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Cover: Emperor Tamarin *Saguinus imperator*: a look into a better world through the mustache lens – mixed media illustration. © Maya Santhanakrishnan.

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ARTICLE

Harmonizing ecology and society: an integrated analysis of vulture conservation in the Nilgiri Biosphere Reserve, India

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Abstract: The Nilgiri Biosphere Reserve (NBR) in southern India is home to several critically endangered vulture species. This study in Mudumalai Tiger Reserve and Sathyamangalam Tiger Reserve of NBR presents an integrated analysis of vulture conservation efforts focusing on harmonizing ecosystem preservation and community engagement. We assessed the current status of all four vulture species in the NBR using the road transect method, covering 2,040 km with 24 replications (January–December 2021). We undertook covert surveys in 82 veterinary pharmacies across four districts of Tamil Nadu to determine the availability of non-steroidal anti-inflammatory drugs (NSAIDs), considering the 100-km vulture safe zone that included vulture nesting and foraging areas. As practical conservation efforts require active local community participation, our assessments include the perception study of local communities in 20 villages (eight tribal and 12 non-tribal) near vulture habitats. We focused on NSAID usage, considering the impact of numerous socio-economic factors on vulture conservation efforts. We surveyed 540 respondents using detailed questionnaires for these evaluations. The study underlined the need for a comprehensive vulture management plan that balances ecological concerns with the well-being and means of subsistence of surrounding communities. This study is helpful for future conservation efforts in other areas with comparable problems at the nexus of ecology and society.

Keywords: Community engagement, ecological balance, NSAID prevalence, road transect method, southern India, vulture habitats, welfare and livelihoods, wildlife conservation.

Tamil: தென்னிந்தியாவில் உள்ள நீலகிரி உயிர்க்கோளக் காப்பகம் (NBR) பல அழியும் தருவாயில் உள்ள பெருங்கழுகு இனங்களின் தாயகமாக உள்ளது. இந்த ஆய்வு NBR இன் முதுமலை மற்றும் மற்றும் சத்தியமங்கலம் புலிகள் காப்பகம் ஆகியவை கழுகு பாதுகாப்பு முயற்சிகளின் ஒருங்கிணைந்த பகுப்பாய்வை முன்வைக்கின்றன. சுற்றுச்சூழல் பாதுகாப்பு மற்றும் சமூக ஈடுபாட்டை ஒத்திசைப்பதில் கவனம் செலுத்துகிறது. NBR இல் சாலை மார்பகமாக கணக்கெடுப்பு முறையைப் பயன்படுத்தி, 24 முறை 2,040 கி.மீ. (ஜனவரி-டிசம்பர் 2021) கணக்கீடு செய்து, நான்கு கழுகு இனங்களின் தற்போதைய நிலையை மதிப்பீடு செய்தோம். மேலும் 100-கிமீ பெருங்கழுகு பாதுகாப்பான மண்டலத்தை கருத்தில் கொண்டு, கழுகு கூடு கட்டுதல் மற்றும் உணவு தேடும் பகுதிகலில் NSAIDs உள்ளதா என்பதை நாங்கள் இரகசியமாக ஆய்வு மேற்கொண்டோம். அதன்படி தமிழ்நாட்டின் நான்கு மாவட்டங்களில் உள்ள 82 கால்நடை மருந்தகங்களில் NSAIDs உள்ளதா என்பதை கண்டறியும் ஆய்வுகளை நடத்தினோம் . நடைமுறை பெருங்கழுகு பாதுகாப்பு முயற்சிக்கு உள்ளூர் சமூகப் பங்கேற்பு தேவை, எனவே பெருங்கழுகு வாழ்விடங்களுக்கு அருகில் உள்ள 20 கிராமங்களில் (8 பழங்குடியினர் மற்றும் 12 பழங்குடியினர் அல்லாதவர்கள்) உள்ளூர் சமூகங்களின் கருத்து ஆய்வு நடத்தினோம். பெருங்கழுகு பாதுகாப்பு முயற்சிகாக பல சமூக-பொருளாதார காரணிகளின் தாக்கத்தை கருத்தில் கொண்டு, NSAID பயன்பாட்டில் கவனம் செலுத்தினோம். இந்த மதிப்பீடுகளுக்கு விரிவான கேள்வித்தாள்களைப் பயன்படுத்தி 540 பதிலளித்தவர்களிடம் நாங்கள் ஆய்வு செய்தோம். ஆய்வு அடிக்கோடிட்டுக் காட்டியது சுற்றியுள்ள சமூகங்களுக்கு ஒரு விரிவான பெருங்கழுகு மேலாண்மை திட்டம் தேவை. இந்த ஆய்வு எதிர்கால பாதுகாப்பு முயற்சிகளுக்கு மற்ற பகுதிகளில் தூழலியல் மற்றும் சமூகம் ஒப்பிடக்கூடிய சிக்கல்களுடன் தொடர்புடையதாக உள்ளது.

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Author contributions: SM—conceptualisation and writing; BH—design, writing and editing; PK—writing

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INTRODUCTION

Nine species of vultures are recorded from India, of which five belong to the genus *Gyps* (Prakash 1999). Seven species of vultures are known to exist in southern India. The four residents are White-rumped Vulture (WRV) *Gyps bengalensis,* Egyptian Vulture (EV) *Neophron percnopterus*, Red-headed Vulture (RHV) *Sarcogyps calvus,* and Long-billed Vulture (LBV) *Gyps indicus.* The three migrants are the Cinereous Vulture *Aegypius monachus,* the Himalayan Griffon Vulture *Gyps himalayensis,* and the Eurasian Griffon Vulture *Gyps fulvus* (Bowden 2018). Vulture populations across southern Asia have drastically declined due to the veterinary use of nonsteroidal anti-inflammatory drugs (NSAIDs) (Pain et al. 2008; Ogada et al. 2012) in farm animals (Ogada et al. 2012; McClure et al. 2018; Buechley et al. 2019). In the 1990s, three species of *Gyps* vultures experienced 95% catastrophic declines as a result of diclofenac administration to cattle (Prakash 1999; Prakash et al. 2003, 2012; Oaks et al. 2004). In India, the use of the drug diclofenac for veterinary purposes was outlawed in 2006 (Prakash et al. 2007). Other NSAIDs, such as nimesulide, flunixin, aceclofenac, and ketoprofen, are also harmful to vultures (Zorrilla et al. 2014; Galligan et al. 2016; Naidoo et al. 2018).

Diclofenac is still being used illegally for veterinary purposes in southern Asia (Cuthbert et al. 2011a,b; Botha et al. 2017). Less than 1% of animal carcasses contaminated with diclofenac could have caused the disaster observed during the Asian vulture crisis, according to Green et al. (2004). Thus, creating vulture protection zones, raising awareness, and teaching the local populace are among the top conservation priorities. These measures, combined with laws and policies about the toxicity of NSAIDs, are the most important conservation needs for Old World vultures (McClure et al. 2018). These drugs remain available in the proposed vulture safe zone in the Nilgiri Biosphere Reserve (NBR) area of southern India (Manigandan et al. 2023b). Inadvertent poisoning is another serious risk to vultures that has not gotten much attention from scientific research. The intentional poisoning of carcasses as retaliation (Harris 2013) and the construction of electrical infrastructure that can electrocute birds (Manigandan et al. 2021) have resulted in a notable loss of vultures.

Given vulture prevalence in human-influenced environments and their critical endangerment, prioritizing social science research is imperative. Vultures play a crucial role in ecosystems by efficiently scavenging carrion and meat waste, thereby aiding in the cleaning of the environment (Thiollay 2017). Their presence in humanized settings, particularly in areas with inadequate solid waste management, can help mitigate the risk of disease outbreaks by reducing the population of mammalian scavengers such as dogs and rodents known to transmit diseases to humans (Ogada et al. 2012), thereby potentially decreasing the transmission of diseases. For instance, the decline of vulture populations in India led to a surge in feral dog populations scavenging carcasses in urban areas, contributing to disease transmission (Guerrero et al. 2012). Hence, the absence of vultures in humanized environments may exacerbate the proliferation of mammalian scavengers and the associated health risks. This study elucidates local community attitudes and actions, pivotal for both positive and negative impacts on vulture survival (Dhakal et al. 2022). Human activities significantly affect vulture conservation efforts, making empirical data on social and ecological aspects vital for effective interventions (Heberlein 2012; Reimer et al. 2013; Henriques et al. 2018). Understanding local perceptions, especially in key breeding areas like NBR in southern India, is crucial for conservation strategies, considering the intersection of economic development and anthropogenic stress (Manigandan et al. 2023a). Such insights inform conservation policies recognizing the role vultures play in ecosystems (Dhakal et al. 2022).

The objectives of the current study are:

1. To estimate the present population of different species of vultures within the study area, with emphasis on the four species currently threatened to be extinct.

2. To assess the level of perceived threat associated with the sale and availability of NSAIDs through direct assessments from the pharmacies of the nearby districts near the vulture nesting and foraging areas of NBR.

3. To evaluate the socio-economic status of the public and their awareness and attitudes regarding vulture conservation within the NBR. This study will contribute to formulating a site-specific management plan for NBR. This strategy will take into account the species status, existing threats, and local people's knowledge and perspectives, thereby updating the current conservation plan for vultures.

METHODS

Study area

In NBR, both Mudumalai Tiger Reserve (MTR) and Sathyamangalam Tiger Reserve (STR) are located in the

southern state of Tamil Nadu and adjoin each other as the study area (Figure 1). MTR Latitude: 11.587627°, Longitude; 76.710485°), covering 688 sq km, is bound by Bandipur Tiger Reserve (BTR) of Karnataka State to the north, Wayanad Forest Division of Kerala State to the west, Nilgiri South Forest Division to the south, and STR to the east. STR , Latitude: 11.586740°, Longitud: 77.157586° , a 1,410 km^2 area bordered to the north by the Biligiri Rangan Hills Tiger Reserve (BTR), to the west by the BTR, to the south by the MTR and Sigur plateau, and to the east by the Bargur Reserve Forest. Tropical evergreen, tropical moist, tropical dry, and scrub and thorny forests are the different types of forests found in STR and MTR. The watershed of the Moyar River includes both MTR and STR. WRVs are prevalent in the extensive area of Moyar Gorge, particularly within the riverine forests dominated by *Terminalia arjuna* trees, which serve as their primary nesting sites. LBVs find good roosting and nesting habitats along the area's numerous cliffs and escarpments.

Estimating the population of vultures

Road-transect methods were used to assess the vulture population at the study site (Venkitachalam & Senthilnathan 2016; Manigandan et al. 2023a). Five transects were chosen based on the nearest accessible tarred and metal roads to the villages as well as the presence of a vulture nesting colony in the protected areas of NBR. The transects (T) are: T1: Bhavanisagar to Thengumarahada; T2: Siriyur to Vazhaithottam; T3: Vazhaithottam to Masinagudi; T4: Masinagudi to Moyar; and T5: Masinagudi to Theppakadu (Figure 1).

The transects were driven between 0800 h and 1100 h, and 1500 h to 1800 h IST at 20–30 kmph by a four-wheeler over a total transect length of 85 km. These transect surveys were conducted twice a month, from January to December 2021. A total of 2,040 km of road were surveyed throughout the study during 24 replications. Whenever we observe the vultures, the vehicle was stopped, and the geo-coordinates noted, species identified, and numbers are recorded using a binocular (Nikon Monarch M5 12x42) from about 100 m to minimize disturbance. These were used for the preparation of maps using QGIS 3.28 (Manigandan et al. 2023a). We did not count the birds that were too far away to be identified.

To assess the accessibility of NSAIDs toxic to vultures we conducted covert surveys at 82 veterinary pharmacies across four districts in Tamil Nadu part of the vulture safe Zone: Nilgiris, Erode, Tiruppur, and Coimbatore, in January and February 2021. The sample comprised pharmacies managed by licensed pharmacists. We initiated contact with each pharmacy through local individuals or livestock owners seeking treatment for sick cows or buffaloes, using expired medication boxes containing diclofenac, ketoprofen, aceclofenac, flunixin, and nimesulide. The initial survey recorded pharmacy names, addresses, and sometimes geographic coordinates. Subsequent surveys located the same pharmacies using this information (Cuthbert et al. 2011a; Manigandan et al. 2023b). Building on the preliminary survey data, we employed the same approach to identify medications intended for human and animal use, commonly sold in the NBR region. Data on the type of compound (defined by active NSAIDs), brands, whether the drug was injectable or in bolus form, and manufacturing date and price were recorded. This enabled us to ascertain the presence of vulture-toxic drugs in the market (Manigandan et al. 2023b).

Local community perception survey

The questionnaire survey encompassed both tribal and non-tribal populations residing near vulture habitats within MTR and STR, where tribal communities are allowed to collect non-timber forest produce (NTFP) and graze cattle. Conducted from November to December 2021 across 20 settlements, eight of which were tribal (Irulas, Betta Kurumbas, Then Kurumbas, and Baniyas), and the rest non-tribal (Phuyal et al. 2016; Dhakal et al. 2022). Figure 1 outlines information on the 12 villages in MTR and eight villages in STR. Perceptions on vulture conservation were gathered from 540 randomly selected respondents, comprising 279 tribal and 261 non-tribal individuals. The random selection process involved drawing household numbers from various study villages as primary targets (Milano et al. 2018). While household heads were the primary respondents, resident adults aged 18 or older within households were also invited to participate (Gandiwa et al. 2013). Interviews were conducted with the aid of a Kannada translator to facilitate open communication as most spoke this language than the local Tamil language, with each interview lasting 20–30 minutes at the respondent's residence. Most questions utilized a 'precise and closed' format (Manigandan et al. 2023b) to effectively capture villagers' perceptions, although this format was not the primary focus (Gandiwa et al. 2013). The questionnaire, largely based on Reson (2012), covered socio-economic factors and local people's knowledge and perceptions regarding vultures and their ecological significance, ensuring clarity and alignment with study objectives. Uniform presentation of questions prevented bias

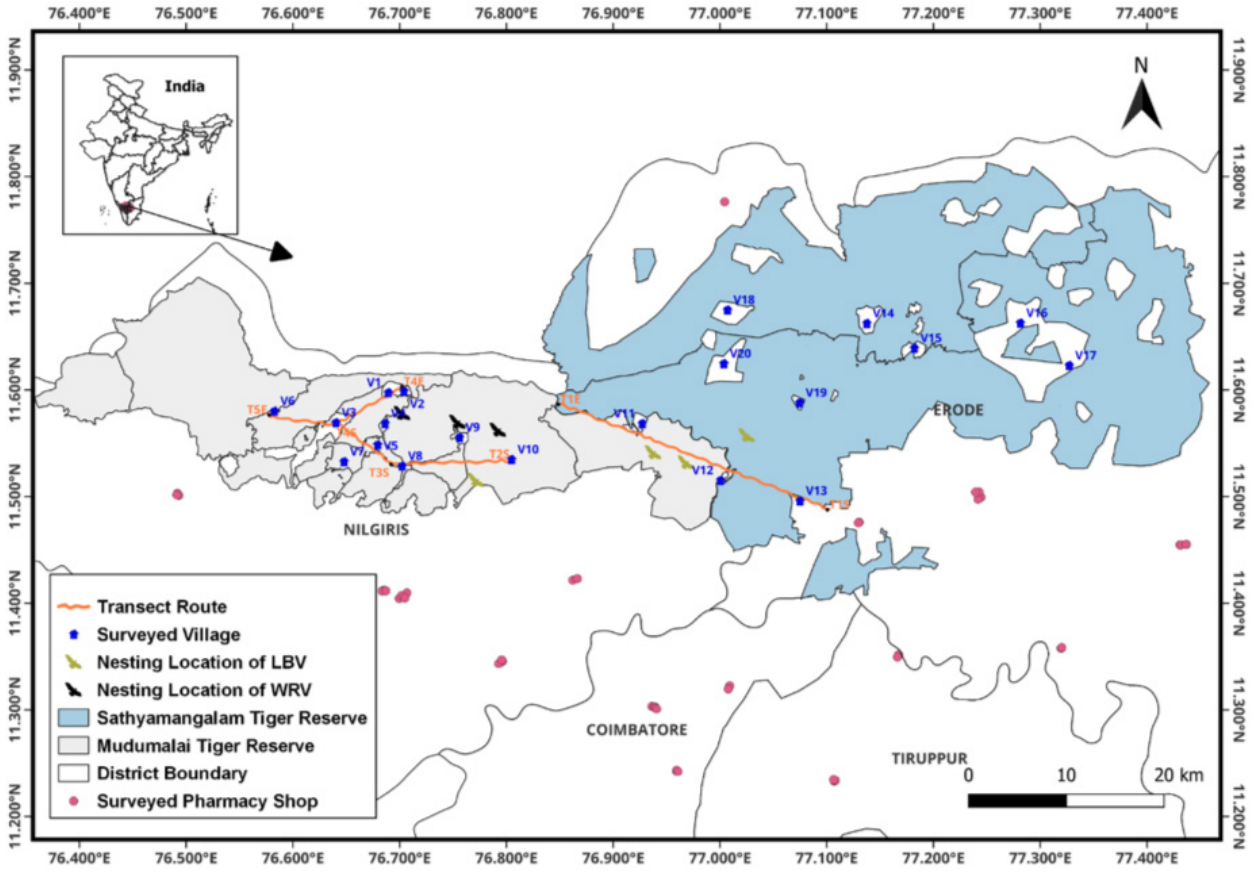

Figure 1. The study area of Mudumalai and Sathyamangalam tiger reserves with the road transect; nesting locations of WRV and LBV; locations of pharmacy shops in nearby districts; and locations of villages.

and ensured consistent responses (Kasunic 2005). Additionally, the questionnaire was pre-tested in a nearby community, and adjustments were made for clarity as needed. Post-survey cross-checking and editing were conducted to minimize data discrepancies and inconsistencies.

Statistical analysis

Basic statistics such as the arithmetic mean and standard error were calculated using (Microsoft Excel and SPSS 23. We also conducted a seasonal evaluation of vulture populations, distinguishing between summer (April–July), monsoon (August–November), and post-monsoon (December–March) periods by the Kruskal-Wallis ANOVA test (Venkitachalam & Senthilnathan 2006). We also examined the relationship between variables on differences between sex, education, gender, age, caste, and economic status regarding awareness of vultures, and their conservation, comparing the groups using the non-parametric test, the chi-square test. To explore the relationship between variables, we used the Pearson correlation coefficient, positive correlation (+1) negative correlation (-1) using the statistical software Origin Lab 2024.

RESULTS

Vulture population estimation

In our survey, we identified four vulture species: WRV, LBV, RHV, and EV. The WRV had the highest recorded numbers, with 1,570 individuals (M±SE, 65.4±2.4), and an encounter rate of 0.85 individual/km. Following this, LBVs were recorded at 151 individuals (M±SE 6.1±2), with an encounter rate of 0.08 individual/km, while RHVs numbered 118 (M±SE 4.9±0.25), with an encounter rate of 0.06 individual/km. The EV had the lowest count throughout the survey, with only 18 individuals (Figure 2). The mean population of WRV was highest during summer, followed by post-monsoon, and then monsoon. However, there was no significant difference between the samples (a). Conversely, the population of LBV did not vary significantly across seasons (B). Similarly, the mean population of RHV showed no seasonal variance

(c), nor did that of EVs (d) (Figure 4 a–d).

NSAID surveys

In a comprehensive covert survey conducted across four districts, a total of 19 different bolus brands and 14 injectable brands of NSAIDs were identified as available for purchase to treat livestock. The survey revealed a diverse array of 11 distinct types of NSAIDs offered for sale: aceclofenac, analgin (also known as metamizole), diclofenac, flunixin, meglumine, ibuprofen, ketoprofen, mefenamic acid, meloxicam, nimesulide, paracetamol (also known as acetaminophen), phenylbutazone, and piroxicam. Interestingly, many of the NSAIDs available for purchase were found to contain more than one active ingredient. Paracetamol was included as a secondary ingredient in 57.5% of bolus formulations and 42.5% of injectable formulations. Notably, paracetamol was commonly combined with bolus forms of nimesulide, as well as both injectable and bolus forms of meloxicam and bolus forms of diclofenac. Additionally, we identified two brands of diclofenac, either alone or in combination with paracetamol. It is worth noting that the two injectable brands of diclofenac, originally manufactured for human use, were being sold for veterinary treatment (Table 1).

Among the four districts, meloxicam (n = 19) had the most prevalence in pharmacy shops, followed by ketoprofen and aceclofenac (n = 2 each); flunixin, and nimesulide (n = 1 each) in Nilgiris. Meloxicam (n = 17) had the highest availability in pharmacies in the Erode district, followed by nimesulide and ketoprofen (n = 3 each), flunixin (n = 2), and aceclofenac (n = 1). Meloxicam (n = 4) was the most widely available in pharmacy shops in the Tiruppur district, followed by aceclofenac (n = 2), ketoprofen, flunixin, nimesulide, and ketoprofen (n = 1 each). Finally, in the Coimbatore district, meloxicam was the most widely available in pharmacy shops (n = 18), followed by aceclofenac (n = 3), flunixin and nimesulide (n = 2 each), and ketoprofen (n = 1) (Figure 3).

Table 1. Analysis of injectable and bolus NSAID formulations in four districts, with a focus on paracetamol-related co-active ingredients (brand names are indicated in parenthesis).

Active ingredient	Bolus	Injectable	Total
Tolfenamic acid		1(1)	1(1)
Meloxicam	4(2)	6(2)	10(4)
Diclofenac	3(1)	2(1)	5(2)
Ketoprofen		1	1
Aceclofenac	1(1)		1(1)
Flunixin		1	1
Ibuprofen	3(2)		3(2)
Nimesulide	6(1)	1	7(1)
Paracetamol		1	1
Analgin	2(1)	1(1)	3(2)
Phenylbutazone butazone2		1(1)	1(1)
Total with paracetamol as a secondary compound	19(8)	14(6)	33(14)

Perception surveys

In the present study, a detailed analysis of the surveyed respondents' socio-economic characteristics revealed the following key findings: The gender distribution was as follows: male respondents (53.1%, n = 287) outnumbered female respondents (46.8%, n = 253). The respondents' ages ranged from 18 to 80 years, with a median of 40 years. Notably, the majority of participants (34.6%) were of middle age (26–50 years; n = 187), closely followed by the young age group at 34.4% (18–25 years; n = 184). The older age group (51–80 years; n = 169) constituted 31% of the sampled population. The assessment of respondents' educational qualifications revealed a predominance of illiteracy, with 35.1% (n =

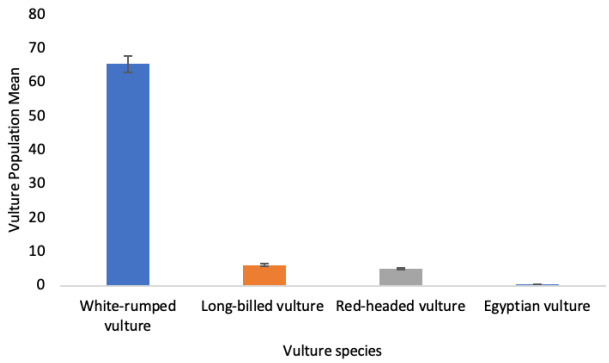

Figure 2. Population status of four vulture species of Mudumalai and Sathyamangalam tiger reserves in 2021.

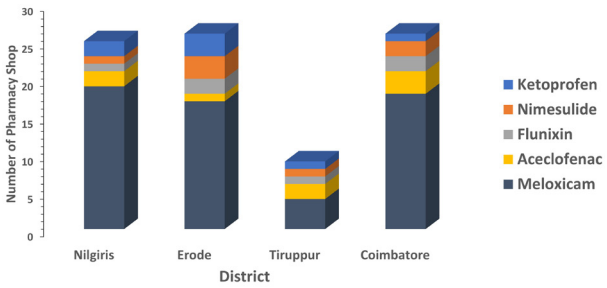

Figure 3. NSAIDs harmful to vultures are available in the Nilgiris Biosphere Reserve.

190) falling into this category. Following this, 22.4% (n = 121) had completed primary school, and an equal percentage (22.1%, n = 119) had completed secondary school. Additionally, 20.4% (n = 110) of participants possessed a college-level qualification.

In terms of source of income, agriculture was found to be the most common, accounting for 38.7% (n = 209) of the total sample, followed by livestock rearing at 30% (n = 162). Private employment accounted for 16.2% of the total (n = 88), while government employment accounted for 9.4% (n = 51). Entrepreneurial activities were less common, with 5.7% (n = 30) of the population involved in some form of business ownership. In addition, the study looked into the economic strata of households in the surveyed area. According to the findings, 32.7% (n = 177) of households were classified as lower-middle class, with 27.9% (n = 151) classified as very poor. The poor category comprised 21.4% (n = 116) of households, while the upper-middle class accounted for 11.4% (n = 62). The remaining 6.6% (n = 34) of households were categorized as affluent (Table 2).

The collective disposition towards vulture conservation was evaluated based on a summation of responses to 15 pertinent questions. Approximately, 66.6% (n = 360) of respondents believed that the vulture populations in the study area were declining. Moreover, a substantial 88.5% (n = 462) disagreed with reported incidents of mass vulture mortality in recent years. A significant majority of 87.4% (n = 472) felt that the availability of carrion, a primary vulture food source, was not increasing. Remarkably, 92.5% (n = 499) stated that they refrained from persecuting vultures. Another 85.7%

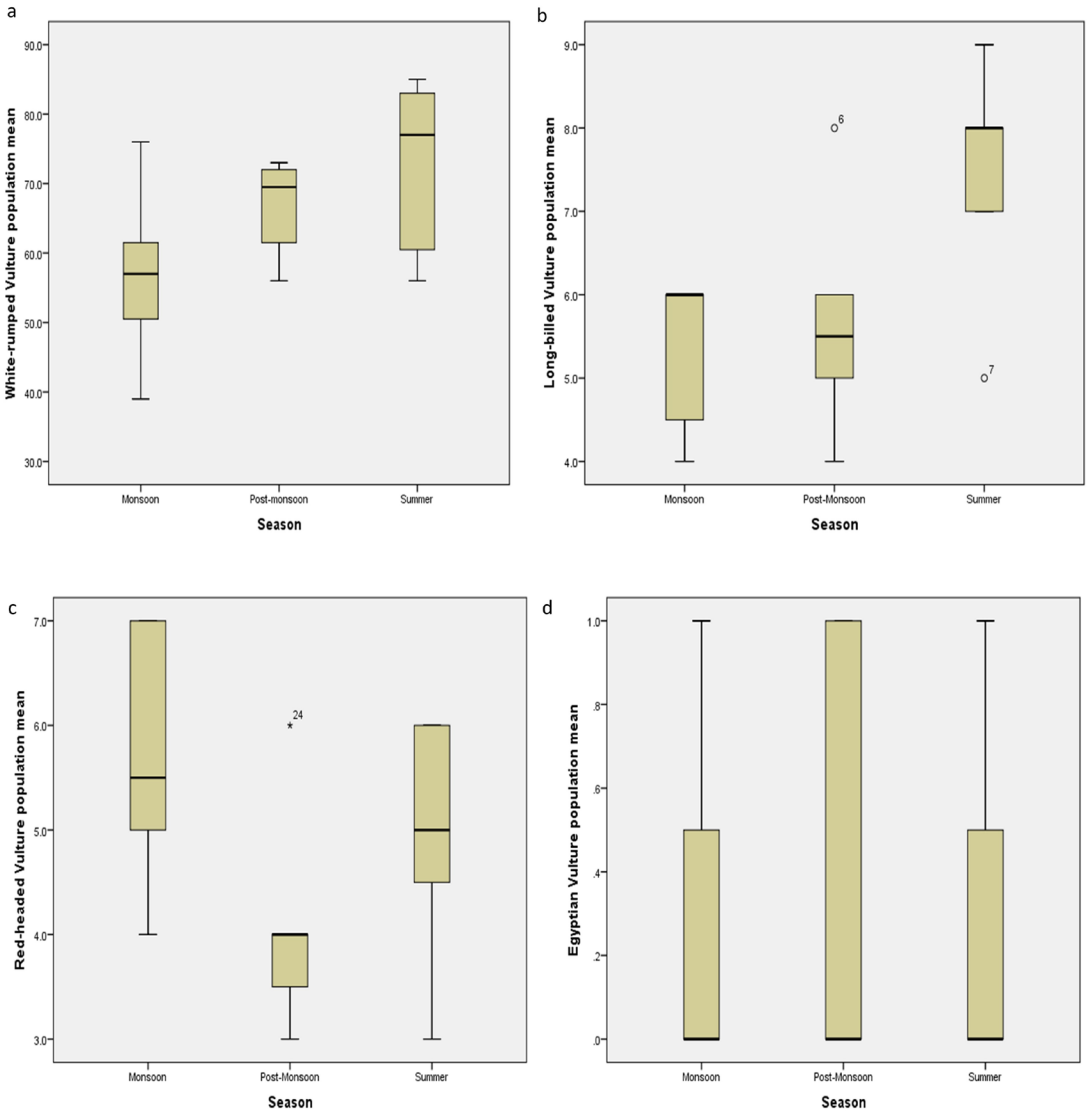

Figure 4. Vulture species population the season-wise in 2021.

Table 2. A comprehensive overview of the socioeconomic distribution of households in Nilgiri Biosphere Reserve.

Respondents' variables	Tribal	Non-tribal	Total
	respondents (%)	respondents (%)	
Gender			
Male	145 (51.9)	142 (54.4)	287 (53.1)
Female	134 (48.1)	119(45.6)	253 (46.8)
Age			
(Young) 18–25 years	82 (29.3)	102 (39)	184 (34.4)
(Middle) 26–50 years	103(36.9)	84 (32.1)	187 (34.6)
(Old) Above 51 years	94 (33.8)	75 (28.9)	169 (31)
Education			
Illiterate	135 (48.3)	55 (21)	190 (35.1)
Primary School	55 (19.7)	66 (25.2)	121 (22.4)
Secondary School	47 (16.8)	72 (27.5)	119 (22.1)
College Level	42 (15.2)	68 (26.3)	110 (20.4)
Source of livelihood			
Agriculture	97 (34.7)	112 (42.9)	209 (38.7)
Livestock rearing	107 (38.3)	55 (21)	162 (30)
Government sector	13 (4.6)	38 (14.5)	51(9.4)
Private sector	55 (19.7)	33 (12.6)	88 (16.2)
Own Business	7 (2.7)	23 (8)	30 (5.7)
Economic Status (Annual income)*			
Very poor (Below 25K)	139 (49.8)	12 (4.5)	151 (27.9)
Poor (26K to 50K)	88 (31.5)	28 (10.7)	116 (21.4)
Lower middle class (50K to 100K)	34 (12.1)	143 (54.7)	177 (32.7)
Upper middle class (100K to 500K)	18 (6.6)	44 (16.8)	62 (11.4)
Rich (Above 500K)	0	34 (13.7)	34 (6.6)

* Largely based on Reson (2012).

(n = 463) expressed the opinion that wildlife should have suitable habitats. A strong consensus of 93.1% (n = 503) recognized the need for increased awareness campaigns focused on vulture conservation. A notable 90.3% (n = 488) endorsed the necessity of safeguarding vultures for the well-being of future generations. A substantial 70% (n = 378) of respondents held vultures in high regard, similar to a deity. A 67.4% (n = 364) acknowledged the ecological benefits vultures provide to human communities. The majority (59.7%; n = 322) of respondents contested the idea of declining forest cover in their localities; 63.4% (n = 342) of respondents did not consider chemical fertilizers and pesticides as major contributors to vulture decline (Figure 5). The correlation coefficient between variables shows an asymmetric distribution with most of the participants having a relatively positive attitude toward vulture conservation, Among the respondents, Q-5,6,7,8,9,12,13,14 and 15 are positive attitudes (Figure 8).

A dichotomized scale was used to assess significant predictors influencing conservation attitudes among the surveyed population. There was a significant difference in conservation attitudes between male and female respondents. Females had a 52.5% (n = 187) positive attitude toward vulture conservation compared to males 47.5% (n = 169) which was statistically significant (χ^2 = 13.579, p <0.001). When we looked at the different age groups, we found that middle-aged participants were more interested in vulture conservation, with 37.4% having positive attitudes. Older and younger participants had slightly lower percentages, with 31.7% and 30.9%, respectively. However, these age differences did not show statistical significance (χ^2 = 5.406, p = 0.634). Among the communities, tribal participants showed a higher positive attitude (57.6%) towards vulture conservation compared to their non-tribal counterparts. However,

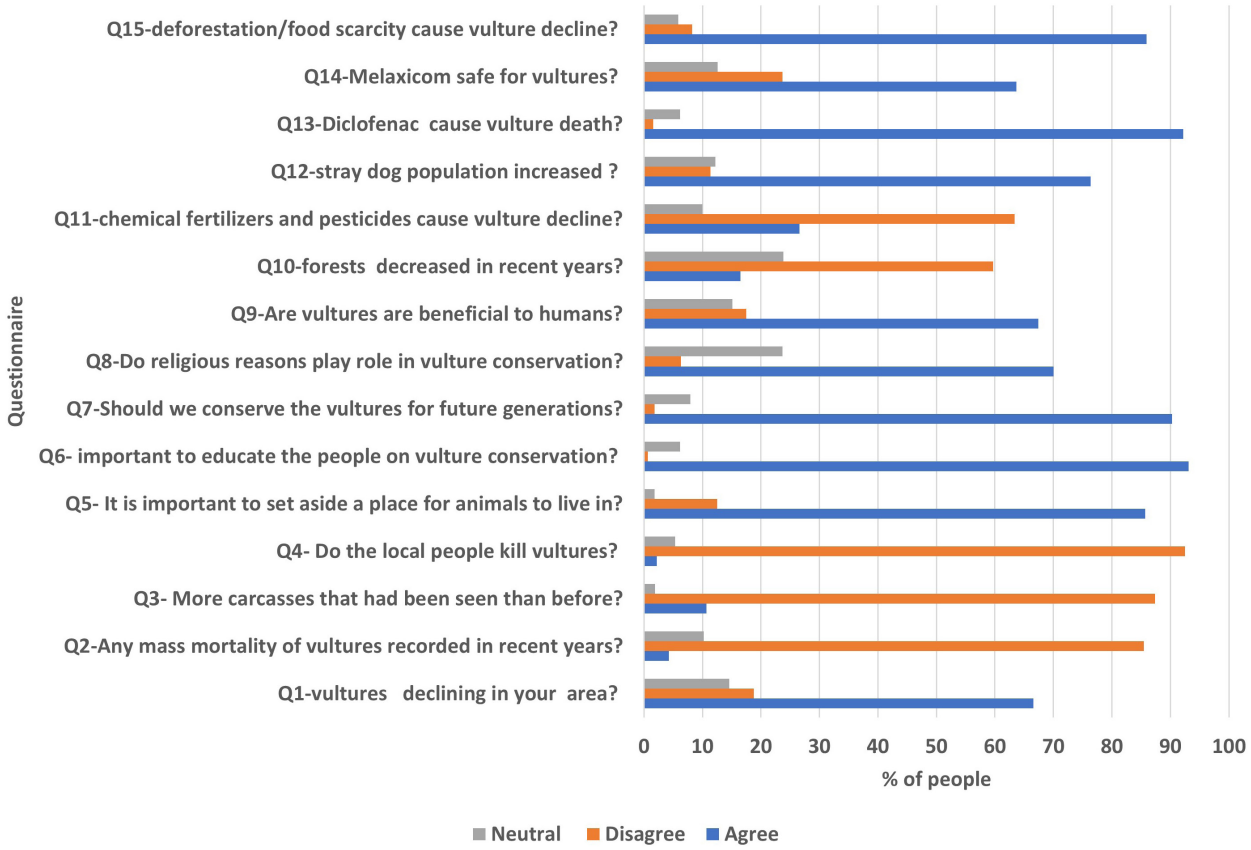

Figure 5. Societal perspectives on vulture conservation among tribal and non-tribal populations in Nilgiri Biosphere Reserve.

statistical analysis indicated no significant differentiation between the two groups (χ^2 = 14.651, p = 0.067).

Education-wise, among the younger respondents, those with college-level education (28.9%) exhibited significantly more positive attitudes towards vulture conservation. Respondents with secondary, primary, or no formal education had lower positive attitudes. This difference was statistically significant (χ^2 = 20.142, p <0.001). Regarding livelihood, livestock holders showed the highest inclination (33.7%) towards vulture conservation, which was statistically significant (χ^2 = 34.379, p <0.0001). Economically, among the low middle-class respondents, there was a positive attitude (36.8%) toward vulture conservation compared to others, but this difference was not statistically significant (χ^2= 8.256, p <0.083). For those living in the MTR, there was a significant positive attitude (64.6%) towards vulture conservation compared to those in STR (χ^2 = 3.73, p <0.053) (Figure 6).

In NBR, 12 village residents have a positive attitude as most of the tribal household has people working in the forest department as guards, anti-poaching watchers, and eight village residents have a negative attitude toward vulture conservation, In MTR, Moyar, Boothanatham, Masinagudi, Mavanallha, Theppakadu, Vazhaithottam, Anaikatty, Siriyur, and Kallampalayam are villages with positive attitudes toward vulture conservation, while Chemmanatham, Bokkapuram, and Thengumarahada are negative. Accordingly, in STR, only three villages have a positive attitude - Kadambur, Thalaimalai, and Ittarai. The remaining village respondents expressed a negative attitude towards vulture conservation (Figure 7). The correlation coefficient between variables shows an asymmetric distribution with most of the villages having a relatively negative attitude towards vulture conservation, among the respondents, villages who are living in the MTR (Village -1,2,3, 5,6,8,9, 10,12) have positive attitudes towards vulture conservation exception village- 4,7 and 11. As well as those who are living STR's negative attitude toward vulture conservation (Figure 9).

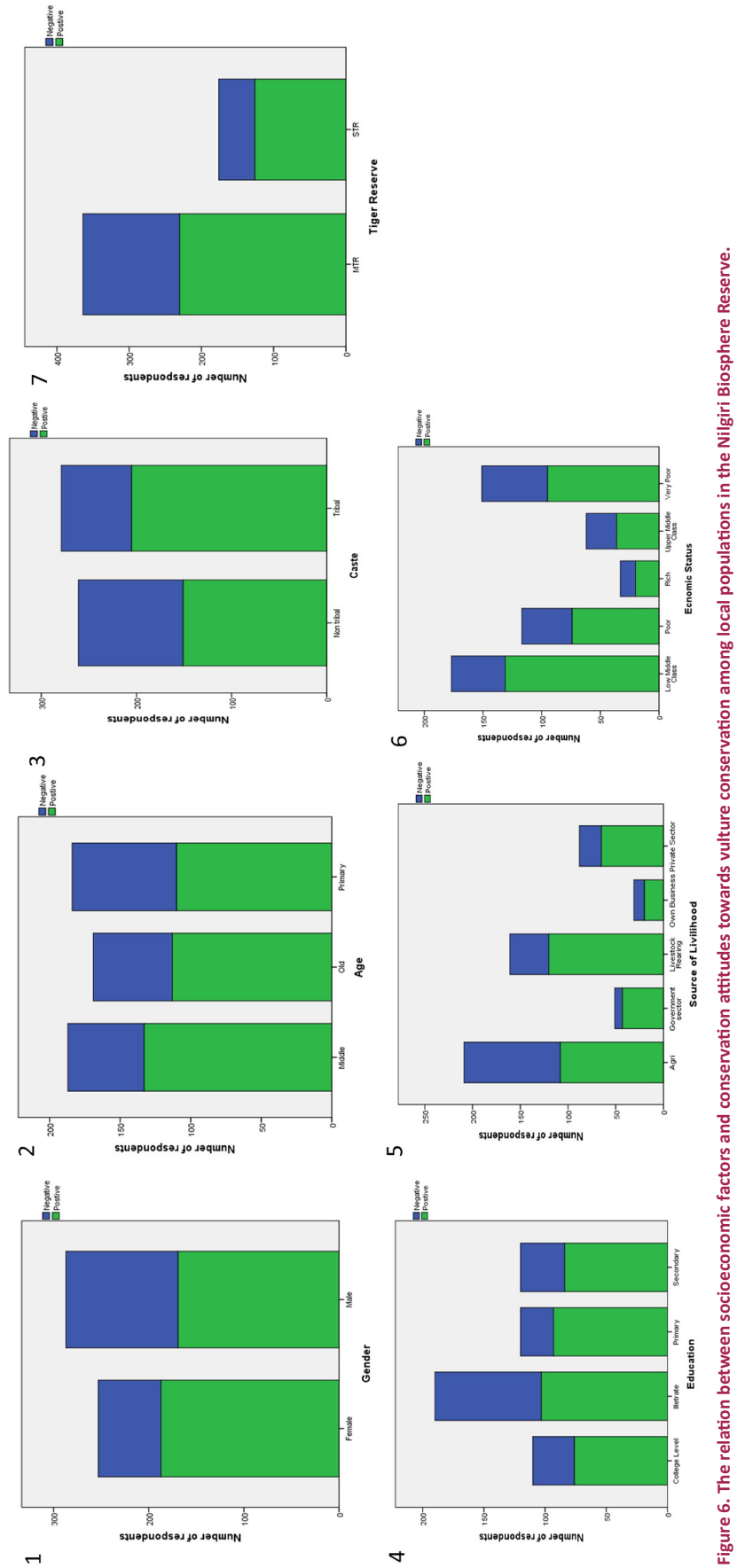

Figure 6. The relation between socioeconomic factors and conservation attitudes towards vulture conservation among local populations in the Nilgiri Biosphere Reserve.

DISCUSSION

Status of the Vulture population

We documented four vulture species, namely WRV, LBV, RHV, and EV. This study confirmed the present status of four vulture species in NBR and underscored the value of local knowledge regarding the threats faced by these species. Bhusal et al. (2019) and Galligan et al. (2019) have previously reported an increase in the vulture population following the ban on diclofenac in 2006. Even though in NBR, vultures faced new threats as forest fire and illegal tourism (Manigandan et al. 2024), our findings suggest that the population appears to be relatively stable (Manigandan et al. 2023a).

Our road-transect surveys of vulture sightings were compared to similar studies in the study area. Specifically, the encounter rates of WRV and LBV were 0.85 and 0.08, which aligns with earlier observations (Venkidachalam et al. 2016; Manigandan et al. 2023a).

Furthermore, we did seasonal comparisons of vulture populations. Venkitachalam & Senthilnathan (2016) had previously noted that WRV populations were higher in the post-monsoon season. In contrast, our study found that the populations of WRV were higher during the summer season. This difference may be attributed to the breeding seasons of these species, which commence in September and end in March, with nestlings gradually growing up by March. During this period, adult birds leave the nest to forage (Stotrambhashyam et al. 2015), resulting in increased vulture sightings from April to July. Notably, EVs, which were documented during the study period, were mostly juveniles, suggesting possible nesting of this species in NBR, consistent with earlier findings (Byju & Raveendran 2022).

Assessment of harmful drugs impacting vultures

Injectable formulations of diclofenac available in NBR were originally intended for human use, making their manufacturing and sales legal. However, these products were being offered for sale for veterinary use (Cuthbert et al. 2011a; Manigandan et al. 2023b), which is illegal. It is important to note that two bolus brands and one injectable brand of diclofenac were found to be manufactured after the ban on its veterinary use in 2006. On the other hand, meloxicam has been recognized as a safe drug for vultures (Swarup et al. 2007). While meloxicam is readily available in pharmacies, other potentially harmful drugs such as aceclofenac, ketoprofen, nimesulide, and flunixin are also widely available in pharmacy shops (Galligan et al. 2021; Manigandan et al. 2023b).

The presence of these harmful drugs on the market

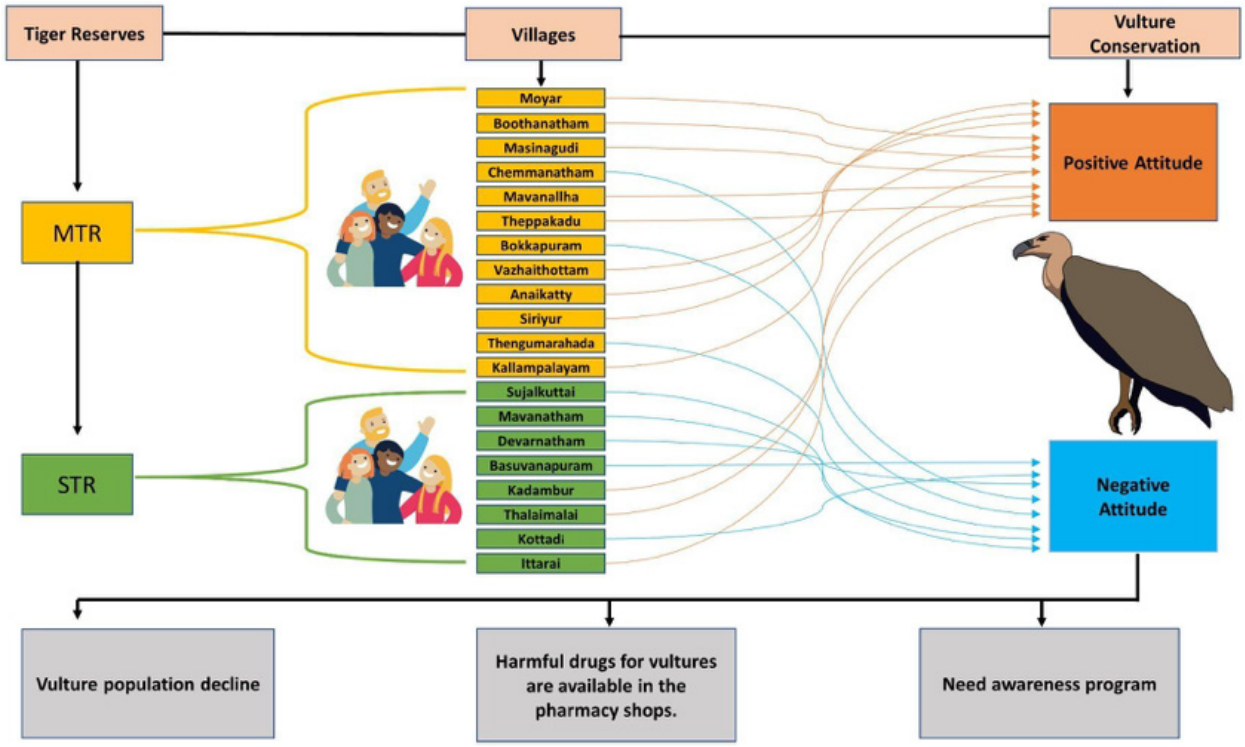

Figure 7. Village-wise attitudes of respondents toward vulture conservation in Nilgiri Biosphere Reserve.

poses a potential threat to vultures. In the MTR, where government veterinary doctors oversee cattle treatment, meloxicam is typically administered to cattle as a painkiller, ensuring the safety of vultures. However, in the case of STR, private veterinarians are responsible for treating livestock, raising concerns that they may use pain relief medications that could be harmful to vultures.

To safeguard vultures, vulture safe zones (VSZ) have been defined as areas within a radius of 100 km from the vulture nesting colony. The zone is divided into 50 km as the core zone and the next 50 km as the buffer zone (Mukherjee et al. 2014) from the nearest nesting colonies. Research has shown that 1% of lethal levels of diclofenac can lead to a significant decline in vulture populations (Green et al. 2004). Given the importance of protecting vultures and the presence of critically endangered species in the NBR, the Government of India has expressed interest in declaring it VSZ (MOEF 2020). However, this declaration must be made after thorough research and assessment to ensure the safety and preservation of vulture populations in the NBR.

Local community and knowledge of vulture conservation

We investigated the awareness and attitudes of local communities, specifically tribal groups, towards vulture conservation. Tribal communities often hold unique knowledge and perceptions about wildlife due to their cultural beliefs and practices. This research aligns with previous studies that emphasize the significance of local perceptions in garnering support for conservation efforts (Sharma et al. 2019; Katuwal et al. 2021; Byju et al. 2023). One interesting finding is that tribal people are more knowledgeable and aware of vultures than non-tribal people, which is likely due to their cultural reverence for vultures as god (Jha et al. 2023). Additionally, personal attitudes play a pivotal role in determining an individual's intentions to support vulture conservation (Byju & Raveendran 2022). Furthermore, our research reveals that various factors, such as ethnicity, age, education, gender, livestock ownership, participation in conservation activities, and perceived benefits, significantly influence conservation attitudes. Interestingly, unlike some indigenous communities in India that engage in hunting for sustenance, the tribal

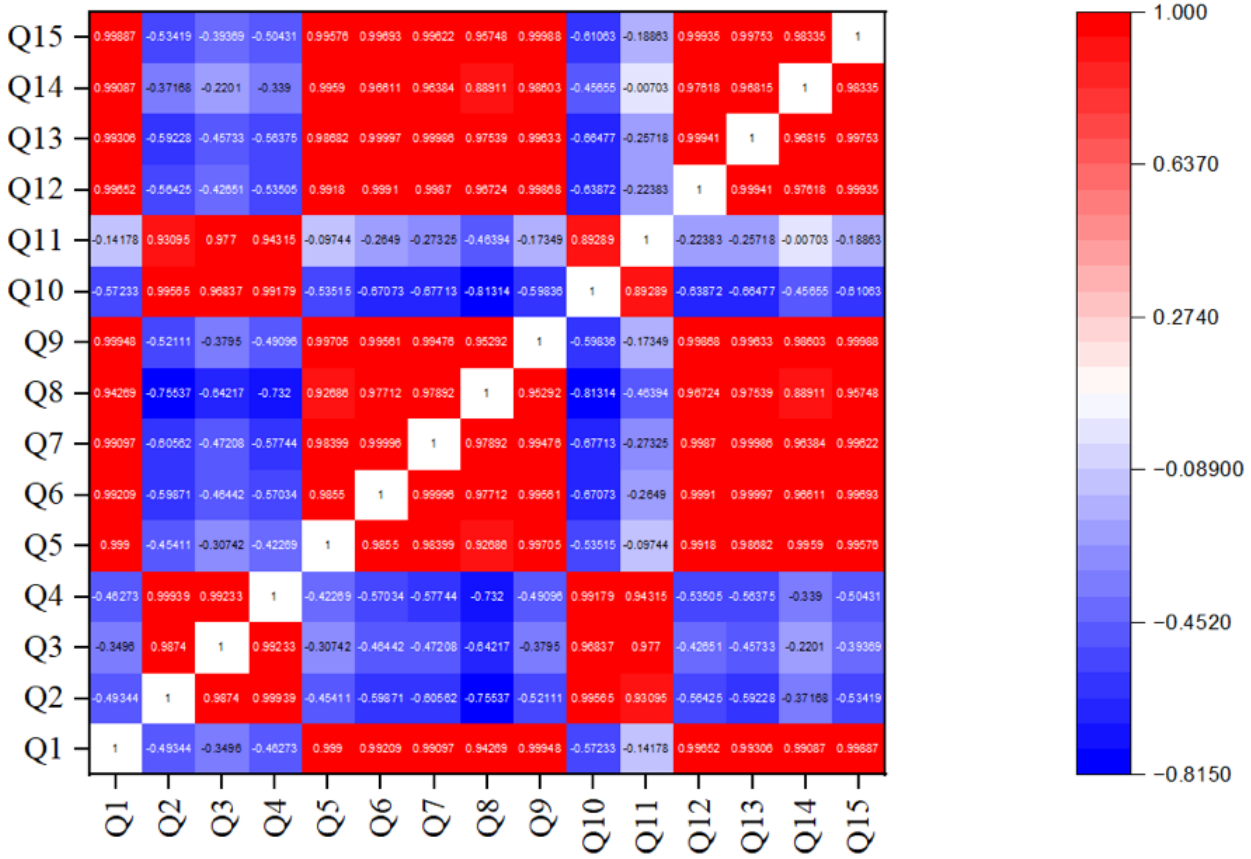

Figure 8. Correlation matrix among the 15 questionnaires with variables (Agree, disagree, and neutral) towards vulture conservation.

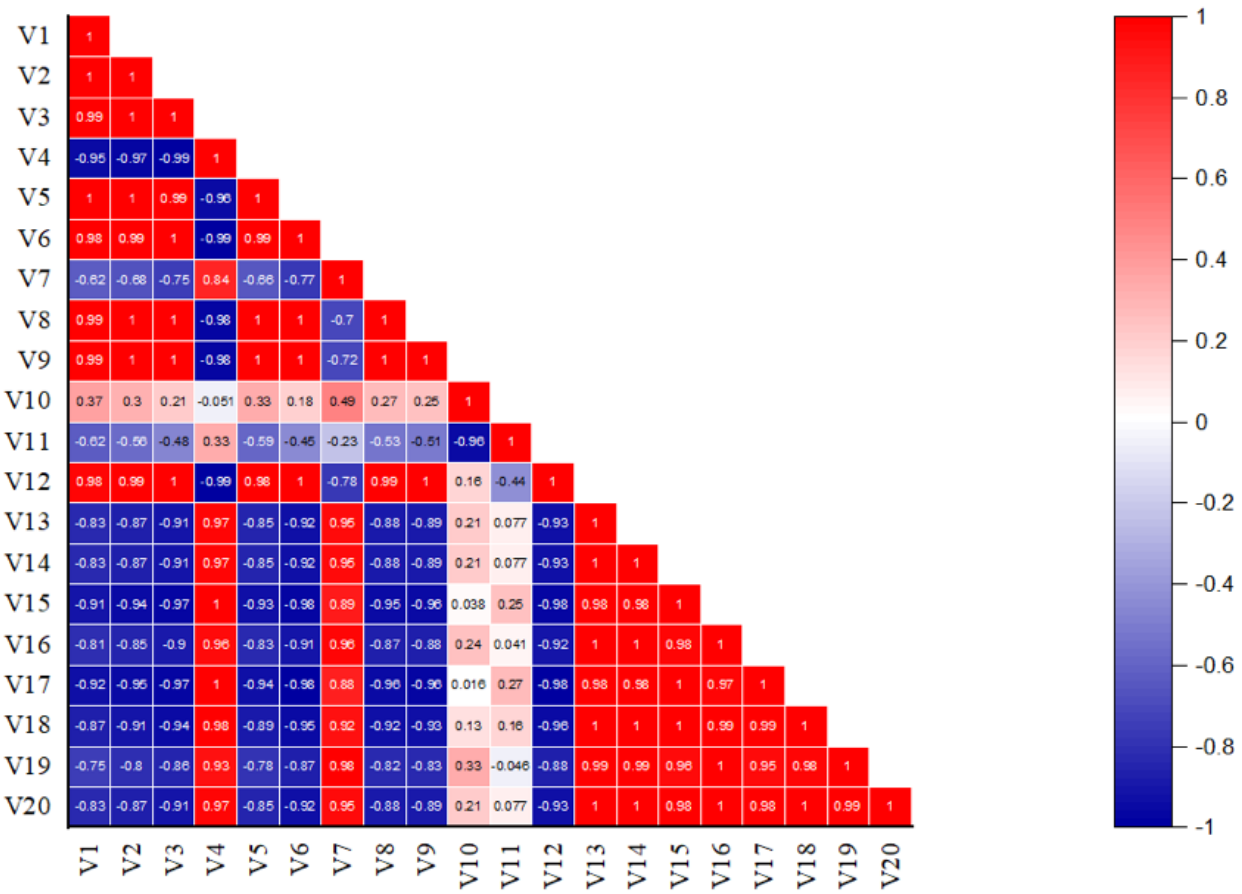

Figure 9. Correlation matrix among the 20 villages with the attitude (positive and negative).

communities in our study area do not hunt birds, including vultures (Jha et al. 2023). This distinction underscores the need for region-specific conservation strategies. Moreover, our study highlights the discrepancy in vulture awareness between the residents of MTR and STR. This difference can be attributed to the focused efforts of the forest department and NGOs on the MTR. As a result, future conservation endeavours should extend their attention to the STR to enhance vulture conservation efforts.

Improved access to primary and secondary education has contributed to an increase in community awareness. In terms of literacy, it was observed that illiterate individuals, especially among tribals, expressed relatively higher awareness of vulture protection compared to the non-tribal illiterate individuals. Furthermore, there were a higher proportion of male respondents, reflecting gender roles in Tamil society (Shumsher & Timilsina 2013). Despite reports of women's limited participation in discussions (Jha et al. 2023), the current study found that women had a more positive attitude toward vulture conservation, emphasizing the importance of vulture conservation education and awareness programs aimed at non-tribal communities and others. None of the disadvantaged groups, such as tribal communities, have a college-level education, emphasizing the importance of environmental education programs to engage them in conservation efforts. Previous research has shown that education can strongly influence conservation attitudes (Heinen 1998; Emtage 2004). The socioeconomic status of the local population, as measured by education, was a primary factor influencing attitudes toward vulture conservation. The data obtained in this study revealed a highly positive attitude among those who received higher secondary and college-level education (Shumsher & Timilsina 2013).

Subsistence agriculture and livestock rearing are the mainstay occupations in the study area, with a majority of households raising livestock. Contrary to the findings of Shumsher & Timilsina (2013) regarding lower caste and livestock producers, livestock owners showed a high level of interest in vulture conservation. Despite the ban on diclofenac in the country since 2006, informal discussions with veterinary personnel revealed

that local people still prefer to use diclofenac due to its cost-effectiveness and efficacy compared to other NSAIDs, posing a serious threat to vultures (Cuthbert et al. 2016). This highlights the need for ongoing efforts to discourage the illegal use of diclofenac for both veterinary and human purposes.

The disposal of carcasses in the region exhibited distinct practices based on the cause of animal death. Residents typically bury the carcasses of animals that died of diseases. Conversely, they prefer to discard carcasses in open fields in the case of natural death and wildlife attacks, facilitating vulture scavenging opportunities. The use of pesticides and chemical fertilizers, although not quantified, was a common practice among local farmers. Ghimire et al. (2013) noted that respondents disagreed with the statement that the "use of chemical fertilizers and pesticides causes vulture decline". Similarly, in the present study, a substantial number of respondents disagreed with the statement that the use of chemical fertilizers and pesticides contributes to vulture decline.

Regarding attitudes towards vulture conservation, the local population has a moderate level of concern. People acknowledged the significant benefits vultures brought to human societies through their ecosystem services, particularly in maintaining a clean and healthy environment by consuming carcasses (Byju & Raveendran 2022). However, for cultural reasons, the local populace did not hold vultures in high regard. Interestingly, the study discovered a higher level of awareness of the harm diclofenac causes to vultures than had previously been noted (Dhakal et al. 2020). Nevertheless, knowledge about other harmful NSAIDs remained limited among the respondents. These findings can contribute to the ongoing discussion on vulture conservation in the region.

Informal discussion with the respondents revealed a negative sentiment regarding vultures nesting in trees within their farmlands. People perceived vultures as pests due to the odour and the adverse effects of vulture droppings on their livestock and farms. To mitigate this, individuals would prune the branches hosting vulture nests near human settlements. This underscores the importance of ongoing awareness campaigns among local communities residing in proximity to vulture habitats (Phuyal et al. 2016; Milano et al. 2018).

CONCLUSION

To conclude, this study from NBR, the southernmost viable vulture breeding site, offers a comprehensive assessment of the status of vulture populations and highlights the critical role of local knowledge in understanding the threats these species face. Despite three of the vulture species being critically endangered, their numbers appear to be relatively stable. The presence of potentially harmful drugs in veterinary use raises concerns for vulture conservation, highlighting the importance of cautious consideration before designating vulture-safe zones. Furthermore, the study underscores the need for inclusive assessments that take into account factors such as education, gender, and socioeconomic status, particularly within tribal communities, as these elements play a significant role in influencing conservation attitudes. Recognizing the importance of awareness campaigns becomes crucial to addressing negative perceptions and mitigating human-vulture conflicts in local communities. Inclusivity and a multidimensional approach are essential for effective vulture conservation strategies.

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