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Long-term monitoring of a flagship bird species in agroecosystems enhances stakeholder engagement in biodiversity conservation

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A B S T R A C T

Conservation efforts are needed in the face of the rapid decline in farmland birds over the past decades. While existing conservation strategies have shown limited success, there is a growing recognition of the role of farmers as primary stakeholders in agroecosystems conservation. We applied the "Human Dimension" approach, which emphasizes the importance of human perspectives on wildlife conservation, to assess whether a long-term monitoring project of barn swallows *Hirundo rustica*, ongoing since 1999, has heightened farmers' awareness regarding biodiversity protection. Indeed, while monitoring serves to track population trends and understand the factors influencing species dynamics, it also provides opportunities for interaction between researchers and farmers. Through in-person administration of the questionnaire, we investigated the impact of the barn swallow monitoring project on farmers' environmental consciousness in terms of their perceptions of the environment, knowledge about priority habitats for biodiversity, and preferences for environmental awareness strategies. Subsequently, we investigated whether environmental consciousness and the participation in the barn swallow monitoring project translated into their inclination to implement costless actions for barn swallow conservation. Our findings suggest that the barn swallow monitoring project may not have enhanced farmers' environmental consciousness. However, a higher environmental consciousness and the engagement in the barn swallow monitoring project were associated to a greater willingness to undertake actions in support of barn swallows. This study highlights the potential of long-term projects in fostering the conservation of charismatic species through establishing a mutual trust between farmers and researchers over years of monitoring, with cascading benefits for the barn swallows.

1. Introduction

The last decades have witnessed a rapid decline in farmland bird populations, which can be attributed to various landscape and management changes (Donald et al., 2001), largely caused by a progressive agricultural intensification, land abandonment and climate change. These changes have led to negative population trends in 71 % of farmland bird species across Europe (Donald et al., 2006), and the decline of long-distance migrants is particularly concerning (Vickery et al., 2014, 2023). There is therefore urgent need for

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conservation efforts addressing the challenges faced by these birds and mitigating the negative consequences of agricultural intensification on their habitats.

Traditional approaches to animal conservation, such as the establishment of protected areas, have shown limited success for farmland birds (Donald et al., 2002; Palacin and Alonso, 2018; Sicurella et al., 2018a), which mostly inhabit human-associated and production-oriented landscapes. Typically, these environments are excluded from protected areas, except for few low-intensity and traditionally farmed landscapes, which are included into protected areas in the European Union according to the requirements of the Habitat Directive (Council Directive 92/43/EEC 1992). In addition, the European Common Agricultural Policy (CAP) has indirectly led to a widespread agricultural intensification, with a resulting decline in suitable habitats for many farmland birds (Donald et al., 2002).

To reduce the contradiction between CAP payments and conservation policies, recent CAP versions have progressively included payments (such as Agro-Environmental Schemes, greening obligations and eco-schemes) mostly targeted to the adoption of biodiversity-friendly practices (Tarjuelo et al., 2020, 2021; Sanz-Pérez et al., 2021). Nevertheless, such efforts are usually limited to extents that are too small to compensate for the negative general effect induced by CAP, as evident from many species-specific examples (Brambilla et al., 2021) as well as from national trends (e.g. the collapse of farmland birds in the Czech Republic after its EU accession in 2004; Reif and Vermouzek, 2019). Therefore, there is a need for new approaches that can promote the conservation of farmland birds without conflicting with other policies and without affecting farmers' profits. To achieve this goal, it is necessary to harness the potential role of farmers as primary stakeholders for the conservation of biodiversity in farmlands (Katuwal et al., 2021). However, this perspective is still relatively limited in the existing scientific literature, even if some examples are arising (e.g. for vineyards Brambilla and Gatti, 2022).

In recent years, a novel approach to managing local biodiversity has gained prominence. Known as the "Human Dimension" approach (Bath, 1998), it underscores the importance of the interactions between humans and the surrounding environment. This approach aims to explore public attitudes, beliefs, and knowledge regarding wildlife species and the associated conservation issues (Bath, 1998). Its core insight is that enhancing species and habitats conservation requires integrating both natural and social sciences, thereby enhancing the robustness and effectiveness of conservation decisions (Bennett et al., 2017). Of particular interest in the human dimension approach is the understanding of people's attitudes and emotions toward conservation to develop engaging, participatory, and locally driven conservation policies (Nesbitt et al., 2023). This approach has been primarily implemented in contexts characterized by high conflict between humans and nature, such as interactions with large predators (Bath and Majic, 2001; Ericsson et al., 2006; Bisi et al., 2007; Bath et al., 2008; Bruskotter and Shelby, 2010; Dickman et al., 2013; Hughes, 2018; Marks, 2019; Nesbitt et al., 2020), while its application in studies related to the decline of farmland birds remains limited (Bonthoux et al., 2010; Kross et al., 2018; Katuwal et al., 2021; Geladi et al., 2022).

Overall, human dimension studies on farmland birds highlight that farmers' perception, knowledge and attitudes towards the focal species significantly influence their engagement with on-farm conservation programs (Katuwal et al., 2021; Geladi et al., 2022). Moreover, educational programs can foster positive perceptions and address knowledge gaps, which often lead to misconceptions about the impact of farmland bird conservation strategies on agricultural activities. Unfortunately, no studies based on the human dimension approach have been conducted in Europe, where most studies addressing the ecological causes of farmland birds decline rely on long-term monitoring projects and/or on species ecological requirements (Fujisaki et al., 2008; Heldbjerg et al., 2018; Busch et al., 2020; Bowler et al., 2021; Díaz et al., 2022).

The barn swallow (*Hirundo rustica*) is a migratory farmland bird whose populations have sharply declined across many parts of its European range (PECBMS, 2021). Renowned for its cultural and aesthetical value, this species plays a charismatic role in agro-ecosystems (Sicurella et al., 2014; Roseo et al., 2024). Since 1999, a long-term monitoring project focusing on this species has been active in northern Italy, at Parco Adda Sud (Ambrosini et al., 2002a, 2012; Sicurella et al., 2014). The collected data highlighted an average yearly reduction of 3.2 % in the number of breeding pairs and the extinction of 18.9 % of the colonies in the study area (Roberto Ambrosini, personal information). The decrease in the population size can be mainly attributed to the transition from traditional to intensive farming (Ambrosini et al., 2012) and to alterations in ecological conditions along migration routes (Saino et al., 2004; Sicurella et al., 2016). The barn swallow monitoring project, which surveyed approximately one hundred farms biweekly between April and July each year, facilitated discussions between researchers and farmers on topics such as biodiversity and nature conservation, as well as the causes underlying the decline of the barn swallows.

Based on this long period of interaction, we applied the human dimension approach to assess whether the farmers who have been participating in the barn swallow monitoring project demonstrate heightened awareness regarding biodiversity protection compared to those who have not participated. In-person administration of the questionnaire was conducted to understand the impact of our barn swallow monitoring project on the farmers' environmental consciousness in terms of their perceptions of the environment, knowledge about priority habitats for biodiversity, and preferences for environmental awareness strategies. Furthermore, we investigated whether different levels of environmental consciousness, and their participation to the barn swallow monitoring project, translated into the farmers' inclination to implement small, costless measures for the conservation of the barn swallows.

2. Methods

2.1. Data collection

The study was conducted in Lombardy, Northern Italy, at Parco Adda Sud, a regional agricultural park of 24,260 ha located in the provinces of Lodi and Cremona (coordinates of the approximate centre 45°19'N, 9°40'E, Fig. 1). From February to May 2022, 44 farmhouse owners who had participated in the barn swallow monitoring project for over 20 years and 64 farmhouse owners who had not previously been involved in the barn swallow monitoring project were contacted. Among the farm-owners participating in the barn swallow monitoring project, only 27 % refused to complete our questionnaire. Conversely, only 50 % of the contacted farm-owners not involved in the barn swallow monitoring project completed it. In both groups, reasons for non-participation included momentary unavailability, distrust towards interviewers, and reluctance to collaborate with academics. The final sample size was thus 32 farm owners involved in the barn swallow monitoring project and 32 not involved. Formal permission for questionnaire and study approval was obtained and signed by the Ethics Committee of the University of Milan (March 28, 2022, n.30/22).

In-person administration of the questionnaire was conducted to ensure a comprehensive understanding of the participants' perspectives, as this method is flexible and interactive and provides a deep understanding of the propensity and aptitude of a relatively small sample of people (Young et al., 2018). The questionnaire underwent a pre-testing phase among a small group of farm owners to ensure its comprehensibility, unambiguousness, and acceptability.

The questionnaire, presented in Table 1, was divided into 4 sections, named "demography", "perception", "priorities", and "awareness" aimed at investigating:

(i) Demography – Demographic data. We collected socio-demographic data of the participants including gender, age, and the highest scholar degree achieved. Age classes were selected according to the definition of "young farmer" given by the CAP: age < 25 years; age included in the range 25–40 years; age included in the range 40–60 years; age > 60 years.

(ii) Perception – interviewee's perception of potential threats to the environment. This section contains questions aimed at investigating: a) the perceived impact of several activities conducted in the park, i.e. crop mosaic, sewage sludge spreading, and transport system; b) the perceived impact of the major known drivers of biodiversity loss, i.e., urbanization, the presence of alien species, and pesticides; c) the interviewee's knowledge regarding the existence of a decline in barn swallow populations; d) the perceived impact of climate change as a driver of this decline;

(iii) Priorities – Habitat-types perceived as priorities for biodiversity conservation, such as e.g. hedgerows and permanent meadows;

(iv) Awareness – The suggested strategies to raise awareness regarding biodiversity conservation, i.e., implementing the number of protected areas, incentivizing large industries to develop sustainable products, and encouraging school visits to protected areas.

In addition to the four sections of questions outlined above, we proposed to farmers eight actions that may potentially encourage barn swallow nesting or prevent colony extinction. These actions are mainly costless; however, they may entail some possible

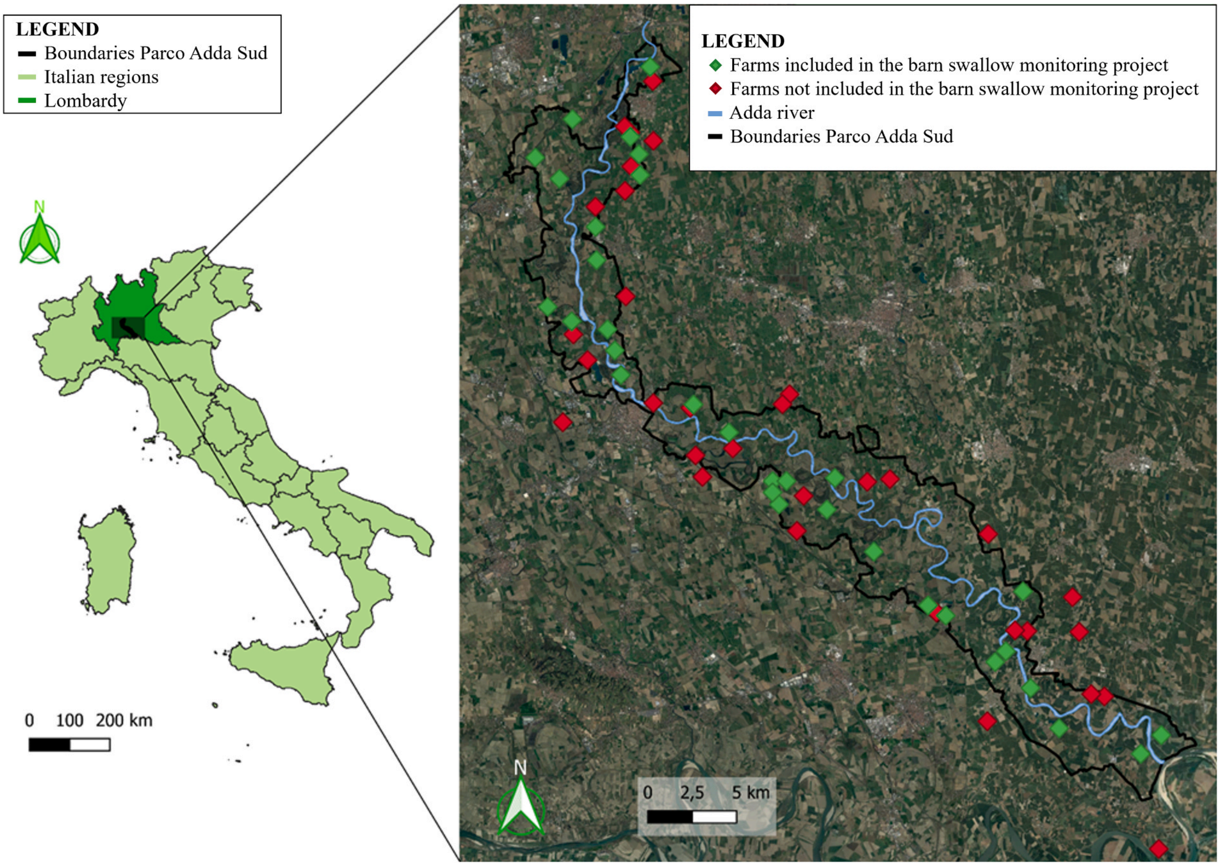


Fig. 1. Map showing the location of the farms where the interviewees were carried out. Number of farms involved in the barn swallow monitoring project =32; number of farms not involved in the barn swallow monitoring project = 32.

Table 1
Questionnaire structure, variables and scale.

Farm code		Involved in the barn swallow monitoring project			☐YES	☐NO
Demography						
Gender	☐Female	☐Male	☐NA			
Age	☐≤ 25	☐$25<x\leq 40$	☐$40<x<60$	☐≥ 60	☐≥ 60	
Education	☐Primary school	☐Secondary school	☐Bachelor's degree	☐Master's degree	☐Ph.D.	
Perception						
What is the impact of the following activities in the Adda Sud Park?	Corn monoculture	☐Extremely negative	☐Negative	☐Neutral	☐Positive	☐Extremely positive
	Permanent meadows	☐Extremely negative	☐Negative	☐Neutral	☐Positive	☐Extremely positive
	Crop mosaic	☐Extremely negative	☐Negative	☐Neutral	☐Positive	☐Extremely positive
	Infrastructures	☐Extremely negative	☐Negative	☐Neutral	☐Positive	☐Extremely positive
	Animal farms	☐Extremely negative	☐Negative	☐Neutral	☐Positive	☐Extremely positive
	Sewage sludge spreading	☐Extremely negative	☐Negative	☐Neutral	☐Positive	☐Extremely positive
	Transport system	☐Extremely negative	☐Negative	☐Neutral	☐Positive	☐Extremely positive
What are the main threats to biodiversity in the Adda Sud Park?	Urbanization	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Pesticides	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Presence of alien species	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Tourism	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
Do you think the barn swallow population decreased in the last ten years?				☐YES	☐NO	☐I don't know
Do you think global warming is a driver of barn swallow population decline?				☐YES	☐NO	☐I don't know
Priorities						
How important are the following environments for biodiversity?	Rivers	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Channels	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Cereal fields	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Permanent meadows	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Hedgerows	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Poplar plantations	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Tree rows (linear elements)	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Woodlands	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Fodder crops	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
Awareness						
How would you raise public awareness about nature conservation and protection?	Encouraging school visits to protected areas	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Incentivizing large industries to develop sustainable products	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Incentivizing farms to adopt sustainable practices	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Encouraging families in sustainable lifestyles	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
	Implementing the number of protected areas	☐Not important	☐Slightly important	☐Fairly important	☐Important	☐Very important
Required costless actions that can improve the conservation status of barn swallow						
1. Let the swallows enter the garage even if it could get dirty					☐YES	☐NO
2. Install artificial nests					☐YES	☐NO
3. Place a bar beneath the nests to prevent the dirt					☐YES	☐NO
4. Avoid removing nests during the breeding season					☐YES	☐NO
5. Forbid removal or, if absent, promote the installation of wooden beams in case building renovation is planned					☐YES	☐NO
6. Avoiding using flypaper					☐YES	☐NO

(*continued on next page*)

Table 1 (*continued*)

Farm code	Involved in the barn swallow monitoring project	☐YES	☐NO
Demography			
7. Place nails or support rods on which the swallows can make their nest		☐YES	☐NO
8. Leave some cattle in the traditional stables		☐YES	☐NO

inconveniences for farmers. For instance, allowing barn swallows to nest in garages could be crucial for populations in colonies where traditional stables, their preferred nesting site (Ambrosini et al., 2002b), are no longer present, but at the same time this may cause inconveniences such as dirt on cars and walls. These eight actions are detailed in Table 1 and were used to measure the farmer's willingness to protect barn swallows. To this end, answers to these questions were summarized in a score, hereafter referred to as the conservation propensity score, corresponding to the proportion of actions a farmer was willing to take in favour of the barn swallows. This score ranged from 0, if the farmer chose to take no actions, to 1, if he or she was willing to implement all of them.

2.2. *Statistical analyses*

To check the collinearity among variables we evaluated the Variance Inflation Factor (VIF) (Zuur et al., 2009). To assess whether the responses to the questionnaire differed between farmers engaged in the barn swallow monitoring project and those who were not we used the Mann-Whitney U test (De Winter and Dodou, 2010). P-values were corrected according to the False Discovery Rate procedure (Benjamini and Hochberg, 1995) separately for each section of the questionnaire.

To assess whether farmers who have been participating in the barn swallow monitoring project demonstrated heightened awareness regarding the barn swallow protection as compared to those who have not participated, we used a two-step approach (Fig. 2) that allowed us to find the most important variables within each section of the survey (i.e. demography, perception, priorities, awareness), while reducing the number of predictors included in a final global model (Anderle et al., 2022).

Initially, to model the farmer's conservation propensity score as a function of the respondents' answers to the questions of each of the 4 sections of the survey, we applied an information-theoretic approach (Burnham and Anderson, 2002) treating each section separately. The conservation propensity score was modelled as the dependent variable in binomial GLMs. Using the dredge function from the R package 'MuMIn' (Barton, 2015), we fitted all possible binomial GLMs that included the answers to up to 4 questions from each section of the questionnaire. Models were then ordered according to increasing AIC values and those with a difference in AIC (ΔAIC) with the best model (i.e. that with the lowest AIC) ≤ 2 were selected for Model Averaging (Johnson and Omland, 2004). In the second step of the analyses, we selected from each section of the questionnaire all the predictors included in the averaged models and re-ran the same procedure. A further dichotomous variable, named "monitored", was entered at this stage of the analyses, indicating whether the farm of the interviewee had ever been part of the barn swallow monitoring project. We thus obtained seven synthetic models by averaging (full average) the most supported ones (ΔAICc < 2).

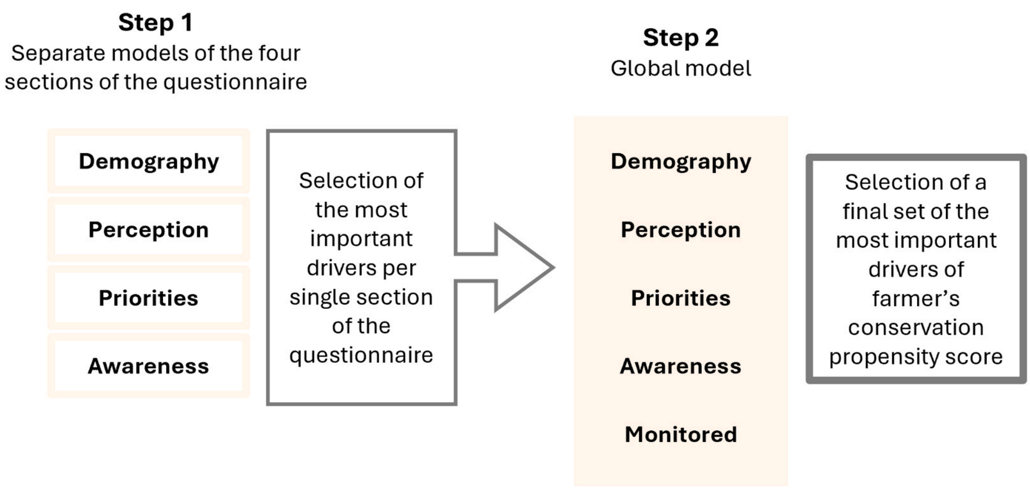


Fig. 2. Scheme showing the statistical framework adopted to evaluate the effects of different predictors included in the four sections of the questionnaire (a. Demography; b. Perception; c. Priorities; d. Awareness), as well as the inclusion in the barn swallow monitoring project, on the conservation propensity score.

3. Results

3.1. Demography

Out of the 64 farmers interviewed, 15 were females (23 %) and the other were males. The majority was more than 40-year-old, with 42 % of respondents in the 40–60 age range, and 41 % over 60-year-old. Only 13 % of the interviewees had a bachelor's or master's degree, 45 % had a high school diploma, and 42 % halted their studies after completing middle school.

The Mann-Whitney U Tests revealed no statistically significant differences between the two groups in the demographic structure of the respondents ($|z| \leq 1.12$, $P_{FDR} > 0.8$).

Model averaging (Supplemental file 1) applied to the section "demography" revealed that the conservation propensity score was higher for women and younger owners as compared to men and elders, while the education level was not included in the averaged models.

3.2. Perception

Approximately 24 % of the interviewees considered practices as crop mosaic and maintenance of permanent meadows or fodder crops as extremely positive for the environment. None of the interviewees believed that the maize monoculture is extremely positive for the environment, although 34 % of them classified it as "positive". The threat perceived as most detrimental was the presence of invasive species, with 69 % of interviewees classifying it as a "highly relevant" problem. It's noteworthy that farmers extensively discussed this issue during the in-person administration of the questionnaire. These in-depth conversations revealed that their primary concerns revolved around the coypu (*Myocastor coypus*), an ecosystem engineer capable of altering environments through its hole-digging activities, which translates into significant economic losses for farmers. Consequently, their concerns appear to be predominantly profit-oriented rather than centred on biodiversity conservation. Most of the interviewees were aware of the strong decline of barn swallow populations over the past decade and attributed this decline to climate change.

The perception of potential threats to the environment did not differ between farmers participating or not in the barn swallow monitoring project ($|z| \leq 2.37$, $P_{FDR} > 0.24$).

Model averaging (Supplemental file 1) applied to the section "perception", suggested the influence of many factors on the conservation propensity score. Indeed, the negative perception of maize monoculture, the use of sewage sludge as soil improvers, transport systems, the use of pesticides and the negative effect of climate change were related to a higher conservation propensity score. Similarly, higher conservation propensity scores were associated with the known positive effect of permanent meadows and crop mosaic on biodiversity, as well as the knowledge regarding the significant decline of the barn swallow population over the last ten-years period. All the other factors were not included into the averaged models.

3.3. Priorities

Rivers and woodlands are considered as the most important habitats for biodiversity conservation by most of the interviewees, who evaluated them as "very important" in 72 % and 59 % of cases, respectively. In contrast, hedgerows were generally perceived as the least important, with 36 % of interviewees that considered them "not important" or "negligible".

No difference in the habitat-types perceived as priorities for biodiversity conservation was found between farmers belonging to the two groups ($|z| \leq 1.63$, $P_{FDR} > 0.94$).

Model averaging (Supplemental file 1) applied to the section "priorities" suggested a negative relationship between the conservation propensity score and the perceived importance of cereal fields and poplar plantations in preserving biodiversity. Similarly, a higher conservation propensity score was associated with high perceived relevance of channels, permanent meadows, hedgerows, tree rows (linear elements) and woodlands to preserve biodiversity in the area. All other factors were not included in the averaged models.

3.4. Awareness

The interviewees believed that to enhance public awareness of nature conservation and protection, it would be pivotal to establish incentives to promote the environmental sustainability of small farms. Most people (70–80 %) considered all the proposed awareness strategies "important". The sole exception was the suggestion to increase the number of protected areas, where opinions were more polarized. Indeed, approximately 30 % of those surveyed deemed protected areas as "not important" or "not very important" for raising public awareness, while 51.5 % claimed them to be "important" or "very important".

The responses from the two groups of interviewees showed no statistically significant differences ($|z| \leq 1.47$, $P_{FDR} > 0.72$).

Model averaging (Supplemental file 1) applied to the section "awareness" revealed that individuals who advocate for incentivizing large industries to develop sustainable products, encouraging families in sustainable lifestyles and responsible consumptions, and for implementing the number of protected areas, tend to have higher conservation propensity scores. This suggests how a strong connection to the agricultural park often translates into a proactive commitment to protect its biodiversity. All other factors were not included in the most parsimonious model.

3.5. Global model

The global model highlighted the importance of seven variables (Table 2, Fig. 3). Among them, four belonged to the "perception" section, and two to the "awareness" section, with effects consistent with those observed in the separate models. Importantly, the "monitored" variable was also included and indicated that those who have been involved in the barn swallow monitoring project tended to have higher conservation propensity scores. No variables of sections "priorities" and "demography" were included.

4. Discussion

This study focused on the farmers community of Parco Adda Sud, and investigated their environmental consciousness and their attitude towards the conservation of a typical farmland bird, the barn swallow. In-person administration of the questionnaire targeted two groups of farmers: those involved in a long-term barn swallow monitoring project started in 1999, and those who had never been involved. The ongoing barn swallow monitoring project played a dual role: on the one hand, it allowed collecting data on the barn swallow breeding biology and population dynamics, and, on the other, it fostered dialogue between farmers and researchers.

Both groups of respondents shared similar demographic structures. The interviewed farmers belonged mostly to the older age classes ($\geq$ 40 years old), consistently with the well-documented age bias in the agriculture workforce (Carillo et al., 2013). Furthermore, our questionnaires were targeted at the farm owners or managers of the farms, which are rarely young farmers. In addition, most of them did not have a university degree, which is consistent with Marcellini et al., (2007), who indicated that the education levels in farmland areas within the Adda Sud Park are lower compared to the nearby urban centre of Milan. A higher conservation propensity score was attained by females, confirming a stronger inclination toward conservation among women compared to men (Czech et al., 2001; Mohai, 2014), and in younger individuals, because of the increased attention toward environmental issues among new generations (Shen and Saijo, 2008; Cialdini and Jacobson, 2021; Wallis and Loy, 2021).

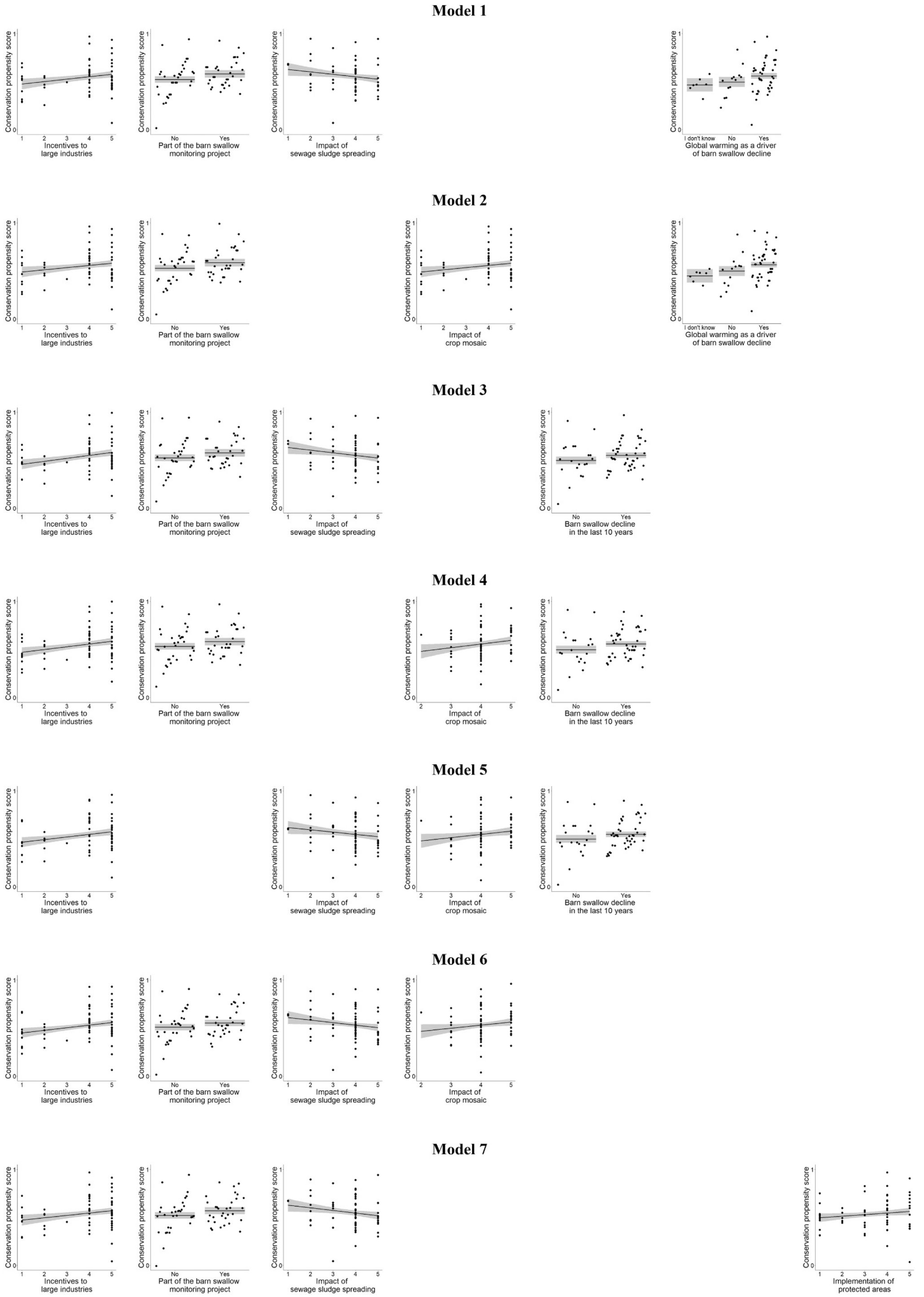
Farmers involved or not in the census demonstrated comparable levels of environmental consciousness, as indicated by the lack of differences in their responses to all questionnaire questions. None of the variables belonging to the "priorities" section included in the global model influenced the willingness to protect the barn swallows through the small-scale actions proposed. Nevertheless, in-person administration of the questionnaire with farmers highlighted important implications for agroecosystem conservation. Indeed, farmers expressed a preference for preserving natural features like rivers and woodlands over agricultural landscape elements such as hedgerows, permanent meadows, and cereal fields. However, human-modified environments, such as fodder crops, play a crucial role in the conservation and diversity of agroecosystems (Ambrosini et al., 2002a; McLendon and Butler, 2022), an information often neglected by many of the interviewees. Therefore, it is important to educate farmers about the positive contributions of some managed environments to biodiversity.

Furthermore, the responses to questions included in the "perception" section, as the impact of corn monoculture, transport system and pesticides on biodiversity, suggested that individual environmental consciousness plays a significant role in farmers' attitudes toward conservation and barn swallow protection. This is confirmed by the importance of the variables "sewage sludge spreading" and

Table 2

Best set of models, (ΔAICc $\leq$ 2 from the model with the minimum AICc), are shown for the global model. Each model is composed of 1–4 variables that can belong to different sections (Demography, Perception, Priorities, Awareness). The Monitored variable is also included. The model averaging summary (Estimate, Standard Error and Importance) for all variables is also reported.

Global model												
			Model N° / ΔAICc							Model averaging		
			1 0	2 0.26	3 1.14	4 1.57	5 1.91	6 1.91	7 1.97	Estimate	SE	importance
Monitored										0.43	0.19	0.9
Demography	Gender											
	Age											
Perception	Impact	Maize monoculture										
		Permanent meadows										
		Crop mosaic								0.28	0.13	0.52
		Sewage sludge spreading								-0.21	0.09	0.67
		Transport system										
	Threat	Pesticides										
	Barn swallow decline in the last ten years									0.43	0.2	0.35
	Global warming as a driver of barn swallow decline									-0.3	0.12	0.47
Priorities	Importance of	Channels										
		Cereal fields										
		Permanent meadows										
		Hedgerows										
		Poplar plantations										
		Tree rows (linear elements)										
		Woodlands										
Awareness	How to raise awareness	Incentives to large industries								0.21	0.07	1
		Encouraging families										
		Implementing n° protected areas								0.13	0.07	0.09



Estimate: 0.21	Estimate: 0.43	Estimate: -0.21	Estimate: 0.28	Estimate: 0.43	Estimate: -0.3	Estimate: 0.13
SE: 0.07	SE: 0.19	SE: 0.09	SE: 0.13	SE: 0.2	SE: 0.12	SE: 0.07
Importance: 1	Importance: 0.9	Importance: 0.67	Importance: 0.52	Importance: 0.35	Importance: 0.47	Importance: 0.09

Fig. 3. Graphical representation of the modelled relationship between the conservation propensity score and the variables included in the global model according to the best set of models (ΔAICc ≤ 2 from the model with the minimum AICc). Each model is composed of 1–4 variables that can belong to different sections (Demography, Perception, Priorities, Awareness). The Monitored variable is also included. The model averaging summary (Estimate, Standard Error and Importance) for all variables is also reported.

"crop mosaic" in the global model. Indeed, a higher willingness to protect the barn swallow through small actions was associated with a negative perception of sewage sludge spreading and a positive perception of crop mosaic for the environment. The spread of sewage sludge as a soil amendment on fields is extensively debated among stakeholders in Europe (Ekane et al., 2021), as well as in our study area (Costanzo et al., 2023) because of the uncertainties regarding their negative effects on both the environment and human health (Mailler et al., 2017). Given the prevailing perception that sewage sludge may have detrimental effects on ecosystems, individuals who are more environmentally conscious in this regard might also exhibit a greater willingness to contribute to barn swallow conservation efforts. The same proximate cause can also explain the positive association between the perceived impact of crop mosaic and the conservation propensity of farmers. The common understanding of the advantages of crop mosaic could also be reinforced by the recent CAP regulation (Donati et al., 2015), which now mandates crop mosaic. Finally, those aware of the decline of the barn swallow population in the park, and those who attributed this decline to climate change, demonstrated a greater inclination to be actively involved in the barn swallow protection. This might indicate that those who correctly recognize the decline of the barn swallow population, despite attributing this decline to a large-scale issue beyond their control, believe that even small-scale actions can play a role for the species' conservation.

In addition, incentives to large industries to develop sustainable products and, to a lesser extent, to families for encouraging sustainable lifestyles and responsible consumption, were perceived as strategic to enhance public awareness about nature protection. Remarkably, those who advocate for large industries to prioritize sustainability often share a genuine commitment to small-scale actions in support of barn swallow conservation within their farms. Therefore, what may seem like a de-responsibility towards large industries reflects the awareness of how deep-rooted the problem of nature conservation is. This understanding highlights the necessity for comprehensive, collaborative interventions to address the issue, which often require active participation and commitment from all the stakeholders.

Interestingly, the polarization of the answers about the importance of protected areas supports the ongoing debate on their effectiveness for farmland birds (Palacin and Alonso, 2018; Sicurella et al., 2018b). A notable percentage of farmers believe that expanding the number of protected areas does not substantially contribute to raising awareness about nature conservation. This point of view is likely influenced by the perception that the establishment of protected areas may result in the imposition of new regulations and restrictions on farmers, without previously consulting them (Nastran, 2015), which may lead to a loss in competitiveness as compared to areas outside the protected areas (Abelairas-Etxebarria and Astorkiza, 2012). At the same time, the farmers who do believe that an increase in protected areas could improve the conservation status of agroecosystems are also the ones more inclined to take specific actions in support of barn swallows.

Finally, the global model highlights the strong importance of involvement in the barn swallow monitoring project in shaping the farmers' attitudes toward barn swallow conservation. This is particularly interesting because farmers involved or not in the monitoring did not differ in their level of general environmental consciousness, thus indicating that monitoring barn swallow for several years had an effect *per se* on farmers' attitude toward the focal species. Enhancing the community's inclination toward a particular species constitutes a fundamental element of all conservation initiatives, which is why many programs focus on charismatic species already widely recognized and appreciated, with outcomes that may not always be favourable (Brambilla et al., 2013). While the long-term barn swallow monitoring project has been successful in enhancing farmers' overall perception of conservation, some key themes, such as the role of agricultural elements in promoting biodiversity and the importance of protected areas, are still not fully acknowledged by farmers. In this context, our barn swallow monitoring project assumes an even greater importance. Not only it has positively influenced farmers' general understanding of biodiversity matters, but it has also pinpointed areas where conservation and educational efforts on farmers should be directed. This targeted approach aims to enhance future cost-effectiveness by intervening precisely where conservation efforts are most needed.

4.1. Study limitations

We acknowledge some potential biases in the data we gathered. Notably, the duration of farmers' involvement in the barn swallow monitoring project varied, and it is reasonable to assume that those participating in the monitoring for 25 years may hold more favourable attitudes toward barn swallow conservation than those who have been involved for a shorter period. Moreover, if we interpret the lack of response to the survey as an indicator of limited interest in environmental and barn swallow protection, all farmers who agreed to respond to our questionnaire may already have a heightened sensitivity to environmental issues as compared to those who declined to participate. Additionally, environmental awareness among interviewees living in or close to a protected area, may be higher compared to that of farmers outside protected areas (Bonaiuto et al., 2002), regardless of their involvement in the barn swallow monitoring project.

5. Conclusions

Our study represents one of the first in Europe that applied the human dimension approach to farmland birds' conservation. We propose that long-term monitoring projects can transform people's sensitivity and encourage active participation in small-scale actions to support biodiversity conservation. This can yield educational benefits, without having to bear any additional costs. Our findings may shape the future willingness of public entities to fund such projects, as they serve not only to collect ecological data on the species of interest but also as an instrument for raising awareness in local communities. This potential increase in funding could lead to a more comprehensive understanding of the challenges faced by farmland birds, while simultaneously enhancing farmer's concern for their well-being, ultimately resulting in improved conservation outcomes. Further research should therefore be aimed at integrating social and conservation sciences to promote the conservation of charismatic species within agroecosystems.

Ethical Approval

Formal permission for questionnaire and study was obtained and signed by the Ethics Committee of the University of Milan (March 28, 2022, n.30/22).

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CRediT authorship contribution statement

Conceptualization: RA, AC; Data curation ARO, AC; Formal analysis ARO, RA, LO, MB, AC; Investigation ARO; Methodology RA, LO, MB, AC; Writing - original draft ARO, RA, MB, AC; and Writing - review & editing ARO, RA, DR, AR, LO, MB, AC.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Alessandra Costanzo reports financial support was provided by Ministry of Education and Merit. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2024.e03090.

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