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Social and ecological drivers of illegal bird hunting in the Indawgyi wetland ecosystem in Myanmar

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Abstract

Hunting and illegal bird killing are major concerns for avian conservation globally. Unsustainable bird hunting in wetland habitats, particularly those located along important flyways, has contributed to avifauna defaunation and species endangerment. Since wetlands are primary habitats for migratory birds and are associated with anthropogenic landscapes, a comprehensive understanding of bird harvesting, and its drivers is fundamental to reduce threats to current avifauna. In this study, we examined the distribution of illegal bird hunting and its socioecological drivers in the Indawgyi wetland ecosystem in Myanmar by integrating data from bird surveys, household surveys, and market surveys. We found that illegal bird hunting using nets, traps, and poisonous substances is prevalent in areas close to water and during the migration season. People who had negative attitudes toward avian species were more likely to engage in bird hunting, primarily because of the conflicts between bird conservation and crop production. Socioeconomic needs were not the major driving factors of bird killing. We therefore suggest sustainable management interventions promoting coexistence by integrating bird conservation and agricultural production, accompanied by increasing awareness to improve avian conservation in an internationally important wetland in Myanmar.

KEYWORDS

attitudes, bird and agriculture interaction, bird conservation, bird hunting, defaunation, flyways, human–wildlife conflict, illegal bird killing

1 | INTRODUCTION

Overexploitation of biological resources is a key driver of global biodiversity loss. The consumptive use of wild species for food, medicine, and trade has diminished several groups of vertebrate taxa and pushed many species to the brink of extinction (IPBES, 2022b). Birds are hunted worldwide for recreational, nutritional, ornamental, therapeutic,

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A contributed paper to policymakers, conservation practitioners, and conservation researchers.

and other nondietary purposes, and hunting affects almost 40% of threatened bird species (Birdlife International, 2022; Ingram et al., 2021). In the Mediterranean region alone, an estimated 11–36 million individuals are hunted or illegally taken every year (Brochet et al., 2016). Hunting affects avian population dynamics through demographic and genetic changes, as well as the species' behavioral, physiological, and reproductive performances (Barbosa, 2001; Brochet et al., 2019; Casas et al., 2009; Clausen et al., 2017; Jiguet et al., 2012; Madsen & Fox, 1995). Thus, the ecological impact of bird hunting is not limited to just affecting the structure of the bird community through reduction in species richness and abundance (Benitez-Lopez et al., 2017) but also implies the loss of ecosystem services that are crucial for human societies (Ramachandran et al., 2017). While hunting occurs in all bird habitats, the avifauna of wetlands are more vulnerable than others due to the predominant impact of anthropogenic exploitation, interacting with increased human accessibility and habitat degradation (Brotherton et al., 2020; Wetland International, 2010; Yong et al., 2022).

The impacts of hunting on wetland bird populations have been extensively recorded in many parts of Asia, and the bird harvest has already surpassed its sustainable thresholds (Gallo-Cajiao et al., 2020). In seven countries of the Indo-Burma region, a recent study by Yong et al. (2022) revealed that 47 wetland bird species were trapped or netted in wetlands and associated cultivated lands. Large-scale netting and trapping of birds is of particular concern in wetlands that overlap with global flyways (Wang et al., 2018). According to MaMing et al. (2012), ~80,000 to 120,000 waterbirds belonging to 40 different species are illegally killed annually along the Yellow and Yangtze Rivers. Gallo-Cajiao et al. (2020) found that migratory shorebirds were hunted in 65% of countries located along the East Asian-Australasian Flyway (EAAF). Previous studies also suggested that hunting in the wintering grounds in Asia is the primary cause of species endangerment for Yellow-breasted Bunting *Emberiza aureola* and Spoon-billed Sandpiper *Calidris pygmaea* (Kamp et al., 2015; Zöckler et al., 2010). However, the impact of hunting on wetland avifauna has been largely overlooked in ecological research in this region as its conservation priorities have thus far emphasized charismatic megafauna, flagship species, and illegal wildlife trade (Yong et al., 2022). With a lack of conservation attention, the decline in avifauna has intensified and silently paved the way for the emergence of "empty wetlands," which could be more severe than the "empty forest" that caused mammal defaunation (Benítez-López et al., 2019; Yong et al., 2022).

To minimize unfavorable ecological consequences, it is imperative to identify patterns and drivers of bird hunting. Previous research has demonstrated that the hunting or collection of birds is a multifaceted phenomenon that is often influenced by a range of socioecological factors, such as the availability of species, accessibility, law enforcement, and socioeconomic development (Benítez-López et al., 2019; Destro et al., 2020; Harrison et al., 2016; Ingram et al., 2021; Ramachandran et al., 2017). Common drivers that have been documented include needs for food, economic income, sport hunting, and cultural needs. However, human–wildlife conflicts have recently been shown to intensify wild bird hunting, and evidence is vast, ranging from large grazing waterbirds (Fox et al., 2017; Wang et al., 2018), and small granivorous birds (Angkaew et al., 2022; Canavelli et al., 2013) to birds of prey (Fairbrass et al., 2016; Santangeli et al., 2016; St John et al., 2019). Araneda et al. (2022) reported that 87% of bird species that caused conflicts were linked to crop damage. Avian utilization of agricultural crops has resulted in significant economic loss to farmers and led to conflicts between bird conservation and agriculture (Angkaew et al., 2022; Fox et al., 2017). Consequently, species that cause damage are often persecuted to avoid both direct economic losses and indirect opportunity costs (Araneda et al., 2022; Fox et al., 2017). Nonetheless, people's intentions to kill or not to kill a wildlife species are mediated by their attitudes and values toward that particular species (Carter et al., 2017; Travers et al., 2019). According to previous studies, hunting is more prevalent among people who lack positive conservation attitudes, whereas it is less prevalent among those who support conservation (Dickman, 2010; Htay, Ringsby, et al., 2022; Travers et al., 2019). Even so, the attitudes, perceptions, and behavior of people harvesting from the avian community can still differ depending on socioecological and cultural contexts, making it crucial to understand the complex interplay in order to manage bird harvesting in a sustainable way (Angkaew et al., 2022; Dickman, 2010).

Myanmar's wetland ecosystems, located along the EAAF, support a wide variety of bird life, including species that are migratory, endangered, and range restricted. The Asia Waterbird Census has approximated that Myanmar's inland and coastal wetlands provide habitat to more than 100,000 waterbirds from 136 species (Li & Mundkur, 2007). Despite this biological significance, hunting is widespread in all wetland bird habitats (BirdLife International, 2012). Chan et al. (2004) found that 65% of important bird areas in Myanmar lacked protection, resulting in hunting taking place to some extent. Yong et al. (2022) conducted a market survey in three regional cities in Myanmar, which revealed that 14 wetland-associated bird species were under hunting pressure. In coastal areas of Myanmar, Zöckler et al. (2010)

observed that local people employ improvised nets and poison baits to trap migratory birds, resulting in an annual catch of more than 30,000 individuals. Although hunting of wild birds is forbidden in Myanmar under the Conservation of Biodiversity and Protected Area Law (CBPA Law), the persistence of unsustainable illegal harvests indicates the need for evidence-based information upon which effective conservation measures can be operationalized (Forest Department, 2018).

According to CBPA Law, hunting is defined as "harming, catching, or killing wild fauna by any means, including transporting wild fauna without permission." With this study, we aimed to examine the spatial distribution where hunting activities are occurring, who were involved in these activities, and the underlying ecological and socioeconomic drivers that influence illegal harvesting and consumption of birds in the Indawgyi wetland ecosystem in Myanmar. Given that the study area is primarily devoted to agriculture, we predicted (P1) that the more negative impacts avian communities have on local crop yields, the higher the engagement in hunting activities in the affected avian communities (Htay, Ringsby, et al., 2022). We predicted that the occurrence of bird hunting by using nets, traps, and poisoning would be higher among people who were subject to higher levels of avian crop damage. In particular, we predicted that (P2) catching and consuming birds would be higher among people who have negative attitudes toward crop-utilizing avian species (Htay, Ringsby, et al., 2022; Travers et al., 2019). As the lakes and streams are primary roosting habitats for birds, we also predicted (P3) that hunting practices, as well as the consumption of eggs and bird meat, would be more prevalent in villages closer to water sources (Benítez-López et al., 2019; Chaves et al., 2020; Destro et al., 2020; Htay et al., 2023; Htay, Ringsby, et al., 2022). Differences in socioeconomic characteristics (i.e., income, education, occupation, and ethnicity) were also predicted (P4) to influence participation in hunting activities (Benítez-López et al., 2019). The insights gained from the investigation of the underlying drivers of bird hunting in this study combined with data from bird surveys, market surveys, and park patrol data to countercheck hunting prevalence, would assist in the development and implementation of conservation strategies locally adapted to the socioecological environment.

2 | MATERIALS AND METHODS

2.1 | Study area

The study was carried out in the Indawgyi wetland ecosystem located in northern Myanmar (25°09′N, 96°21′ E, Figure 1). The study area encompassed 47,884.4 ha and consisted of a large lake in the center, surrounded by seasonally flooded grasslands, riparian forests, and extensive agricultural fields (Convention on Wetlands, 2022). The unique combination of different habitats provides a prime location for diverse groups of birds, with a total of 312 documented species. The lake and associated wetland are important wintering sites and home to thousands of migratory birds (Forest Department, 2015). The wetland's surrounding area is inhabited by ~50,000 people living in 36 villages (Convention on Wetlands, 2022). The local population is mainly composed of Shan, Bamar, and a small number of other ethnicities. The main means of supporting livelihoods is through agriculture, with a cultivation system that focuses on single cropping. Rain-fed rice is the major crop grown throughout the region (Htay, Ringsby, et al., 2022). Agricultural intensification and land encroachment pose a major threat to bird species in Indawgyi, with many wetland areas converted to agricultural use annually (Forest Department, 2015). Although hunting is not practiced as a livelihood activity, earlier research and park patrolling records indicated that it is widely prevalent in all wetland habitats (Zöckler & Win, 2016).

2.2 | Data collection

From April to July 2021, interview surveys were conducted in local villages around the Indawgyi wetland. Among 36 villages, three villages were excluded due to local security constraints. Therefore, face-to-face interviews were conducted in 33 villages with 396 households (i.e., 12 households from each of 33 villages). Permission to conduct this research was granted from the Ministry of Natural Resources and Environmental Conservation, Myanmar. The study design and sampling protocol followed Htay, Ringsby, et al. (2022) (see details in Supporting information S1). Before conducting household surveys, prior informed consent was obtained from each participant, and their anonymity was assured. The questionnaire was structured into three sections (Table S1). In the first section, we recorded demographic and socioeconomic background data: age (years), gender (male/female), ethnicity (Shan/Bamar/Mix/Others), education (number of years of schooling), occupation (farmers/non-farmers), land ownership (yes/no), farmland size (hectare), household size (number of family members), and household income (annual income in Myanmar Kyats-MMK). In the second section, we collected data related to human–bird interactions and attitudes toward coexistence with crop-exploiting avian species. Respondents were asked if they had experienced an avian impact on their agricultural production during the last

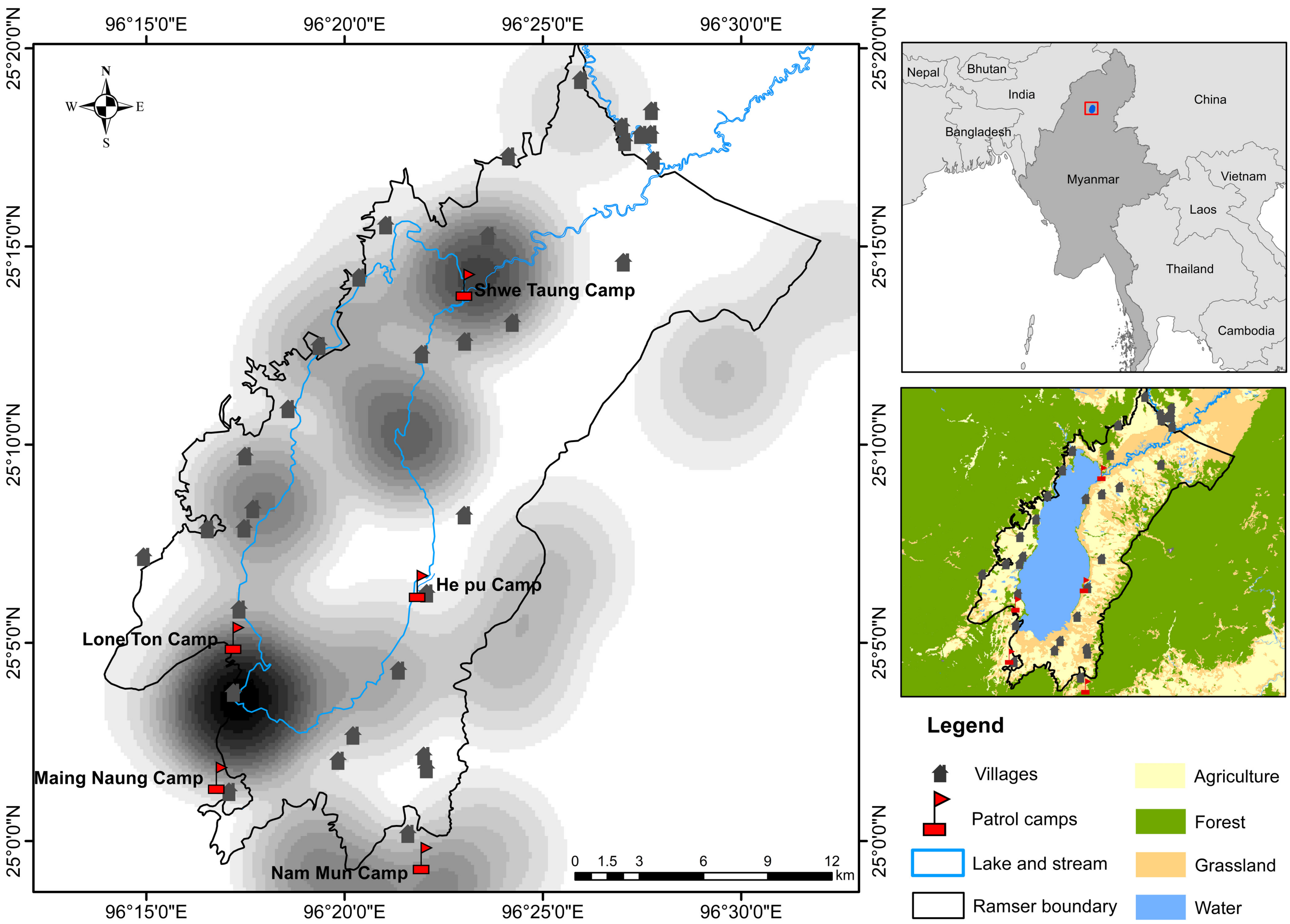

FIGURE 1 Location of the Indawgyi wetland ecosystem in Myanmar in the upper right inset and constituted land cover types in the lower right inset (*Source*: Forest Department, 2015). The main map shows the distribution of study villages within the Ramsar boundary in relation to the lake and stream, hunting hotspots that are predicted from monthly patrol data and bird survey data (the hunting intensity increases from light to dark gray) and the location of patrolling camps.

12 months (yes/no), total farmland size (hectare), perceived area of crop damage (hectare), and crop type (rice/mix). Concerning attitudes, we asked respondents whether they were satisfied with the presence of crop-eating birds on their farms (yes/no), whether they want to protect the birds of Indawgyi in general (yes/no), whether they feel the need to conserve the birds that caused crop loss to them (yes/no), whether they think that the killing or control management of damage-causing birds is acceptable to reduce crop damage (yes/no), whether the respondents consider the park office to be responsible or should provide damage mitigation measures to the problem of crop damage (yes/no), and whether they support the requirement of compensation mechanisms for local farmers' economic losses (yes/no).

In the last section, we asked the respondents about the occurrence of bird hunting and consumption of bird eggs and meat. However, hunting is not legally allowed in the Indawgyi region, and participants could be reluctant to disclose information (Marques et al., 2022; Podsakoff et al., 2003). In this regard, specialized questioning techniques have been used to acquire robust information on sensitive topics (Davis et al., 2019; Nuno & John, 2015). However, methodological complexity and low literacy rates limited the implementation of this method. We therefore adopted direct questioning techniques and triangulated the same topic with different questions (Ibbett, Keane, et al., 2021; Podsakoff et al., 2003). To reduce sensitivity and social desirability bias, we targeted most questions at the village level (Ibbett, Jones, & St John, 2021). In our interviews with local inhabitants, we avoided questions about their own engagement in hunting birds but instead examined their knowledge about the occurrence of catching birds and the consumption of bird eggs and meat in their villages (Parry & Peres, 2015; Santangeli et al., 2016). The questions investigated (1) whether the respondents had seen individuals catching birds by using nets, traps, or toxic chemicals around their village or farm (Ibbett, Keane, et al., 2021), the habitat and the season where each of these activities mostly occurred, (2) whether the respondents perceived people in their village who had consumed bird eggs or meat (Knapp et al., 2010), (3) whether the respondents themselves had tasted bird eggs or meat in their lifetime (Davis et al., 2020, Jenkins et al., 2011, Merson et al. 2019, p. 4) whether they had tasted bird eggs or meat during the last 12 months, and finally the identity of three species they had mostly consumed for both eggs and meat (Ibbett, Keane, et al., 2021; Newth et al., 2022; Razafimanahaka et al., 2012; Table S1). We used photo cards of bird species to confirm the reported species. We also carried out market surveys in the local markets of the study villages during May, June, October, and November 2021 and February and March 2022. Among 33 study villages, small villages ($n = 12$) do not have markets. Therefore, a total of 21 markets were visited during the survey. Each village market was randomly visited every 15 days (i.e., twice per month and 12 times throughout the study) and checked if bird eggs or meat were available in the market.

In order to account for the spatial distribution of the avian communities as well as human hunting pressure (Brashares et al., 2011; Brodie & Fragoso, 2021), we categorized our study villages into lake villages or stream villages (Htay, Ringsby, et al., 2022). The human population density of all study villages was provided by the park administration office (Forest Department, 2015). Based on hunting records from the park's monthly patrol data (2019 and 2020) and bird survey data (2021 and 2022) from Htay et al. (2023), we created hunting hotspots and measured the distance of each village to its nearest hunting hotspot. We also measured the village distance to the nearest patrolling camp and distance to the nearest source of water. Data on species abundance were obtained from Htay et al. (2023), where 120 bird sampling plots were randomly distributed throughout the study area and each sampling point was visited six times from June 2021 to March 2022. To calculate bird abundance in each village, we first created a 3 km buffer area from the center of each village using the "buffer" tool in ArcMap Desktop v.10.8 (i.e., mean distance of each village to its nearest hunting hotspot = 2.29 km, SD = 1.33). Then, we overlaid the buffer area with bird sampling points and identified the points that were completely within the 3 km buffer area using the "select by location" tool and calculated the mean bird abundance from those sampling points for each village.

2.3 | Statistical analysis

To examine factors related to bird hunting, we performed a generalized linear mixed-effects model (GLMM), where each question investigating the occurrence of catching as well as consumption of birds was set as a binary response variable (i.e., 0 = No, 1 = Yes; Table 1). As explanatory variables, we included spatial- (distance to water, distance to hunting hotspot, distance to patrolling camp and village type), socioeconomic (age, gender, education, occupation, ethnicity, residency, land ownership, crop type, household size, household income, and population density), biological- (bird abundance), crop damage (proportion of crop damage area to farmland area), and attitudinal variables (Table 1). The identity of the village was included as a random factor to account for spatial dependence among observations. We constructed 44 candidate models from different combinations of biologically relevant predictor variables. First, we fitted separate models for each explanatory variable. Then, we fitted a model with distance to water, bird abundance, and crop damage to test how the proximity to bird populations and avian impacts influenced the prevalence of hunting. Finally, to understand how socioeconomic and attitude variables influenced the effects of accessibility to huntable resources and human–wildlife interaction, we added distance to water, bird abundance, and crop damage to the models that were fitted with each explanatory variable (Table S2). We fitted main effects only models because the interaction terms were not significant in our tested models. All models were fitted using the *glmmTMB* package and were ranked according to Akaike information criterion corrected for small samples (AICc) values (Brooks et al., 2017). Models with ΔAICc <2 were considered the best-supported models (Burnham & Anderson, 2002). Collinearity among predictors was checked using the *performance* package (Lüdecke et al., 2021). As there was a correlation between distance to water and distance to nearest hunting hotspot ($r_{\text{pearson}} = 0.57$), as well as between distance to water and distance to patrolling camp ($r_{\text{pearson}} = -0.55$), we only used distance to water when combined with other predictors (Htay, Ringsby, et al., 2022). All continuous predictors were mean scaled with one standard deviation (Gelman, 2008; Schielzeth, 2010). Residual diagnostics and the fit of the top-ranked models were evaluated using the *DHARMA* package (Hartig, 2018). As our data included 12 incomplete questionnaires, we removed them from the analysis (Jenkins et al., 2011). Therefore, our sample size finally included 384 respondents. All statistical analyses were conducted in R version 4.1.1 (R Core Team, 2022).

3 | RESULTS

3.1 | Occurrence of bird hunting using nets, traps, and poisoning

When the respondents were asked "Have you seen the nets catching birds around your village or farms?" 25.3% ($n = 97/384$) answered "yes." Nets were mostly reported

TABLE 1 Overview of variables included in the statistical models, their description and factor levels, and their respective data type (type).

Variables	Description	Type
Response variables		
Occurrence of capturing birds		
Net capture of birds	Whether the respondents had seen individuals catching birds by using nets around their villages or farms (Yes = 1or No = 0)	Binary
Trapping birds	Whether the respondents had seen individuals catching birds by using traps around their villages or farms (Yes = 1or No = 0)	Binary
Poisoning birds	Whether the respondents had seen individuals catching birds by using toxic substances around their villages or farms (Yes = 1or No = 0)	Binary
Consumption of bird eggs and meat (village level)		
Consumption of bird eggs in the village	Whether the respondents perceived people in their villages who had consumed bird egg (Yes = 1or No = 0)	Binary
Consumption of bird meat in the village	Whether the respondents perceived people in their villages who had consumed bird meat (Yes = 1or No = 0)	Binary
Consumption of bird eggs and meat duringlifetime (individual level)		
Consumption of bird eggs during the lifetime	Whether the respondents themselves had tasted bird eggs in their lifetime (Yes = 1or No = 0)	Binary
Consumption of bird meat during the lifetime	Whether the respondents themselves had tasted bird meat in their lifetime (Yes = 1or No = 0)	Binary
Consumption of bird eggs and meat during the last 12 months (Individual level)		
Consumption of bird eggs during the last 12 months	Whether the respondents themselves had tasted bird eggs during the last 12 months (Yes = 1or No = 0)	Binary
Consumption of bird meat during the last 12 months	Whether the respondents themselves had tasted bird meat during the last 12 months (Yes = 1or No = 0)	Binary
Predictor variables		
Spatial factors		
Distance to hunting hotspot	Each village distance to the nearest hunting hotspot (km). Hunting hotspots were derived from illegal hunting records provided by the park's monthly patrol data (2019 and 2020) and from bird survey data (2021 and 2022) by Htay et al. (2023)	Continuous
Distance to patrolling camp	Each village distance to the nearest patrolling camp (km). Location of the patrolling camp is provided by the park administration office	Continuous
Distance to water	Each village distance to the nearest source of water (km). Distribution of lake and streams data is provided by the Myanmar Forest Department	Continuous
Village type	Whether the village is in the lake area or stream outlet area (Lake village =1 or Stream village = 0)	Binary
Socio-economic factors		
Population density	Population size of each village	Continuous
Age	Age of the respondent (Years)	Continuous
Gender	Gender of the respondent (Female =1 or Male = 0)	Binary
Occupation	Main occupation of the respondent (Farmers = 1 or Nonfarmers = 0)	Binary
Education	Number of years of schooling (years)	Continuous
Ethnicity	Ethnicity of the respondent (Shan = 1 or Bamar = 2 or Mix = 3 or Others = 4)	Categorical

TABLE 1 (Continued)

Variables	Description	Type
Residency	Whether the respondent is native to the village or not (Native = 1 or Migrant = 0)	Binary
Land ownership	Whether the respondent owned land or not (Landowner = 1 or Landless = 0)	Binary
Crop type	Type of the crop grown (Rice = 1 or Mixed = 0)	Binary
Household size	Number of family members in a household	Continuous
Household income	Annual household income (Myanmar kyats)	Continuous
Biological factor		
Bird abundance	Mean bird abundance within 3 km around each village. Bird abundance data were taken from Htay et al. (2023) and mean abundance of birds was calculated from the sampling points that located within 3 km buffer of each village	Continuous
Avian impact on agriculture and attitudinal factors		
Crop damage area	Area of crop damaged by avian species calculated as the proportion of crop damage area to the total farmland size	Continuous
Attitude toward the presence of crop-eating bird species	Whether the respondents were satisfied with the presence of crop eating birds in their farms (Yes = 1 or No = 0)	Binary
Attitude toward conservation of birds in general	Whether the respondents want to protect the birds of Indawgyi in general (Yes = 1 or No = 0)	Binary
Attitude toward conservation of crop-damaging bird species	Whether the respondents feel the need to conserve the birds that caused crop loss to them (Yes = 1 or No = 0)	Binary
Attitude toward control management of crop-damaging species	Whether the respondents think that the killing or control management of damage-causing birds is acceptable to reduce crop damage (Yes = 1 or No = 0)	Binary
Attitudes toward park office responsibility in the mitigation of crop damage problem	Whether the respondents consider the park office to be responsible or should provide damage mitigation measures to reduce the problem of crop damage (Yes = 1 or No = 0)	Binary
Attitude toward the need of compensation mechanism	Whether the respondents support the requirement of compensation mechanisms for local farmers' economic losses (Yes = 1 or No = 0)	Binary

Note: The upper section shows the response variables used, and the lower section shows the fixed effects grouped into spatial, socioeconomic, biological, agriculture and attitudinal.

in agricultural land (76.3%, $n = 74/97$) and during the harvest season (89.7%, $n = 88/97$; Table S3 and Figure S1). Among the candidate models predicting the occurrence of nets, three models had ΔAICc <2 (Table S4, Section I). The highest ranked model revealed that respondents who lived in villages closer to water ($\beta_{\text{Distance to water}} = -0.557$ [−1.044, −0.071], SE = 0.248, Figure 2a) and who supported the need for compensation mechanisms concerning avian impacts on agriculture were more likely to report bird net occurrence (Model 1: $\beta_{\text{Compensation}} = 0.942$ [0.383, 1.501], SE = 0.285, Figure 2b). The second-ranked model also showed the same effect of attitude toward compensation (Table S4, Section I). The third-ranked model revealed that respondents who supported the park office's responsibility to provide damage mitigation measures were more likely to report the occurrence of bird nets ($\beta_{\text{PA responsibility}} = 0.846$ [0.297, 1.396], SE = 0.280, Figure 2c). Thus, altogether our results showed that respondents who asked for various crop damage mitigation measures were more likely to report the occurrence of nets.

When asked about the occurrence of bird traps, 39.84% ($n = 153/384$) of respondents confirmed that trapping of avian species occurred in their villages. Most trapping incidents took place during the harvest season (74.5%, $n = 114/153$) and were distributed across agricultural land (50.9%, $n = 78/153$), grassland (28.8%, $n = 44/153$) and water (22.2%, $n = 34/153$) (Table S3 and Figure S1). Among the candidate models that predicted the occurrence of trapping birds, two models had ΔAICc <2 (Table S4, Section II). Both models revealed that respondents who agreed with the killing or control management of

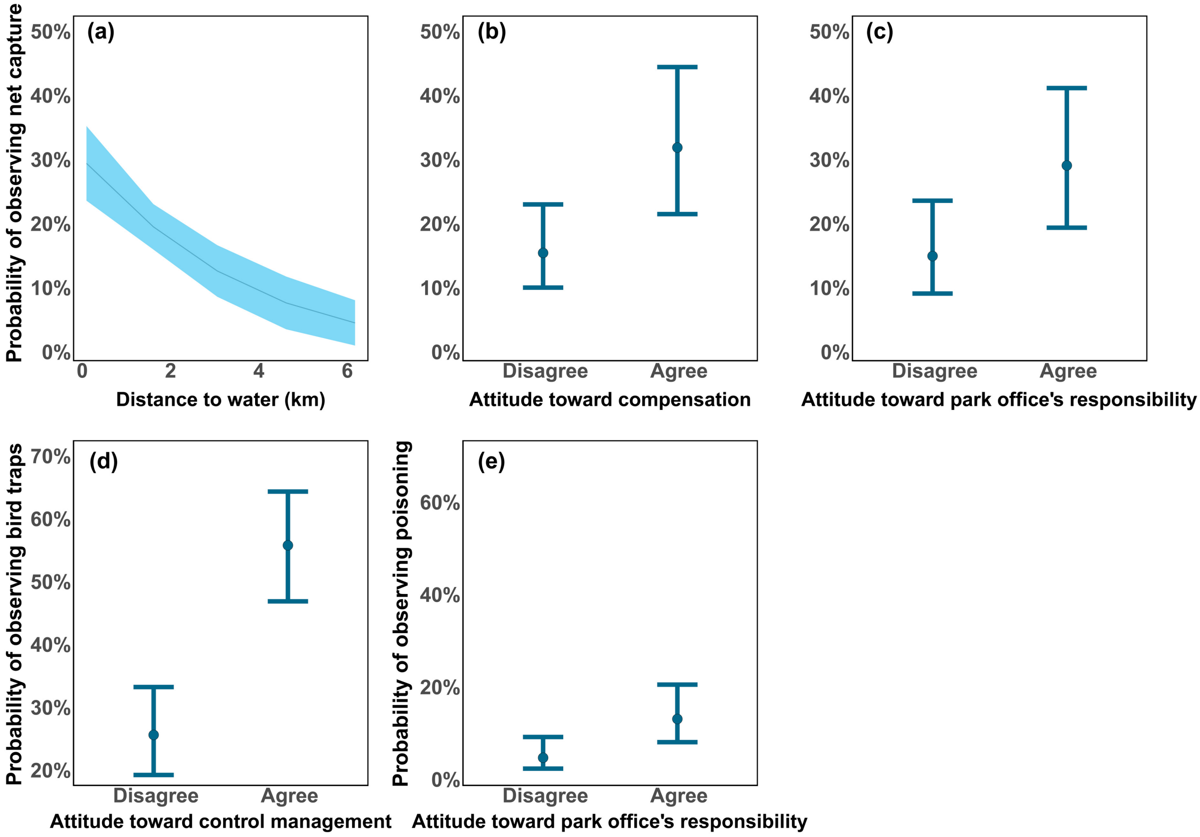

FIGURE 2 Probability of observing net capture of birds in relation to a) distance to water (Model 1 from Table S4, Section I), (b) attitude toward the need of compensation scheme (Model 1 from Table S4, Section I), (c) attitude toward the park office responsibility to mitigate avian crop damage (Model 3 from Table S4, Section I), and (d) probability of observing bird trapping in relation to attitude toward killing or control management of crop-exploiting bird species (Model 1 from Table S4, Section II) and (e) probability of observing bird poisoning in relation to attitude toward the need of park office intervention to mitigate avian crop damage (Model 1 from Table S4, Section III).

crop-exploiting avian species were more likely to report bird trapping (Model 1: $\beta_{\text{Control management}} = 1.299$ [0.838, 1.758], SE = 0.234, Figure 2d; Model 2: $\beta_{\text{Control management}} = 1.265$ [0.798, 1.733], SE = 0.239).

Of the total respondents, 9.6% ($n = 37/384$) reported the application of toxic substances to harm avian species. The poisoning of birds mostly occurred in agricultural land (54.1%, $n = 20/37$), water (29.7%, $n = 11/37$), and grassland (24.3%, $n = 9/37$). Most of these events were reportedly observed during the harvest season (72.9%, $n = 27/37$; Table S3 and Figure S1). Only one model had ΔAICc <2 (Table S4, Section III), revealing that reporting was higher among respondents who agreed with the park office's responsibility to mitigate avian damage to agriculture ($\beta_{\text{PA responsibility}} = 1.12$ [0.358, 1.881], SE = 0.389; Figure 2e).

3.2 | Consumption of bird eggs and meat at the village level

More than half of the respondents answered that people in their villages consumed bird eggs (56.8%, $n = 218/384$). Among the models that predicted the consumption of bird eggs, we found two models that had ΔAICc <2 (Table S5, Section I). The top-ranked model revealed higher consumption of eggs among people who supported the killing or control management of bird species that cause crop damage (Model 1: $\beta_{\text{Control management}} = 1.553$ [1.005, 2.100], SE = 0.279; Figure 3a). The second-ranked model also revealed the effect of attitude toward control management and additionally indicated that egg consumption was lower in villages farther away from water (Model 2: $\beta_{\text{Distance to water}} = -0.565$ [−1.047, −0.083], SE = 0.246; Figure 3b).

Concerning bird meat consumption, 64.6% ($n = 248/384$) of the respondents answered that people in their village consumed bird meat. Among the models that predicted the consumption of bird meat, three models had ΔAICc <2 (Table S5, Section II). The two highest ranked models revealed that respondents who agreed with the management of crop-exploiting species were more likely to report higher consumption of bird meat (Model 1: $\beta_{\text{Control management}} = 0.949$ [0.427, 1.472], SE = 0.267; Figure 3c; Model 2: $\beta_{\text{Control management}} = 0.898$ [0.363, 1.432], SE = 0.273). The third-ranked model revealed that

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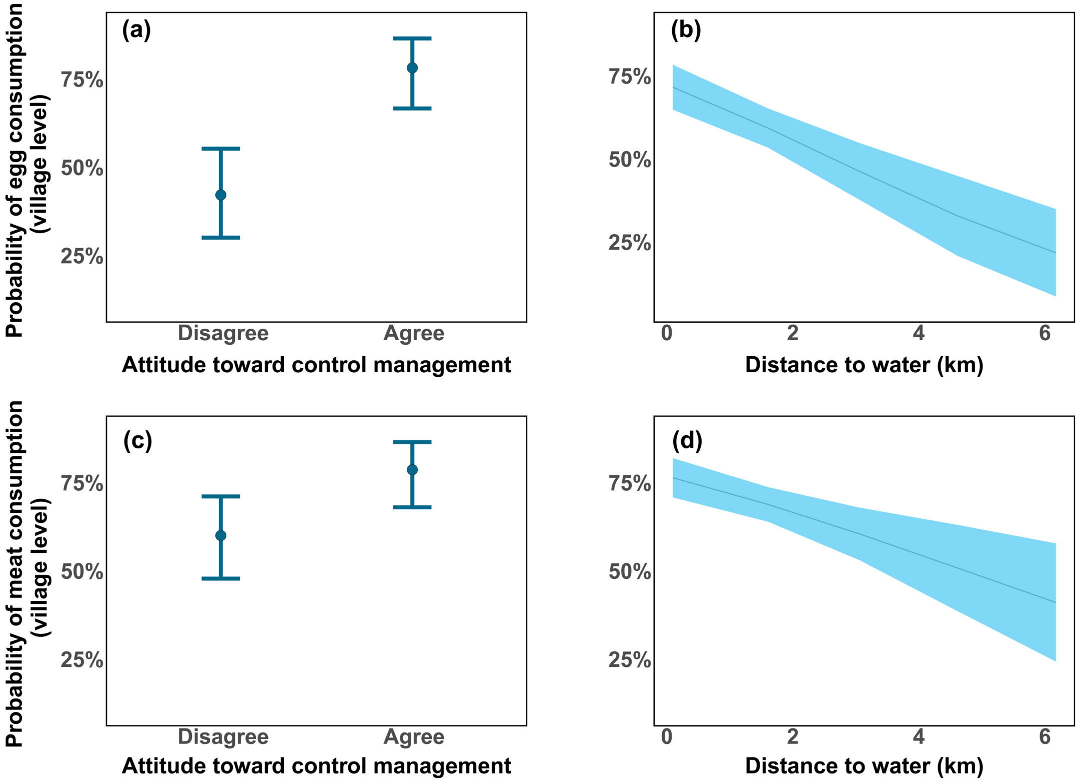

FIGURE 3 The probability of bird egg consumption in villages in relation to (a) attitude toward control management of crop-exploiting bird species (Model 1 from Table S5, Section I), and (b) distance to water (Model 2 from Table S5, Section I). Likewise, the probability of bird meat consumption in villages in relation to (c) attitude toward control management of crop-exploiting bird species (Model 1 from Table S5, Section II), and (d) the distance to water (Model 3 from Table S5, Section II).

meat consumption was negatively related to the distance to water (Model 3: $\beta_{\text{Distance to water}} = -0.545$ [-1.024, -0.064], SE $= 0.245$; Figure 3d).

3.3 | Consumption of bird eggs and meat at the individual level

When the respondents were asked if they had eaten bird eggs during their lifetime, 27.3% ($n = 105/384$) answered that they had eaten bird eggs. Among the models that predicted the respondent's experience of tasting bird eggs, one model was within ΔAICc <2 (Table S6, Section I). The experience of consuming bird eggs was lower among residents of villages with higher population densities (Model 1: $\beta_{\text{Population}} = -0.477$ [-0.887, -0.066], SE $= 0.209$; Figure 4a). Regarding their consumption during the last 12 months, 16.9% ($n = 64/384$) confirmed consumption of bird eggs during the last year. Eggs were collected from the Lesser Whistling Ducks *Dendrocygna javanica* (59.4%, $n = 38/64$), Egret species (32.8%, $n = 21/64$), and Purple Swamphen *Porphyrio porphyrio* (17.2%, $n = 11/64$; Table S7). In most cases, respondents or their family members collected the eggs themselves (Table S7). The model that included population density was also ranked as the best model in the prediction of egg consumption during the last 12 months (Table S6, Section II). Although we found a tendency of decreasing bird egg consumption in high-populated villages (Figure 4b), the confidence interval overlapped zero (Model 1: $\beta_{\text{Population}} = -0.341$ [-0.916, 0.233]; SE $=$ 0.292; Table S6).

When asked about bird meat consumption, 44.5% ($n = 171/384$) of respondents confirmed having eaten it at least once in their lifetime. Among the models assessing the consumption of bird meat during their lifetime, we found one model ranked within ΔAICc <2 (Table S6, Section III). The lifetime experience of bird meat consumption decreased with increasing distance to water ($\beta_{\text{Distance to water}} = -0.483$ [-0.803, -0.163], SE $= 0.163$; Figure 4c). When asked about consumption of bird meat during the last year, 24.5% admitted eating bird meat ($n = 121/384$). The most consumed bird species for meat included Purple Swamphen (38.8%, $n = 47/121$), Lesser Whistling Duck (30.6%, $n = 37/121$), Common Coot *Fulica atra* (20.7%, $n = 25/121$). The main sources of meat were reported to be hunted by respondents themselves, followed by acquisition from hunters and hunting by family

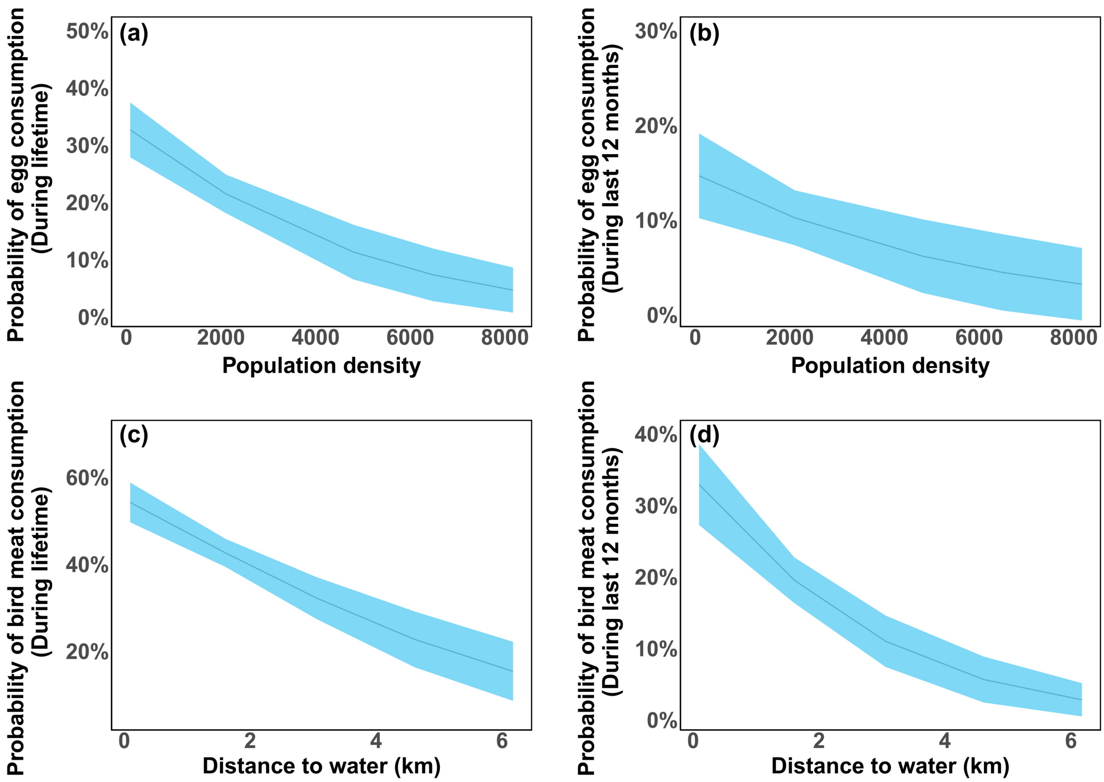

FIGURE 4 (a) Individual experience of bird egg consumption during their lifetime in relation to village population density (Model 1 from Table S6, Section I), (b) consumption of bird eggs during the last year in relation to village population density (Model 1 from Table S6, Section II), (c) individual experience of bird meat consumption during their lifetime in relation to distance to water (Model 1 from Table S6, Section III), (b) consumption of bird meat during the last year in relation to distance to water (Model 1 from Table S6, Section IV).

members (Table S7). The model that included distance to water also ranked as the top model (Table S6, Section IV) and revealed that bird meat consumption was lower in areas farther away from water ($\beta_{\text{Distance to water}} = -0.727$ [-1.230, -0.224], SE $= 0.256$; Figure 4d).

3.4 | Market surveys

We detected only two cases where bird meat was sold in one local market. In the first case, we found one Tufted Duck *Aythya fuligula* and in the second case, we found three Purple Swamphens. We did not find any cases where bird eggs were sold in the markets.

4 | DISCUSSION

In this study, we have taken an interdisciplinary approach by combining social, ecological, and market survey data to understand the prevalence of illegal bird hunting and its correlates in the Indawgyi wetland ecosystem. Our results revealed that, in an agriculture-associated wetland landscape, the killing and consumption of birds is not driven by socioeconomic requirements but rather influenced by the interactions between birds and agriculture, farmers' attitudes toward crop-utilizing avian species, and the accessibility of huntable resources. Our findings provide clear recommendations on how to prioritize conservation efforts, in order to safeguard biodiversity in an internationally important wetland bird habitat in Myanmar.

4.1 | Bird and agriculture interaction, and its link with avifauna hunting

We found that the way people perceive crop-exploiting avian species is an important factor in the prediction of the occurrence of bird netting, trapping, and poisoning. Although we found a positive relationship between crop damage area and bird hunting (Tables S4–S6), the effect was not significant and our prediction P1 cannot be supported. Instead, we found that attitudes toward crop-utilizing avian species were much stronger predictors for the occurrence of bird killings, supporting our prediction, P2. These findings suggest that bird hunting in our study system is not solely determined by direct economic impact; rather it is influenced by indirect impacts (for instance, opportunity costs of time and manpower to guard crops) and other sociopsychological factors (Kansky et al., 2021; Merson et al., 2019). Our findings concur with a study in Argentina about farmers' preferences toward different management strategies over crop-damaging Monk Parakeet *Myiopsitta monachus* (Canavelli et al., 2013). They found that attitudes toward the species were stronger predictors than the magnitude of crop damage in the prediction of acceptance over population control management (Canavelli et al., 2013). Furthermore, Htay, Ringsby, et al. (2022) investigated avian impacts on agriculture in the Indawgyi ecosystem and found that despite higher levels of crop damage in areas close to water, some farmers in these areas exhibited tolerance toward crop-exploiting birds. Htay, Ringsby, et al. (2022) highlighted that conservation education, tangible benefits obtained from the conservation programs (e.g., tourism opportunities and livelihood support programs) and appreciation of intangible benefits provided by the birds (e.g., pest control and aesthetics) were the main factors influencing farmers' tolerance toward birds. Several other studies have also underlined that human behavior and tolerance toward the species involved in human–wildlife conflicts are moderated by attitudes and values toward that species (Cerri et al., 2017, Htay, Htoo, et al., 2022, Kansky et al., 2016, 2021, Liordos et al., 2017, Manfredo et al., 2021, Merson et al., 2019; St John et al., 2019; Travers et al. 2019). We also found that attitude statements that are related to domination preferences (such as attitude about killing or control management, compensation for crop loss, and PA responsibility to provide damage management interventions) are more influential in predicting bird killing than those related to mutualistic preferences (attitude about species presence, protection of bird species and conservation of crop-damaging species). Our findings support the results of global wildlife value surveys by Manfredo et al. (2016) and IPBES (2022a) as well as previous research that specifically focused on human and bird interactions, indicating that people with domination motivations were more likely to have a higher propensity for the lethal control of bird species (Cerri et al., 2017; Fairbrass et al., 2016; Ibbett, Keane, et al., 2021; Sijtsma et al., 2012; St John et al., 2019).

Furthermore, conflicts of interest among different stakeholder groups and a lack of management intervention were found to trigger negative attitudes and often resulted in reactionary killing of various wildlife species (Dickman, 2010; St John et al., 2019). Newth et al. (2022) found that individuals who have negative attitudes toward protective laws and management are more likely to engage in Bewick's swan hunting. We also found that the installation of bird nets and poisoning were more abundant in areas where people asked for park office intervention and compensation to mitigate avian crop damage, as documented in other previous studies (Datta, 2022; MaMing et al., 2012; Wang et al., 2018). Our findings about the occurrence of killing birds corresponded with the pattern of bird meat and egg consumption. People who approved of species management were found to eat more bird eggs and meat in their localities, in line with our prediction, P2. Although many species that cause crop damage are eaten, not all of them face the same degree of hunting pressure. Large waterbirds are more affected than small granivorous birds, and this difference can be related to hunters' demand for a larger quantity of meat and cost-effectiveness in biomass return (Benítez-López et al., 2019; Gallo-Cajiao et al., 2020). Studies on illegal hunting of birds in Bangladesh and India revealed that larger bird species, such as herons, bitterns, egrets, ducks, geese, and waterfowl, were the most preferred groups, although smaller ones, such as pigeons, doves, and starlings, were also taken (Datta, 2022; Ramachandran et al., 2017). In Thailand's central plains, Angkaew et al. (2022) observed that large waterbirds were hunted for their meat, whereas small passerines were captured alive and sold for religious merit release activities. However, we did not observe selling birds for religious release in our market surveys. We detected only two instances of bird meat being sold, and both times it was a type of waterbird—a Tufted Duck in the first case and Purple Swamphens in the second. Large waterbirds are not only consumed for meat, but also consumed for the eggs. However, egg consumption was lower in populated villages, which might be related to decreased nest site selection in those villages due to high levels of human disturbances (Madsen & Fox, 1995; Price, 2008).

4.2 | Hunting correlates with spatial, biological, and socioeconomic factors

Our results showed a significant spatial pattern in the occurrence of bird hunting using nets. Additionally, the consumption of bird eggs and meat was found to be higher in villages near water, and people in these areas had more exposure to its taste compared with villages farther away. This finding is consistent with our prediction, P3, and the pattern could be explained by the greater availability of target resources (particularly waterfowl, which are utilized for meat and egg consumption), which are easily accessible in areas close to water (Pangau-Adam et al., 2012). Our findings are supported by several lines of evidence (Benitez-Lopez et al., 2017;

Brashares et al., 2011; Brodie & Fragoso, 2021; Nyahongo et al., 2009). The effect of bird abundance was also predicted to be positive and related to the occurrence of nets, as well as meat consumption in the village. However, the effect was not significant, which can be attributed to seasonal variation in bird abundance caused by changes in wetland habitat characteristics (Htay et al., 2023). Depending on the season, bird abundance among different functional groups, such as waterbirds, wetland-associated birds, and nonwaterbirds, might also be different. Areas near water tend to have a higher consumption of birds, particularly during the migration season, as they are the primary habitat for waterbirds that are hunted for their meat and eggs. In line with our findings, survey participants reported fluctuations in bird catching and consumption across habitats and seasons, with the peak observed in the migratory season. The park's monthly patrol records also revealed that hunting occurred most frequently during migration periods. However, in this study, we used overall bird abundance as a predictor, and its coarse resolution may mask spatial–temporal variations in bird abundance, resulting in an effect that is not significant (Knapp et al., 2010). We therefore suggest that further studies explore this relationship by integrating population data that are spatially and temporally explicit and by separating them into different functional groups.

Although several previous studies concluded that hunting is culturally or socioeconomically driven (Datta, 2022; Merson et al., 2019; Morsello et al., 2015), the influences of these variables were not evident in this study and our prediction P4 is not supported. In our study area, agriculture is the main livelihood and occupation types were not diversified. Some respondents who have achieved higher education were even engaged in agriculture because there are very few employment opportunities unless they move to other urbanized places (Forest Department, 2015). Furthermore, the prevalence of hunting is not ethnically different since both Shan and Bamar communities, being Buddhists and engaged in agriculture, are not culturally linked to hunting (Forest Department, 2015; Htay, Htoo, et al., 2022; Htay, Ringsby, et al., 2022). Nutritionally, local households in Indawgyi rely on fish as a major source of protein as it is legally allowed for subsistence use, easily available and inexpensive (Htay, Htoo, et al., 2022). The availability of affordable alternative protein sources has been shown to reduce reliance on wild meat consumption (Ibbett, Jones, & St John, 2021; Ibbett, Keane, et al., 2021; Jenkins et al., 2011; Morsello et al., 2015; Nyahongo et al., 2009). These factors, acting together, could result in a low variation in the explanatory power of socioeconomic factors in predicting bird hunting and possibly lead to these factors becoming nonsignificant (Mendonça et al., 2016). The sensitivity of the questions that we used also necessitates discussion. When the question's sensitivity increased from the village level to the individual level, the response rate decreased because individuals may feel hesitant to disclose their illicit behavior because of high-risk perception (Cerri et al., 2017; Chave et al. 2020). Consequently, when predicting bird meat consumption on an individual level, only the effect of spatial factors might remain operating. Therefore, our study may have underestimated the actual level of hunting prevalence, and further studies should address this gap with well-designed specialized questioning techniques (Cerri et al., 2017; Chave et al. 2020).

5 | CONCLUSION AND RECOMMENDATIONS FOR CONSERVATION

Our research revealed that bird hunting and consumption are widespread in the Indawgyi ecosystem, and the findings bring us three main conclusions along with conservation-relevant recommendations. First, we found that catching and consumption of birds in the Indawgyi ecosystem is a localized problem; therefore, conservation efforts should be focused on areas with high hunting pressure. As hunting is higher in proximity to water, the concentration of current enforcement patrols around lake and stream areas is one relevant approach. However, it has limited effectiveness because patrol activities are only enforced within protected lake and wetland habitats, and a large area of unprotected agricultural habitat, where most hunting occurs, remains unpatrolled. Therefore, illegal killing continues despite these patrolling efforts. Farmers are the primary stakeholders to lessen these documented hunting pressures, and future conservation actions should be tailored to them. Second, the driving force behind bird killing is mainly due to the negative interaction between humans and wildlife, not household socioeconomic needs. The importance of the attitude variables investigated in this study suggests the need for locally adapted conservation measures to mitigate crop damage and enhance the tolerance of local communities toward crop-exploiting species. The implementation of sustainable coexistence strategies such as compensation programs and agrienvironmental schemes is of utmost importance in villages where avian crop damage has caused negative attitudes so that both people and wild species can coexist in a shared environment. Although crop protection was the main reason for catching birds, the currently used bird control methods were not socially or ecologically sustainable due to their indiscriminate nature and the negative consequences on avian population dynamics. In regard to obtaining meat for consumption, many people obtained it by hunting on their own and by their family members, while some acquired it from markets. Children are also involved in the collection of eggs and bird trapping. Therefore, as a final note, we recommend raising awareness among the local public as well as children in the schools. Informing people regarding the status of bird populations, the ecosystem services provided by avian species and the consequences of unsustainable bird control methods will raise their awareness and reduce the intensity of hunting. Therefore, conservation actions aimed at reducing bird hunting pressures in the Indawgyi wetland ecosystem will be successful when these recommended conservation conditions converge.

AUTHOR CONTRIBUTIONS

Study design and conceptualization: Thazin Htay, Eivin Røskaft, Thor Harald Ringsby, and Peter Sjolte Ranke. *Data preparation and collection*: Thazin Htay and Kyaw Kyaw Htoo under the guidance from Eivin Røskaft, Thor Harald Ringsby, and Peter Sjolte Ranke. *Formal Analysis and interpretation*: Thazin Htay and Kyaw Kyaw Htoo under the supervision of Eivin Røskaft, Thor Harald Ringsby, and Peter Sjolte Ranke. *Writing original draft*: Thazin Htay; Maps: Kyaw Kyaw Htoo. *Review and editing*: All. *Funding acquisition*: Eivin Røskaft.

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CONFLICT OF INTEREST STATEMENT

Authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data sets of the study are available from the corresponding author upon reasonable request.

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REFERENCES

Angkaew, R., Round, P. D., Ngoprasert, D., Powell, L. A., Limparungpatthanakij, W. Y., & Gale, G. A. (2022). Collateral damage from agricultural netting to open-country bird populations in Thailand. *Conservation Science and Practice*, *4*(11), e12810. https://doi.org/10.1111/csp2.12810

Araneda, P., Ohrens, O., & Ibarra, J. T. (2022). Socioeconomic development and ecological traits as predictors of human–bird conflicts. *Conservation Biology*, *36*(1), e13859. https://doi.org/10.1111/cobi.13859

Barbosa, A. (2001). Hunting impact on waders in Spain: Effects of species protection measures. *Biodiversity and Conservation*, *10*, 1703–1709. https://doi.org/10.1023/A:1012066109518

Benitez-Lopez, A., Alkemade, R., Schipper, A. M., Ingram, D. J., Verweij, P. A., Eikelboom, J. A. J., & Huijbregts, M. A. J. (2017). The impact of hunting on tropical mammal and bird populations. *Science*, *356*(6334), 180–183. https://doi.org/10.1126/science.aaj189

Benítez-López, A., Santini, L., Schipper, A. M., Busana, M., & Huijbregts, M. A. (2019). Intact but empty forests? Patterns of hunting-induced mammal defaunation in the tropics. *PLoS Biology*, *17*(5), e3000247. https://doi.org/10.1371/journal.pbio.3000247

BirdLife International. (2012). Overexploitation is a threat to many large and conspicuous bird species. http://www.birdlife.org

BirdLife International. (2022). State of the world's birds 2022.

Brashares, J. S., Golden, C. D., Weinbaum, K. Z., Barrett, C. B., & Okello, G. V. (2011). Economic and geographic drivers of wildlife consumption in rural Africa. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(34), 13931–13936. https://doi.org/10.1073/pnas.101152610

Brochet, A. L., Van den Bossche, W., Jbour, S., Ndang'ang'a, P. K., Jones, V. R., Abdou, W. A. L. I., Al-Hmoud, A. R., Asswad, N. G., Atienza, J. C., Atrash, I., Barbara, N., Bensusan, K., Bino, T., Celada, C., Cherkaoui, S. I., Costa, J., Deceuninck, B., Etayeb, K. S., Feltrup-Azafzaf, C., … Butchart, S. H. (2016). Preliminary assessment of the scope and scale of illegal killing and taking of birds in the Mediterranean. *Bird Conservation International*, *26*(1), 1–28. https://doi.org/10.1017/S0959270915000416

Brochet, A. L., Van Den Bossche, W., Jones, V. R., Arnardottir, H., Damoc, D., Demko, M., Driessens, G., Flensted, K., Gerber, M., Ghasabyan, M., Gradinarov, D., Hansen, J., Horváth, M., Karlonas, M., Krogulec, J., Kuzmenko, T., Lachman, L., Lehtiniemi, T., Lorgé, P., … Butchart, S. H. (2019). Illegal killing and taking of birds in Europe outside the Mediterranean: Assessing the scope and scale of a complex issue. *Bird Conservation International*, *29*(1), 10–40. https://doi.org/10.1017/S0959270917000533

Brodie, J. F., & Fragoso, J. M. (2021). Understanding the distribution of bushmeat hunting effort across landscapes by testing hypotheses about human foraging. *Conservation Biology*, *35*(3), 1009–1018. https://doi.org/10.1111/cobi.13612

Brooks, M. E., Kristensen, K., van Benthem, K. J., Magnusson, A., Berg, C. W., Nielsen, A., Skaug, H. J., Mächler, M., & Bolker, B. M. (2017). glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. *R Journal*, *9*, 378–400.

Brotherton, S., Joyce, C. B., & Scharlemann, J. P. (2020). Global offtake of wild animals from wetlands: Critical issues for fish and birds. *Hydrobiologia*, *847*(7), 1631–1649. https://doi.org/10.1007/s10750-020-04188-z

Burnham, K. P., & Anderson, D. R. (2002). *Model selection and multi-model inference: A practical information-theoretic approach* (Second ed.). Springer.

Canavelli, S. B., Swisher, M. E., & Branch, L. C. (2013). Factors related to farmers' preferences to decrease monk parakeet damage to crops. *Human Dimensions of Wildlife*, *18*(2), 124–137. https://doi.org/10.1080/10871209.2013.745102

Carter, N. H., López-Bao, J. V., Bruskotter, J. T., Gore, M., Chapron, G., Johnson, A., Epstein, Y., Shrestha, M., Frank, J., Ohrens, O., & Treves, A. (2017). A conceptual framework for understanding illegal killing of large carnivores. *Ambio*, *46*, 251–264. https://doi.org/10.1007/s13280-016-0852-z

Casas, F., Mougeot, F., Viñuela, J., & Bretagnolle, V. (2009). Effects of hunting on the behaviour and spatial distribution of farmland birds: Importance of hunting-free refuges in agricultural areas. *Animal Conservation*, *12*(4), 346–354. https://doi.org/10.1111/j.1469-1795.2009.00259.x

Cerri, J., Mori, E., Vivarelli, M., & Zaccaroni, M. (2017). Are wildlife value orientations useful tools to explain tolerance and illegal killing of wildlife by farmers in response to crop damage? *European Journal of Wildlife Research*, *63*, 1–8. https://doi.org/10.1007/s10344-017-1127-0

Chan, S., Crosby, M. J., Islam, M. Z., & Tordoff, A. W. (2004). *Important bird areas in*. Key Sites for Conservation. BirdLife International.

Chaves, L. S., Alves, R. R., & Albuquerque, U. P. (2020). Hunters' preferences and perceptions as hunting predictors in a semiarid ecosystem. *Science of the Total Environment*, *726*, 138494. https://doi.org/10.1016/j.scitotenv.2020.138494

Clausen, K. K., Christensen, T. K., Gundersen, O. M., & Madsen, J. (2017). Impact of hunting along the migration corridor of pink-footed geese Anser brachyrhynchus–implications for sustainable harvest management. *Journal of Applied Ecology*, *54*(5), 1563–1570. https://doi.org/10.1111/1365-2664.12850

Convention on Wetlands. (2022). Indawgyi wildlife sanctuary: Ramsar sites information service. https://rsis.ramsar.org/ris/2256

Datta, A. K. (2022). Status of illegal bird hunting in Bangladesh: Online news portal as the source. *Human Dimensions of Wildlife*, *27*(2), 183–192. https://doi.org/10.1080/10871209.2021.1895380

Davis, E. O., Crudge, B., Lim, T., O'Connor, D., Roth, V., Hunt, M., & Glikman, J. A. (2019). Understanding the prevalence of bear part consumption in Cambodia: A comparison of specialised questioning techniques. *PLoS One*, *14*(2), e0211544. https://doi.org/10.1371/journal.pone.0211544

Davis, E. O., Gaffi, L., Mussoni, G., Zaw, T., & Glikman, J. A. (2020). Insights into medicinal wildlife consumption and bear part use in Rakhine, Myanmar. *Journal for Nature Conservation*, *58*, 125923. https://doi.org/10.1016/j.jnc.2020.125923

Destro, G. F. G., De Marco, P., & Terribile, L. C. (2020). Comparing environmental and socioeconomic drivers of illegal capture of wild birds in Brazil. *Environmental Conservation*, *47*(1), 46–51. https://doi.org/10.1017/S0376892919000316

Dickman, A. J. (2010). Complexities of conflict: The importance of considering social factors for effectively resolving human–wildlife conflict. *Animal Conservation*, *13*(5), 458–466. https://doi.org/10.1111/j.1469-1795.2010.00368.x

Fairbrass, A., Nuno, A., Bunnefeld, N., & Milner-Gulland, E. J. (2016). Investigating determinants of compliance with wildlife protection laws: Bird persecution in Portugal. *European Journal of Wildlife Research*, *62*, 93–101. https://doi.org/10.1007/s10344-015-0977-6

Forest Department. (2015). *Management plan of Indawgyi wildlife sanctuary*. Ministry of Natural Resources and Environmental Conservation.

Forest Department. (2018). *Conservation of biodiversity and protected area law*. Ministry of Natural Resources and Environmental Conservation.

Fox, A. D., Elmberg, J., Tombre, I. M., & Hessel, R. (2017). Agriculture and herbivorous waterfowl: A review of the scientific basis for improved management. *Biological Reviews*, *92*(2), 854–877. https://doi.org/10.1111/brv.12258

Gallo-Cajiao, E., Morrison, T. H., Woodworth, B. K., Lees, A. C., Naves, L. C., Yong, D. L., Choi, C.-Y., Mundkur, T., Bird, J., Jain, A., Klokov, K., Syroechkovskiy, E., Chowdhury, S. U., Fu, V. W. K., Watson, J. E. M., & Fuller, R. A. (2020). Extent and potential impact of hunting on migratory shorebirds in the Asia-Pacific. *Biological Conservation*, *246*, 108582. https://doi.org/10.1016/j.biocon.2020.108582

Gelman, A. (2008). Scaling regression inputs by dividing by two standard deviations. *Statistics in Medicine*, *27*, 2865–2873.

Harrison, R. D., Sreekar, R., Brodie, J. F., Brook, S., Luskin, M., O'Kelly, H., Rao, M., Scheffers, B., & Velho, N. (2016). Impacts of hunting on tropical forests in Southeast Asia. *Conservation Biology*, *30*(5), 972–981. https://doi.org/10.1111/cobi.12785

Hartig, F. (2018). DHARMa: residual diagnostics for hierarchical (multi-level/mixed) regression models. R package version 0.2.0.

Htay, T., Htoo, K. K., Mbise, F. P., & Røskaft, E. (2022). Factors influencing communities' attitudes and participation in protected area conservation: A case study from northern Myanmar. *Society & Natural Resources*, *35*(3), 301–319. https://doi.org/10.1080/08941920.2022.2032515

Htay, T., Ringsby, T. H., Røskaft, E., & Ranke, P. S. (2022). Promoting bird conservation in wetland-associated landscapes: Factors influencing avian crop damage and farmers' attitudes. *Global Ecology and Conservation*, *38*, e02212. https://doi.org/10.1016/j.gecco.2022.e02212

Htay, T., Røskaft, E., Ringsby, T. H., & Ranke, P. S. (2023). Spatio-temporal variation in avian taxonomic, functional, and phylogenetic diversity and its relevance for conservation in a wetland ecosystem in Myanmar. *Biodiversity and Conservation*, *32*, 2841–2867. https://doi.org/10.1007/s10531-023-02632-9

Ibbett, H., Jones, J. P., & St John, F. A. (2021). Asking sensitive questions in conservation using randomised response techniques. *Biological Conservation*, *260*, 109191. https://doi.org/10.1016/j.biocon.2021.109191

Ibbett, H., Keane, A., Dobson, A. D., Griffin, O., Travers, H., & Milner-Gulland, E. J. (2021). Estimating hunting prevalence and reliance on wild meat in Cambodia's Eastern Plains. *Oryx*, *55*(6), 878–888. https://doi.org/10.1017/S0030605319001455

Ingram, D. J., Coad, L., Milner-Gulland, E. J., Parry, L., Wilkie, D., Bakarr, M., Benítez-López, A., Bennett, E. L., Bodmer, R., Cowlishaw, G., El Bizri, H. R., Eves, H. E., Fa, J. E., Golden, C. D., Iponga, D. M., Minh, N. V., Morcatty, T. Q., Mwinyihali, R., Nasi, R., … Abernethy, K. (2021). Wild meat is still on the menu: Progress in wild meat research, policy, and practice from 2002 to 2020. *Annual Review of Environment and Resources*, *46*, 221–254. https://doi.org/10.1146/annurev-environ-041020-063132

IPBES. (2022a). In U. Pascual, P. Balvanera, M. Christie, B. Baptiste, D. González-Jiménez, C. B. Anderson, S. Athayde, D. N. Barton, R. Chaplin-Kramer, S. Jacobs, E. Kelemen, R. Kumar, E. Lazos, A. Martin, T. H. Mwampamba, B. Nakangu, P. O'Farrell, C. M. Raymond, S. M. Subramanian, … A. Vatn (Eds.), *Summary for policymakers of the methodological assessment report on the diverse values and valuation of nature of the intergovernmental science-policy platform on biodiversity and ecosystem services*. IPBES secretariat. https://doi.org/10.5281/zenodo.6522392

IPBES. (2022b). In J. M. Fromentin, M. R. Emery, J. Donaldson, M. C. Danner, A. Hallosserie, D. Kieling, G. Balachander, E. S. Barron, R. P. Chaudhary, M. Gasalla, M. Halmy, C. Hicks, M. S. Park, B. Parlee, J. Rice, T. Ticktin, & D. Tittensor (Eds.), *Summary for policymakers of the thematic assessment report on the sustainable use of wild species of the intergovernmental science-policy platform on biodiversity and ecosystem services*. IPBES secretariat.

Jenkins, R. K., Keane, A., Rakotoarivelo, A. R., Rakotomboavonjy, V., Randrianandrianina, F. H., Razafimanahaka, H. J., Ralaiarimalala, S. R., & Jones, J. P. (2011). Analysis of patterns of bushmeat consumption reveals extensive exploitation of protected species in eastern Madagascar. *PLoS One*, *6*(12), e27570. https://doi.org/10.1371/journal.pone.0027570

Jiguet, F., Godet, L., & Devictor, V. (2012). Hunting and the fate of French breeding waterbirds. *Bird Study*, *59*(4), 474–482. https://doi.org/10.1080/00063657.2012.731378

Kamp, J., Oppel, S., Ananin, A. A., Durnev, Y. A., Gashev, S. N., Hölzel, N., Mishchenko, A. L., Pessa, J., Smirenski, S. M., Strelnikov, E. G., Timonen, S., Wolanska, K., & Chan, S. (2015). Global population collapse in a superabundant migratory bird and illegal trapping in China. *Conservation Biology*, *29*(6), 1684–1694. https://doi.org/10.1111/cobi.12537

Kansky, R., Kidd, M., & Fischer, J. (2021). Does money "buy" tolerance toward damage-causing wildlife? *Conservation Science and Practice*, *3*(3), e262. https://doi.org/10.1111/csp2.262

Kansky, R., Kidd, M., & Knight, A. T. (2016). A wildlife tolerance model and case study for understanding human wildlife conflicts. *Biological Conservation*, *201*, 137–145. https://doi.org/10.1016/j.biocon.2016.07.002

Knapp, E. J., Rentsch, D., Schmitt, J., Lewis, C., & Polasky, S. (2010). A tale of three villages: Choosing an effective method for assessing poaching levels in western Serengeti, Tanzania. *Oryx*, *44*(2), 178–184. https://doi.org/10.1017/S0030605309990895

Li, Z. W. D., & Mundkur, T. (2007). Numbers and distribution of waterbirds and wetlands in the Asia-Pacific region. In *Results of the Asian Waterbird census: 2002–2004*. Wetlands International.

Liordos, V., Kontsiotis, V. J., Georgari, M., Baltzi, K., & Baltzi, I. (2017). Public acceptance of management methods under different human–wildlife conflict scenarios. *Science of the Total Environment*, *579*, 685–693. https://doi.org/10.1016/j.scitotenv.2016.11.040

Lüdecke, D., Mishchenko, A. L., Pessa, J., Smirenski, S. M., Strelnikov, E. G., Timonen, S., & Wolanska, K. (2021). Performance: An R package for assessment, comparison and testing of statistical models. *Journal of Open-Source Software*, *6*, 3139. https://doi.org/10.21105/joss.03139

Madsen, J., & Fox, A. D. (1995). Impacts of hunting disturbance on waterbirds-a review. *Wildlife Biology*, *1*(4), 193–207. https://doi.org/10.2981/wlb.1995.0025

MaMing, R., Zhang, T., Blank, D., Ding, P., & Zhao, X. (2012). Geese and ducks killed by poison and analysis of poaching cases in China. *Goose Bulletin*, *15*, 2–11.

Manfredo, M. J., Berl, R. E., Teel, T. L., & Bruskotter, J. T. (2021). Bringing social values to wildlife conservation decisions. *Frontiers in Ecology and the Environment*, *19*(6), 355–362. https://doi.org/10.1002/fee.2356

Manfredo, M. J., Teel, T. L., & Dietsch, A. M. (2016). Implications of human value shift and persistence for biodiversity conservation. *Conservation Biology*, *30*(2), 287–296. https://doi.org/10.1111/cobi.12619

Marques, A. K., da Silva Novato, T., de Albuquerque, U. P., & Taboada Soldati, G. (2022). Can socioeconomic variables influence bird hunting activity in the Brazil's semi-arid region? *Human Ecology*, *50*(3), 515–530. https://doi.org/10.1007/s10745-022-00330-8

Mendonça, L. E., Vasconcellos, A., Souto, C. M., Oliveira, T. P., & Alves, R. R. (2016). Bushmeat consumption and its implications for wildlife conservation in the semi-arid region of Brazil. *Regional Environmental Change*, *16*, 1649–1657. https://doi.org/10.1007/s10113-015-0901-3

Merson, S. D., Dollar, L. J., Johnson, P. J., & Macdonald, D. W. (2019). Poverty not taste drives the consumption of protected species in Madagascar. *Biodiversity and Conservation*, *28*, 3669–3689. https://doi.org/10.1007/s10531-019-01843-3

Morsello, C., Yagüe, B., Beltreschi, L., Van Vliet, N., Adams, C., Schor, T., Quiceno-Mesa, M. P., & Cruz, D. (2015). Cultural attitudes are stronger predictors of bushmeat consumption and preference than economic factors among urban Amazonians from Brazil and Colombia. *Ecology and Society*, *20*(4), 21. https://doi.org/10.5751/ES-07771-200421

Newth, J. L., McDonald, R. A., Wood, K. A., Rees, E. C., Semenov, I., Chistyakov, A., Mikhaylova, G., Bearhop, S., Cromie, R. L., Belousova, A., Glazov, P., & Nuno, A. (2022). Predicting intention to hunt protected wildlife: A case study of Bewick's swan in the European Russian Arctic. *Oryx*, *56*(2), 228–240. https://doi.org/10.1017/S0030605320000435

Nuno, A., & John, F. A. S. (2015). How to ask sensitive questions in conservation: A review of specialized questioning techniques. *Biological Conservation*, *189*, 5–15. https://doi.org/10.1016/j.biocon.2014.09.047

Nyahongo, J. W., Holmern, T., Kaltenborn, B. P., & Røskaft, E. (2009). Spatial and temporal variation in meat and fish consumption among people in the western Serengeti, Tanzania: The importance of migratory herbivores. *Oryx*, *43*(2), 258–266.

Pangau-Adam, M., Noske, R., & Muehlenberg, M. (2012). Wildmeat or bushmeat? Subsistence hunting and commercial harvesting in Papua (West New Guinea), Indonesia. *Human Ecology*, *40*, 611–621. https://doi.org/10.1007/s10745-012-9492-5

Parry, L., & Peres, C. A. (2015). Evaluating the use of local ecological knowledge to monitor hunted tropical-forest wildlife over large spatial scales. *Ecology and Society*, *20*(3), 15. https://doi.org/10.5751/ES-07601-200315

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879

Price, M. (2008). *Too close for comfort: Contentious issues in human-wildlife encounters*. Royal Zoological Society of New South Wales, Mosman, NSW, Australia, 163–196.

R Core Team. (2022). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria.

Ramachandran, R., Kumar, A., Gopi Sundar, K. S., & Bhalla, R. S. (2017). Hunting or habitat? Drivers of waterbird abundance and community structure in agricultural wetlands of southern India. *Ambio*, *46*, 613–620. https://doi.org/10.1007/s13280-017-0907-9

Razafimanahaka, J. H., Jenkins, R. K., Andriafidison, D., Randrianandrianina, F., Rakotomboavonjy, V., Keane, A., & Jones, J. P. (2012). Novel approach for quantifying illegal bushmeat consumption reveals high consumption of protected species in Madagascar. *Oryx*, *46*(4), 584–592. https://doi.org/10.1017/S0030605312000579

Santangeli, A., Arkumarev, V., Rust, N., & Girardello, M. (2016). Understanding, quantifying and mapping the use of poison by commercial farmers in Namibia–Implications for scavengers' conservation and ecosystem health. *Biological Conservation*, *204*, 205–211. https://doi.org/10.1016/j.biocon.2016.10.018

Schielzeth, H. (2010). Simple means to improve the interpretability of regression coefficients. *Methods in Ecology and Evolution*, *1*(2), 103–113. https://doi.org/10.1111/j.2041-210X.2010.00012.x

Sijtsma, M. T., Vaske, J. J., & Jacobs, M. H. (2012). Acceptability of lethal control of wildlife that damage agriculture in The Netherlands. *Society & Natural Resources*, *25*(12), 1308–1323. https://doi.org/10.1080/08941920.2012.684850

St John, F. A., Steadman, J., Austen, G., & Redpath, S. M. (2019). Value diversity and conservation conflict: Lessons from the management of red grouse and hen harriers in England. *People and Nature*, *1*(1), 6–17. https://doi.org/10.1002/pan3.5

Travers, H., Archer, L. J., Mwedde, G., Roe, D., Baker, J., Plumptre, A. J., … Milner-Gulland, E. J. (2019). Understanding complex drivers of wildlife crime to design effective conservation interventions. *Conservation Biology*, *33*(6), 1296–1306. https://doi.org/10.1111/cobi.13330

Wang, X., Kuang, F., Tan, K., & Ma, Z. (2018). Population trends, threats, and conservation recommendations for waterbirds in China. *Avian Research*, *9*, 1–13. https://doi.org/10.1186/s40657-018-0106-9

Wetland International. (2010). *State of the world's waterbirds*. Wetlands International.

Yong, D. L., Jain, A., Chowdhury, S. U., Denstedt, E., Khammavong, K., Milavong, P., Aung, T. D. W., Aung, E. T., Jearwattanakanok, A., Limparungpatthanakij, W., Angkaew, R., Sinhaseni, K., Le, T. T., Nguyen, H. B., Tang, P., Taing, P., Jones, V. R., & Vorsak, B. (2022). The specter of empty countrysides and wetlands-impact of hunting take on birds in Indo-Burma. *Conservation Science and Practice*, *4*(5), e212668. https://doi.org/10.1111/csp2.12668

Zöckler, C., Syroechkovskiy, E. E., & Atkinson, P. W. (2010). Rapid and continued population decline in the spoon-billed sandpiper *Eurynorhynchus pygmeus* indicates imminent extinction unless conservation action is taken. *Bird Conservation International*, *20*(2), 95–111. https://doi.org/10.1017/S0959270910000316

Zöckler, C., & Win, L. (2016). The Survey of the Bird Fauna of the Indawgyi Lake.

SUPPORTING INFORMATION

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

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