce in countries with emerging economies, where it is especially important that such work be promoted. The purpose of this review is to provide a summary of the current state of knowledge regarding the effects of intensive agriculture on birds. Additionally, it aims to identify strategies for conservation, areas of potential progress, and future research opportunities.

MATERIALS AND METHODS

We conducted a thorough review to find scientific publications concerning the ecology and interaction between birds in areas under intensive agricultural management. This search was conducted across various specialized databases: EBSCOhost, Web of Knowledge (Thomson Reuters), Scopus (Elsevier), Current Contents Connect (Thomson Reuters), Biological Abstracts (Thomson Reuters), the Journal Storage Project-JSTOR (ITHAKA), Google Scholar (Google), the Scientific Electronic Library Online (SciELO, BIREME-PAHO-WHO), and the Network of Scientific Journals of Latin America, the Caribbean, Spain, and Portugal (Redalyc-Autonomous University of the State of Mexico).

A reference list was generated containing the search terms or a combination of them in the title, abstract, keywords, or full text. Studies were identified for all available years up to 2021 using the keywords in Spanish and English. Terms were selected and combined: intensive agriculture* OR agroecosystem* OR monocultures* OR crops* OR intensive crops* OR agricultural transformation* OR cropland* OR agricultural expansion* OR modified habitats* OR plantations* OR fragmentation* OR land use change* OR grasslands* AND birds* OR avifauna* OR biodiversity* OR diversity* OR wildlife*.

Several filters were used: (i) including only publications in the research areas of agronomy, biology, biodiversity conservation, ecology, environmental sciences, and forestry; (ii) including only scientific articles and reviews, i.e., excluding manuscripts "under review", "preprints" or "in press", degree theses, conference proceedings, books, book chapters, technical brochures, and other types of non-peer-reviewed literature; (iii) including only publications that evaluated the impacts of intensive agriculture on birds, classified as intensive based on an index or gradient of land use intensification by agriculture; and (iv) including only publications considering cereal, vegetable, and perennial crops such as vineyards, excluding other agroecosystems such as oil palm, cacao, and commercial plantations such as coffee plantations, since these agroecosystems have already been subject to recent reviews.

The studies were categorized in a systematic manner based on the topics of ecology, management, and conservation covered in each publication. This led to the identification of seven primary research themes: 1) Intensive agriculture and its general impacts; 2) food resources and intensive agriculture; 3) impacts on phenotype and health characteristics; 4) impacts on breeding biology; 5) agrochemicals and other contaminants; 6) impacts on population and community structure; and 7) conservation practices.

RESULTS AND DISCUSSION

Intensive agriculture and its general impacts

The interest in the global problem of agricultural intensification and its impact on bird populations is demonstrated both in the frequency of studies published on all continents (Figure 1A) and in the conservation efforts in various agroecosystem types. Our literature review revealed 890 papers containing information on the impact of intensive agriculture on bird ecology up to 2021 (Figure 2). Most of the information and studies regarding the interaction between birds and this agricultural system are from developed European countries such as the United Kingdom, Spain, and France, as well as the United States of America, Canada, and Latin American countries such as Argentina, Mexico, and Costa Rica (Figure 1B).

This is consistent with the increasing agricultural intensification in these countries in recent decades. Most of the publications evaluated bird interactions with this agroecosystem type, mainly referring to population and community structure, which is the most abundant topic on a global scale, accounting for more than 30 % of the published studies (Figure 3A). On this topic, there are reports on the diversity and density of some species, particularly those that are threatened or have some other vulnerability status. Such is the case of raptors that have experienced dramatic population declines due to effects on eggshell thickness, delay in laying, and chick malformations (Johnson *et al*., 2011).

Another example is vultures, whose population decline is mainly due to the use of pesticides and has affected ~78 % of vulture species in various regions of the world (Plaza *et al*., 2019). The Otididae family, particularly the Little Bustard (*Tetrax tetrax*), has

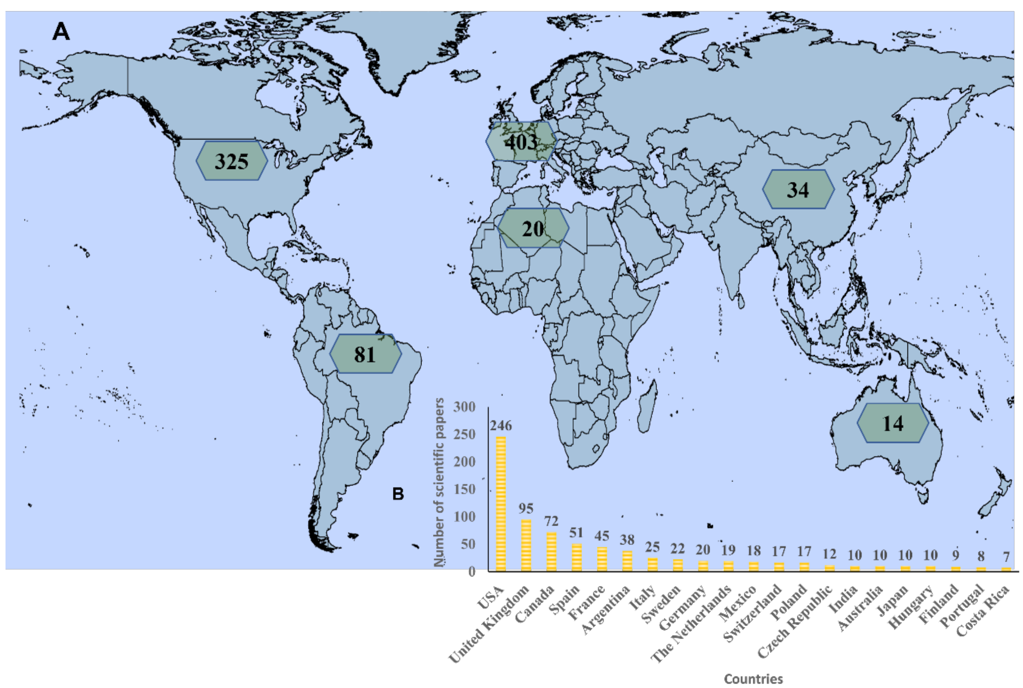

Figure 1. A: Geographical distribution of published studies (N = 890); B: best represented countries in terms of the number of publications.

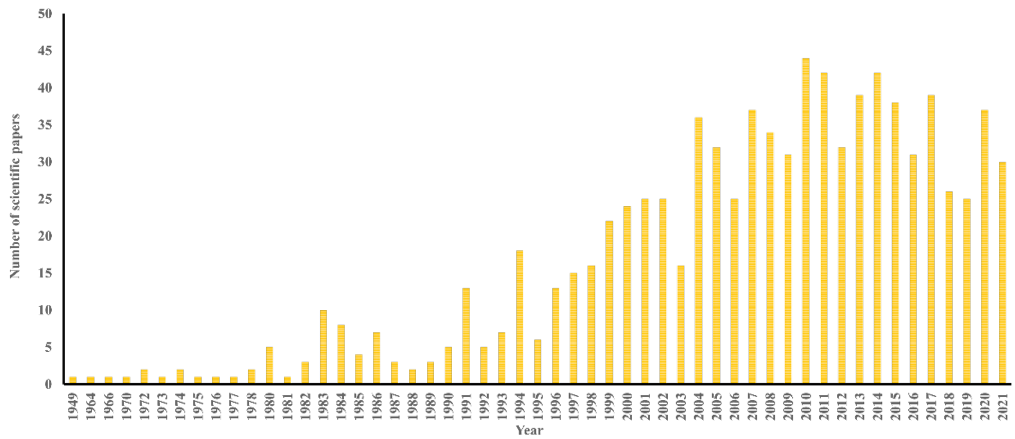

Figure 2. Temporal distribution of published studies (N = 883).

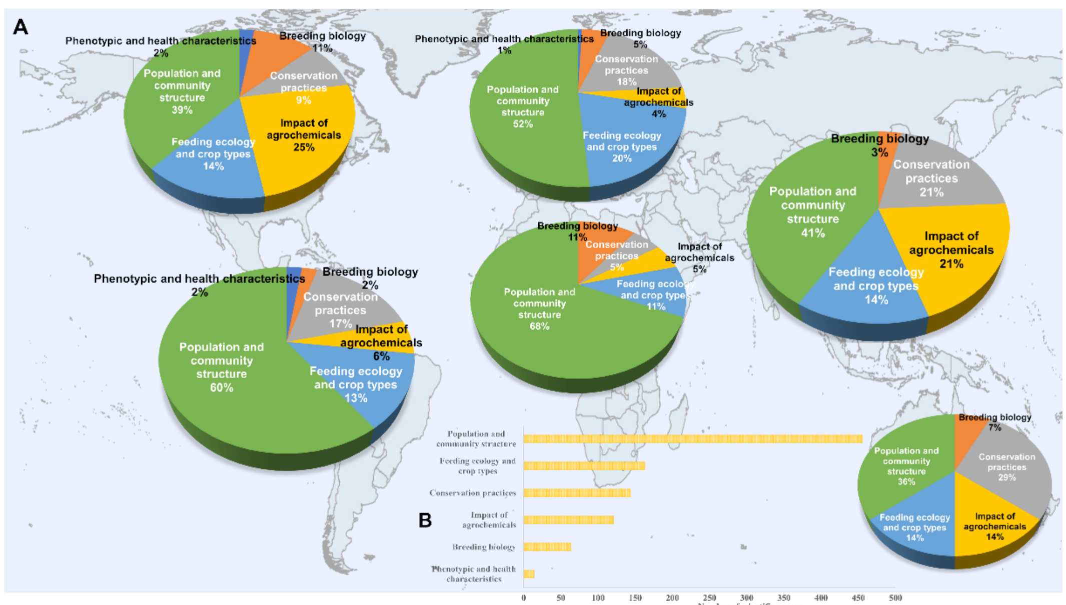

Figure 3. Geographical distribution of published studies according to the topic. A: by region; B: global.

also been significantly affected. This is a globally near-threatened bird species, with an estimated population in southeastern France of more than 500 male individuals at the beginning of the twenty-first century; however, there has been a population decline of ~50 % in recent years due to the loss of grasslands (Delgado and Moreira, 2010).

On the other hand, the direct and indirect effects of these systems on reproduction, survival, body condition, and physiology have been reported in species such as aerial insectivores such as the Corn Bunting (Emberizidae: *Emberiza calandra*) and Tree Swallow (Hirundinidae: *Tachycineta bicolor*), among others (Rioux-Paquette *et al*., 2014), although studies on these topics are scarce in the literature (Figure 3A). There appears to be a shortage of research on the functional diversity, dietary patterns, toxicology, and overall impact on the health of birds in areas with intensive agriculture practices (Figure 3B). This is an area of opportunity since birds are sensitive to changes in agriculture, with effects on individual characteristics such as sex ratio, immunology, and body weight.

Food resources and intensive agriculture

The presence of birds in agricultural areas is largely determined by food availability. Nonetheless, the use of agrotoxics to increase crop yields can decrease the population of insects, reducing food sources. This makes insectivorous birds particularly vulnerable, contributing to the global decline of this group (Reif and Hanzelka, 2020). Many studies on this topic have focused on Europe and North America. Specifically, in Europe, research has indicated that a large portion (77 % of the threat faced by birds) can be traced back to the depletion of food resources due to alterations in agroecosystems (Johnson *et al*., 2011). In the Netherlands, Geiger *et al*. (2013) reported that the Skylark (Alaudidae: *Alauda arvensis*), a typical farmland bird whose populations have decreased sharply, prefers cereal grains. However, at the end of the harvest, the number of grains in their diets decreases and is replaced by less profitable foods such as seeds and leaves. It has also been documented that in vineyards, conventional management systems provide fewer food resources for birds than alternative systems (Assandri *et al*., 2017).

In North America, a decrease in insectivorous birds has been documented. This includes the Tree Swallow, a species that primarily feeds on Diptera and has been greatly affected by agricultural intensification (Rioux-Paquette *et al*., 2014). Bellavance *et al*. (2018) analyzed the boluses (the food provided by adult birds to their chicks) of this swallow, finding that the dipterans that composed most of the diet (67.1 % of the samples) became less abundant as intensively cultivated areas increased. On the other hand, the edges of agricultural fields represent an important habitat for insectivorous birds as they support higher prey densities than crops (Bellavance *et al*., 2018; Šálek *et al*., 2021). Another factor determining resource availability is pesticide use, which alters the abundance, phenology, and behavior of insects (Stanton *et al*., 2018).

The crops grown can have a significant impact on the nesting and feeding habits of various bird species, and these habits differ across the world. Differences in age, flowering season, fruiting, and crop management practices influence bird behavior and how they use agroecosystems (Johnson *et al*., 2011). For example, the Eurasian Skylark lives mainly in cultivated areas with low heights and vegetation cover, with a higher density of individuals in cereal and potato (*Solanum tuberosum* L.) crops (Geiger *et al*., 2013).

Vineyards located in the European Mediterranean region are one of the most widely grown perennial crops. From 1988 to 2010, their cultivation area expanded by 70 % in non-Mediterranean regions. This growth has resulted in increased local intensification, which has had an impact on habitat loss and biodiversity (Assandri *et al*., 2017). For example, the presence of plant cover on the ground is the primary factor that affects the selection of feeding sites for the Woodlark (Alaudidae: *Lullula arborea*); this condition is met in integrated production vineyards but not in conventional vineyards, which cover more than 95 % of the area and have no plant cover due to the use of herbicides (Assandri *et al*., 2017).

In North America, corn and soybean fields are the habitats least visited by female Peregrine Falcons (Falconidae: *Falco peregrinus*) during the nesting season, as they prefer wetlands. It has also been pointed out that certain grassland-type crops, such as switchgrass (*Panicum virgatum* L.), provide a higher-quality habitat, which favors the bird community. Species associated with forest habitats benefit the most from this heterogeneity, although high heterogeneity may have the opposite effect in landscapes with large amounts of crop cover since biodiversity decreases regardless of crop heterogeneity (Wilson *et al*., 2017).

In contrast, waterfowl benefit from irrigated crops such as lucerne (*Medicago sativa* L.), grasses, and rice (Katayama *et al*., 2015). In Latin America, soybean fields account for more than 50 % of agricultural production in Argentina; however, granivorous, insectivorous, and omnivorous species have responded negatively to this crop type. Pigeons use the fields more frequently before planting, while aerial foragers use the interior of the fields more frequently (Johnson *et al*., 2011).

Impacts on phenotype and health characteristics

Most of the studies on the impact of intensive agriculture on bird phenotypes and health have focused on the Tree Swallow. For example, Pigeon *et al*. (2013) evaluated the effect of habitat quality on the proinflammatory response to phytohemagglutinin (PHA), an indicator of immune function, under contrasting agricultural practices; reproductive adult females from intensive agriculture habitats exhibited a lower proinflammatory response to PHA than those from non-intensive areas.

For their part, Stanton *et al*. (2017) documented that changes in insect biomass can influence antioxidant levels, leading to oxidative stress that affects health. In another study, the variation in the body mass of adult individuals of the Tree Swallow showed a substantial decline of the population (19 % occupancy rate), mirrored by decreasing body mass. This trend was especially severe in females, representing a total loss of 8 % of their mass (Rioux-Paquette *et al*., 2014).

The food guild has an impact on the body condition of birds in agriculture. During migration, the Snow Goose (Anatidae: *Anser caerulescens*) uses both marshlands and cereal crops such as rice, corn, and wheat to increase its lipid content. Studies have revealed that geese that choose to spend the winter season in marsh habitats possess lower lipid amounts compared to those that prefer crops. This indicates that there is a higher energetic compensation for the abundance of food in agricultural areas (Fowler *et al*., 2020).

Impacts on breeding biology

Bird reproductive success is important to population dynamics. While many studies have been conducted in Europe (Figure 3A), the impact of intensive agriculture on this topic remains one of the least studied areas (Figure 3B). In temporarily abandoned fields or in systems that were set aside, Skylarks had a reproductive success rate of 44 %, which is much higher than the reported 11 % in cereal fields that are under intensive management (Geiger *et al*., 2013).

In France, Eurasian Stone-curlew populations (Burhinidae: *Burhinus oedicnemus*) decreased by more than 20 %, and the nest survival rate decreased by 80 % over 14 years of monitoring due to resource scarcity (Gaget *et al*., 2018). In Switzerland, monitoring the effects of landscape structure on Barn Owl (Tytonidae: *Tyto alba*) reproductive performance showed no significant associations, indicating little variability between habitats due to landscape homogenization (Frey *et al*., 2011).

Other studies have evaluated the reproductive success of Corn Bunting, reporting that the foraging habitat of adults was significantly biased toward sites of higher invertebrate density, particularly in areas with a high abundance of herbaceous plants and sites that received fewer herbicide applications. This factor was correlated with the weight and survival of the chicks. The effect of pasture arrangement on crops and the selection of nesting sites by Buntings has been studied. It was discovered that placing strips of pasture in the middle of fields increased the survival rate of nests by 400 % and improved the population trend. In areas with a different type of pasture structure nearby, a lower survival rate was observed.

Negative impacts on reproductive success have been reported in vineyards. Assandri *et al*. (2017) evaluated the nesting density, nesting site selection, and reproductive success of various birds in a highly intensive vineyard system, finding high nesting success in the Common Chaffinch (Fringillidae: *Fringilla coelebs*) and the Song Thrush (Turdidae: *Turdus philomelos*). However, despite the high nesting success, overall reproductive success was low since more than 50 % of the nests were abandoned before egg-laying. This depended largely on on-site selection, food availability, and nest predation.

On the other hand, some birds take advantage of the resources offered by intensive agricultural systems. The Common Quail (Phasianidae: *Coturnix coturnix*) is attracted to agricultural fields and adapts its reproductive strategies to the new habitat, which could be because fertilizers increase crop yield and thus seed abundance, a basic component in the quail diet (Kosicki *et al*., 2014). In Asia, the loss of wetlands has been documented to affect the habitat quality of waterfowl such as the Sarus Crane (Gruidae: *Grus antigone*) and the Black-necked Stork (Ciconiidae: *Ephippiorhynchus asiaticus*), two large waterbirds of conservation concern. This loss reflected a 9.7 % reduction in crane pairs and a 6.7 % reduction in jabiru pairs (Gopi-Sundar, 2011).

Agrochemicals and other contaminants

Over the past century, the populations of many bird species have significantly declined, mostly because of exposure to pesticides. This can occur through direct contact or indirectly by consuming contaminated food or water. For example, in the United States, it has been estimated that 10 % of bird mortality is caused directly by pesticides, while in Canada, 2.7 million cases of avian mortality are reported annually (Stanton *et al*., 2018).

The increased frequency of the application of pesticides, such as fungicides and insecticides, has gone hand in hand with the population decline of various birds, specifically insectivores (Reif and Hanzelka, 2020). Among the potential risks of pesticides are acute toxic effects caused by direct consumption through treated seeds, as well as indirect effects such as the depletion of food resources (Hallmann *et al*., 2014). Organochlorine (OC) pesticides were introduced in the 1950s, and their effects were so blatantly harmful to birds that authorities were forced to ban their use; however, due to their high persistence and biomagnification capacity, they may still present potential risks (Tassin de Montaigu and Goulson, 2020).

Herbicide use has also been linked to fewer specialized species than generalist species in agricultural fields. The effect is exacerbated by herbicide-tolerant genetically modified crops that negatively impact birds due to the reduced availability of seeds and insects (Chiron *et al*., 2014). It has been found that the use of insecticides in North America has a greater negative effect on birds compared to other factors, such as the size of the cultivation area. It has also been noted that the rate of application and toxicity of the insecticides are important factors that contribute to mortality. Mineau and Whiteside (2006) evaluated the lethal risk of insecticides from 1991 to 2003 in different crop types, with the pesticides used in maize, cotton, and alfalfa being responsible for the highest potential mortality in birds.

This risk has decreased to some extent with the replacement of highly toxic pesticides with less toxic ones. In Canada, studies have been conducted to evaluate the exposure of Tree Swallows and Eastern Bluebird (Turdidae: *Sialia sialis*) to organophosphate pesticides in apple orchards, reporting significant cholinesterase inhibition in exposed individuals. In another study, populations of American Robin (Turdidae: *Turdus migratorius*), House Sparrow (Passeridae: *Passer domesticus*), Mourning Dove (Columbidae: *Zenaida macroura*), and Western Meadowlark (Icteridae: *Sturnella neglecta*) were negatively correlated with the use of carbamate and organophosphate insecticides such as carbofuran and terbufos applied to canola crops (*Brassica napus* L.) (Mineau *et al*., 2005).

In Argentina, Swainson's Hawk populations (Accipitridae: *Buteo swainsoni*) collapsed due to the extremely high use of the organophosphate insecticide monocrotophos (Johnson *et al*., 2011). Similarly, high concentrations of organochlorines have been found in Patagonian raptors compared to species from other regions, which suggests that they are still widely used in agricultural areas. Other contaminants of emerging concern (bioaccumulative CECs, such as polybrominated diphenyl ethers (PBDEs) and perfluorinated substances) can be found along a gradient from intensive agriculture to highly urbanized and industrialized areas, finding effects in the Tree Swallow on some bioindicators such as DNA damage. Other studies have shown decreased cerebral and plasmatic enzyme activity due to the use of less persistent compounds, such as organophosphates and carbamates, in several bird species that inhabit agricultural areas (Tassin de Montaigu and Goulson, 2020).

Impacts on population and community structure

In Europe, the decline in bird population abundance has been linked to agricultural intensification because of policies implemented by the European Union. For example, a decrease in bird richness has been reported in landscapes with 80 % crop cover (Zingg *et al*., 2018), while agricultural landscapes have been shown to favor the abundance of species that prefer open fields, such as Corn Bunting and Ortolan Bunting (Emberizidae: *Emberiza hortulana*) and Little-ringer Plover (Charadriidae: *Charadrius dubius*), whose populations have found ideal conditions in cornfields, coupled with the availability of water sources and sandy or rocky patches that favor the construction of their nests. Bird diversity can vary according to the type of crop as well as the availability of non-agricultural habitats such as fallow land and grasslands. In the Baltic region, the bird community was compared in areas with annual crops at different degrees of intensity, finding that the population abundance of specialist birds was 20 % lower in the more intensive areas compared to the less intensive ones (Herzon *et al*., 2008). Austria is dominated by small-scale agriculture, compared to the Czech Republic. Large-scale agriculture, bird abundance, and richness were about 1.5 times greater in Austria, which was attributed to the heterogeneity of the landscape (e.g., the surface of the cultivation area, edge vegetation) (Šálek *et al*., 2021). Similarly, in olive orchards (*Olea europaea* L.), it has been reported that approximately half of the bird species evaluated (14 of 32 species) decreased in response to intensification, resulting in a decline in species richness by 22 and 44 %, respectively, when comparing intensive and super-intensive orchards to traditional orchards.

Landscape homogenization and agricultural practices are partly responsible for the marked loss of bird diversity representative of farmland. Several species have been used as models to evaluate population changes due to agricultural intensification, including the Skylark. This species is common to European agricultural lands and is used as a model due to its sensitivity to agricultural practices. Population decline in this species has been associated with the degree of intensification (Geiger *et al*., 2013). However, several reports indicate that their populations tend to benefit from open crop fields and low-lying pastures, while their abundance is lower in areas of corn and canola crops (*Brassica napus* L.). A similar trend has been observed in the Little Bustard, whose populations have decreased between 48 and 50 % due to the loss of grasslands in recent decades (Delgado and Moreira, 2010).

In another study, intensification, evaluated by the degree of pesticide use, altered the composition of bird communities; the proportion of herbivorous birds decreased, and although generalist species dominated the remaining population, they were also negatively affected by the simplification of the landscape (Chiron *et al*., 2014). In Asia, intensive rice fields (*Oryza sativa* L) provide an important habitat for waterfowl by creating artificial wetlands that provide suitable feeding and shelter habitats. However, agricultural intensification in this crop is considered a threat to some species, such as herons (Ardeidae) and shorebirds, due to a decrease in the abundance of important prey species, such as invertebrates, fish, and frogs (Katayama *et al*., 2015).

In Latin America, the publications primarily focus on the fields of the Argentine Pampas, where agricultural expansion and intensification have affected diversity in different ways. In this region, the loss of grasslands due to the expansion of crops such as soybean has contributed to the decline in species richness and abundance. However, the abundance of generalist species, such as the Rufous-collared Sparrow (Emberizidae: *Zonotrichia capensis*), has increased as more areas are expanded for agricultural practices, indicating a greater tolerance of this species to farming activities, reaching similar abundances both in large-scale farmlands with greater intensification and in smaller-scale farmlands (Bellocq *et al.*, 2011).

An important factor in intensive agricultural systems is the irrigation network, since important riparian environments are created for many birds and maintain a high richness in this agroecosystem. In Mexican agricultural regions, irrigated agriculture can increase food resources by increasing insect abundance, which in turn is reflected in a greater abundance of insectivorous birds (Villaseñor and Hutto, 1995). Despite the variability of farming practices and wide variation in the scale of research on bird community structure, studies of the effects of intensive farming systems have generally shown lower bird richness and abundance compared to forest habitats and even compared to smaller-scale and/or less intensified agricultural systems.

Conservation practices

The impact of agriculture on natural ecosystems like forests, grasslands, and wetlands is clear. These environments have been converted into vast areas of monoculture, which has had a significant impact on the populations of resident and migratory birds. The transformation has affected the structure of bird communities, their reproductive success, and the availability and timing of food and nesting habitats. In addition to reduced health due to exposure to a high number of agrochemicals. Currently, alternatives are being explored within intensive agriculture to mitigate negative effects and even benefit bird populations by incorporating landscape designs such as vegetation corridors, conservation of natural patches, and water bodies, among others (Conover *et al*., 2014; Hiron *et al.*, 2013).

Strategies aimed at conserving birds in agricultural contexts involve providing funds to develop agro-environmental plans that compensate landowners. This has been implemented in the European Union and has been positively correlated with bird diversity (Hiron *et al*., 2013). Other conservation strategies are to maintain the heterogeneity of the agricultural landscape since this can have a similar or greater benefit for biodiversity than the increase in semi-natural cover or even the decrease in the intensity of land use. It has also been pointed out that some management practices, such as leaving fallow land, positively influence bird diversity.

Another strategy could be organic farming, which has increased bird abundance in areas of more intensive agriculture. Specifically, in Canada, organic farms do not use conventional pesticides and synthetic fertilizers and have been reported to support higher bird richness as they provide greater feeding opportunities for birds, corroborating reports from other regions (Kirk *et al*., 2020). The presence of wetlands is also bird-friendly and could be implemented as a beneficial alternative for their conservation. Additionally, several authors have proposed other strategies that offer important ecological benefits, favoring not only the increase in bird diversity but also nesting success by providing nesting, feeding, and resting habitat, movement corridors, and protection against predators, such as buffer zones, patches, and edges with various types of vegetation (Conover *et al*., 2014).

While changes in some agricultural practices may be relevant at the local scale (e.g., decreasing the use of pesticides), other management actions should take place at the landscape scale (maintaining specific habitats for the nesting of different species with different needs), allowing landscape complementation or supplementation. Preserving biodiversity and limiting biotic homogenization require the conservation of heterogeneous landscapes to promote taxonomic diversity. Agricultural policies need to be adapted according to the regional landscape. Reducing farming intensity through moderated pesticide and mechanical practices may increase bird biodiversity, as is typically the goal of integrated management systems and "good farming practices", and this must be considered mainly in emerging countries. These strategies can be applied in intensive agricultural regions of Latin American countries, such as Argentina, Mexico, and Costa Rica, whose expansion and agricultural intensification have been increasing in the last decades, resulting in habitat and landscape heterogeneity loss.

CONCLUSIONS

Agricultural intensification has had a negative impact on many birds around the world, resulting in declining population sizes and reduced species diversity. The effects are particularly severe for birds that rely on insects, seeds, or meat for food, and they are observed not only within crop fields but also in the surrounding areas. These have occurred largely due to landscape simplification, i.e., homogenization, and associated practices such as the use of agrochemicals. Intensive agriculture has specific effects on immune function, increased oxidative stress, decreased body mass, decreased reproductive success, and bird mortality due to agrochemicals. Conservation efforts for bird diversity and "good farming" practices have shown promising results. However, continued long-term monitoring is necessary to detect changes in bird abundance, particularly in topics such as functional diversity, diet, health, and genetic alterations, and mainly in countries with emerging economies.

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