Digital predation: scale, drivers and conservation implications of illegal online trade in raptors in Pakistan

Zeeshan Khalid*[1], Muhammad Jamshed Iqbal Chaudhry[1], Saba Fatima[2] Farhan Khan[1] and Campbell Murn[3,4]

Abstract Illegal wildlife trade is a major driver of biodiversity loss, and online platforms are increasingly used to advertise protected wildlife. In Pakistan, raptor trade is increasingly mediated by online marketplaces, reflecting a wider global transition. As a case study, we assessed the online trade in raptors in Pakistan from January 2021 to December 2023 by monitoring groups on the social media platforms Facebook, Instagram, YouTube, TikTok and WhatsApp, and local e-commerce websites, using keyword-based searches, with cross-checking to reduce duplication and misidentification. We recorded 310 raptors advertised for sale from 92 seller accounts, representing 24 species across four families. Falconidae comprised 61% of individuals and Accipitridae 37%, with peregrine falcon *Falco peregrinus* and saker falcon *Falco cherrug* the most frequently advertised species. A substantial proportion of listings involved species protected under provincial wildlife legislation, as well as species listed under CITES and categorized as threatened on the IUCN Red List. Using a generalized linear model, we found that asking prices were higher for threatened and visitor species. Seller activity was concentrated in Punjab and Khyber Pakhtunkhwa, and Facebook accounted for the largest share of records, indicating that improved monitoring and enforcement on this platform is a priority. Our findings provide baseline evidence to support demand-reduction outreach, community reporting and capacity building within wildlife agencies, alongside improved online detection tools and updated assessments of raptor population status in Pakistan, particularly for migratory species using the Central Asian Flyway.

Keywords Birds of prey, CITES, digital market, falconry, Pakistan, social media, wildlife crime, wildlife trade

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*Corresponding author, chz39@hotmail.com
[1]Research and Conservation, WWF Pakistan, Lahore, Pakistan
[2]GIS Lab, WWF Pakistan, Lahore, Pakistan
[3]Hawk Conservancy Trust, Andover, UK
[4]School of Biological Sciences, University of Reading, Reading, UK

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Introduction

Illegal wildlife trade is a major driver of biodiversity loss and a form of environmental crime with ecological, economic and social consequences (Rosen & Smith, 2010). This trade involves the unauthorized exploitation, trade or possession of wild fauna and is estimated to generate USD 7–23 billion annually, placing it among the most lucrative transnational criminal activities alongside drug and human trafficking (Nellemann et al., 2016; Fukushima et al., 2020; UNODC, 2020; Andersson et al., 2021). This illicit trade accelerates biodiversity loss, with overexploitation recognized as a primary driver of species declines, in some contexts rivalling or exceeding impacts of habitat loss and climate change (Maxwell et al., 2016). Despite international frameworks such as CITES, which regulates international trade in over 38,700 species, enforcement gaps and expanding online marketplaces have enabled illegal wildlife trade to persist and diversify (Barber-Meyer, 2010; Challender et al., 2015; Lees et al., 2022; CITES, 2024).

Legal and illegal trade in live raptors has been documented across multiple countries, including Indonesia, Japan, Thailand and Russia (Wyatt, 2009, 2011; Nijman, 2010; Eaton et al., 2017; McClure et al., 2018; Vall-Llosera & Su, 2019; Siriwat & Nijman, 2020). Recent studies have increasingly identified social media as a key conduit for raptor trade because these platforms offer anonymity, wide reach and low barriers to advertising (Iqbal, 2015; Gunawan et al., 2017; Sung & Fong, 2018; Nijman, 2020; Panter & White, 2020). Here, we use the term raptors for diurnal predatory birds (Accipitriformes and Falconiformes), acknowledging that the broader term birds of prey is also sometimes used to include owls (Strigiformes; McClure et al., 2019). Raptors contribute to ecosystem functioning as apex predators and ecological indicators, and their removal can alter trophic dynamics and ecosystem stability (Newton, 1990; Panter et al., 2023). Furthermore, unregulated trade can also elevate public and animal health risks, including zoonotic pathogen transmission, and raptors have been implicated as hosts of highly pathogenic avian influenza A/H5N1 (Van Borm et al., 2005; Steensels et al., 2007; Shivakoti et al., 2010).

In Pakistan, raptors are traded despite provincial wildlife protection laws and international regulation under CITES, with online platforms increasingly facilitating

advertising and exchange (Shafiq & Idrees, 2006; Challender et al., 2015; Aljazeera, 2021; Haq et al., 2023). Falconry remains culturally important and contributes to demand for high-value taxa, including the saker falcon *Falco cherrug* and peregrine falcon *Falco peregrinus*, with both domestic and international demand shaping capture and trade (Roberts, 1991; Wakefield, 2012; Kovács et al., 2014; Panter et al., 2023). Reported prices can reach tens of thousands in USD, although the same nominal price can represent different purchasing power across countries, influencing incentives to supply and willingness to pay (Aisha & Khan, 2020). Previous studies have documented social media use and trader activity in Pakistan, including the presence of organized groups and individual traders, but they have offered limited species-specific assessment and limited evaluation of advertised prices over time (Aisha & Khan, 2020; Haq et al., 2023).

Here we investigate the scale and dynamics of illegal online trade in wild-caught raptors within Pakistan. Specifically, we (1) analyse species composition and temporal patterns in advertised asking prices, (2) identify geographical and platform-specific trade patterns, and (3) examine socio-economic and ecological drivers associated with trade and price variation. Through integrated descriptive, geospatial and statistical analyses, we aim to provide actionable evidence for policymakers, conservation practitioners and enforcement agencies seeking to curb illegal raptor trade and reduce associated threats to Pakistan's avifauna, thereby informing conservation measures for raptors in Pakistan and beyond.

Study area

This study was conducted across Pakistan, using digital platforms to monitor illegal online trade in raptors. Pakistan's position at the intersection of Central, South and West Asia, together with major overland and maritime trade routes, creates opportunities for transboundary wildlife trafficking (UNODC, 2020; Panter et al., 2023). Pakistan also lies along the Central Asian Flyway, a key migratory corridor for raptors that breed in Eurasia and winter in the Indian subcontinent or Africa (BirdLife, 2023). These geographical and geopolitical features, combined with growing internet access and social media use, support decentralized online trade networks that operate across urban and semi-urban areas, complicating detection and enforcement.

Methods

Study design

We monitored online posts offering raptors for sale in Pakistan from January 2021 to December 2023 across groups on the social media platforms Facebook (2021), Instagram (2021), YouTube (2021), TikTok (2022) and WhatsApp (2023), and on locally managed e-commerce/classified websites (Gunawan et al., 2017; Sung & Fong, 2018; Nijman, 2020; Panter & White, 2020; Siriwat & Nijman, 2020; Haq et al., 2023). We conducted repeated monthly monitoring throughout the study period across platforms and groups, and during each session we screened newly available content returned by keyword searches, hashtags and group feeds (Siriwat & Nijman, 2020). Searches used English, Urdu, Punjabi and Pashto keywords and hashtags, comprising 'falcon', 'baz/baaz/baaza' (general falconry term for raptors), 'shaheen' (peregrine falcon), 'bari' (large raptor), 'chiri-mar' (small-bird-hunting hawk/eagle), 'saker', 'peregrine', 'baaz for sale', 'uqabb' (eagle), 'shikari parinday' (birds of prey) and 'falconry' (Sonricker Hansen et al., 2012; Gunawan et al., 2017; Panter & White, 2020). Searches were iterative, with additional terms added when new colloquial names or trade phrases appeared. We accessed a WhatsApp group via a publicly shared invitation link posted on Facebook and identified locally managed e-commerce and classified websites through the same keyword-based manual searches.

Where required, we used fictitious identities to join groups and conducted covert observations without interacting with users (Roulet et al., 2017). Because sellers sometimes avoided direct commercial language, using coded communication such as images without text or vague references to price and availability, we retained records only when species' identity and listing details could be verified from a seller's descriptions or visual evidence (Sung & Fong, 2018; Nijman, 2020; Muller et al., 2022). For each advertisement we recorded the date, platform, species identity, number of individuals offered for sale, stated location and advertised price.

Prices were recorded in PKR and converted to USD using the contemporaneous exchange rate (OANDA, 2024; USD 1 = PKR 280) for data analysis. To reduce duplication and misidentification, each advertisement was independently reviewed by at least three members of the research team and cross-checked across platforms using species' identity, number of individuals, location, price and accompanying images or videos. Duplicate, reposted or unverifiable records were excluded (Nijman, 2020; Siriwat & Nijman, 2020). We recorded raptor sex when it could be inferred from photographs or explicit descriptions; unclear cases were coded as not assessed (Gunawan et al., 2017; Nijman, 2020).

Following established practice in online wildlife trade monitoring, we limited data collection to information displayed in posts and group feeds, did not contact sellers or buyers, and did not access private profile content. Seller identifiers were treated as sensitive and were anonymized after duplicate checks, and any downloaded media used for verification were stored securely and used only for

TABLE 1 Candidate variables included in the generalized linear model (GLM) to explain advertised asking price of raptors traded online in Pakistan during 2021–2023.

Variable	Definition/reason
Year	Captures temporal variation in asking prices for 2021–2023
Raptor family	Used as a proxy for market demand differences among raptor groups
IUCN Red List status	Indicator of conservation concern that may influence price
Migratory status	Based on IUCN movement information, resident vs visitor (e.g. summer breeder, winter visitor, passage migrant); tests whether seasonal occurrence relates to price differences
National status (Pakistan)	Rare vs abundant (Roberts 1991, 1992; recoded); baseline national reference used in absence of updated standardized assessments
CITES Appendix	Appendix I includes species for which international commercial trade is generally prohibited (allowed only under strict exceptions); Appendix II includes species for which trade is permitted but regulated through permits to avoid unsustainable use. Included to test whether stricter international controls align with higher asking prices
Region	North vs south (seller-reported location); broad spatial grouping to capture geographical structure without province-level over-parameterization
Sex (as advertised)	Male vs female; included because sex preferences can influence falconry market value
Age (as advertised)	Adult vs juvenile; included because age/size and training potential may affect price

research purposes (Roulet et al., 2017; Sung & Fong, 2018; Nijman, 2020).

Data analysis

We summarized the dataset to describe trade volume (advertisements and individuals), species composition by raptor family, legal and conservation status, seller-reported location, temporal patterns and advertised prices. Where local rarity status was required, we used Roberts (1991–1992) as a baseline reference because no updated, standardized national assessment of raptor status is currently available for Pakistan. Spatial patterns in seller activity were assessed in *ArcGIS 10.5* (Esri, USA) by georeferencing seller-reported locations to districts and mapping hotspots using kernel density estimation. We visualized seller-reported locations with kernel density estimation, and mapped family-level patterns to identify recurring trade hotspots (Lecours et al., 2017).

We modelled variation in advertised asking price using *R 4.3.2* (R Core Team, 2023). Candidate predictors were defined a priori (Table 1) to represent biological, legal and geographical factors. We checked associations among categorical predictors using the phi coefficient (threshold > 0.5) and retained all predictors as no strong associations were detected. We initially fitted generalized linear mixed models with random effects for year and species, but sparse data across several factor levels caused convergence issues. We therefore fitted a generalized linear model (GLM) (Wood & Scheipl, 2025). Asking price was log-transformed to reduce right-skew, and we fitted a gamma distribution with a log link. We used the dredge function in *MuMIn* (Bartoń, 2023) to compare all candidate model combinations and ranked models using the Akaike information criterion adjusted for small sample size (AICc). Models with ΔAICc < 2 (difference from the top-ranked model) were retained as the supported set (Burnham & Anderson, 2002). Because the top five models all met this criterion, we averaged them to account for model selection uncertainty (Burnham & Anderson, 2002). We assessed model fit using residual diagnostics in *DHARMa* (Hartig et al., 2022).

Results

From January 2021 to December 2023, we recorded 310 wild-caught raptors of 24 species advertised for sale online in Pakistan, from 92 unique seller accounts across five international digital platforms (Facebook, Instagram, YouTube, TikTok and WhatsApp) and local e-commerce websites. Most individuals were Falconidae (189, 61.0%) and Accipitridae (115, 37.1%), with fewer Strigidae (5, 1.6%) and Pandionidae (1, 0.3%).

Across the 24 recorded species (Table 2), four (16.7%) are categorized as threatened (Endangered and Vulnerable) and two (8.3%) as Near Threatened on the IUCN Red List (IUCN, 2023), and 18 (75.0%) as Least Concern. Three species are listed in CITES Appendix I and 20 in Appendix II; one species was not recorded in a CITES Appendix. Global population trends were decreasing for 12 species, with 11 listed as stable or increasing, and one recorded as unknown. Species are common to rare in Pakistan (Roberts, 1991–1992), and occurrence in Pakistan includes year-round residents, winter visitors, summer breeders and passage migrants.

Across all records, the combined seller-advertised value was PKR 99,269,146 (USD 354,532). Annual totals varied. We recorded 88 (USD 75,355), 91 (USD 45,207) and 131 (USD 233,970) individuals in 2021, 2022 and 2023, respectively.

Seller activity was concentrated in Punjab and Khyber Pakhtunkhwa, with additional activity in Sindh and fewer

TABLE 2 Summary of raptor species advertised for sale online in Pakistan during 2021–2023, with family, local name, IUCN Red List category (IUCN, 2023), national status (Roberts, 1991, 1992), number offered for sale, global population trend (IUCN, 2023), occurrence in Pakistan and CITES Appendix, in descending order by number offered for sale.

Species	Family	Local name	Red List category[1]	National status	Number offered for sale	Global trend	Occurrence	CITES Appendix
Peregrine falcon *Falco peregrinus*	Falconidae	Behri/ Shaheen	LC	Rare	76	Stable	Summer breeder	I
Laggar falcon *Falco jugger*	Falconidae	Laghar	NT	Rare	35	Decreasing	Year-round resident	I
Saker falcon *Falco cherrug*	Falconidae	Charrug	EN	Frequent	27	Decreasing	Winter visitor	II
Eurasian sparrowhawk *Accipiter nisus*	Accipitridae	Chiri-mar	LC	Occasional	27	Stable	Summer breeder	II
Steppe eagle *Aquila nipalensis*	Accipitridae	Uqaab	EN	Abundant	20	Decreasing	Winter visitor	II
Eurasian hobby *Falco subbuteo*	Falconidae		LC	Rare	18	Decreasing	Summer breeder	II
Common kestrel *Falco tinnunculus*	Falconidae		LC	Common	18	Decreasing	Winter visitor	II
Northern goshawk *Accipiter gentilis*	Accipitridae	Goshaak	LC	Occasional	15	Unknown	Passage migrant	II
Golden eagle *Aquila chrysaetos*	Accipitridae	Uqaab	LC	Rare	13	Stable	Year-round resident	II
Red-headed falcon *Falco chicquera*	Falconidae		NT	Rare	13	Decreasing	Year-round resident	II
Eastern imperial eagle *Aquila heliaca*	Accipitridae	Uqaab	VU	Occasional	9	Decreasing	Winter visitor	I
Bonelli's eagle *Aquila fasciata*	Accipitridae	Uqaab	LC	Scarce	8	Decreasing	Winter visitor	II
Eurasian eagle-owl *Bubo bubo*	Strigidae	Ulloo	LC	Scarce	5	Decreasing	Year-round resident	II
Black-winged kite *Elanus caeruleus*	Accipitridae		LC	Common	4	Increasing	Year-round resident	II
Black kite *Milvus migrans*	Accipitridae	Cheel	LC	Common	4	Stable	Year-round resident	II
Shikra *Accipiter badius*	Accipitridae		LC	Common	4	Stable	Year-round resident	II
Booted eagle *Hieraaetus pennatus*	Accipitridae		LC	Rare	3	Stable	Winter visitor	II
Tawny eagle *Aquila rapax*	Accipitridae		VU	Scarce	3	Decreasing	Year-round resident	II
Brahminy kite *Haliastur indus*	Accipitridae		LC	Common	2	Decreasing	Year-round resident	
Merlin *Falco columbarius*	Falconidae		LC	Common	2	Stable	Winter visitor	II
Eurasian buzzard *Buteo buteo*	Accipitridae		LC	Common	1	Increasing	Year-round resident	II
White-eyed buzzard *Butastur teesa*	Accipitridae		LC	Common	1	Stable	Year-round resident	II
Black eagle *Ictinaetus malayensis*	Accipitridae		LC	Rare	1	Decreasing	Passage migrant	II
Osprey *Pandion haliaetus*	Pandionidae		LC	Common	1	Increasing	Winter visitor	II

[1]EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern.

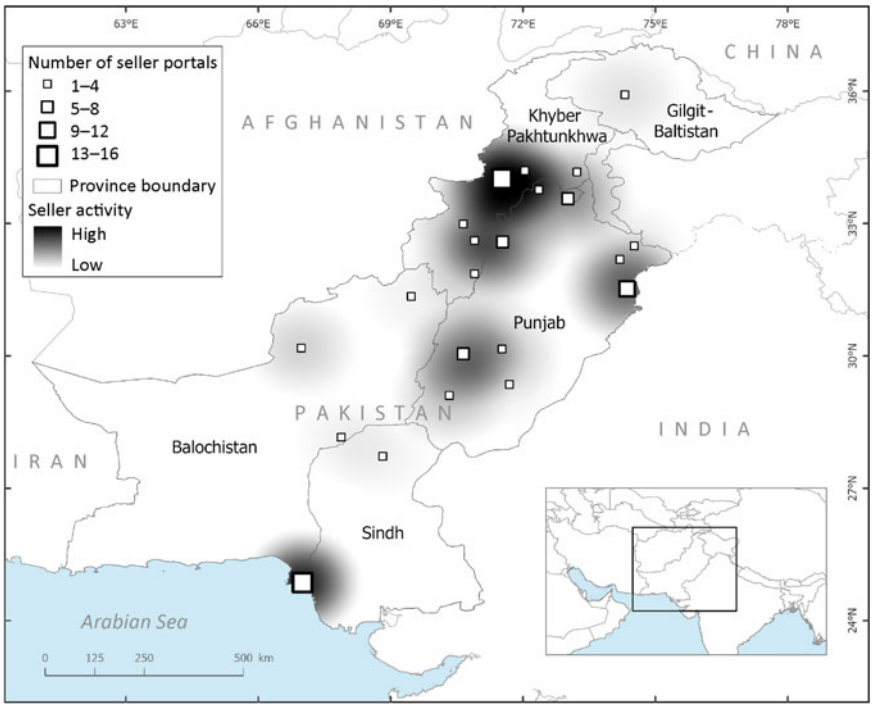

FIG. 1 Kernel density map of seller-reported locations in online advertisements of raptors for sale in Pakistan during 2021–2023. Concentrations of activity indicate areas with higher density of unique seller accounts based on the locations provided in posts.

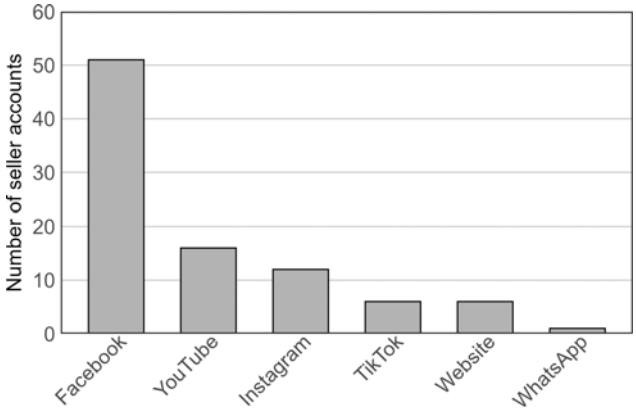

FIG. 2 Number of unique seller accounts detected on each digital platform during monitoring of online raptor trade in Pakistan. Seller accounts were counted once per platform after duplicate screening; values are therefore the minimum number of distinct sellers recorded using each platform during 2021–2023. 'Website' refers to local e-commerce or classified websites.

hotspots in Balochistan and Gilgit-Baltistan (Fig. 1). Facebook accounted for the largest share of seller accounts, followed by YouTube and Instagram, with fewer accounts recorded on TikTok, local e-commerce websites and WhatsApp (Fig. 2).

Age class was identified more often than sex. Adults were advertised more frequently than juveniles (174 adults, 56.1%; 136 juveniles, 43.9%). Sex was not assessed for 176 individuals (56.8%). Among records with sex reported or assessed, 75 were male (24.2%) and 59 were female (19.0%).

Asking prices varied widely among species. Peregrine falcons were the most frequently recorded species (76 individuals) and had a wide price range (up to PKR 7,000,000, USD 25,000). The highest asking price overall was recorded for the Saker falcon (up to PKR 7,200,000, USD 25,714). Of the Accipitridae, the steppe eagle *Aquila nipalensis*, Eurasian sparrowhawk *Accipiter nisus* and golden eagle *Aquila chrysaetos* were repeatedly advertised, with substantial variation in asking prices among taxa.

We evaluated 20 candidate GLMs of log-transformed asking price and identified five supported models (ΔAICc < 2; Table 3). In the top-ranked model (ΔAICc = 0), asking prices were higher for species categorized as Threatened and Near Threatened than for Least Concern species ($\beta = 0.160 \pm 0.060$, $P = 0.008$), and higher for visitor species than for resident species ($\beta = 0.278 \pm 0.063$, $P < 0.0001$; Table 4, Supplementary Fig. 1). Asking prices were lower in the southern than in the northern region ($\beta = -0.181 \pm 0.077$, $P = 0.019$). Family was retained in the top-ranked model but was not significant (Table 4). CITES Appendix listing, sex and age were not significant predictors in the supported model set (Table 4). No single model dominated the candidate set (highest Akaike weight = 0.126; Table 3).

Discussion

We documented 310 wild-caught raptors advertised for sale online in Pakistan across 24 species and four families. Falcons were the most frequently advertised group, and high-value falcons (especially peregrine and saker falcons) were prominent in both volume and asking price. This pattern is consistent with work showing that high-demand

TABLE 3 Top five supported GLMs explaining variation in log-transformed asking price (USD) for raptors advertised online in Pakistan during 2021–2023.

Predictor variables	K[1]	Log-likelihood	AICc[2]	ΔAICc[3]	Akaike weight (ωi)
~ Family + IUCN Red List status + Distribution + Region	6	−175.305	363.5	0	0.126
~ CITES Appendix + Family + IUCN Red List status + Distribution + Region	7	−174.578	364.3	0.85	0.082
~ CITES Appendix + IUCN Red List status + Distribution + Region	6	−175.845	364.6	1.08	0.073
~ Family + IUCN Red List status + Distribution + Region + Sex	7	−174.964	365.1	1.62	0.056
~ Age + Family + IUCN Red List status + Distribution + Region	7	−175.107	365.4	1.9	0.048

[1]Number of parameters.
[2]Akaike information criterion corrected for small sample size.
[3]Difference of AICc from the top-ranked model.

TABLE 4 Model-averaged (full) parameter estimates (± SE) for the five top-ranked GLMs (ΔAICc < 2; Table 3, Supplementary Fig. 1) for the log-transformed asking price (USD) of raptors advertised online in Pakistan during 2021–2023.

Predictor	Estimate ± SE	z	P
(Intercept)	1.357 ± 0.100	13.413	< 2e–16***
Family (Falconidae)	0.120 ± 0.082	1.450	0.14704
IUCN_status (threatened)	0.160 ± 0.059	2.651	0.00803**
Local_distribution (visitor)	0.278 ± 0.062	4.400	1.08e–05***
Region (south)	−0.181 ± 0.076	2.342	0.01917*
CITES Appendix (II)	−0.046 ± 0.073	0.632	0.52722
Sex (male)	−0.006 ± 0.026	0.239	0.81079
Age (juvenile)	−0.004 ± 0.023	0.184	0.85429

*P < 0.05, **P < 0.01, ***P < 0.001.

taxa, especially those perceived as rare or prestigious, often attract the highest attention and prices in illegal online markets (Sonricker Hansen et al., 2012; Stretesky et al., 2018; Sung & Fong, 2018).

Falconry provides the clearest cultural and economic context for these patterns. In Pakistan, falconry has longstanding links to demand from Arabian falconers, and is closely associated with the use of saker and peregrine falcons for hunting of the houbara bustard *Chlamydotis undulata* (Ali & Ripley, 1983; Roberts, 1991; Khan et al., 1996; Kovács, et al., 2014; Koch, 2015). Sport falconry has expanded in recent decades, sustaining demand in both domestic and international markets (Wakefield, 2012; Koch, 2015; Panter et al., 2023). Enforcement actions and reporting also indicate that trafficking systems prioritize high-value falcons (BBC, 2020; Aljazeera, 2021), which aligns with the dominance of falcons in our online records.

Our findings also show that asking prices were higher for species categorized as globally threatened and for visitor species, and they differed between northern and southern regions of Pakistan. This aligns with the pattern that scarcity, legal status and access can shape market valuation, and is consistent with findings from other regions where rarity and conservation status are linked to higher advertised prices (Sung & Fong, 2018; Leupen et al., 2022). However, model support was distributed across several plausible predictor sets, which suggests that asking price variation in this system is not explained by a single dominant factor.

Owls were uncommon in our dataset (five individuals across the study period) despite the global prominence of owls in many wildlife trade contexts (Panter & White, 2020). In Pakistan, the species pool and price structure we observed appear more consistent with a market shaped by falconry rather than by the pet trade. A second possibility for the low number of owl records is detectability, because different trader networks may use different platforms, posting styles and degrees of openness, which could reduce visibility in our monitoring approach (Iqbal, 2015; Panter & White, 2020).

Online trade carries public and animal health considerations. We did not assess pathogens, but handling and movement of live raptors can increase opportunities for pathogen transmission, and reducing such activity may therefore have benefits beyond biodiversity outcomes (Steensels et al., 2007; Shivakoti et al., 2010).

We found strong geographical clustering of seller activity, with a concentration in Punjab and Khyber Pakhtunkhwa. As it is possible that online activity tracks human population density and major towns, we explored this relationship using raster-based population density but

found only a weak positive association with seller hotspot density. Given its limited explanatory value, we treat the concentration of seller activity as descriptive rather than causal, and we focus on the implications for monitoring and enforcement priorities.

The distribution of records across platforms suggests where enforcement efforts could be most effectively focused. Facebook accounted for the largest share of seller accounts, followed by YouTube and Instagram, with limited use of other platforms. We only detected WhatsApp activity after encountering a publicly shared invitation link posted on Facebook. This was a single seller account, which is consistent with the largely closed, invitation-based structure and the low visibility of trade activity outside private groups on WhatsApp. Our findings regarding the use of multiple, interconnected platforms reflect the wider literature showing that social media can lower transaction costs and expand market reach for wildlife traders (Sonricker Hansen et al., 2012; Pham & Sakamoto, 2018; Panter & White, 2020). Online trade also changes how enforcement must operate. Posts are ephemeral, traders use coded language and closed groups, and cross-posting can fragment records across platforms. These constraints likely bias detection toward sellers that operate more openly, and they make market size harder to estimate even when monitoring effort is sustained (Harrison et al., 2016). A practical implication is that online monitoring should be paired with periodic physical market assessments, because without parallel surveillance it is difficult to distinguish any true shift in trade from a shift in detectability (Gunawan et al., 2017; Siriwat & Nijman, 2020).

Our findings also highlight discrepancies between legal protection and observed online advertising. Raptors listed as protected under provincial wildlife legislation continue to be advertised openly, including in provinces where relevant schedules prohibit hunting, trapping and trade. This pattern points to an enforcement problem rather than a lack of policy, and it supports the need for coordinated monitoring across provinces and stronger operational capacity within wildlife agencies (Aisha & Khan, 2020).

Several limitations frame the interpretation of our findings. Firstly, our values represent seller-advertised asking prices rather than confirmed transaction values. Actual sale prices may differ because of negotiation, incomplete sales or enforcement actions. Secondly, our coverage was not exhaustive. It was constrained by platform access, changing group visibility, moderation and the use of coded language. These limitations reinforce the case for adaptive monitoring approaches, including automated screening tools that combine image and text-based flagging with human verification ('t Sas-Rolfes et al., 2019). Although our sampling post-dates the peak Covid-19 restrictions in Pakistan and we did not test for pandemic-related effects, post-pandemic shifts in online activity, economic conditions and enforcement capacity may have influenced observed patterns.

Taken together, our findings indicate that online raptor trade in Pakistan is structured around high-demand falcons, includes globally threatened and visitor species, and is concentrated in specific provinces and on particular platforms. We recommend a combined response that matches this structure, with targeted engagement and monitoring on high-use platforms (especially Facebook), clear public reporting pathways, and coordinated enforcement across provinces. Automated screening tools and platforms utilizing artificial intelligence (AI), including image- and text-based detection systems, could support monitoring at scale when paired with verification workflows and consistent legal follow-through. We also recommend monitoring for high-demand species and clarifying how online listings relate to capture locations, movement routes and enforcement pressure, to better target interventions and evaluate outcomes.

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Competing interests None.

Ethical standards This research complies with the ethical standards of *Oryx*. The study involved no direct interaction with live animals or human participants, no experimentation, no specimen collection, and no engagement in wildlife trade. All data were obtained through observational review of publicly accessible online content (social media posts and listings on locally managed e-commerce or classified websites) and were collected in accordance with platform terms of use. Under institutional policy at WWF–Pakistan and applicable provincial and national regulations in Pakistan, formal ethics committee approval is not required for research based exclusively on publicly accessible online data when it does not involve human subjects, animal handling or intervention. The study therefore did not require approval from an institutional ethics committee. Data were aggregated and anonymized prior to analysis, and we excluded personal identifiers and other sensitive information.

Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

Aisha, H. & Khan, U. (2020) *An Assessment of the Scale of Illegal Wildlife Trade in Pakistan*. WWF–Pakistan, Lahore, Pakistan.

Ali, S. & Ripley, S.D. (1983) *Handbook of the Birds of India and Pakistan: Together with Those of Bangladesh, Nepal, Bhutan and Sri Lanka*. Oxford University Press, Delhi, India.

Aljazeera (2021) Poachers' paradise: Gulf hunts fuel Pakistan falcon trafficking. *Aljazeera*, 4 January 2021. aljazeera.com/news/2021/1/4/poachers-paradise-gulf-hunts-fuel-pakistan-falcon-trafficking [accessed 5 May 2024].

Andersson, A.A., Tilley, H.B., Lau, W., Dudgeon, D., Bonebrake, T.C. & Dingle, C. (2021) CITES and beyond: illuminating 20 years of global, legal wildlife trade. *Global Ecology and Conservation*, 26, e01455.

Barber-Meyer, S.M. (2010) Dealing with the clandestine nature of wildlife-trade market surveys. *Conservation Biology*, 24, 918–923.
Barton, K. (2023) *MuMIn: Multi-model Inference*. cran.r-project.org/web/packages/MuMIn/index.html [accessed 18 August 2024].
BBC (2020) Pakistan stops bid to smuggle endangered falcons. *BBC News*, 17 October 2020. bbc.co.uk/news/world-asia-54583248 [accessed 5 May 2024].
BirdLife (2023) *Central Asian Flyway*. BirdLife International, Cambridge, UK. birdlife.org/news/flymap/central-asian-flyway [accessed 15 August 2024].
Burnham, K.P. & Anderson, D.R. (2002) *Model Selection and Multi-Model Inference: A Practical Information-Theoretic Approach*. 2nd edition. Springer, New York, USA.
Challender, D.W.S., Harrop, S.R. & MacMillan, D.C. (2015) Understanding markets to conserve trade-threatened species in CITES. *Biological Conservation*, 187, 249–259.
CITES (2024) *The CITES Appendices*. CITES Secretariat, Geneva, Switzerland. cites.org/eng/app/index.php [accessed 15 August 2024].
Eaton, J.A., van Balen, B., Brickle, N.W. & Rheindt, F.E. (2017) Birds of the Indonesian Archipelago: Greater Sundas and Wallacea. *Kukila*, 23, 213–216.
Facebook (2021) Meta Platforms, Menlo Park, USA. facebook.com [accessed 05 January 2021].
Fukushima, C.S., Mammola, S. & Cardoso, P. (2020) Global wildlife trade permeates the Tree of Life. *Biological Conservation*, 247, 108503.
Gunawan, A., Paridi, A. & Noske, R.A. (2017) The illegal trade of Indonesian raptors through social media. *Kukila*, 20, 11.
Haq, R.U., Abdulabad, A., Asghar, S. & Szabo, J.K. (2023) Clicks and comments: representation of wildlife crime in Pakistan in social media posts. *Global Ecology and Conservation*, 43, e02473.
Harrison, J.R., Roberts, D.L. & Hernandez-Castro, J. (2016) Assessing the extent and nature of wildlife trade on the dark web. *Conservation Biology*, 30, 900–904.
Hartig, F., Lohse, L. & Souza leite, M. de (2022) *DHARMa: Residual Diagnostics for Hierarchical (Multi-Level/Mixed) Regression Models*. cran.r-project.org/web/packages/DHARMa/index.html [accessed 25 August 2024].
Instagram (2021) Meta Platforms, Menlo Park, USA. instagram.com [accessed 05 January 2021].
Iqbal, M. (2015) Looking at online bird trading in Indonesia; a case study from South Sumatra. BirdingASIA, 24, 132–135.
IUCN (2023) *The IUCN Red List of Threatened Species*. iucnredlist.org [accessed 15 August 2024].
Khan, A.A., Khan, R., Ullah, A., Ali, M., Mahmood, J.A. & Sheikh, K.M. (1996) Conservation perspectives of the imperial *Aquila heliaca* and steppe eagle *Aquila nipalensis* in Pakistan. In *Eagle Studies* (eds B.-U. Meyburg & R.D. Chancellor), pp. 459–461. World Working Group on Birds of Prey and Owls, Berlin, Germany.
Koch, N. (2015) Gulf nationalism and the geopolitics of constructing falconry as a 'Heritage Sport'. *Studies in Ethnicity and Nationalism*, 15, 522–539.
Kovács, A., Williams, N.P. & Galbraith, C.A. (2014) *Saker Falcon (*Falco cherrug*) Global Action Plan (Saker GAP), Including a Management and Monitoring System, to Conserve the Species*. CMS Technical Series No. XX, Bonn, Germany. cms.int/sites/default/files/document/Inf_10_8_SakarFalcon_GAP_Eonly.pdf [accessed 08 May 2024].
Lecours, V., Devillers, R., Simms, A.E., Lucieer, V.L. & Brown, C.J. (2017) Towards a framework for terrain attribute selection in environmental studies. *Environmental Modelling & Software*, 89, 19–30.
Lees, A.C., Haskell, L., Allinson, T., Bezeng, S.B., Burfield, I.J., Renjifo, L.M. et al. (2022) State of the World's Birds. *Annual Review of Environment and Resources*, 47, 231–260.
Leupen, B.T.C., Gomez, L., Nguyen, M.D.T., Shepherd, L. & Shepherd, C.R. (2022) A brief overview of the online bird trade in Vietnam. *Asian Journal of Conservation Biology*, 11, 176–188.
Maxwell, S.L., Fuller, R.A., Brooks, T.M. & Watson, J.E.M. (2016) Biodiversity: the ravages of guns, nets and bulldozers. *Nature*, 536, 143–145.
McClure, C.J.W., Schulwitz, S.E., Anderson, D.L., Robinson, B.W., Mojica, E.K., Therrien, J.-F. et al. (2019) Commentary: defining raptors and birds of prey. *Journal of Raptor Research*, 53, 419.
McClure, C.J.W., Westrip, J.R.S., Johnson, J.A., Schulwitz, S.E., Virani, M.Z., Davies, R. et al. (2018) State of the world's raptors: distributions, threats, and conservation recommendations. *Biological Conservation*, 227, 390–402.
Muller, J.R., Selier, S.J., Drouilly, M., Broadfield, J., Leighton, G.R.M., Amar, A. & Naude, V.N. (2022) The hunter and the hunted: using web-sourced imagery to monitor leopard (*Panthera pardus pardus*) trophy hunting. *Conservation Science and Practice*, 4, e12789.
Nellemann, C., Henriksen, R., Kreilhuber, A., Stewart, D., Kotsovou, M., Raxter, P. et al. (eds) (2016) *The Rise of Environmental Crime: A Growing Threat to Natural Resources, Peace, Development and Security*. United Nations Environment Programme, Nairobi, Kenya.
Newton, I. (1990) *Birds of Prey*. Merehurst Press, London, UK.
Nijman, V. (2010) An overview of international wildlife trade from Southeast Asia. *Biodiversity and Conservation*, 19, 1101–1114.
Nijman, V. (2020) Illegal trade in Indonesia's national rare animal has moved online. *Oryx*, 54, 12–13.
OANDA (2024) *Currency converter (PKR to USD)*. OANDA, Toronto, Canada. oanda.com/currency-converter/en/?from=PKR&to=USD&amount=1 [accessed 5 October 2024].
Panter, C. & White, R.L. (2020) Insights from social media into the illegal trade of wild raptors in Thailand. *TRAFFIC Bulletin*, 32, 5–12.
Panter, C.T., Jones, G.C.A. & White, R.L. (2023) Trends in the global trade of live CITES-listed raptors: trade volumes, spatiotemporal dynamics and conservation implications. *Biological Conservation*, 284, 110216.
Pham, C.T. & Sakamoto, M. (2018) Online trade in wildlife in Southeast Asia: a rapid survey of bird and reptile species in the Philippines. *TRAFFIC Bulletin*, 29, 58–63.
R Core Team (2023) *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. R-project.org [accessed 1 January 2023].
Roberts, T.J. (1991) *The Birds of Pakistan. Volume 1: Regional Studies and Non-Passeriformes*. Oxford University Press, Karachi, Pakistan.
Roberts, T.J. (1992) *The Birds of Pakistan. Volume 2: Passeriformes: Pittas to Buntings*. Oxford University Press, Karachi, Pakistan.
Rosen, G.E. & Smith, K.F. (2010) Summarizing the evidence on the international trade in illegal wildlife. *EcoHealth*, 7, 24–32.
Roulet, T.J., Gill, M.J., Stenger, S. & Gill, D.J. (2017) Reconsidering the value of covert research: the role of ambiguous consent in participant observation. *Organizational Research Methods*, 20, 487–517.
Shafiq, M.M. & Idrees, M. (2006) Trapping methods used for the migratory falcons in Pakistan. *The Pakistan Journal of Forestry*, 56, 9.
Shivakoti, S., Ito, H., Otsuki, K. & Ito, T. (2010) Characterization of H5N1 highly pathogenic avian influenza virus isolated from

a mountain hawk eagle in Japan. *Journal of Veterinary Medical Science*, 72, 459–463.

Siriwat, P. & Nijman, V. (2020) Wildlife trade shifts from brick-and-mortar markets to virtual marketplaces: a case study of birds of prey trade in Thailand. *Journal of Asia-Pacific Biodiversity*, 13, 454–461.

Sonricker Hansen, A.L., Li, A., Joly, D., Mekaru, S. & Brownstein, J.S. (2012) Digital surveillance: a novel approach to monitoring the illegal wildlife trade. *PLOS One*, 7, e51156.

Steensels, M., Van Borm, S., Boschmans, M. & Van Den Berg, T. (2007) Lethality and molecular characterization of an HPAI H5N1 virus isolated from eagles smuggled from Thailand into Europe. *Avian Diseases*, 51, 401–407.

Stretesky, P.B., McKie, R.E., Lynch, M.J., Long, M.A. & Barrett, K.L. (2018) Where have all the falcons gone? Saker falcon (*Falco cherrug*) exports in a global economy. *Global Ecology and Conservation*, 13, e00372.

Sung, Y.-H. & Fong, J.J. (2018) Assessing consumer trends and illegal activity by monitoring the online wildlife trade. *Biological Conservation*, 227, 219–225.

't Sas-Rolfes, M., Challender, D.W.S., Hinsley, A., Veríssimo, D. & Milner-Gulland, E.J. (2019) Illegal wildlife trade: scale, processes, and governance. *Annual Review of Environment and Resources*, 44, 201–228.

TikTok (2022) ByteDance, Beijing, China. tiktok.com [accessed 15 May 2022].

UNODC (2020) *World Wildlife Crime Report: Trafficking in Protected Species, 2020*. United Nations, Vienna, Austria.

Vall-Llosera, M. & Su, S. (2019) Trends and characteristics of imports of live CITES-listed bird species into Japan. *Ibis*, 161, 590–604.

Van Borm, S., Thomas, I., Hanquet, G., Lambrecht, B., Boschmans, M., Dupont, G. et al. (2005) Highly pathogenic H5N1 influenza virus in smuggled Thai eagles, Belgium. *Emerging Infectious Diseases*, 11, 702–705.

Wakefield, S. (2012) Falconry as heritage in the United Arab Emirates. *World Archaeology*, 44, 280–290.

WhatsApp (2023) Meta Platforms, Menlo Park, USA. whatsapp.com [accessed 25 March 2023].

Wood, S. & Scheipl, F. (2025) *gamm4: Generalized Additive Mixed Models using 'mgcv' and 'lme4'*. cran.r-project.org/web/packages/gamm4/index.html [accessed 18 August 2024].

Wyatt, T. (2009) Exploring the organization of Russia Far East's illegal wildlife trade: two case studies of the illegal fur and illegal falcon trades. *Global Crime*, 10, 144–154.

Wyatt, T. (2011) The illegal trade of raptors in the Russian Federation. *Contemporary Justice Review*, 14, 103–123.

YouTube (2021) Google, Mountain View, USA. youtube.com [accessed 15 January 2021].