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Evaluating the impacts of law enforcement and market outreach campaigns on the Indonesian caged bird trade in Kalimantan

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ABSTRACT

Indonesia is the epicenter of the Asian songbird crisis, yet few studies test whether enforcement and outreach can curb trade. We evaluated a combined market-outreach and law-enforcement program targeting caged birds in West Kalimantan. We compiled 2014–2025 data from annual surveys of 374 bird shops and 2019–2025 Facebook sales data from thousands of seller accounts. We analyzed temporal changes in bird abundance using negative binomial and logistic mixed models. In physical markets, sales of protected species declined by 40–59% relative to pre-intervention levels, and the share of shops selling protected species fell from 88.7% to 21.6%. Using a dose-response model, districts with more arrests showed progressively fewer birds per shop, with especially strong declines in protected species. Online, protected species per post and per seller account declined by 5–8% per year, while non-protected species remained broadly stable. These results show that trader outreach coupled with consistent enforcement can sharply suppress open trade in protected songbirds. The intervention appears to shift markets toward non-protected taxa rather than simply displacing trade to new venues. Our findings provide rare quantitative evidence that entrenched wildlife trades respond to targeted interventions and offer a scalable model for reducing illegal bird trade in Indonesia.

1. Introduction

Wildlife trade is a major driver of biodiversity loss globally, with many species experiencing severe declines due to overexploitation (Hinsley et al., 2023; Hughes et al., 2022; Ripple et al., 2016). A recent quantitative meta-analysis estimated that populations of terrestrial vertebrates have declined by an average of nearly 62% in areas where exploitation for trade occurs (Morton et al., 2021). Thus, overharvesting for trade has emerged as a significant threat to species survival on par with habitat destruction in many regions (Akhtar, 2012; Maxwell et al., 2016).

This issue is especially acute in Indonesia as it is the epicenter of Southeast Asia's bird trade, which has led to the "Asian Songbird Crisis"(Nijman et al., 2021). Estimates suggest millions of birds from hundreds of species are being taken from the wild each year to supply Indonesia's markets and households (Indraswari et al., 2020). Such high levels of overextraction of birds from their habitats are

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contributing to the *empty forest* syndrome in which forests fall silent as their birdlife is stripped away (Subekti et al., 2021).

2. Scale of songbird trade in Indonesia

Surveys in Java have found that roughly one-third of households keep caged birds as pets, which amounts to an estimated 66–84 million caged birds in captivity on Java alone (Nuruliawati et al., 2023). Most of these birds are believed to be wild-caught rather than captive-bred due to limited facilities for commercial pet bird breeding in Indonesia (Marshall et al., 2020a; Marshall et al., 2020b; Nijman et al., 2018).

While most bird owners simply keep birds at home, a significant minority use their birds to enter competitive bird singing events that continue to stimulate demand for prized songbird species (Jepson and Ladle, 2009; Marshall et al., 2020a; Marshall et al., 2020b). The cultural popularity of bird-keeping, reinforced by active bird clubs and frequent contests, has created strong economic incentives for trappers to harvest large numbers of wild birds for this market (Krishna et al., 2019). Hence, the demand encompasses hundreds of species, from melodious songsters prized for their vocal competitions to colorful or rare birds kept as status symbols, causing local extirpations of multiple formerly common species ((Conservationist) et al., 2015; Krishna et al., 2019).

Species-level studies reveal severe population declines and elevated extinction risk for dozens of endemic songbirds that are popular in Indonesia's caged-bird trade (Marshall et al., 2020a; Marshall et al., 2020b). For example, mass trapping of the Javan Pied Starling (*Gracupica jalla*) has rendered the species *Extinct in the Wild*(Baveja et al., 2020). Similarly, wild populations of the Critically Endangered Black-winged Myna (*Acridotheres melanopterus*) have been virtually eliminated in Java and Bali(Nijman et al., 2018), while the global population of the Critically Endangered Straw-headed Bulbul (*Pycnonotus zeylanicus*) has been severely reduced(Bergin et al., 2017). As a result, many Indonesian forest sites that were once abundant in birds now have noticeably lower bird densities, which is a clear sign of overexploitation(Symes et al., 2018).

2.1. Physical markets and online bird trade

Across Indonesia, birds have been traded through traditional brick-and-mortar markets and recently through online platforms (Grimwood et al., 2024). In Java and Sumatra, physical bird markets provide access to tens of thousands of birds for purchase every week (Grimwood et al., 2024). As native populations in Java have declined, traders are now increasingly sourcing birds from other islands through a vast national network funneling birds from forests into urban marketplaces (Harris et al., 2017),((Conservationist)) et al., 2015). Similarly, the trade in Java and Sumatra has expanded has expanded into Kalimantan and Sulawesi, where new markets and trapping pressure now supply the local demand and also markets in Java and Sumatra(Rentschlar et al., 2018).

Online trade of songbirds, especially through social media such as Facebook and WhatsApp groups has surged over the past decade, acting as an extension of the physical markets and adding new challenges for monitoring and enforcement (Okarda et al., 2022), (Grimwood et al., 2024). Automated surveillance detected 284,000 songbirds offered for sale on a single platform in just 18 months, with over 6% being threatened species (Okarda et al., 2022). Compared to physical markets, internet-based platforms afford traders anonymity, a broader customer reach, and shield traders of protected species from detection by law enforcement (Lavorgna, 2014; Morgan and Chng, 2017; Nijman et al., 2022). As many species now appear in both physical and online channels, understanding the dynamics of both arenas is essential for effective strategies to curb exploitation (Okarda et al., 2022).

2.2. Indonesia's protected species regulations

Until 2018, only a small fraction of Indonesia's bird species was legally protected, while many others were heavily traded without legal protection(Marshall et al., 2020a; Marshall et al., 2020b). Thus, for decades, traders could openly sell wild-caught birds, often rare and endemic species, in markets without fear of legal consequences (Marshall et al., 2020a; Marshall et al., 2020b). In 2018, spurred by the songbird crisis, the government undertook a major revision of its protected species list for the first time in nearly 20 years, adding numerous bird species that were previously unprotected (Indraswari et al., 2020). This enabled government authorities and conservation organizations to pursue approaches that include market raids, interception of smuggling operations, and prosecutions that have led to large confiscations (Nuruliawati et al., 2023). Experts suggest that these seizures represent only a small fraction of the total annual volume of trade.

Compounding this issue are low convictions of wildlife trade offenses (Sherman et al., 2022) and lenient penalties for offenders (Eryan, 2024). Studies have found that a small portion of cases involving the illegal trade of protected species leads to convictions (Sherman et al., 2022); among cases resulting in convictions, nearly 70% of convicted traders received jail terms of one year or less, accompanied by relatively small fines ranging from $70 to $700 (Padang et al., 2025).

2.3. Outreach programs to tackle songbird trade

In recent years, conservation NGOs and government agencies have implemented outreach and demand-reduction initiatives to tackle the root causes of the songbird trade, including public awareness campaigns, community engagement, and promotion of sustainable alternatives. Awareness campaigns to mainstream the crisis facing songbirds in Indonesia and the threat of "silent forests," organizations such as the IUCN SSC Asian Songbird Trade Specialist Group have used such campaigns to discourage the purchase of wild-caught birds, while community patrol programs now employ former trappers to protect bird populations. Research into bird-keepers' motivations shows that many hold misconceptions about wild bird welfare and the suitability of wild birds for competitions,

suggesting that education campaigns could correct false beliefs and shift social norms around ownership (Dai, 2022; Wallen and Daut, 2018).

Despite the growing number of interventions, there are critical knowledge gaps about how effective these efforts have been at stemming the songbird trade. Much of the research on Indonesia's bird trade to date has focused on documenting its scale and impacts on biodiversity (e.g., market surveys and population assessments) rather than evaluating solutions (Harris et al., 2017; Marshall et al., 2020a; Marshall et al., 2020b). Few studies have quantitatively examined whether intensified law enforcement leads to a measurable decrease in the availability of protected species for sale, or whether traders simply adapt by shifting to other species and channels. Similarly, the long-term impact of outreach and demand-reduction campaigns on consumer preferences and trapping rates remains unclear(Veríssimo and Wan, 2018).

In this paper, we address these gaps by evaluating the impact of law enforcement actions combined with market outreach initiatives on songbird trade in West Kalimantan, Indonesia. We compiled songbird sales data from both physical markets and online platforms to analyze trends before and after key outreach and enforcement interventions such as community awareness campaigns and major market raids. Specifically, we compare patterns for legally protected versus unprotected species to assess whether enforcement efforts impacted protected species, and displaced trade pressure onto non-protected taxa, which acts as a 'pseudo-control.' Using indicators such as the number of individuals of specific species observed in markets or online listings over time, we test whether enforcement and outreach correlate with reductions in the availability of birds, with findings aiming to inform policy on the effectiveness of wildlife protection laws and enforcement strategies, while guiding conservation practice toward approaches that yield measurable benefits and help prevent further declines in Southeast Asia's avian biodiversity.

3. Methods

3.1. Law enforcement and market-outreach intervention

Beginning in 2018, a coordinated intervention was implemented in West Kalimantan by the Provincial Government, the Natural Resources Conservation Agency (BKSDA), the Environmental Law Enforcement Agency (GAKKUM), the Indonesian National Police, and local non-profit organizations to strengthen enforcement of wildlife protection laws and promote compliance among bird traders. Historically, many shop owners and market sellers were exempted from penalties during inspections because they were unaware of wildlife regulations. To address this, a comprehensive market-outreach campaign was launched to eliminate ignorance of the law as a valid defense.

All identified bird shops across the 14 surveyed districts were visited and provided with educational materials summarizing the list of protected species under Ministerial Regulation P.106/2018. Each shop received a printed poster featuring photographs and names of protected birds, along with an explanation of the legal penalties for selling them. Shop owners were then asked to sign an official declaration stating that they had received and understood this information. Enforcement authorities retained the signed forms as formal documentation that could serve as legal evidence in court should the shop later be found selling protected species. This created a transparent first warning mechanism linking outreach to potential legal action. Following the distribution of these materials, joint monitoring and enforcement operations were conducted by BKSDA, GAKKUM, the Police, and local non-profit partners. These collaborative patrols targeted markets, trade hubs, and transport routes identified through prior surveillance and community reports. Authorities transferred confiscated birds to rescue facilities for rehabilitation and release, and data on arrests and seizures has been systematically recorded between 2015 and 2025.

Together, these combined outreach and enforcement measures aimed to (i) increase trader awareness of applicable wildlife laws, (ii) remove lack of knowledge of regulations as a justification for selling such species, (iii) establish a documented trail for prosecution of repeat offenders, and (iv) strengthen long-term compliance through both education and deterrence.

3.2. Data collection

To estimate the impact of the intervention, we compiled data on the bird trade from physical market surveys and sales posts on animal trading groups on Facebook originating from West Kalimantan, Indonesia.

For bird data from physical markets, we compiled availability data from 374 physical bird shops surveyed annually between 2014 and 2025 across 14 districts in West Kalimantan, Indonesia. During these surveys, data collectors visited listed bird shops in each district, recording their operational status (active or closed since the previous year's survey), the species names and number of individuals present in the store, and the protection status of the birds based on the Indonesian wildlife regulations (P.106/2018). In total, the data collected during the survey period comprised information on 44,728 individual birds from over 297 species.

We used Facebook as a proxy for online bird trade data, as it is a widely used online platform for buying and selling birds and wildlife in Indonesia (Grimwood et al., 2024). We focused on compiling songbird trade data solely from Facebook groups originating from the West Kalimantan Province. The data used in this research comprises sales posts compiled from 2019 to 2025 through monthly monitoring of popular Facebook songbird trading groups. We performed keyword searches of Indonesian bird names using the Facebook search option to identify groups selling songbird species. Subsequently, data from sales posts were recorded based on the species name, number of individuals offered for sale, quoted prices, the birds' legal status under Indonesia's P.106/2018 regulation, their IUCN Red List status, their CITES Appendix status, along with the post link, group name, and the name of the account. The dataset included 9764 posts from 4942 unique seller accounts across, representing 249 bird species.

3.3. Statistical analyses

Species were classified as Protected if listed under *Indonesian Regulation P.106/2018* and Non-protected otherwise. Missing or inconsistent entries (e.g., blank fields or ambiguous values) were flagged and removed. Sale quantities were converted to integers, with missing values set to zero. Prices were log-transformed to normalize variance, and extreme outliers ($>1.5 \times$ IQR on the log scale) were excluded. For online data, each sale post was treated as a sampling unit; for offline data, the analytical unit was shop $\times$ year.

We used generalized linear mixed models (GLMMs) implemented in *glmmTMB* (R version 4.3.3) to quantify temporal trends and the effects of the 2018 policy intervention that expanded species protections. GLMMs were well suited to these data because they accommodate non-normal count distributions, hierarchical sampling structures, and unbalanced repeated observations, all key features of wildlife trade monitoring datasets. All models included random intercepts for shop identity and/or species identity to account for repeated measures and shared ecological traits.

For the primary analysis, we applied an event-study framework using negative binomial GLMMs to estimate year-specific changes in bird abundance relative to pre-intervention levels. The event-study design allowed us to assess dynamic policy impacts over time, distinguishing immediate from delayed effects of the 2018 protection expansion. Negative binomial models were chosen over Poisson models due to clear overdispersion in the count data, ensuring robust and unbiased inference. Two specifications were used for robustness: one using 2017 as the reference year, and another pooling all pre-2018 years as the baseline. Fixed effects included year, protection status, and their interaction. Model coefficients were exponentiated to yield rate ratios (RRs), interpreted as proportional changes relative to baseline conditions.

To evaluate shop-level participation in the protected bird trade, we fitted a logistic GLMM modeling the probability that a shop sold ≥ 1 protected species in a given year. Random intercepts for shop identity accounted for repeated observations, and results were expressed as odds ratios (ORs) with predicted probabilities. Because protected species were frequently absent, we also fitted a zero-inflated negative binomial GLMM, which jointly modeled abundance and the probability of observing excess zeros. This approach provided a more realistic fit for sparse ecological trade data that included many zero counts.

To assess the relationship between enforcement intensity and bird abundance, we linked shop-level survey data with district-level arrest records. Enforcement exposure was quantified in three complementary ways: (i) before vs. after the first arrest in each district, (ii) cumulative number of arrests (dose–response); and (iii) number of arrests per year. The dose–response framework tested whether stronger or repeated enforcement activity was associated with progressively greater reductions in trade, providing a direct measure of intervention intensity. Each shop–year record included total bird abundance and the number of protected species, which were modeled using negative binomial GLMMs with random intercepts for shop and district to control for repeated sampling and spatial clustering. Model fit was verified using the *DHARMa* package, confirming no residual overdispersion or zero inflation. Results are presented as rate ratios with 95% confidence intervals.

For all models, coefficients were exponentiated to rate ratios (RRs) or odds ratios (ORs) with 95% confidence intervals (CIs). Statistical significance was assessed using Wald z-tests. Model outputs were interpreted as percentage changes in abundance or probability of occurrence to facilitate conservation relevance.

For the online trade dataset, we modeled bird abundance using negative binomial GLMMs at two analytical levels: per post and per account. The per-post model included year, protection status, and their interaction as fixed effects, with Facebook group and species identity as random intercepts to account for the nested structure of posts within groups and repeated measures across species. The per-account model used the same fixed-effect structure but aggregated data by seller account and year, with account identity included as a random effect to capture repeated observations of individual sellers. The negative binomial structure was appropriate given the right-skewed count distribution and heterogeneity in account activity levels. Model diagnostics indicated good fit for both specifications, and fixed-effect coefficients were expressed as rate ratios, representing the expected number of individuals per post or per account-year, respectively.

Generalized linear mixed models (GLMMs) with negative binomial error distributions provide a robust approach for handling overdispersed count data, which are typical of market or trade surveys where a few sellers or posts account for most individuals. The inclusion of random intercepts for shops, districts, species, and online accounts addresses non-independence arising from repeated measurements of the same entities and the hierarchical nature of trade data (e.g., species nested within shops or posts nested within groups). The event-study design enables the identification of temporal policy impacts by comparing outcomes across multiple pre- and post-intervention years, while the dose–response specification captures gradual, cumulative effects of enforcement intensity that are not detectable through simple before–after contrasts. Together, these models allow for a rigorous, ecologically meaningful assessment of how enforcement and regulatory changes influenced both the probability and intensity of wildlife trade activity over time.

4. Results

4.1. Descriptive patterns

Between 2014 and 2025, we recorded a total of 44,732 birds offered for sale in offline markets in West Kalimantan. Annual totals peaked in 2017 at 7512 individuals, before declining to only 1219 in 2025 (−84%). Protected species comprised 17% of sales in 2017 (1262 individuals) but virtually disappeared from markets by 2025 (18 individuals; 1.5%). Non-protected species also contracted sharply, from 5889 individuals in 2017–1201 in 2025 (−80%). The number of active shops increased from 85 in 2014–113 in 2017, but subsequently fell to 32 by 2025. Online monitoring showed that most Facebook posts offered 1–2 birds per advertisement, although occasional bulk sales exceeded 50 individuals. Across the study period (2019–2025), the online dataset comprised a total of 18,054

birds offered by 4942 unique seller accounts. The number of birds advertised increased from 1087 individuals in 2019 to a peak of 3945 in 2022, before declining slightly to 2847 in 2025. The number of active seller accounts followed a similar pattern, rising from 392 in 2019 to over 1000 accounts annually between 2020 and 2022 and then tapering to 874 accounts in 2025.

Raw trend plots show broad declines in both protected and non-protected birds after the intervention period, with a particularly pronounced contraction in protected birds. A pre-intervention parallel-trends test found no evidence that protected and non-protected trajectories differed prior to the intervention (time×protected interaction: $\beta = -0.0167$, $p = 0.50$), supporting the use of non-protected species as a pseudo-control. Consistent with this, a Differences-in-Differences model with shop and year fixed effects indicates that protected bird abundance declined significantly relative to non-protected birds in the post-intervention period (protected×post: $\beta = -0.130$, $p = 0.032$; ≈12% relative decrease on the log(1 +count) scale). An event-study extension further suggests that this divergence strengthens in later post-intervention years, with significant relative declines appearing around 2021 and 2023 (Supp material).

4.2. Offline market models

The event-study negative binomial GLMMs revealed substantial post-2018 declines in protected species abundance (Fig. 1). When using 2017 as the baseline, sales of protected species were 40% lower in 2019 (RR = 0.60, 95% CI: 0.44–0.81, p = 0.002) and 47% lower in 2020 (Fig. 1; RR = 0.53, 95% CI: 0.35–0.75, p = 0.002), with sustained suppression through 2025 (59% lower than 2017; RR = 0.41, 95% CI: 0.20–0.80, p = 0.022). Using a pooled pre-2018 baseline, protected species again showed marked declines, dropping 28% in 2019 (RR = 0.72, 95% CI: 0.53–0.95, p = 0.026) and 36% in 2020 (RR = 0.64, 95% CI: 0.43–0.90, p = 0.022). Interestingly, a temporary rebound occurred in 2022 (RR = 1.74, 95% CI: 1.15–2.63, p = 0.009), although sales again declined thereafter.

The zero-inflated GLMM confirmed this pattern, indicating an increased probability of shops recording zero protected species after 2018. In contrast, non-protected species showed no significant temporal trend, remaining relatively stable across the study period (Fig. 1; RR = 0.99, 95% CI: 0.97–1.01, p = 0.52).

4.3. Shop-level models

At the shop level, the logistic GLMM revealed a sharp contraction in the likelihood of shops selling protected species after 2018 (Fig. 2). Before the intervention, 88.7% of shops (Fig. 2; 95% CI: 83.9–92.2%) offered at least one protected species, compared with only 21.6% after 2018 (95% CI: 16.4–28.1%). This corresponds to an odds ratio of 0.035 ($z = -11.74$, $p < 0.001$), equivalent to a 96% absolute reduction in shop participation in the protected bird trade (Fig. 2).

4.4. Dose-response ("exposure") to arrests

To assess whether enforcement intensity produced proportional conservation benefits, we applied a dose–response framework, modeling how bird abundance in shops changed with increasing enforcement exposure (Fig. 3). Using negative binomial mixed models with shop and district random intercepts, we find that enforcement is associated with large, statistically robust declines in birds per shop, with consistently stronger effects for protected species. In post-arrest models, shops in districts following the first enforcement

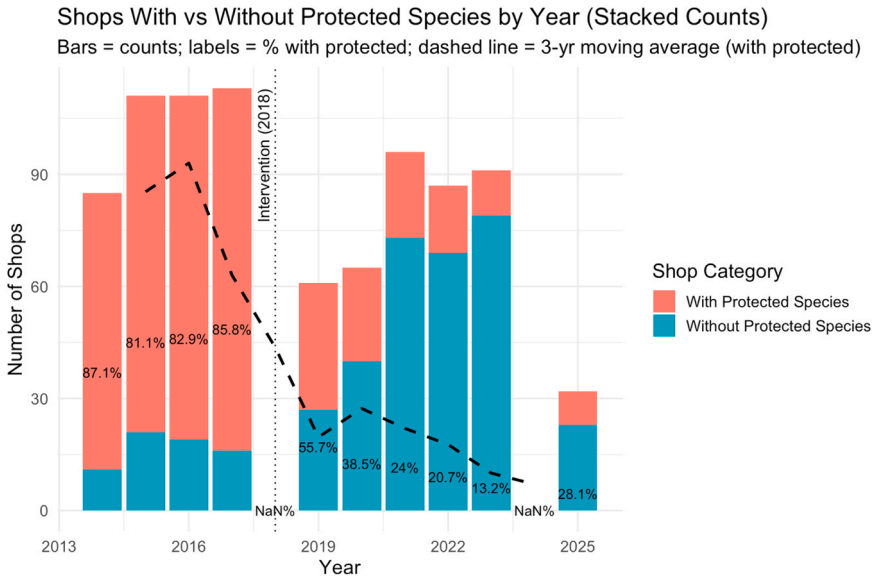

Fig. 1. Percent of shops with and without protected species prior to the increase in law enforcement and outreach campaigns to bird shop owners starting in 2018 (intervention year).

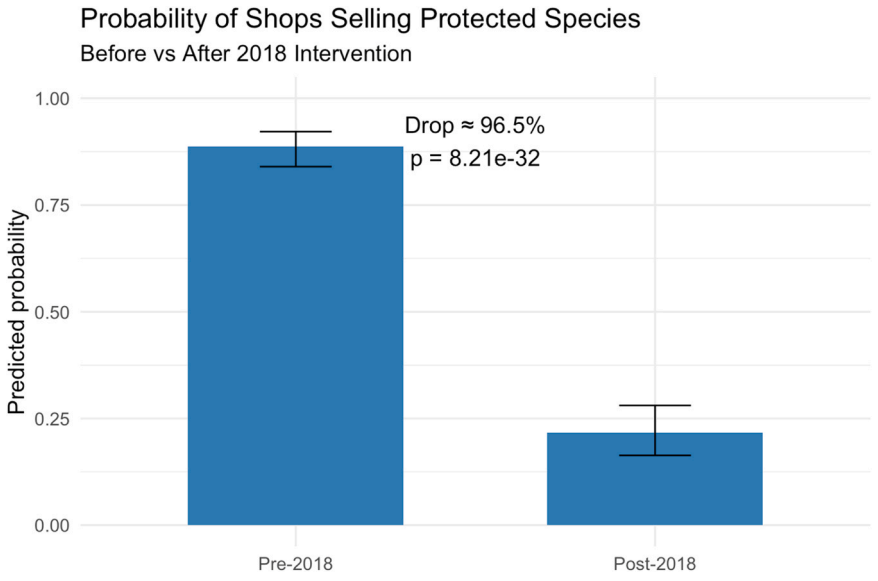

Fig. 2. Probability of shops selling protected species post-2018 legislation and start of the combined intervention period.

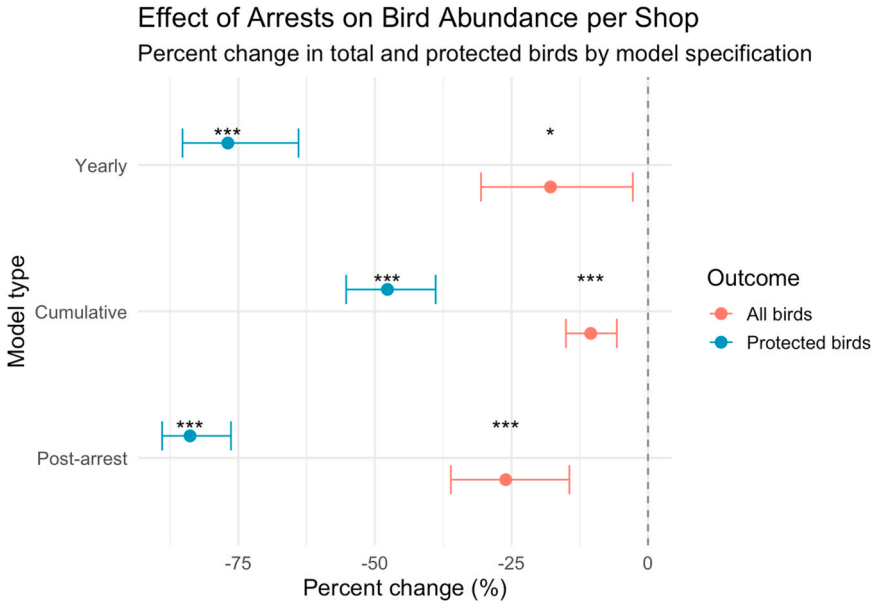

Fig. 3. Each point represents the rate ratio (with 95% confidence interval) from negative binomial mixed models assessing three complementary enforcement specifications: (i) Post-arrest: comparison of shop-level bird counts before versus after the first arrest in a district; (ii) Cumulative arrests: the effect of each additional arrest accumulated to date (dose–response); and (iii) Yearly arrests: the immediate effect of arrests occurring within that specific year.

event recorded 26% fewer total birds (rate ratio [RR] = 0.74, 95% CI: 0.64–0.86, $z = -4.04$, $p < 0.001$) and 84% fewer protected birds (RR = 0.16, 0.11–0.24, $z = -9.39$, $p < 0.001$) relative to the pre-arrest period (Fig. 3). In cumulative dose–response models, each additional district-level arrest corresponded to a 10.5% reduction in total birds (RR = 0.895, 0.850–0.943, $z = -4.18$, $p < 0.001$) and a 47.7% reduction in protected species (RR = 0.523, 0.447–0.611, $z = -8.15$, $p < 0.001$). Yearly frequency models yielded similar patterns: in survey years with arrests, totals were 17.8% lower (RR = 0.822, 0.694–0.972, $z = -2.29$, $p = 0.022$) and protected species were 76.9% lower (RR = 0.231, 0.148–0.360, $z = -6.46$, $p < 0.001$) than in years without arrests. Event-study estimates showed no significant pre-trends (relative years −8 to −1 were all nonsignificant) and sharp, persistent post-arrest declines in protected species from year + 1 onward (e.g., year +4: RR ≈ 0.053, 95% CI: 0.013–0.11, $z = -4.19$, $p < 0.001$). Model diagnostics were satisfactory: DHARMa tests indicated no problematic overdispersion (all $p \geq 0.13$) and no excess zero-inflation (all $p \geq 0.18$), thus, supporting the

validity of these inferences (Fig. 3).

4.5. Online trade models

Across 2019–2025, online trade records included a total of 19,054 individual birds posted by 4942 unique seller accounts. The GLMM negative binomial models revealed consistent differences between protected and non-protected species (Fig. 4).

At the per-post level, non-protected species abundance remained stable over time (RR per year = 0.99, 95% CI: 0.97–1.03, $p = 0.50$), whereas protected species declined significantly by about 5% per year (interaction RR = 0.95, 95% CI: 0.92–0.98, $p = 0.001$). Model predictions indicated that protected species posts decreased from an average of 1.82 birds per post in 2019 (95% CI: 1.49–2.21) to 1.62 birds per post by 2021 (95% CI: 1.35–1.94), while non-protected species posts remained stable at around 1.8–1.9 birds per post (Fig. 4).

At the per-account level, patterns were similar: total birds listed per account-year remained stable for non-protected species (RR per year = 1.01, 95% CI: 0.99–1.03, $p = 0.25$) but declined significantly for protected species, dropping by approximately 7–8% per year (interaction RR = 0.92, 95% CI: 0.90–0.96, $p < 0.001$). This suggests that the reduction in protected-species listings over time is consistent both in individual posts and in overall annual activity per seller (Fig. 4).

5. Discussion

Our findings provide one of the first quantitative evaluations of targeted interventions aimed at curbing Indonesia's protected songbird trade. They provide empirical evidence that integrating law enforcement interventions through proactive market outreach activities followed by consistent and intensified actions can lead to a sharp reduction in the open availability of protected birds for sale in physical markets. Previous research into wildlife trade has lamented the failure to rely solely on traditional enforcement efforts to protect wildlife (Bennett, 2011) and has called for more evidence-based interventions to combat illegal trade (Rytwinski et al., 2024). Hence, this outcome is significant given that much of the prior literature on Indonesia's bird crisis has focused on documenting the problem's enormous scale and biodiversity impacts (Harris et al., 2017; Symes et al., 2018; Marshall et al., 2020a; Marshall et al., 2020b) but has rarely been able to demonstrate the efficacy of solutions.

5.1. Removing excuses through outreach activities

The outreach campaign described in this research was essentially a preventive compliance effort that required shop owners to sign an official declaration stating they had been informed by authorities about the regulations related to the trade of protected species. By directly engaging shop owners through informational visits and requiring them to sign acknowledgments confirming their understanding of the regulations, the intervention established a formal "first warning" that encouraged voluntary compliance. This simple act

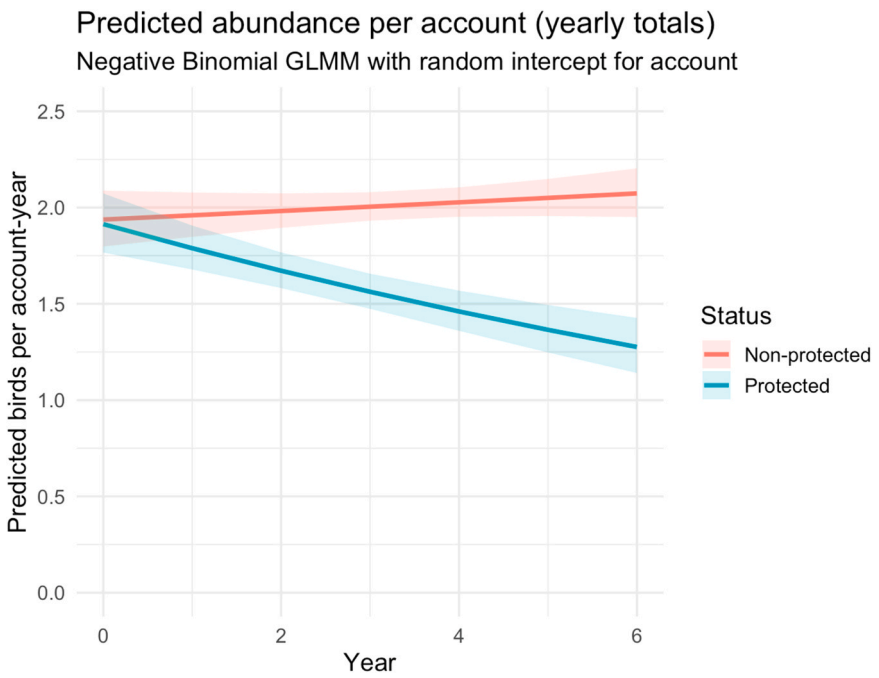

Fig. 4. Between 2019–2025, online bird trade posts have become increasingly dominated by non-protected species. The rate of protected species per post and per account is dropping each year significantly (~5–8% annual decline), while non-protected species remain steady.

invalidated a shop owner's future claim of ignorance to avoid conviction for non-compliance and served as an effective deterrent against the open sale of protected bird species. Research into social marketing and psychology shows that using public pledges, especially those that are written, fosters sustained pro-environmental behavior as they serve as concrete reminders of the promises (Alonso-Paulí et al., 2025) and, by enlisting the traders themselves as partners in understanding and adhering to the law, extend beyond traditional top-down raids by enlisting the traders themselves as partners in understanding and adhering to the law. Additionally, the outreach likely eroded any social license to deal in protected birds, making it a less acceptable practice within the marketplace community. Public commitments favoring pro-environmental behavior activate social norms that people, especially those belonging to groups, want to adhere to (Lokhorst et al., 2009).

5.2. *Effective deterrence through consistent enforcement*

Consistent enforcement actions played a crucial role in creating the perception among bird shop owners regarding the consequences for violators. Weak sentencing and inconsistent enforcement have long been identified as major obstacles to combating wildlife trade in Southeast Asia. However, there is a growing body of evidence in criminology that suggests that increasing the certainty of apprehension is a more effective deterrent than increasing the severity of punishments(Nagin, 2013). This is particularly relevant in Indonesia, where wildlife crime penalties have historically been lenient and infrequently applied – for example, many convicted wildlife traffickers have received minimal fines or jail terms under one year, undermining the deterrent effect (Padang et al., 2025). Nevertheless, studies have found that when penalties in an industry are publicized, this acts as a deterrent signal for others in that industry by making the consequences of non-compliance visible through peer effects (Yun et al., 2019). Consequently, publicizing successful market busts and confiscations likely amplified the perceived risk of engaging in the illegal trade among peers. Hence, strong outreach regarding regulations followed by penalties for non-compliance likely reduced the number of shops openly selling protected species from nearly 89% to just 22%, and the overall number of birds recorded by over 80% after market intervention activities started in 2018.

5.3. *Post-enforcement displacement effects*

Our results also shed light on how the songbird trade through physical markets responds to enforcement pressure, aligning with patterns observed in other illegal wildlife trades. The dramatic decline in protected bird species being openly sold after the 2018 outreach activities mirrors observations from other illegal wildlife trades (Siriwat and Nijman, 2018). Notably, the total number of active bird shops fell by about two-thirds after 2018, indicating that some traders went out of business entirely or shifted to other livelihoods. This contraction of the physical marketplace is consistent with patterns observed elsewhere once legal protections are strengthened. However, consistent with theories of adaptive or "restrictive" deterrence, we observed signs of offenders adjusting their tactics once the initial shock of enforcement passed.

Our results revealed that after the steep drop in 2018–2019, some traders appeared to shift to selling unprotected species or selling protected species more covertly, as evidenced by a small rebound in such sales in 2022. Hence, while enforcement efforts clearly reduced the overt market for protected birds, they did not entirely extinguish the trade because a portion of protected species sales likely went underground or online, illustrating the well-known "whack-a-mole" challenge faced by wildlife crime enforcement agencies. This adaptive behavior is emblematic of broader illicit trade dynamics: when enforcement closes one avenue, wildlife traffickers often modify their methods or move operations elsewhere to evade detection (Shepherd et al., 2016).

Researchers have documented that when physical markets become too risky, wildlife dealers increasingly exploit online platforms and private networks to continue trading (Nijman et al., 2022). In Indonesia, recent monitoring efforts have confirmed that online platforms have become a major conduit for bird trade as physical markets came under greater scrutiny (Nijman et al., 2022). Our analysis of over 19,000 sale posts on Facebook bird-selling groups revealed a small but significant decline over time in the average number of protected birds per online posting in West Kalimantan. While this may be an encouraging sign of a spillover effect in cyberspace from the two-pronged intervention (possibly by driving traders to be more cautious or by reducing the availability of certain rarer species), we acknowledge that the online marketplace remains vast and more difficult to police, and likely harbors a significant portion of the remaining illegal trade that has been pushed out of public view. There is broad agreement that combating wildlife trafficking in the digital realm will require enhanced cyber monitoring, better regulation of online commerce, and continued intelligence-led investigations (Okarda et al., 2022).

5.4. *Contrasting intervention success with trade in other Taxa*

The songbird trade in West Kalimantan is an understudied area of wildlife trade, with specific characteristics such as a smaller scale and rural traders (Rentschlar et al., 2018). This understudied status may be partially due to these inherent characteristics of the trade in Kalimantan(Rentschlar et al., 2018). Additionally, enforcement success is higher for lower-value or fast-reproducing species than for high-value species because the financial incentives of the latter group (e.g., rhino horn, tiger parts, ivory) often outweigh the risks of enforcement for traders (Öckerman et al., 2024), (Challender and MacMillan, 2014). This may be the case for certain protected songbird species, such as the Straw-headed Bulbul, which are highly prized and remain at risk from clandestine trade (Bergin et al., 2017).

Similar two-pronged approaches that combined proactive outreach with strong enforcement have shown promise elsewhere. For example, in Nepal and other parts of Asia, a combination of community-based policing and public awareness campaigns has been

credited with dramatic declines in poaching of tigers and rhinos in recent years (Lamichhane et al., 2020; Martin et al., 2013). Likewise, international conservation strategies have increasingly emphasized the need to combine law enforcement efforts with community-based approaches that engage local stakeholders to yield tangible results in addressing IWT (Rios, 2024). Hence, an integrated, two-pronged approach that combines market outreach and multi-agency enforcement efforts reflects best practices in wildlife trade management (Browne et al., 2021).

5.5. *Scaling the outreach-enforcement approach nationally*

The intervention outcomes presented in this study offer a scalable model for reducing the illegal trade of protected species through physical markets across Indonesia. While Indonesia's 2018 expansion of legal protections for hundreds of species provides a strong legislative foundation (Indraswari et al., 2020), consistent enforcement and public understanding remain critical for compliance (Maulany et al., 2021). Institutionalizing outreach by enforcement agencies through formal notifications and signed compliance agreements with wildlife traders, followed by consistent enforcement to detect non-compliance, provides a replicable mechanism that ensures accountability and compliance. Provinces such as Sumatra, Sulawesi, and parts of Java, which continue to host active bird markets and trapping hubs, represent logical next steps for expansion (Marshall et al., 2020a; Marshall et al., 2020b; Shepherd and Leupen, 2021). Importantly, the success of such a combined intervention will hinge on collaboration between multiple stakeholders such as conservation NGOs, local authorities, and other resource agencies, especially during nationwide scaling.

In addition to scaling up outreach activities followed by monitoring of physical markets and enforcement against non-compliance with national regulations, we recommend that enforcement agencies be flexible and adapt as traders evolve their modus operandi (Öckerman et al., 2024). Done well, this model can have a lasting impact because our results demonstrate that even a deeply embedded wildlife trade, such as the songbird trade, is not immune to sustained, well-coordinated interventions.

6. Conclusions and conservation recommendations

This study provides empirical evidence that conservation actions can mitigate an entrenched illegal trade in Indonesia. Our findings demonstrate that interventions can reduce the availability of protected species in Indonesian bird markets and the overall trade volume of these species. Market-outreach campaigns improved awareness and acted as a "warning" regarding legally permissible sales, while enforcement disrupted open sales.

The following recommendations, informed by evaluations of wildlife-trade enforcement efforts, are offered to practitioners and policymakers implementing similar two-pronged strategies to reduce illegal wildlife trade. First, existing legal frameworks must be consistently applied and strengthened through research and lobbying to include protections for heavily traded taxa (Indraswari et al., 2020). Second, enforcement should expand beyond transit hubs to include source regions, such as Kalimantan, with improved resourcing and community partnerships (Lam et al., 2023; Rentschlar et al., 2018). Third, awareness campaigns should be evidence-based, culturally tailored, and sustained over time, ideally evaluated using rigorous behavioral metrics (Veríssimo and Wan, 2018).

Overall, this study contributes to a growing body of evidence that the songbird trade, while culturally ingrained (Marshall et al., 2019) and economically important (Marthy and Farine, 2018), is not immune to conservation action. If interventions are scaled up and maintained, Indonesia could avert further extinctions and preserve its unique avifauna. Conversely, failure to act decisively risks repeating the trajectory of species like the Straw-headed Bulbul (Yong et al., 2017), leading to silent forests across the archipelago (Bušina et al., 2020).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper. The research was conducted independently and without financial support from organizations that could benefit from the findings. All analyses, interpretations, and conclusions are solely those of the authors. There are no conflicts of interest, financial or professional, related to the bird trade, enforcement agencies, or conservation organizations involved in the study.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2026.e04193.

Data availability

Data will be made available on request.

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