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Mismatch between planned and realized harvests: integrating hunter demography, harvest records and waterbird monitoring to inform game bird management in Poland

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Bird hunting, with deep historical and cultural significance, faces sustainability challenges, particularly for migratory species. In Poland, the calibration of annual harvest ceilings (quotas) relative to realized harvest and current abundance is debated. This study: (i) examined the Słupsk Hunting District by comparing district annual quotas (plans) with realized harvest, (ii) examined alignment between nationwide mid-winter (January) goose counts and season-long district harvest totals (Sep–Jan), and (iii) surveyed hunter demographics and preferences. Results showed significant discrepancies, with realized harvest totals well below planned levels (median = 11%). Goose abundance correlated moderately with harvests ($r = 0.647$, $p < 0.0001$), though phenological (mid-winter vs season-long) and effort mismatches limit interpretations. Among the hunters surveyed, more than one-third were over 45 years of age (36.2%). Most of these hunters chiefly targeted ducks (*ca*. 80% of respondents) and, to a lesser extent, geese (*ca*. 40%). These findings highlight that the maximum set quotas (ceilings) often exceed locally attainable harvest and emphasize the need for standardized monitoring, transparent quota recalibration and adaptive harvest strategies, and policy reforms to align hunting practices with ecological realities (current abundance and seasonal availability under observed effort), ensuring viable and sustainable wildlife management in Poland.

1. Introduction

Bird hunting has deep historical roots and today operates as a regulated practice, having shifted from subsistence to structured management (Grzegorczyk *et al*. 2024, Hill 1982). Two motives frame avian take: harvest—voluntary removal for food or recreation—and culling—targeted removals for population control or disease mitigation (MacDonald 2007, Duffy & St John 2013, Buss 2015, Gawin *et al*. 2015, Kamieniarz *et al*. 2020). Hunting delivers socioeconomic benefits and recreation and can foster stewardship (Lindsey *et al*. 2007, Hansen

et al. 2012, Dai & Hu 2017, Shephard *et al*. 2024), yet remains contested for ecological and ethical reasons, especially where management is weak (Mitrus & Zbyryt 2015, Barca *et al*. 2016, Alba-Patiño *et al*. 2024). This tension underscores the need for balanced policies that reconcile economic gains, cultural values, and environmental sustainability (Madden & Sage 2020, Madden *et al*. 2023).

In Poland, the Hunting Law (October 13, 1995) governs game management. Each year, district hunting plans set harvest ceilings (quotas) prepared by lessees/managers, reviewed by local authorities and the agricultural chamber, and approved by the forest district manager with the Polish Hunting Association: park directors co-review plans for bordering districts. Migratory game birds are exempt from inventories (Article 8a), so their quotas rely on monitoring evidence rather than local counts. We treat quotas as ceilings, not targets, and evaluate their alignment with realized harvest and abundance. Game is classified as large or small (birds). Under the Regulation of March 11 2005, 13 bird species are huntable. The International Ornithological Congress (IOC) World Bird List and the North American Classification Committee (NACC) of the American Ornithological Society (AOS) recognize a split of the former Bean Goose *Anser fabalis* into *A. fabalis* (Taiga Bean Goose) and *A. serrirostris* (Tundra Bean Goose), a change not yet reflected in Polish law. Removals of invasive alien species (IAS)—*e.g.*, Canada Goose (*Branta canadensis*) under the Act on Alien Species (2021)—are authorized as culls and fall outside game harvest quotas.

Effective management of migratory game birds requires flyway-scale coordination, because populations cross multiple jurisdictions with differing rules and monitoring (Adams *et al*. 2014, Gallo-Cajiao *et al*. 2020). Along these routes, cumulative pressures—notably habitat loss and multi-country harvest—can destabilize populations (Sanderson *et al*. 2006, Newton 2004, Raine *et al*. 2015, Buchan *et al*. 2022). Trends diverge: Bean Goose (*Anser fabalis s.l.*) has declined, whereas Greylag Goose (*Anser anser*) and other residents have increased in parts of Europe (BirdLife International 2024). Yet species- and unit-specific abundance data are often sparse or inconsistent, complicating quota setting and risking misalignment between ceilings and population dynamics. We therefore ask whether legally prescribed annual harvest ceilings (quotas) align with ecological realities: (a) current abundance and trends, (b) residency–migratory phenology (including the September–January season vs. winter peaks), and (c) availability as reflected by realized harvest.

We pursue three objectives. First, we compared planned quotas with realized harvest in the Słupsk Hunting District (*ca*. 7,812 km²) (107 hunting subdistricts) for the 13 legally huntable bird species across three seasons (2017/18–2019/20). We quantified alignment as harvest efficiency and predicted higher and less variable efficiency for residents than for migrants, as well as a positive association between interannual quota changes and abundance indices. Second, to place quotas and harvest in the context of independent abundance evidence, we assessed alignment between the season-long district goose harvest (September–January) and the nationwide mid-winter (January) Wintering Water Bird Survey (MZPW) indices for geese across 43 hunting districts (including Słupsk Hunting District). We expected a positive but moderate association owing to phenological and effort mismatches. Removals of Canada Goose and other IAS are managed as culls outside district game quotas and are excluded from our analyses. Lastly, we explored hunter-level correlates using a nationwide anonymous survey (n = 47) capturing age, experience, effort, and species preferences. We expected greater per-capita harvest with increasing experience/specialization. These data provide context rather than calibration for district-level outcomes.

2. Materials and methods

2.1. Planned *vs.* harvested game birds

To examine the functional aspect of hunting (*i.e.*, how planning aligns with realized outcomes), we utilized datasets encompassing each of the thirteen species listed on the Polish game species list (Regulation of the Minister of the Environment, 11 March 2005), across three hunting

seasons (2017/2018; 2018/2019; 2019/2020), subdivided by hunting subdistricts. Data were collected from the Słupsk Hunting District (Fig. 1). The Hazel Grouse (*Tetrastes bonasia*) was omitted, as there was no planned or actual harvest recorded for this species. It should be emphasized that these are confidential data, not commonly disclosed. An analysis was conducted on 107 hunting subdistricts in the Słupsk Hunting District (part of the Pomeranian and West Pomeranian voivodeships) comparing the established plan (annual harvest ceiling) for acquiring game birds with the execution of this plan (realized harvest). "Hunting district" refers to the administrative unit leased/managed for hunting, whereas "hunting subdistricts" are the district's internal planning/reporting units (n = 107 in Słupsk). For analysis, we extracted per-species plan (ceiling) and realized harvest totals for each season. It was essential to know how many birds of each species were planned for harvest and how many were harvested. Here, "plan" denotes the district's annual harvest ceiling (quota) as set in the approved district plan (prepared by the lessee/manager), while "execution" means the recorded harvest for that season.

To determine if there is a statistically significant difference between the planned and executed harvest of birds within individual species in separate hunting seasons, a chi-square test of independence was used. To test whether realized harvest deviated from the plan at the species × season level, we used an exact one-sample Poisson test, treating the plan as the expected mean under a Poisson model for counts, p-values by species and season are reported in Table 1. The analyses were conducted using the R statistical software, (version 4.3.1; R Core Team 2023), and figures were produced with ggplot2 (version 3.4.4; Wickham 2016).

2.2. Geese abundance in comparison with actual harvest

Data on the number of counted geese from 2011 to 2018 were obtained from the MZPW, which is a part of the official State Environmental Monitoring. The MZPW monitors the abundance of wintering birds in Poland, including geese:

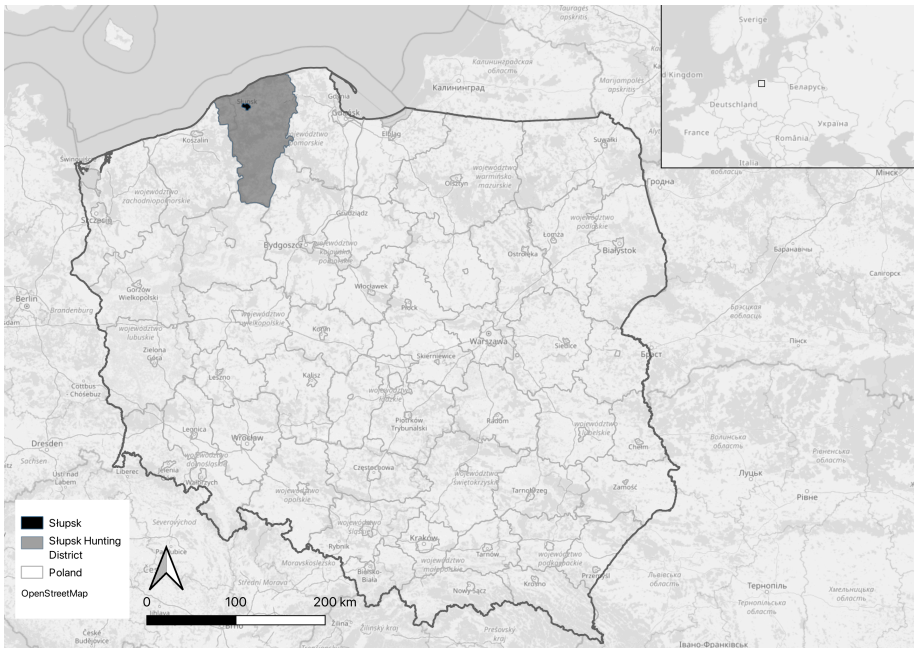

Fig. 1. Location of the Słupsk Hunting District (grey) within Poland in Europe.

Greylag Goose, Greater White-fronted Goose (*Anser albifrons*), Tundra Bean Goose, and Taiga Bean Goose. In cases where identifying the species is problematic, the geese are categorized into groups: unspecified goose, Taiga/Tundra Bean Goose, and Taiga/Tundra/White-fronted Goose. The MZPW counts are conducted mid-winter (January) at representative wintering sites (major lakes and reservoirs). In this study we use these January indices as an abundance backdrop to test alignment with harvest, we do not interpret them as denominators for a harvest rate. Season-long goose harvest totals for the same hunting districts (without species breakdown) were extracted from Hunting Report Data (*e.g.*, 2018). The goose hunting season runs from September 1st to December 21st across Poland, and until January 15th in the regions of Greater Poland, Lower Silesia, and West Pomerania (Regulation of the Minister of the Environment, 16 March 2005). For the present analysis, all counted geese were pooled in the same way as all harvested geese, while Canada Goose removals are treated separately as IAS culls.

Data from the MZPW (mid-winter) were mapped onto the administrative boundaries of Poland's hunting districts using geographic information system software (QGIS 3.16.4; QGIS Development Team 2020) to estimate goose abundances within each district. This allowed for a within-district comparison between the season-long (September–January) goose harvest totals (extracted from Hunting Report Data) and the mid-winter MZPW indices. To avoid erroneous results, only districts with MZPW count sites were included in the analysis. Geese are mobile and may forage in agricultural fields or other habitats away from their roosting sites, which could lead to some spatial mismatches between the locations of counted and harvested geese. However, the average area utilized by geese for roosting and foraging (*ca*. 10 km² (Boos *et al*. 2019)) is considerably smaller than the average size of a hunting district (*ca*. 6,400 km²), and districts often encompass diverse habitats such as waterbodies and adjacent farmlands. Consequently, spatial mismatches are much more likely to occur within the same district than between districts. Data analysis conducted using the R statistical software (version 4.3.1; R Core Team 2023), comprised a Pearson correlation to quantify the association between the numbers of counted and harvest geese.

This subsection concerns geese only. In the MZPW section we pool only game geese at the mid-winter index level (January), without separating residents *vs.* migrants at this data scale. We visualized district–year harvest versus mid-winter counts with a scatterplot including an ordinary least squares (OLS) fit with 95% confidence interval (CI).

2.3. Age structure and hunting preferences

The first step was to obtain reliable information on: (i) the age structure of the hunting community, (ii) the frequency of bird hunting, (iii) the species composition of the harvest, and (iv) hunters' opinions on bird hunting as a management/conservation tool. For this, we employed a mixed-mode questionnaire approach (online survey and paper forms) to reach respondents nationwide, including remote areas. All survey participants provided prior informed consent. Because these topics are sensitive and respondents may fear their data being used against them (public criticism of hunting, anti-hunter sentiment), which typically limits sample sizes (see Kupren & Hakuć-Błażowska 2021), participation was voluntary and anonymous. The study was not designed to be statistically representative of all Polish hunters and is descriptive/exploratory in scope. The questionnaire comprised 7 closed questions, 2 of which allowed multiple selections (the questionnaire is provided in the online supplementary material). In total, we obtained 47 complete responses from hunters across different districts. Associations between hunting experience (years since obtaining a hunting license) and the number of bird hunts (self-reported number of bird-hunting outings per season), and between age and hunting activity, were tested using Pearson's correlation.

3. Results

3.1. Planned vs. harvested game birds

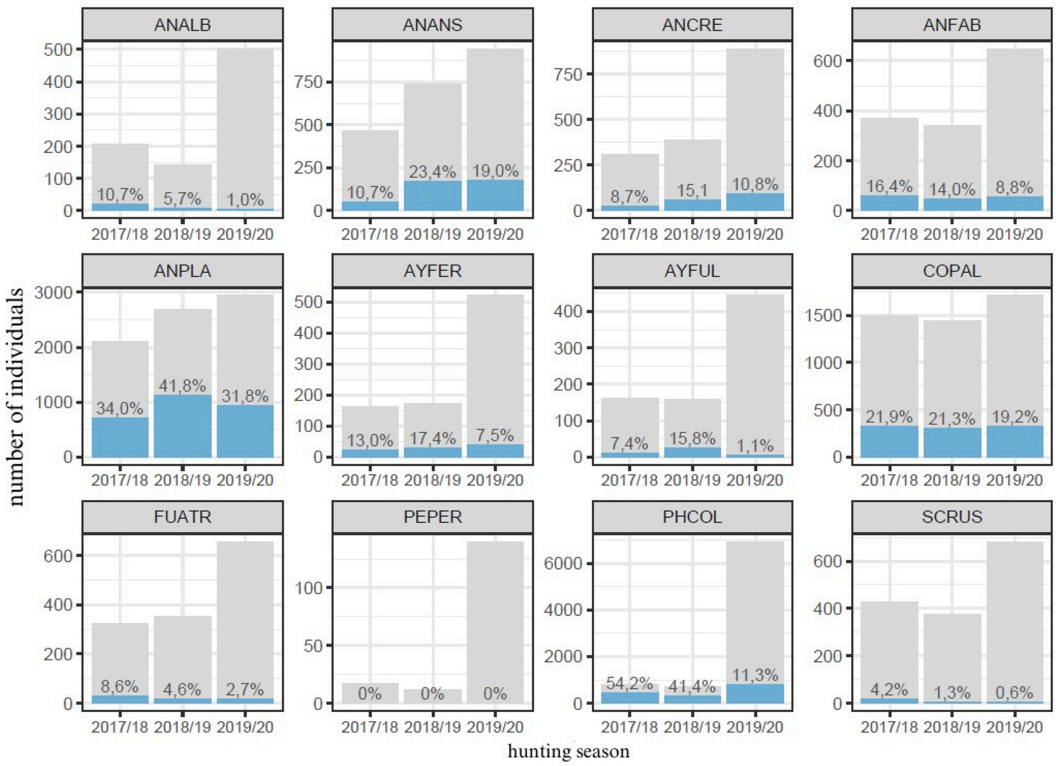

Fig. 2. Plan (in grey) and execution (in blue) of bird harvest in the Słupsk Hunting District during the studied hunting seasons 2017/18 – 2019/20. Each of the panel presents different species: ANALB - White-fronted Goose (*Anser albifrons*); ANANS - Greylag Goose (*Anser anser*); ANCRE - Teal (*Anas crecca*), ANFAB - Bean Goose (*Anser fabalis*); ANPLA - Mallard (*Anas platyrhynchos*), AYFER - Common Pochard (*Aythya ferina*); AYFUL - Tufted Duck (*Aythya fuligula*); COPAL - Wood Pigeon (*Columba palumbus*); FUATR - Eurasian Coot (*Fulica atra*); PEPER - Partridge (*Pedrix pedrix*); PHCOL - Pheasant (*Phasianus colchicus*); SCRUS - Woodcock (*Scolopax rusticola*).

For almost all bird species (except Wood Pigeon and Partridge) there were statistically significant differences between the planned and realized harvest across hunting seasons. Only Mallard showed a relatively high harvest in relation to quotas, with the highest harvest efficiency in the 2018/2019 season (41.84%). Moreover, this is the only species for which such an increase was noted, while a downward trend is observed for other species, with partridges not being harvested at all. For example, for the White-fronted Goose harvest efficiency dropped from 10.68% in the 2017/2018 season to just 1.00% in the 2019/2020 season. A similar trend is evident for species such as the Bean Goose, Pochard, Tufted Duck, Coot and Woodcock, which may indicate increasing difficulties in achieving the quotas or changes in the populations of these species. The median harvest efficiency (11 %) shows that half of the quotas were fulfilled at one-tenth or less of their ceiling, underscoring a systemic overestimation of quotas. Across the three seasons, realized harvest was substantially lower than the annual plans for most species (Table 1). The graphical visualization of the dynamics of acquisition in the studied hunting periods is presented in Fig. 2, for each species separately.

3.2. Geese abundance in comparison with actual harvest

The results indicate that the average number of counted geese was 4,422 while the average number of harvested geese was 301. The highest number of geese was recorded in the Wrocław

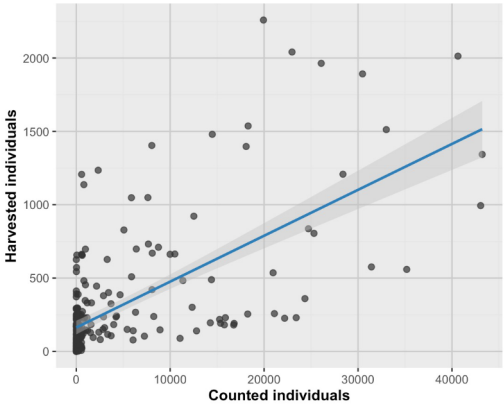

Fig. 3. Relationship between counted and harvested geese at the district level. Grey area represents 95% CI of the Ordinary Least Squares (OLS) regression.

Hunting District in 2013, where 43,223 individuals were counted. In the same district, the realized harvest was 1,343 individuals, representing 3.11% of the counted geese. The highest harvest was recorded in the Szczecin District in 2011, where 2,259 individuals were harvested. In the same year, the number of counted geese in there was 19,932, thus 11.33% of the counted geese were harvested.

We found a significant correlation between the number of geese counted and the realized harvest, with a correlation coefficient of 0.647 ($p < 0.0001$). The R^2 value was 0.419, indicating that counts explained 41.9% of the variance in harvest. The F-statistic value was 162.4, indicating statistical significance of the model, while the estimated slope was 0.0313. At the district–year scale, season-long goose harvest totals increased with mid-winter (January) MZPW counts within the same district boundaries (Fig. 3). Each point represents one district–year. An ordinary least-squares fit (solid line, 95% CI) indicated a positive association (Pearson $r = 0.647$, $R^2 = 0.419$, $p < 0.0001$; slope > 0), with substantial among-district/year variation. Some district–years show comparatively high harvest relative to their January counts, plausibly reflecting temporal-window mismatches between the mid-winter index and season-long harvest, differences in effort or access.

3.3. Age structure and hunting preferences

Among the surveyed hunters, the largest share is represented by individuals over the age of 45, accounting for 36.17% of the sample. They are followed by those aged 36 to 45 years, who make up 31.91%, and hunters aged 27 to 35 years, comprising 25.53%. The least numerous groups include individuals aged 18 to 26 years, representing only 6.38% of the respondents. We found no significant correlation between the experience of the hunter (years since obtaining a hunting license), age and the number of bird-hunting outings per season hunts ($r = 0.238$, $N = 47$, $P = 0.107$ and $r = 0.073$, $N = 47$, $P = 0.628$, respectively).

Out of 47 hunters: 79.56% harvested ducks, 40.43% harvested geese, 17.02% Wood Pigeons, 36.17% harvested Pheasants. The other species—Partridges, Hazel Grouse, Coots and Woodcocks—were taken only sporadically or not at all, together accounting for just 4.3% of respondents (never more than one hunter per species).

Regarding the motivations of hunting: 46.81% participate in bird hunting for consumption reasons, 17.02% harvest birds due to hunting damage, 14.89% did it for sports and recreational purposes. It was rare for a respondent to admit hunting without giving a reason, and some hunters left the question unanswered.

When asked about reducing the procurement plan, the overwhelming majority (70.2%) responded that the plan should not be reduced for any species as it does not pose a threat to bird populations. Roughly 12.8% of the hunters want to cut back the take of the Partridge, Hazel Grouse, Woodcock and Coot. Seventeen percent voice assorted concerns (unspecified views, fear of population declines). All respondents believe that hunting for birds should not be ceased.

These descriptive survey summaries provide context on who hunts and what is targeted, they do not calibrate Słupsk outcomes and are interpreted cautiously in the Discussion.

4. Discussion

The analysis of bird harvest data in the Słupsk

Table 1. Planned (n) and harvested (N) individuals of respective game bird species in the Słupsk Hunting District across three hunting seasons (2017/2018–2019/2020), with corresponding harvest efficiency (%) and statistical comparison. P-values in bold indicate statistically significant departures of realized harvest from the planned quota. For Wood Pigeon, the p-value is not bold because the pooled test was not significant (p = 0.142).

	Hunting season									
	2017/2018			2018/2019			2019/2020			
	Plan	Harvested		Plan	Harvested		Plan	Harvested		
Species	n	N	%	n	N	%	n	N	%	p[a]
W-F Goose[b]	206	22	10.68	141	8	5.67	501	5	1.00	**< 0.001**
Greylag Goose	469	50	10.66	734	172	23.43	941	179	19.02	**< 0.001**
Teal	310	27	8.71	390	59	15.13	887	96	10.82	**0.020**
Bean Goose	371	61	16.44	343	48	13.99	647	57	8.81	**0.001**
Mallard	2109	716	33.95	2679	1121	41.84	2943	937	31.84	**< 0.001**
Pochard	161	21	13.04	172	30	17.44	521	39	7.49	**0.001**
Tufted Duck	162	12	7.41	158	25	15.82	444	5	1.13	**< 0.001**
Wood Pigeon	1496	328	21.93	1445	308	21.31	1710	329	19.24	0.142
Eurasian Coot	325	28	8.62	351	16	4.56	656	18	2.74	**< 0.001**
Partridge	17	0	0	12	0	0	140	0	0	-
Pheasant	815	442	54.23	723	299	41.36	6925	781	11.28	**< 0.001**
Woodcock	427	18	4.22	377	5	1.33	682	4	0.59	**< 0.001**

[a]Test of equality of proportions without continuity correction, for the total counts across all hunting seasons.

[b]White-fronted Goose

Hunting District shows large discrepancies between annual quotas and realized harvests. Median harvest efficiency was *ca*. 11% across seasons. Across species, we observed very low realized-harvest ratios. As we cannot independently audit the validity of the harvest reporting, we analyzed the data as provided, assuming that managers of the hunting districts fulfilled statutory reporting obligations. Accordingly, we treat the low harvested values as credible and reflective of actual take (*e.g.*, Teal: 27 *vs.* 310 [8.7%], Table 1). This pattern mirrors broader challenges in managing migratory bird populations, a critical issue both in Poland—where 10 of 13 game bird species are migratory—and globally along flyways like the East Atlantic Flyway. Declining Bean Goose populations and rising Greylag Goose numbers, as reported by BirdLife International (2024), underscore the urgency of adaptive, cross-border management. Even resident species are affected: the planned pheasant quota jumped from 723 birds in 2018/2019 to 6,925 in 2019/2020, whereas the actual harvest plunged from 41.36 % to 11.28 %, indicating abrupt shifts in abundance or accessibility. These fluctuations are best explained by management practices for this species—large numbers of pen-reared pheasants are released into hunting grounds (Flis 2012, Madden *et al*. 2018). By contrast, Mallard are not released in

Poland, so the recorded totals reflect wild birds. Even without releases, harvest efficiency for Mallard was relatively high, peaking at 41.84% in 2018/2019.

In Poland, the Hunting Law's omission of mandatory population inventories, coupled with difficulties distinguishing resident breeders from transient migrants, results in overestimated quotas that function as theoretical ceilings rather than achievable goals. The consistent underfulfilment of quotas (low harvest efficiency) suggests that current ceilings are set too high relative to attainable harvest. Because the rules and inputs used to set ceilings are not publicly available, we cannot discuss and propose revisions the method. To ensure sustainability and transparency, such methodology should be made fully public and open to scientific scrutiny. It should utilize up-to-date abundance indices (MZPW) and—when available—standardized hunting-effort metrics. Globally, the lack of reliable population estimates makes it difficult to manage hunting sustainably, numerous studies show that quotas and other regulations are often set without reference to the true size and trend of the targeted bird populations. (Gallo-Cajiao *et al*. 2020). The moderate correlation between geese monitoring data and harvests ($r = 0.647$, $p < 0.0001$) suggests monitoring informs quotas to some extent, yet the low R^2 (0.419) points to unaccounted variables—hunter behavior, habitat shifts, or weather patterns—consistent with global findings where socioeconomic dynamics often override ecological intent (Raine *et al*. 2015).

Methodological constraints further complicate interpretation. We treat mid-winter (January) MZPW counts as an abundance backdrop to test alignment with season-long harvest and quotas. We do not use January counts as denominators for a population harvest rate. The hunter survey's limited sample size ($n = 47$) restricts its generalizability across Poland's diverse hunting community, and the lack of standardized effort data limits inference. The apparent inconsistency—stable harvest totals (228–241 geese) despite large variation in mid-winter counts (250–4,228)—is consistent with a decoupling of harvest from abundance under low or variable effort and access constraints, accordingly, weak quota–abundance alignment may arise even if ceilings respond to monitoring. Without effort metrics (*e.g.*, hunter-days), we cannot distinguish between effort-driven and abundance-driven variation in the harvest. These gaps expose vulnerabilities in current practices, necessitating robust solutions. A practical first step is to implement standardized, ground-based counts conducted on the same dates each month at fixed sites (like the United Kingdom Wetland Bird Survey approach), which would yield comparable indices across districts and reduce turnover/phenology bias. As a minimum data standard, districts should annually publish quotas, realized harvest, and basic effort metrics (*e.g*., hunter-days), enabling routine, independent evaluation of quota calibration. Remote-sensing approaches (*e.g*., GPS tracking, drones; Bouten *et al*. 2018) can then complement these counts by quantifying movements and improving detection in inaccessible habitats. Rather than implying overharvest, a pragmatic next step is to adopt flexible harvest limits that are recalibrated annually to current abundance and—when available—standardized effort, akin to Norway's Willow Ptarmigan system (Aanes *et al*. 2002), to improve calibration and reduce both over- and under-harvest risk. This recommendation aims at better calibration and transparency rather than demonstrating current overharvest under the analyzed conditions. Given our data limitations (no standardized effort metrics; mid-winter counts; pooled geese), we do not estimate population harvest rates or sustainability and frame this recommendation as a process improvement, not evidence of overharvest. The aging hunter demographic (36.17% over 45, 6.38% aged 18–26) signals a need for targeted education to recruit and train younger hunters in sustainable practices, a pressing concern echoed in Europe and North America (Dzięciołowski 2013, Van der Merwe & Saayman 2019). Policy reforms, such as amending the Hunting Law to mandate inventories, enforce quota transparency, and incentivize compliance via subsidies—drawing from Scandinavian successes (Dressel *et al*. 2021)—could bridge ecological and practical divides. Finally, integrating citizen science, where hunters report sightings via mobile apps (Nokelainen *et al*. 2024, Zanet *et al*. 2024), could further bolster

data granularity, aligning Poland's strategies with innovative global models (Sullivan *et al*. 2009). These steps collectively aim to harmonize hunting with conservation, ensuring sustainable migratory bird management.

Epäsuhta suunniteltujen ja toteutuneiden saaliiden välillä: metsästäjien demografian, saalistietojen ja vesilintujen seurannan integrointi riistanhoidon tueksi Puolassa

Lintujen metsästys, jolla on vahva historiallinen ja kulttuurinen merkitys, kohtaa nykyisin merkittäviä kestävyyshaasteita, erityisesti muuttolintulajien osalta. Puolassa keskustellaan siitä, miten vuotuiset saaliskiintiöt tulisi säätää vastaamaan toteutunutta saalista ja lajien nykyistä runsautta. Tässä tutkimuksessa: (i) tarkasteltiin Słupskin metsästysaluetta vertaamalla alueen vuotuisia kiintiöitä (suunnitelmia) toteutuneeseen saaliiseen, (ii) arvioitiin valtakunnallisten keskitalven (tammikuu) hanhilaskentojen ja koko metsästyskauden (syyskuu–tammikuu) alueellisten saalistietojen välistä vastaavuutta, ja (iii) kartoitettiin metsästäjien demografiaa ja preferenssejä. Tulokset osoittivat merkittäviä eroja: toteutuneet saaliit jäivät selvästi suunniteltujen tasojen alapuolelle (mediaani = 11 %). Hanhien runsaus korreloi kohtalaisesti saaliiden kanssa ($r = 0{,}647$, $p < 0{,}0001$), vaikka fenologiset (keskitalvi vs. koko kausi) ja metsästyspanostuksen epäsuhtaisuudet rajoittavat tulkintoja. Kyselyyn vastanneista metsästäjistä yli kolmannes oli yli 45-vuotiaita (36,2 %). Suurin osa näistä metsästäjistä keskittyi pääasiassa sorsiin (*n*. 80 % vastaajista) ja vähemmässä määrin hanhiin (*n*. 40 %). Havainnot osoittavat, että asetetut enimmäiskiintiöt ylittävät usein paikallisesti saavutettavissa olevan saaliin ja painottavat tarvetta standardoidulle seurannalle, läpinäkyvälle kiintiöiden uudelleenkalibroinnille ja sopeutuville saalisstrategioille sekä politiikkauudistuksille, jotta metsästyskäytännöt saadaan vastaamaan ekologisia realiteetteja (nykyinen runsaus ja kausittainen saatavuus suhteessa havaittuun metsästyspanostukseen), mikä varmistaa elinkelpoisen ja kestävän riistanhoidon Puolassa.

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Online supplementary material

Supplementary material available in the online version of the article includes the questionnaire given to the hunters.

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Estimating the population and related dynamics of the cave-dwelling Edible-nest Swiftlet in the Andaman Islands, India

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Apodids (Swifts and Swiftlets) are among the under-studied bird species. They are hard to identify, and their breeding habitats are inaccessible, making studying their population estimation and related dynamics challenging. In this study, we aimed to estimate the populations using the capture-mark-recapture (CMR) and nest count methods. Conducted at the Baratang cave complex in the Andaman Islands, our study used stratified sampling to choose 12 study caves based on the breeding population for capture and recapture in all possible caves occupied by Edible-nest Swiftlet (*Aerodramus fuciphagus*). The use of the Lincoln Index to estimate the populations of the Edible-nest Swiftlet in each cave by analyzing the capture-mark-recapture data and using the program MARK with the Live Recaptures. The Lincoln Index and total population count estimated 486 and 505 birds, respectively, with no significant difference ($p > 0.05$). The best-fit model indicates that the annual survival rate was consistent throughout the study period (0.97–1.00), and the capture probability was 0.35 ± 0.02. The study evidently showed that using only one method is inadequate for accurately estimating the Edible-nest Swiftlet populations. The CMR method is recommended as an alternative when it is necessary to understand related population dynamics, and the nest and roost count methods are not feasible. The study confirms the effectiveness of the CMR method when used in combination with other traditional methods.

1. Introduction

Fluctuations in animal populations can significantly influence conservation action and planning (Gregory *et al*. 2004). Therefore, estimating and monitoring populations is crucial for prioritizing species, research design, policy making, conservation practice, and wildlife management (Sankaran, 2001, Brouwer *et al*. 2003, Taylor & Pollard, 2008, Moussy *et al*. 2021). It is essential to have robust population monitoring to conserve cave-dwelling birds, as

they are crucial in providing energy for subterranean habitats (Manchi *et al*. 2022). Numerous survey methods have been developed to estimate the population of terrestrial birds (Sutherland *et al*. 2004, Bibby *et al*. 2000). However, estimating the cave-dwelling bird populations is difficult due to the inaccessibility and limited knowledge of the subterranean habitat, including caves (Wynne *et al*. 2021). Echolocating cave-dwelling birds are observed to enter and exit their roosting caves during twilight (dawn and dusk) and dark hours (Mane & Manchi 2019). Estimating population and understanding factors like annual survival rates is difficult due to the inaccessibility or unknown nature of their roosting and nesting places in caves.

The Edible-nest Swiftlet (*Aerodramus fuciphagus*) is a cave-dwelling species belonging to the Order Apodiformes and Family Apodidae. The species is of ecological and economic importance (Medway 1963, Lau & Melville 1994, Sankaran 2001). It builds nest wholly of the mucilaginous secretion of the paired sublingual glands (Marshall & Folley 1956), which enlarge during the breeding season (Medway 1962a). Since the species uses saliva as nest material, which gets degraded because of the percolated water and high humidity in the limestone caves after every breeding season, the birds need to make new nests every year. The species has an adaptation wherein their salivary glands enlarge every breeding season which helps them to produce more saliva to build their nest (Manchi 2009). The Andaman and Nicobar Islands mark the easternmost limit of the Edible-nest Swiftlet, which is occasionally considered a subspecies, the Andaman Edible-nest Swiftlet (*Aerodramus fuciphagus inexpectatus*), which is endemic to the Andaman and Nicobar Islands (Cranbrook *et al*. 2013). According to Sankaran (2001), > 80% population was lost between mid-1980s and mid-1990s (Sankaran 2001) in Andaman and Nicobar Islands. It is because of the two-decade long conservation efforts the Edible-nest Swiftlet populations have recovered across the islands at Chalis-Ek, Interview and Baratang Islands (Manchi & Sankaran 2014).

In the unique ecological setting of the Andaman and Nicobar Islands, previous studies (Sankaran 2001, Manchi 2009, Mane & Manchi 2017a, 2017b, 2019) have used the nest count and roost count (arrival and departure surveys) methods for the Edible-nest Swiftlet's population estimation. Engbring *et al*. (1986) used the Variable Circular-Plot (VCP) method in 1982 to estimate the Mariana Swiftlet's (*Aerodramus bartschi*) population on Saipan in the Northern Mariana Islands (Cruz *et al*. 2008). A more appropriate method could be the nest count and evening arrival survey (roost count) using night vision technology, as suggested by Johnson (2015) and Johnson *et al*. (2018). A study by McFarlane *et al*. (2015) in the Gomantong, Sabah, and Borneo caves used high-resolution terrestrial laser scanning to assess swiftlet nest densities on high cave roofs, even in complete darkness. To enhance our understanding of cave-dwelling bird population trends, the taxonomic scope of monitoring should be broadened to include a wider range of species, life histories, environments, and ecologies (Borges *et al*. 2018).

Early researchers have highlighted the unsuitability of a single method for population estimation that is universally applicable in avian studies (Berthold 1976, Shields 1979). However, Nichols *et al*. (1981) suggest that the capture-mark-recapture method can provide valuable estimates for evaluating other population estimation methods and may be the most suitable way to estimate population size in certain circumstances. A few researchers used the capture-mark-recapture method in studying the Apodids (Swifts and Swiftlets) such as Alpine Swift (*Tachymarptis melba*; Hammersley 1953), Biscutate Swift (*Streptoprocne biscutata*; Pichorim & Monteiro-Filho 2010), Pallid Swift (*Apus pallidus*; Boano *et al*. 2020), Common Swift (*Apus apus*; Boano *et al*. 2020), White-rumped Swiftlet (*Aerodramus spodiopygius*; Tarburton 1987), Edible-nest Swiftlet in the Andaman Islands (Gurjarpadhye *et al*. 2021). The capture-mark-recapture was scarcely used for population estimation and annual survival rate of the Apodids across their entire distribution range. Hence, we attempted the capture-mark-recapture method for the Edible-nest Swiftlet in the Andaman Islands.

2. Materials and methods

2.1. Study area

From the Arakan-Yoma mountains of Western Myanmar (Burma) in the north to Sumatra in the south, the Andaman and Nicobar Island arc is located between 06°45'9" N to 13°41'9" N and 92°12'9" E to 93°57'9" E (Fig. 1). The Andaman and Nicobar Islands comprise 572 islands. The archipelago borders the Bay of Bengal in the West and the Andaman Sea in the East. Andaman and Nicobar Islands experience tropical to subtropical climate with 79–89% humidity, 21–33 °C temperature, and 3100 mm rainfall from May to December. The region is predominantly covered by a dense tropical forest (Champion & Seth 2005). The Andaman group comprises 394 limestone caves identified in the Andaman and Nicobar Islands (Manchi & Sankaran 2014, Mane & Manchi 2017b). We conducted the study at the cave complex on Baratang Island (12° 05′ N, 92° 45′ E), situated between Wraffter's Creek and Naya Dera, which contains over 175 caves within an area of 0.77 km² (Sankaran 2001, Manchi & Sankaran 2014, Mane & Manchi 2017a, Mane *et al*. 2019).

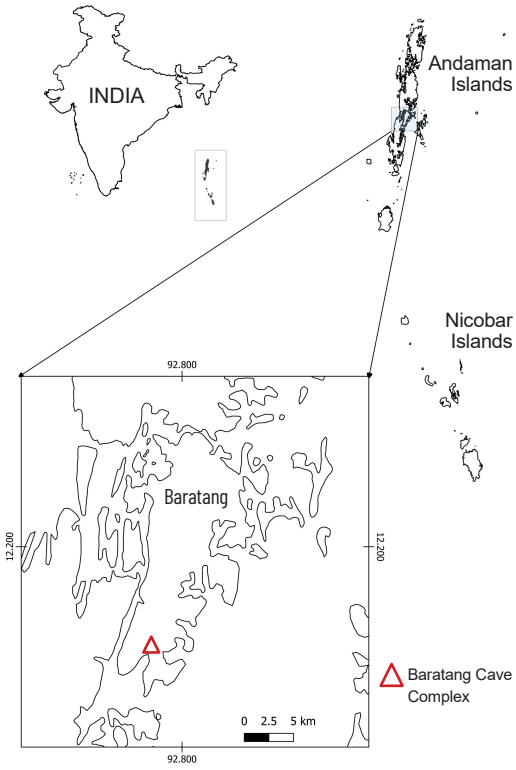

Fig. 1. The geographic location of the study area (Baratang Cave Complex) in the Andaman Islands.

2.2. Data collection

We determined the breeding population of the Edible-nest Swiftlet using the nest count method (Medway 1962b, Manchi & Mane 2012, Manchi & Sankaran 2014, Mane & Manchi 2017a). The breeding season (2 broods) of the species begins in December and continues till September (Medway 1962a, Sankaran 2001, Manchi & Sankaran 2014, Manchi & Mane 2012). However, we sampled only during the first brood because of the accessibility and feasibility issues. The highest count recorded was considered as the breeding population of that specific cave. The Edible-nest Swiftlet is monogamous (Koon & Cranbrook 2002, Winkler *et al*. 2020), with each nest representing a pair of birds (Sankaran 2001, Manchi & Sankaran 2014). Mane (2017) documented that the Edible-nest Swiftlet colonies in North and Middle Andaman Islands, including the Baratang cave complex, consist of an average of 8.05% non-breeding and 91.95% breeding individuals. Accordingly, we estimated the non-breeding and total populations using Equations 1 and 2, respectively:

$$NP = (8.05 \times BP) / 91.95 \quad (1)$$

$$TP = BP + NP \quad (2)$$

Where TP = Total Population, BP = Breeding Population and NP = Non-breeding Population.

A survey conducted at the beginning of 2017 helped us know that the Edible-nest Swiftlet inhabited 112 of the 175 caves in the Baratang cave complex. Then, we selected the caves for conducting the CMR based on cave accessibility, mist-netting feasibility, and the practical difficulties of doing CMR. We used a stratified random sampling method and divided 112 caves into various population classes (0–10; 11–20; 21–30; 31–40 pairs, Fig. 2) to select 12 study caves, *i.e.,* little above 10% of 112 (Fig. 3). It helped us

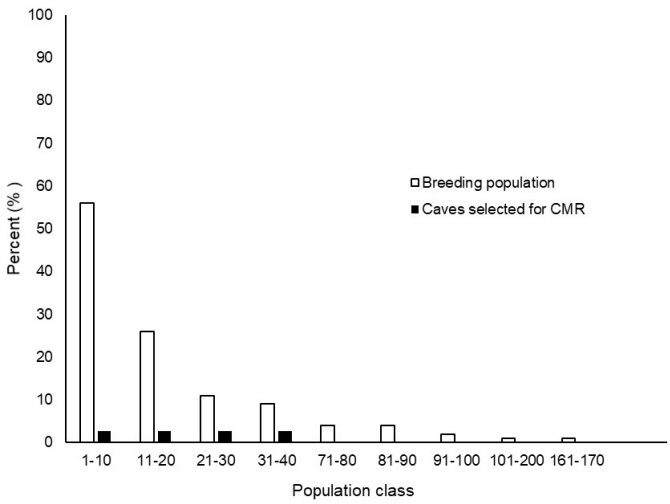

Fig. 2. Caves in Baratang classified based on breeding population, with three caves from each class (0–10, 11–20, 21–30, and 31–40 pairs) selected for Capture-Mark-Recapture.

avoid the risk of losing birds while capturing and errors in population estimation.

Between 2017 and 2019, we used the mist net (6 m × 2.6 m; 30 mm mesh) at the cave entrance to capture and recapture the adult birds at the cave openings during early nest-building, specifically between December and January (Dunn & Ralph 2004, Gurjarpadhye *et al*. 2021, Manchi 2009, Manchi & Mane 2012). The capture was conducted once in the 12 selected caves during the peak roosting hours, *i.e.,* between 17:00 hrs and 20:00 hrs (IST), when most adult birds return to caves for roosting (Mane & Manchi 2017a) during sunset which is mostly between 17:30 hrs to 17:45 hrs. Each bird captured for the first time was marked using aluminum Z-rings with a unique identification code number and then released. We attempted to recapture the marked birds after the capture during the first brood (*i.e.,* June 2018–June 2019). According to Ryan & Collins (2020), there is inter-colonial dispersal in Apodids however, Gurjarpadhye *et al*. (2021), documented no inter-colonial dispersal in adult Edible-nest Swiftlet individuals in the Andaman Islands. As findings from both studies are contradictory we conducted the recapture (two effort night per cave; 58 effort nights) in 29 caves in the study area, including those initially selected for capture. Each captured individual was monitored for the ring and its unique code number. After collecting the required information, all the individuals were promptly released to their respective caves. Thus, period 1 (January–March 2017) was when we captured the individuals in 12 caves and marked them, period 2 (December 2017–June 2018) and period 3 (December 2018–June 2019) when we re-captured the birds in all the Edible-nest Swiftlet 29 caves (including the original 12 caves). Hence, we could also estimate the survival rate between period 2 to period 3.

We used the Lincoln Index also known as Lincoln-Peterson estimator (Cooch & White 2001) to estimate the populations of the Edible-nest Swiftlet in each cave based on the capture-recapture data (Eq. 3). The index is based on some assumptions:

1. Individuals with marks have the same probability of survival as other members of the population.
2. Births and deaths do not occur in significant numbers between the time of release and the time of recapture.
3. Immigration and emigration do not occur in significant numbers between the time of release and the time of recapture.
4. Marked individuals mix randomly with the population at large.
5. Marked animals are neither easier, nor harder, to capture a second time.
6. Recapture rates are high enough to support an accurate estimate (Cooch & White 2001).

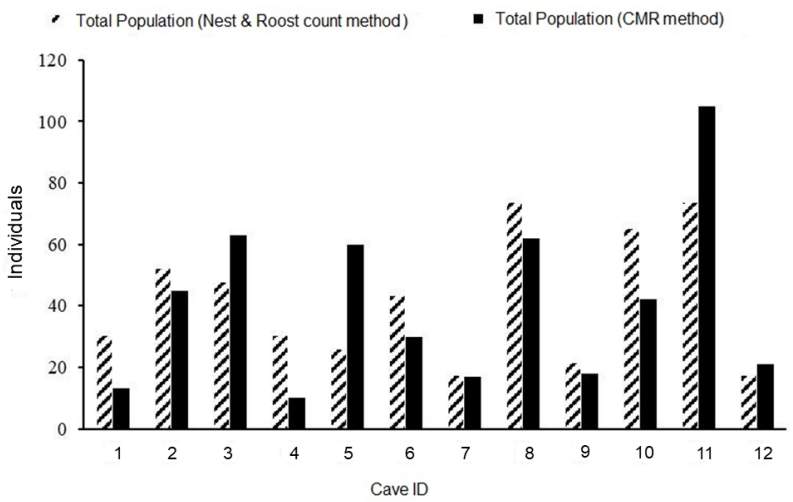

Fig. 3. Population estimation using total population (Nest & Roost Count Method) and Total population (CMR method) in the study caves.

The Lincoln-Peterson calculation tends to overestimate the population size, especially if the number of recaptures is small. We performed a goodness of fit test (Student's *t*-test) to determine the significance of the difference between the population counts from using CMR and total count method.

The formula of the Lincoln Index is as follows:

$$N = (M \times T) / R \quad (3)$$

Where, N = Total population size, M = Initially marked birds, T = Total in the second sample, R = Marked recaptures.

We used the program MARK (Ver. 9.0, Build 9200) with the Live Recaptures (CJS) option (Cooch & White 2001) for survival estimates and capture probability. We used the four predefined models to check the dependence of survival and capture probabilities as the function of time:

1. $\phi(t)p(t)$ (standard Cormack-Jolly-Seber model; Cormack 1964, Jolly 1965, Seber 1965, 1982, Cormack 1989) with time-dependent survival and capture probability
2. $\phi(.)p(t)$, with constant survival and time-dependent capture probability
3. $\phi(t)p(.)$, with time-dependent survival and constant capture probability
4. $\phi(.)p(.)$, with constant survival and capture probability

The best model fit was selected based on the lowest Akaike's Information Criterion (AICc), Delta AICc > 2 (difference in AICc between models), and superiority of the Akaike's Information Criterion Weight (AICc weight). We used the Likelihood Ratio Test (LRT) to assess the goodness of fit of two competing statistical models based on the ratio of their likelihoods (Seber & Schofield 2019, Boano *et al*. 1993).

3. Results

In 2019, we counted in total 230 nests in the 12 study caves, so using the nest count method, the breeding population (BP) was 460 birds. Using Eqs.1 and 2, the estimated Non-Breeding Population (NP) and total population were 40.64 ~41 birds and 501 birds, respectively. The Lincoln Index (Eq. 3), using CMR data, estimated a total population of 486 ± 28 (estimate ± SE), *i.e.*, 486 birds (Fig. 3). We did not encounter any inter-colonial dispersal in adult Edible-nest Swiftlet. The goodness of fit test between the total populations estimated using nest count and CMR methods revealed no significant difference between the population estimates from both

Table 1. Outputs of the pre-defined Capture-Mark-Recapture (CMR) models. AIC: Akaike Information Criterion; No. Par: Number of parameters; SE: standard error.

Model no.	Candidate models	AICc	Delta AICc	AICc weight	Model Likelihood	No. Par.	Deviance	-2Log(L)	(ϕ) ± SE (Annual survival)	p (capture probability)
1	{ϕ*t p*t} Both survival and encounter probability time dependent	621.90	0.00	0.50	1.00	3	615.83	615.83	0.97 ± 0.10	0.21 ± 0.03
2	{ϕ.*pt*} Survival constant over time, encounter probability time dependent	621.90	0.00	0.50	1.00	3	615.83	615.83	0.97 ± 0.10	0.21 ± 0.03
3	{ϕ*t p*.} Survival time dependent, encounter probability constant over time	664.81	42.90	0.00	0.00	3	44.10	658.73	1.00 ± 0.00	0.35 ± 0.02
4	{ϕ.*p*.} Both survival and encounter probabilities constant over time	662.77	40.86	0.00	0.00	2	44.10	658.73	1.00 ± 0.00	0.35 ± 0.02

methods ($p > 0.05$). Around 3.76% less population was estimated by the Lincoln index compared to the population estimated by the nest count method.

Out of the estimated population of 501 birds, 75.64%, *i.e.,* 379 adult individuals, were captured and marked between December 2017 and June 2018. Around 31.5% ± 17.1% of birds were captured from every study cave. During December 2018 and June 2019 we recaptured 160 individuals which is equivalent to a 42.2% recapture rate. The CMR models (Table 1), along with the LRT (Table 2), indicated that the two models $\{\phi_t p_t\}$ and $\{\phi . p .\}$ are statistically competing based on the goodness of fit ($p < 0.0001$). The first model's time-dependent predicted annual survival rate is 0.97, with a capture probability of 0.21 ± 0.03. The other competing model states that the annual survival rate remains constant at 1.00 for the Edible-nest Swiftlet; the capture probability is 0.35 ± 0.02.

4. Discussion

Between December 2017 and June 2019, a total population of 501 birds was estimated based on the nest count method in the 12 study caves, while CMR estimated 486 birds. The present recapture efforts reconfirmed the findings of Gurjarpadhye *et al*. (2021), that the adult Edible-nest Swiftlet individuals do not depict the inter-colonial dispersal. The statistical analysis confirmed that both methods yielded similar population estimates for the species ($p < 0.05$). This can be attributed to the rigorous capture and recapture efforts, which provide reliable estimates that are significantly similar to those given by the total count. Contrastingly, there have been studies such as Rees *et al*. (2011), wherein the population estimation for small mammals was poor because of low number of sampling efforts ($n = 5$ trapping nights). However, according to Nichols *et al*. (1981), no single population estimation method is universally appropriate for avian studies and that CMR method can provide estimates that are useful in assessing the appropriateness of other estimation methods. It can also provide the most reasonable means of estimating population sizes in some situations.

Table 2. Likelihood-ratio (LR) test between the predefined models of Capture-Mark-Recapture model. PIM: Parameter Index Matrix; NA: signifies that the LR test could not be performed.

Reduced model	General model	Chi-sq	Degrees of freedom (df)	Probability (p)
{ϕ (.) p (.) PIM}	{ϕ (t) p(t) PIM}	42.901	1	< 0.0001
{ϕ (t) p (t) PIM}	{ϕ (.) p (t) PIM}	0.00	0	NA
{ϕ (.) p (.) PIM}	{ϕ (t) p (.) PIM}	0.00	1	NA
{ϕ (.) p (t) PIM}	{ϕ (t) p (.) PIM}	-42.901	0	NA
{ϕ (t) p (t) PIM}	{ϕ (t) p (.) PIM}	-42.901	0	NA

On the other hand, the total count which is a result of roost and nest count method, have been proved non-invasive and suitable for the Edible-nest Swiftlet's population monitoring in Andaman and Nicobar Islands (Sankaran 2001, Manchi 2009, Gurjarpadhye *et al*. 2021). Further, it is important to understand the combination of the methods can always give a better understanding of population dynamics of the species as in the present study.

The Edible-nest Swiftlet shows high annual survival rates ranging between 97–100%, whereas the recapture probability is 42.2%. The Jolly-Seber model using the Capture-Mark-Recapture data suggested that the swifts have high rates of annual survival (34%–100%) and a life span (Collins 1985). However, survival during the first year of life is much lower in most Apodid species (Boano *et al*. 1993, Chantler & Driessens 1995). The Edible-nest Swiftlet shows high annual survival rates similar to the tendency shown by the Biscutate Swift (34%–100%; Pichorim & Monteiro-Filho, 2010). Comparatively, the annual survival rate of the White-rumped Swiftlet is higher (64%–73%), and high annual survival rates are also recorded in the Common (78%; Boano *et al*. 2020) and the Pallid Swifts (71%-76 %; Boano *et al*. 1993).

Swifts are known to be long-lived and the survival in Apodiformes is very high as compared to passerine aerial feeders such as swallows (Hirundinidae; Masoero *et al*. 2016). Pichorim and Monteiro-Filho (2010) proposed that the survival estimate based on capture-recapture data should be considered as a minimum, owing to the dispersal of some individuals to other colonies. Hence, according to Boano *et al*. (1993), the CMR can be useful in the case of birds that show philopatry. Further studies are required to understand philopatric behaviors in swiftlets to get reliable estimates.

Four CMR models were tested for the collected data (Table 1). The best-fit model for the Edible-nest Swiftlet colonies in the caves of Baratang exhibits characteristics of a closed population with constant survival. The capture probability (0.35) remained consistent, independent of time. Thus, in the present study the model could reliably estimate the size of the breeding and non-breeding populations with a recapture rate of 35% between 17:00 and 20:00 (IST), regardless of the capture season.

Capture probabilities vary depending on the species, sex, and whether the populations are closed, partially open, or open (Nichols *et al*. 1981). Terrestrial birds' capture probabilities (when using mist nets) are interpreted to understand the adult-sex ratios (Senar *et al*. 1999, Amrhein *et al*. 2012, Lovász *et al*. 2018) and estimate the population size (Whitman *et al*. 1997, Dunn & Ralph 2004, Sutherland *et al*. 2004). Due to a lack of knowledge about cave ecosystems with closed populations and the scarcity of relevant research, it is challenging to draw definitive conclusions about the suitability of the CMR method for estimating population size in cave-dwelling birds, especially Apodids. Studies on seals and dolphins indicate that capture probabilities above 0.3 are reliable and reflect the accuracy of mark-recapture estimates

(Otis *et al*. 1978, Speakman *et al*. 2010). According to the occupancy models, the capture probability of insectivores and frugivorous birds is from 0.43 to 0.60 and is not influenced by habitat types (Hernandez *et al*. 2013). Additional studies using alternative methods and statistical models could potentially corroborate the findings from CMR in the present study.

Conclusion

This study adds to our current understanding of *Aerodramus sp*. Estimating the population of the cave-dwelling colonial birds is challenging due to various factors. Thus, a single method is insufficient for accurately estimating the population of cave-dwelling birds under different conditions; instead, a combination of roost and nest count methods can be relied upon. This information is solely based on our firsthand experiences and knowledge regarding the species, drawn from extensive studies on swiftlets. The CMR method is recommended as an alternative only when the nest and roost count methods are not feasible, despite its ability to estimate the population close to the total count derived from the breeding and non-breeding population. The study validates the use of the CMR method in combination with the nest and roost count methods.

Luolissa pesivän jaavansalangaanin populaation ja dynamiikan arviointi Andamaaneilla, Intiassa

Salangaanit ja kiitäjät (Apodidae) kuuluvat vähiten tutkittuihin lintulajeihin. Ne ovat vaikeasti tunnistettavia, ja niiden pesimäympäristöt ovat usein saavuttamattomia, mikä tekee populaation arvioinnista ja niihin liittyvän dynamiikan tutkimisesta haastavaa. Tässä tutkimuksessa pyrimme arvioimaan populaatioita käyttämällä merkintä–uudelleenpyynti -menetelmää (CMR) sekä pesälaskentaa. Tutkimus toteutettiin Baratangin luolakompleksissa Andamaaneilla, ja siinä käytettiin ositettua otantaa valittaessa 12 tutkimusluolaa pesimäpopulaation perusteella merkintää ja uudelleenpyyntiä varten kaikissa mahdollisissa luolissa, joissa jaavansalangaani (*Aerodramus fuciphagus*) esiintyy.
Populaatioarviot laskettiin Lincolnin indeksin avulla analysoimalla CMR-dataa sekä käyttämällä MARK-ohjelmaa Live Recaptures -mallilla. Lincolnin indeksi ja kokonaispopulaation laskenta arvioivat vastaavasti 486 ja 505 yksilöä, ilman tilastollisesti merkittävää eroa ($p > 0,05$). Parhaiten sopiva malli osoitti, että vuotuinen selviytymisaste pysyi tasaisena koko tutkimusjakson ajan (0,97–1,00), ja pyydystämistodennäköisyys oli $0,35 \pm 0,02$.
Tutkimus osoitti selvästi, että pelkän yhden menetelmän käyttö ei riitä jaavansalangaanin populaatioiden tarkkaan arviointiin. CMR-menetelmää suositellaan vaihtoehtona silloin, kun populaatiodynamiikan ymmärtäminen on välttämätöntä eikä pesä- tai yöpymislaskentaa voida toteuttaa. Tutkimus vahvistaa CMR-menetelmän tehokkuuden, kun sitä käytetään yhdessä perinteisten menetelmien kanssa.

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Author contributions. PG: Data curation, Conceptualization, Investigation, Writing - original draft, DK: Formal analysis, Writing - original draft, Writing – review & editing, Methodology, Software,

RPS: Project administration, Writing - review & editing, SM: Conceptualization, Methodology, Funding acquisition, Resources, Validation, Writing – original draft, Writing – review & editing

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Citizen science perceptions into the distribution and impacts of the Common Myna (*Acridotheres tristis*) in Jordan

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The Common Myna (*Acridotheres tristis*) is a globally recognized invasive alien species with documented ecological and social impacts. This study employed a citizen science approach to investigate the distribution and perceived ecological and economic effects of the Common Myna in Jordan. An online questionnaire yielded 201 valid responses from all 12 governorates, of which only 50.2% of respondents who recognized the species were included in the subsequent data analysis. Reports from 113 localities indicated that the species is concentrated in urbanized areas of northwestern Jordan. Increased sightings since 2019 suggest population growth and continued expansion across human-modified landscapes. Increased occurrences near protected and in agricultural areas raise ecological concerns. Respondents identified competition with native birds as the main impact, while effects on crops and human health (*e.g.*, noise) were perceived as minor. Urban expansion and food waste were viewed as key drivers of the spread. Beyond data collection, the survey also functioned as an awareness tool, highlighting the dual value of citizen science for both monitoring and education. Overall, the study highlights the importance of implementing coordinated management measures that integrate regulation, waste management, and public awareness.

1. Introduction

Invasive alien species (IAS) are organisms introduced beyond their native geographic ranges, posing significant threats to global biodiversity, ecosystem services, and socio-economic systems (Pyšek *et al*. 2020). Their impacts include the displacement of native species, alteration of habitat structures, and economic damage to agriculture, infrastructure, and public health (Colautti & MacIsaac 2004, Meyerson & Mooney 2007, CBD 2024). These species are often introduced through deliberate releases, unintentional escapes from captivity, and usage in biological control programs (Pyšek *et al*. 2020). Extensive evidence documents the ecological and economic consequences of such introductions, including biodiversity loss, disruption of ecological communities, and long-term changes in native species composition

(Thomas *et al*. 2016, Pyšek *et al*. 2020, Siddiqui *et al*. 2021, Fantle-Lepczyk *et al*. 2022). Beyond ecological harm, IAS can also adversely affect human well-being by threatening food security and acting as a vector for zoonotic diseases (Pyšek *et al*. 2020, Siddiqui *et al*. 2021).

The Common Myna (*Acridotheres tristis*) is among the world's 100 most harmful invasive alien species due to its ecological flexibility, aggressive behavior, and capacity to thrive in urban environments (Lowe *et al*. 2000). The species appears to thrive in urban and agricultural systems, resembling the ecological conditions of its native range (Holzapfel *et al*. 2006). In the Middle East, its spread has been documented across Saudi Arabia, the United Arab Emirates (UAE), Egypt, Palestine, Lebanon, Syria, and Jordan, often originating from pet trade releases and facilitated by irrigated, human-modified habitats (Rabia *et al*. 2015, Symes *et al*. 2015, Ramadan-Jaradi *et al*. 2020, Handal & Qumsiyeh 2021, Alshamlih *et al*. 2022, Aidek & Khoury 2024, Alatawi 2024).

In Jordan, reports suggested the presence of the Common Myna in the Jordan Valley since 2010 (Khoury *et al*. 2012, Khoury *et al*. 2021), followed by the first records confirmed by the Jordan Bird Records Committee (Jordan Bird Records Committee 2013). These were at the Queen Alia International Airport in Amman, Madaba, and the Jordan Valley, with signs of breeding observed near the airport and in Kafrein village (Khoury & Alshamlih 2015). A recent study showed that the species has been increasing in number and expanding into agricultural and urban areas since 2010 (Khoury *et al*. 2021). In addition, it has been identified as a potential agricultural pest in the southern Jordan Valley, where it occasionally forages on fruits without affecting the more widespread vegetable crops (Khoury 2023). However, a knowledge gap remains regarding its impacts on biodiversity, the human economy, and health in various parts of Jordan.

Studying public perceptions is essential, as citizen observations can enable the early detection of biological invasions, draw attention to ecological concerns that may be missed by formal monitoring, and inform socially acceptable management strategies. This approach aligns with the national priorities outlined in Jordan's National Biodiversity Strategy and Action Plan (NBSAP) 2025–2050, which underscores the importance of early detection, public engagement, and integrated species management. Accordingly, this study aims to: (1) document public perceptions of the distribution and abundance of the Common Myna across Jordan; (2) assess views on its ecological and socio-economic impacts; and (3) evaluate perceived drivers of its spread and levels of public support for potential control measures.

2. Materials and methods

A structured online questionnaire was developed using Google Forms. The structure and content of the questionnaire were informed by prior invasive species studies utilizing citizen science and behavioral ecology frameworks (Delaney *et al*. 2008, Bonney *et al*. 2009). Section 1 contained respondent demographics (*e.g*., gender, age, education, and governorate). In Section 2, we assessed species recognition through direct image-based identification and self-reported familiarity. In Section 3, we assessed the perception of invasiveness by asking participants to classify the species as native or non-native and to explain their reasoning, such as observed aggressive behavior toward other birds, rapid population increase, or prior knowledge from media or personal experience. In Section 4, we investigated first sightings and geographic occurrence of Common Myna. In Section 5, we assessed perceived ecological and agricultural impacts of the species through Likert-scale responses (*e.g*., effects on native birds, crop damage, noise, and disease transmission), and in Section 6 we studied attitudes toward and preferences for control strategies.

In this study, "invasiveness" refers to the ability of the Common Myna to establish, spread, and cause ecological or socio-economic harm in areas beyond its native range, as defined by international standards (Colautti & MacIsaac 2004, CBD 2024). Within the questionnaire, this concept reflects the respondents' perceived assessment of the species' impacts and status in Jordan, rather than direct ecological

measurements. The questionnaire was initially pilot-tested with 10 colleagues to ensure clarity and cultural appropriateness, and modifications were made based on their feedback.

Following the pilot phase, the finalized questionnaire was disseminated between March and April 2025 using three main online platforms: WhatsApp, LinkedIn, and Facebook. The distribution was conducted through the authors' personal and professional networks to reach a broad and diverse audience across Jordan. Participation was voluntary and anonymous. Responses were automatically recorded and stored in a Google Sheets database, which was later exported to Microsoft Excel for analysis. Duplicates were manually reviewed and excluded where necessary. A total of 201 complete and valid responses were collected across all 12 governorates. To ensure data quality and reliability, only responses from individuals who self-reported the ability to recognize the Common Myna were included in the analyses. This criterion ensured that participants were genuinely familiar with the species, thereby reducing potential bias or misinterpretation from respondents who were unable to identify it. Including only confirmed recognizers strengthened the validity of the spatial, perceptual, and impact-related findings.

No personal identifiers were collected, and

Table 1. Summary of respondents' demographics, species recognition, and perceptions of the Common Myna's (*Acridotheres tristis*) invasiveness (*n* = 201).

Category	Subcategory	*n* (%)
Gender	Male	157 (78.1%)
	Female	44 (21.9%)
Age Group	<24	11 (5.5%)
	25–34	30 (14.9%)
	35–44	61 (30.3%)
	45–54	63 (31.3%)
	≥55	36 (17.9%)
Education	High school or less	17 (8.5%)
	Diploma (A two-year post-Tawjihi technical or community college diploma)	14 (7.0%)
	Bachelor's degree	86 (42.8%)
	Postgraduate	84 (41.8%)
Governorate	Amman	104 (51.7%)
	Other governorates (combined)	97 (48.3%)
Species Recognition	Recognized Common Myna	101 (50.2%)
	Correct visual ID (among recognizers)	99 (99 of 101; 99%)
Perceived Status	Considered invasive/non-native	92 (45.8%)
	Not invasive	4 (2.0%)
	Unsure	5 (2.5%)

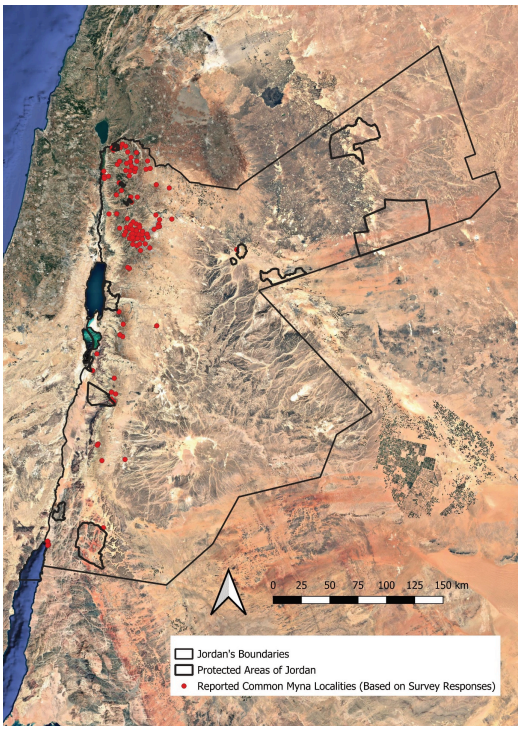

Fig. 1. Questionnaire-based observations of Common Myna (*Acridotheres tristis*) in Jordan and overlap with protected areas.

participants were informed about the purpose of the research at the beginning of the questionnaire. With consent, image or video contributions were solicited and were to be used exclusively for research purposes. The questionnaire was developed and distributed in Arabic, and an English translation is provided in the supplementary material for reference.

3. Results

The survey results presented here are based on 201 valid responses gathered across Jordan's 12 governorates. Unless otherwise indicated, all analyses presented in this section refer to the subset of respondents (n = 101; 50.2%) who recognized the Common Myna and were therefore included in the data analysis. The highest proportion of respondents was from Amman (51.7%, n = 104). Of all respondents, 50.2% (n = 101) reported recognizing the Common Myna, and 99.0% (n = 99) of these respondents correctly identified it from the provided images. Among this group, 45.8% (n = 92) of all respondents considered the species invasive and non-native to Jordan, while 2.0% (n = 4) disagreed and 2.5% (n = 5) were unsure. Demographic profiles, recognition accuracy, and perceptions of invasiveness are summarized in Table 1.

Among respondents who recalled their first observation of the Common Myna, sightings were most frequently reported between 2019 and 2024, suggesting a recent expansion. Group size at initial sightings was typically small (2–5 individuals), but larger flocks were also observed over time. The majority of respondents (n = 72) perceived an increase in local populations. A summary of sighting patterns, group sizes, and trends is presented in Table 2.

Among respondents who recognized the Common Myna (n = 101), 46.5% (n = 47) stated that they observed it regularly in their area, while 30.7% (n = 31) reported seeing it rarely. Meanwhile, 15.8% indicated they have not seen the species, and 6.9% were unsure of its presence. Additionally, 83.2% of respondents reported observing the Common Myna in regions of Jordan beyond their local area. The reported sites include initial sighting locations and areas where the species is frequently encountered, indicating an ongoing expansion of its geographic range within the country. Survey respondents reported a total of 113 distinct localities across Jordan where they have observed the Common Myna (Fig. 1).

A total of 84.2% (n = 85) of respondents reported seeing the Common Myna most frequently in residential neighborhoods. Other commonly cited habitats included agricultural lands (41.6%, n = 42), public parks (37.6%, n = 38), forests or natural areas (24.8%, n = 25), and waste collection or landfill zones (22.8%, n = 23). Industrial or artisanal zones were the least frequently mentioned, with only 9.9% of respondents reporting sightings in these environments. Regarding the time of day when the Common Myna is most frequently observed, 43.6% of participants indicated sightings occurred multiple times throughout the day. In comparison, 39.6% most often saw the species in

Table 2. Summary of Common Myna (*Acridotheres tristis*) sighting patterns, group sizes, and perceived population trends among respondents who recognized the species (*n* = 101).

Variable	Category	Respondents *n* (%)
First sighting year	2019–2024	45 (44.6%)
	2014–2018	7 (6.9%)
	2002–2013	3 (3.0%)
	Vague response ("2 years ago", etc.)	46 (45.5%)
Group size at first sighting	1 individual	17 (16.8%)
	2–5 individuals	47 (46.5%)
	6–10 individuals	15 (14.9%)
	>10 individuals	12 (11.9%)
Largest group size seen	2–5	50 (49.5%)
	6–10	27 (26.7%)
	>10	24 (23.8%)
Perceived population trend	Strong increase	44 (43.6%)
	Slight increase	28 (27.7%)
	Stable	7 (6.9%)
	Decrease	3 (3.0%)
	Not sure	19 (18.8%)

the morning (6:00–10:00 AM). 23.8% reported afternoon sightings (2:00–6:00 PM), and 15.8% noted occurrences during midday (10:00 AM–2:00 PM).

Only 2.0% (*n* = 4 of 201) of respondents reported having previously purchased a Common Myna. Among these, one person (*n* = 1) cited attraction to its appearance or vocal mimicry, and another (*n* = 1) reported buying it spontaneously after seeing it at a market. No respondents indicated that they purchased the bird for resale, gifting, experimentation, or economic reasons. Additionally, 2.0% (*n* = 4) reported having released a Common Myna into the wild. Among those who had released the bird (*n* = 4), the primary reasons cited included the belief that the bird would be freer (*n* = 1) and that the bird was noisy or disruptive at home (*n* = 3).

A total of 45.5% of survey participants (*n* = 46 out of 101 who responded to this question) reported witnessing problems or damage attributed to the Common Myna in their local areas. In comparison, 54.5% (*n* = 55) indicated no such observations. Among those who reported observing impacts (*n* = 46), the majority (*n* = 34; 73.9%) had directly witnessed these effects in their neighborhoods. Additional sources of information included social media content from within Jordan (*n* = 6; 13.0%) and verbal reports from friends or acquaintances (*n* = 4; 8.7%). Participants were further asked to assess the type and severity of the observed or perceived impacts. The most frequently cited severe impacts were related to ecological disruption. Around two-thirds of the respondents stated that the Mynas would have impacts on biodiversity and cause the displacement of native species by antagonistic behavior (Fig. 2). Respondents also expressed concern about potential disease transmission, which they associated with the Common Myna's observed scavenging behavior in waste sites. While no specific disease incidents were reported, 18 participants rated this risk as low and 14 as moderate.

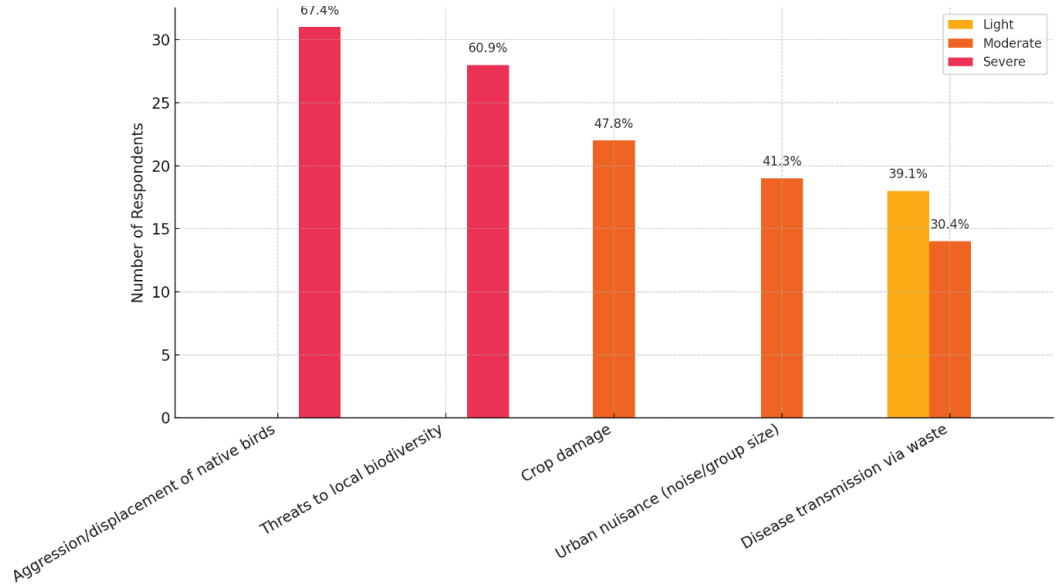

Fig. 2. Perceived ecological and anthropogenic impacts of the Common Myna (*Acridotheres tristis*) in Jordan by type and severity.

Findings indicate that the species' high adaptability to various environmental conditions was the most widely agreed-upon explanation for its successful establishment and spread in Jordan, with 81.0% (n = 163) of respondents highlighting its ability to thrive in urban, peri-urban, and human-modified landscapes. In addition, 69 participants (34.3%) emphasized the Myna's behavioral flexibility as a key trait enabling successful establishment across diverse habitats. The most agreed-upon factor was the availability of human-derived food resources, with 147 respondents (73.1%) linking the species' success to abundant anthropogenic food sources near human settlements. This was followed by 143 respondents (71.2%) who cited urban expansion and associated land-use changes, such as the growth of residential areas, public parks, and unmanaged waste zones, as key drivers of establishment and spread. The availability of human-derived food resources, particularly organic waste, was the second most agreed-upon factor, with 73.1% of participants linking the species' success to abundant anthropogenic food sources near human settlements.

Institutional and legislative shortcomings in invasive species governance also emerged as significant concerns, with 145 respondents (72.2%) highlighting the weak enforcement of regulations, minimal oversight of the pet trade, and insufficient monitoring of bird ownership and releases as contributing factors to the spread of the species. Environmental drivers were acknowledged to a slightly lesser degree, with 133 respondents (65.9%) emphasizing the lack of regulatory mechanisms governing the release of individual birds into the wild. Some participants (n = 21) also mentioned climate variability, including rising temperatures and decreased rainfall, as indirect facilitators of Myna spread.

Recreational activity and tourism were noted by 110 respondents (54.7%), but with lower agreement compared to drivers such as food waste and urban expansion. Similarly, the absence of natural predators was mentioned by 87 respondents (43.3%), although responses showed greater variability in perceived importance, suggesting less certainty about this factor relative to more strongly supported drivers, such as regulatory gaps (72.2%) and food availability (73.1%).

4. Discussion

Citizen science significantly enhances invasive species research by broadening monitoring efforts, involving the public in data collection, and supporting conservation initiatives that inform management strategies and increase public awareness (Cooper *et al*. 2007, Delaney *et al*. 2008, Bonney *et al*. 2009). Our survey provided additional and recent occurrence data for the Common Myna in Jordan, as well as information about the public's awareness of this invasive species. Moreover, we assume it fostered public awareness and likely had an educational function. The high rate of accurate identification by respondents indicates a strong level of public recognition, which aligns with previous studies showing the species' widespread presence in urbanized and agricultural areas in Jordan (Khoury *et al*. 2021) and Egypt (Rabia *et al*. 2015).

There was overwhelming support among respondents for implementing control programs to manage Jordan's Common Myna population. Approximately 90.1% of participants supported such programs, only 5.9% opposed the idea, and 4.0% indicated indifference. This strong endorsement reflects a growing public awareness of the ecological and social impacts of invasive species, aligning with findings from citizen-based studies elsewhere (*e.g*., Grarock *et al*. 2014, Cohen *et al*. 2019). The preference for evidence-based and humane interventions underscores the growing societal expectation that invasive species management should strike a balance between ecological effectiveness and ethical considerations (Feare *et al*. 2022). Comparable attitudes have been reported in Australia and South Africa, where the control measures for the Common Myna are more widely accepted when coupled with educational outreach and protection of native species (Peacock *et al*. 2007). These findings suggest that participatory approaches integrating public engagement, research, and non-lethal management can enhance long-term program acceptance and success. For Jordan, this highlights the opportunity to design culturally sensitive and community-supported management frameworks that combine scientific assessments, public awareness, and waste management to curb further expansion of the species while reinforcing conservation ethics.

The spatial distribution of the Common Myna in Jordan is concentrated in the northwestern and central-western regions, particularly in urban centers such as Amman, Irbid, and Zarqa, where human density and food availability support establishment (Khoury *et al*. 2021). While arid zones with low human activity, such as Jordan's eastern deserts, remain largely uncolonized, there has been notable expansion along transportation corridors in central desert areas, enabling the species to reach villages and towns, as predicted by previously prepared distribution models (Khoury *et al*. 2021). The respondents did report the colonization of two new areas after 2020 (Ma'an and Tafila), which can be used to validate and confirm the model for predicted distribution. A sharp increase in observations by the respondents between 2019 and 2024 suggests a recent surge in urban populations of this species, echoing trends observed in neighboring countries such as Lebanon and Syria (Ramadan-Jaradi *et al*. 2020). The earliest record in Jordan, dating back to around 2010, aligns with regional colonization timelines (Holzapfel *et al*. 2006, Khoury *et al*. 2021). Of particular concern is the Common Myna's presence near protected areas such as Dibeen, Ajloun, Fifa, Mujib, and Dana, where it may pose risks to the ecosystems and native avifauna through competition and habitat disturbance (Feare & Craig 1998).

Group size trends and perceived population in sightings increases highlight the social nature and opportunistic foraging strategy of the Common Myna. While the high frequency of sightings in synanthropic environments such as residential, agricultural, and parkland areas reflects the species' known preference for urban and edge habitats (Peacock *et al*. 2007), it is important to acknowledge that these patterns may also be shaped by observer bias, as citizen scientists are more likely to report from areas they frequently visit or reside in. The respondent's identification of behavioral flexibility, urban expansion, and food waste as key drivers aligns with invasion models and parallel findings from Australia, Jordan, and other locations (Grarock *et al*. 2014, Cohen *et al*. 2019, Khoury *et al*. 2021).

Nearly 74% of respondents expressed

concerns about native bird displacement, and many claimed to have had direct observations of interactions with native species. Such interactions are not unexpected and may mirror global findings on Myna's competitive exclusion for nesting and food (Lowe *et al*. 2000, Peacock *et al*. 2007, Cohen *et al*. 2019). Common Mynas have been suggested as a cause for declines in native species in Lebanon (Ramadan-Jaradi *et al*. 2020) and reduced breeding success in Egypt's Sinai (Rabia *et al*. 2015). While impacts on human health and economy, such as crop loss, noise, and disease risk were considered moderate in our survey, they align with conflicts reported in Australia and South Africa (Grarock *et al*. 2014, Cohen *et al*. 2019). The urban sprawl and inadequate waste management which have facilitated the successful colonization of the Common Myna in Jordan is potentially increasing the risk of disease transmission and associated public health concerns.

Our study revealed strong support (90.1%) for controlling the Common Myna, reflecting widespread concern about its ecological and social impacts. Respondents favored non-lethal strategies such as education, nest removal, and humane trapping, underscoring the need for socially acceptable approaches (Grarock *et al*. 2014, Feare *et al.* 2022). Additionally, the survey functioned as an awareness-raising tool, echoing findings from other regional initiatives that leveraged citizen engagement to increase the understanding of invasive species (Ramadan-Jaradi *et al*. 2020, Handal *et al*. 2023).

Previous market surveys found no evidence of Myna trade in Amman (Eid *et al*. 2011), which aligns with our results, where only 2% of respondents reported prior ownership. Additionally, analyses of hunting-related social media did not record the species, indicating it is neither targeted for consumption nor trade (Eid & Handal 2018). These findings confirm that intentional introduction through local trade is currently minimal. However, there was strong support among respondents for strengthening the legislation and enforcement mechanisms to regulate the trade and possession of the species in local markets, reflecting growing public awareness of its ecological impact. The continued spread of the Common Myna in Jordan appears to be driven primarily by its ecological adaptability and human-mediated factors, including urban expansion, weak enforcement of pet ownership regulations, and the widespread availability of anthropogenic food waste. As such, the Myna's invasion represents not just a biological issue but a complex socio-ecological challenge, reinforcing the urgency for multidisciplinary management approaches that integrate public engagement, legal frameworks, and urban planning (Holzapfel *et al*. 2006).

Although some respondents reported direct observations of Common Myna impacts, others likely reflected general beliefs or secondhand information. We therefore interpret these perceptions with caution, viewing them as indicative of public sentiment rather than definitive ecological evidence. This underscores the role of citizen science as a complementary tool for awareness and early detection. Furthermore, because most respondents reside in or frequent urban and peri-urban environments, reported sightings may be influenced by sampling bias. The observed concentration of the species in synanthropic areas may partly reflect higher human presence and observation effort in those landscapes.

This study contributes to the growing body of literature on public perceptions of invasive alien species by using the Common Myna in Jordan as a case study. By integrating spatial sighting data with perception-based responses, the research underscores both the ecological visibility and social salience of the species. Findings reveal a rising public awareness of the Myna's spread and impacts, alongside mixed levels of support for various management actions. While not a substitute for formal ecological monitoring, these insights highlight the value of citizen science, particularly in data-limited regions such as Jordan. Moreover, the study provides an important entry point for broader public engagement and sets the stage for future interdisciplinary research in invasive species management.

In light of these findings, the upcoming release of the Ministry of Environment's Black Book of Invasive Species, alongside Jordan's National Biodiversity Strategy and Action Plan (NBSAP) 2025–2030, marks a timely and

strategic advancement. As a key national policy instrument, the Black Book is expected to guide efforts to monitor, prevent, control, and mitigate threats from invasive species. This study contributes to the existing data set, directly supporting its implementation by offering insights to inform action planning and national response measures. It is essential to note, however, that the study employed a combination of convenience and snowball sampling strategies, utilizing the researchers' networks and online platforms for dissemination. While this approach successfully captured a geographically and demographically diverse sample, the results reflect the perceptions of participating respondents and should not be generalized to the broader Jordanian population. This limitation, a standard in citizen science methods that rely on self-selection, underscores the need for future research to adopt more representative sampling frameworks.

Medborgarvetenskapliga uppfattningar om utbredning och effekter av brunmajnan (*Acridotheres tristis*) i Jordanien

Brunmajnan (*Acridotheres tristis*) är en globalt erkänd invasiv främmande art med dokumenterade ekologiska och sociala effekter. I denna studie använde vi ett medborgarvetenskapligt tillvägagångssätt för att undersöka utbredningen samt de upplevda ekologiska och ekonomiska effekterna av den vanliga majnan i Jordanien. En webbaserad enkät gav 201 giltiga svar från samtliga tolv guvernement, varav endast 50,2 % av respondenterna, som kände igen arten, inkluderades i den efterföljande dataanalysen.

Rapporter från 113 lokaler visade, att arten är koncentrerad till urbaniserade områden i nordvästra Jordanien. En ökning av observationer sedan 2019 tyder på populationsökning och fortsatt spridning över människopåverkade landskap. Ökad förekomst nära skyddade områden och jordbruksmarker väcker ekologiska farhågor. Respondenterna identifierade konkurrens med inhemska fåglar som den främsta påverkan, medan effekter på grödor och människors hälsa (t.ex. buller) uppfattades som mindre. Stadsutbredning och livsmedelsavfall ansågs vara de viktigaste drivkrafterna bakom spridningen. Utöver datainsamlingen fungerade enkäten även som ett verktyg för medvetandegörande och visade på det dubbla värdet av medborgarvetenskap – både för övervakning och utbildning. Sammanfattningsvis betonar studien vikten av att genomföra samordnade förvaltningsåtgärder som integrerar reglering, avfallshantering och allmän medvetenhet.

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Online supplementary material

Supplementary material available in the online version of the article includes the questionnaire in Arabic and English.