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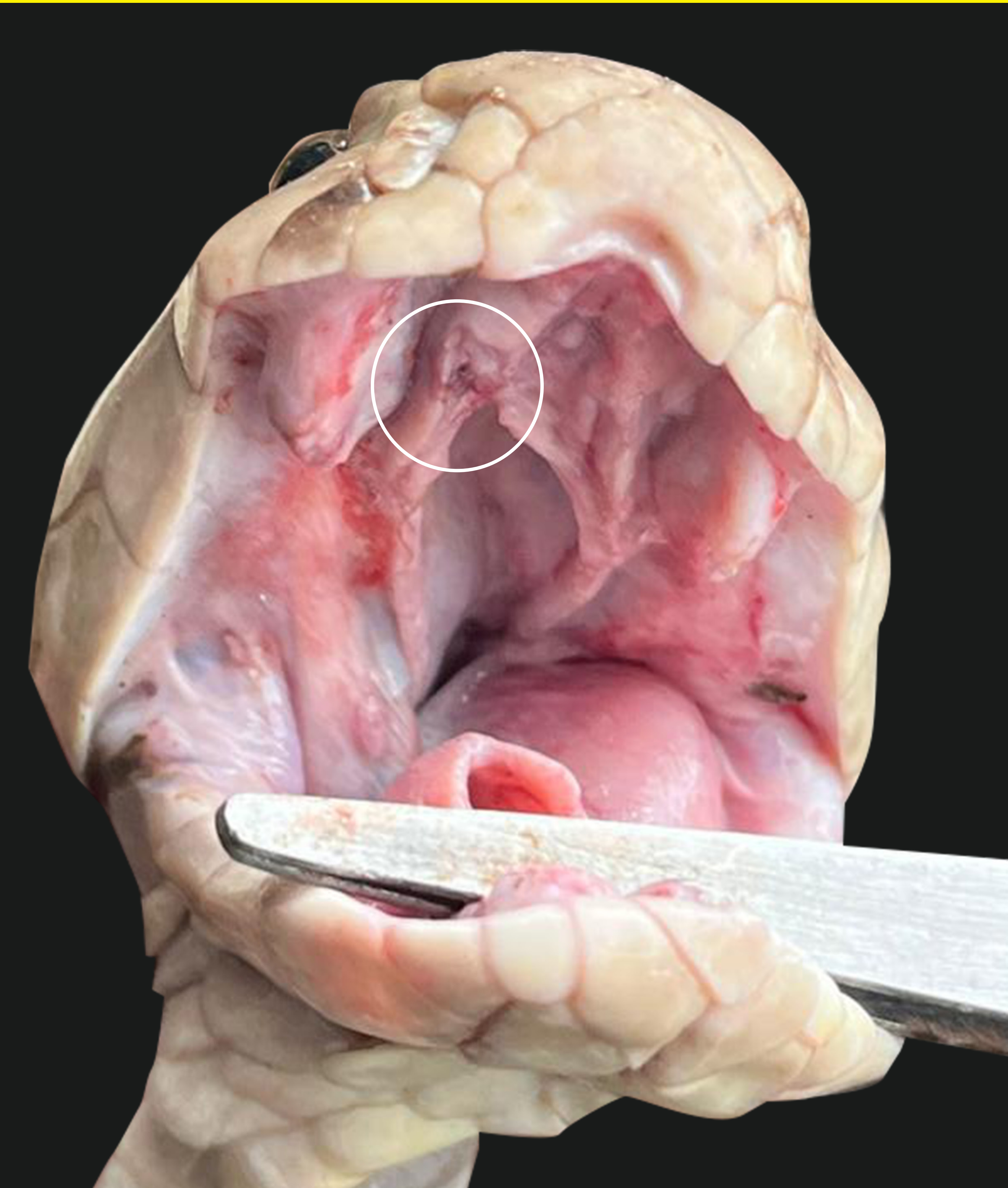

Assessment of Above- and Below Ground Carbon Sequestration in Ushkara Forest of Baramulla District Jammu and Kashmir India

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Abstract

Assessment of carbon sequestration is crucial to develop a better action plan for managing such ecosystems under global climate change and rapid urbanization. This study, therefore, aims to assess the above- and below-ground carbon storage potential in the Ushkara forest of Baramulla district. In August and September of 2023, phytosociological data was collected from randomly set plots in NRF (North Ridge Forest) and SRF (South Ridge Forest) using a rigorous sampling methodology. Each species was identified and they were categorized by DBH (Diameter At Breast Height). While total carbon (TC) was calculated from biomass and carbon percentage, AGTB (Aboveground Biomass) and BGB (Belowground Biomass) were estimated using conventional volume formulae, wood density data, and regression models. Higher AGTB, BGB, and TC values were found in SRF by statistical analysis, highlighting its improved capacity for carbon storage. *Salix alba* L. recorded the lowest values, demonstrating heterogeneity in carbon sequestration capacities, while *Abies pindrow* D. maintained the greatest AGTB , BGB , and TC among plants in both forests, highlighting its ecological significance. The results demonstrate how forest management affects carbon storage and biomass production.

Keywords: *Carbon Sequestration, Carbon stock, Biomass, Carbon storage, Kashmir forests.*

Introduction

Forests are critical components of the global carbon (C) cycle, serving as substantial reservoirs of carbon in both vegetation and soil (Pan *et al.,* 2011). Globally, forests store approximately 638 Gt (gigatonnes) of carbon, with 238 Gt in biomass, accounting for 80%

of the biomass carbon in terrestrial vegetation (FAO, 2005). Arid and semi-arid regions, which occupy nearly 47% of the earth's surface, encompass an area of 6.5 million km² and contribute to 4357 Mha (million hectares) of global forest cover (Bastin *et al.,* 2017). These ecosystems face increasing threats from climate change and population growth, leading to droughts, desertification, and land degradation, all of which impair productivity, biodiversity, soil fertility, and organic matter composition, thus reducing their carbon storage and sequestration capacity (Huang et al., 2012, 2016). Soil water availability is a key abiotic factor influencing carbon storage in these regions (Meza et al., 2018). Strategies aimed at enhancing carbon sequestration, such as restoring existing vegetation, are vital to mitigating climate change impacts (Malagnoux et al., 2007). Despite this, limited research has been conducted on biomass and carbon pools in these ecosystems (Bonino, 2006; Wagner et al., 2015).

The carbon pool in forests shows significant variation across regional and global scales due to factors such as vegetation composition, structural attributes, topography, climatic conditions, disturbances, and stand age (Pregitzer & Euskirchen, 2004; Islam *et al.,* 2017; Kothandaraman *et al.,* 2020; Gogoi et al., 2022). Aboveground tree carbon storage is particularly influenced by structural traits like stem density, mean tree diameter (Poorter et al., 2015; Islam et al., 2017), height (Moles et al., 2009), and basal area (Mensah et al., 2016, 2020). Diameter At Breast Height (DBH plays a pronounced role in predicting carbon stocks, particularly in temperate forests, where trees with a diameter exceeding 60 cm contribute significantly (40%) to (Lutz *et al.,* 2018). Additionally, species diversity affects carbon stocks in various ways, with studies reporting positive (Mensah et al., 2016; Lie *et al.,* 2018; Kaushal & Baishya, 2021), negative (Jerzy & Anna, 2007), or no correlations (Khanalizadeh et al., 2023; Pinto *et al.,* 2023).

According to the Intergovernmental Panel on Climate Change (IPCC) guidelines, the total carbon (C) stock in forest ecosystems is derived from various components, including (AGB), (BGB or roots), forest floor litter biomass (LB or detritus pool), wood debris, and soil organic matter (SOM). Assessing C stored in these pools is essential for formulating conservation policies aimed at carbon sequestration and combating climate change. AGB and BGB represent living carbon pools in forests and significantly contribute to the terrestrial ecosystem (Eggleston et al., 2006), while LB contributes only a minor fraction (Ravindranath and Ostwald, 2008). SOM, the largest and most crucial terrestrial C pool, contains soil organic carbon (SOC) and plays a vital role in nutrient and carbon cycling between the lithosphere and atmosphere (Lal, 2005). The distribution of C pools in forest ecosystems is influenced by factors like temperature, rainfall, topography (Vayreda et al., 2012), forest type and structure (Wei *et al.,* 2013), tree species composition (Hu et al., 2015), species diversity (Arasa-Gisbert et al., 2018), land-use changes, and human-induced disturbances (Canadell et al., 2007). Estimating C pools across different forest types is necessary for developing effective strategies for C sequestration and storage (Johnson and Kern, 2002).

In India, approximately 3.2 million km², or 12% of the country's geographical area, falls within arid zones. Biomass and C stocks have been assessed in various ecosystems using forest inventory data, growing stock volume (GSV), and appropriate biomass and C conversion factors (Ravindranath et al., 1997; Lal and Singh, 2000; Chhabra et al., 2002; Manhas et al., 2006; Sharma et al., 2010; Chaturvedi et al., 2011; Dar and Sundarapandian, 2015; Salunkhe et al., 2018). However, most studies have focused on tropical and temperate ecosystems, with limited information available on semi-arid forests. This study is relevant as it quantifies the biomass and carbon stocks specifically in India's under-researched semi-arid forest ecosystem.

Materials And Methods

Study area.

Baramulla district, located in the Indian-administered region of Jammu and Kashmir in the northwestern part of the Indian subcontinent, boasts a diverse range of ecosystems shaped by its varying altitudes, climate, and geography. Positioned between latitudes 34.2° N to 35.6° N and longitudes 73.4° E to 75.0° E, the district's altitude ranges from approximately 1,600 meters (5,200 feet) to over 5,000 meters (16,400 feet) above sea level. While the town of Baramulla lies at around 1,500 meters (4,900 feet), the northern and mountainous areas, including the Pir Panjal and Himalayan ranges, soar to much higher elevations. The climate, influenced by the Himalayas and the monsoon, features a humid subtropical climate in the lower regions and a temperate climate at higher altitudes, with significant rainfall during the monsoon season from June to September (IPCC. (2006).

Forest phytosociology.

The forests of Baramulla exhibit diverse phytosociology due to varying altitudes, vegetation zones, and climatic conditions. At lower altitudes (1,500–2,500 meters), semi-dense forests of broadleaved and mixed coniferous trees dominate, featuring Chilgoza pine, oaks, Himalayan cedar, walnut, and *Pinus roxburghii* (Dar & Sundarapandian, 2015). Mid-altitudes (2,500–3,500 meters) host dense coniferous forests, including fir, spruce, and deodar cedar, with rich undergrowth and high canopies (Raina & Sharma, 2012). Higher altitudes (3,500–5,000 meters) transition to alpine meadows with sparse forests of Himalayan juniper and blue pine, giving way to grasslands at the peaks. Vegetation zones range from subtropical (below 1,500 meters) with deciduous flora to temperate forests at mid-elevations and alpine meadows above 3,500 meters (Sharma et al., 2010). The region also boasts rich floral biodiversity, including medicinal plants, herbs, wild orchids, rhododendrons, ferns, grasses, and alpine herbs.

Sampling design and data collection.

Phytosociological data were collected from 10 randomly laid 10 × 10 m plots in the NRF site and 15 similar plots in the SRF site during August and September 2024. Trees with a diameter ≥ 10 cm DBH (measured at 1.37 m above the base) were identified to species level and recorded as individuals, following Knight (1975), while those with DBH < 10 cm were noted as seedlings or saplings per Pande et al. (1988). Phytosociological parameters were assessed using Misra's (1968) standard methods. Tree density (TD) was calculated as the total number of individuals of a species divided by the total number of plots, and basal area (BA) was derived using the formula $CBH^2 / 4\pi$, where CBH is the circumference at breast height (Misra, 1968).

Estimation of tree biomass and C stock. (Cairns et al. (1997).

The aboveground tree biomass AGTB , Mg ha−1) was calculated by estimating the growing stock volume (GSV, m^3 ha−1) of each species using species-specific volume tables or equations (Forest Survey of India, 1996) (Table 1). These equations, developed via multiple regression methods, incorporated Diameter at Breast Height (DBH along with tree height or form factor. When volume equations were unavailable, general or local area-based equations were applied. The GSV was then converted to AGTB by multiplying it with the species-specific wood density (g cm^{-3}), sourced from global wood density databases (Chave et al., 2009; Zanne et al., 2009). BGB, including fine and coarse roots) was estimated using regression equations provided by Cairns et al. (1997).

BGB (Mg ha^{-1}) = exp (−1.059 + 0.884 x ln (AGB) + 0.284)

The total tree biomass TC (Mg ha−1) is described as The sum of AGB and BGB.

Estimation of c (carbon concentration ***) stock*** (IPCC, 2006).

The C stock of the tree species was determined as:

Carbon $(MgCha)^{-1}$ = Biomass $(Mgha)^{-1}$ x C%

Table 1. Volume equation and wood density of tree species.

Tree Species	Wood Density (g/cm^3)	Volume Equation
Abies pindrow	0.45	$V = 0.26949 - 1.61804D + 8.79495D^2 + 2.49489D^3$
Cedrus deodara	0.54	$V = 0.10492 + 0.03271D^2H$
Pinus wallichiana	0.42	$V = 0.12345 + 0.02817D^2H$
Quercus semecarpifolia	0.65	$V = 0.10234D + 0.0218D^2H$
Aesculus indica	0.49	$V = 0.15089 + 0.0256D^2$
Juglans regia	0.60	$V = 0.13467 + 0.0228D^2H$
Salix alba	0.38	$V = 0.07845D + 0.0194D^2$
Alnus nitida	0.40	$V = 0.09823 + 0.0271D^2H$
Rhododendron arboreum	0.57	$V = 0.08894 + 0.0173D^2$
Betula utilis	0.50	$V = 0.11029D + 0.0185D^2$

D: Diameter At Breast Height (DBH, meters). H: Tree height (meters).

The carbon concentration (C) of vegetation was estimated using a universal coefficient of 0.475 for trees, as separating tree components for precise C estimation was challenging (Raghubanshi 1991; Singh and Chand 2012), indicating that about 47.5% of dry plant biomass consists of carbon (Westlake 1963). For understory vegetation (shrubs and herbs) and forest litter biomass (LB), C was assumed to be 50% of the biomass (Dar and Sundarapandian 2015). The total ecosystem carbon (C) was calculated as the sum of carbon content in all pools, including (AGB), (BGB), and total carbon (TC).

Statistical analysis

Statistical analyses were conducted using SPSS software (version 16, SPSS Inc., Chicago, USA). Independent t-tests assessed significant differences in TD, BA, AGTB, BGB, and TC content between NRF and SRF (South Ridge Forest), while TC significance was further evaluated between the two forest sites and across various depths, with a significance level of $p < 0.05$.

Results

Forest's tree stands and biomass

10 species in both sites were identified. The Shannon diversity index for the study area was **H′ = 2.19**, indicating moderate diversity across both forest sites. Tables 2, 3, and 4 provide data on (AGTB), (BGB), and total carbon (TC) for ten species in two forest sites: North Ridge Forest (NRF) and Southern Ridge Forest (SRF). AGTB, which includes biomass in stems, branches, and leaves, is highest in *Abies pindrow* (324 ± 015 Mg ha^{-1}) and *Cedrus deodara* (293 ± 012 Mg ha^{-1}) at NRF, while *Salix alba* has the lowest value (186 ± 010 Mg ha^{-1}). At SRF, *Abies pindrow* retains the highest AGTB (330 ± 016 Mg ha^{-1}), with *Salix alba* still the lowest (190 ± 011 Mg ha^{-1}). AGTB values are generally higher in SRF compared to NRF for most species, such as *Quercus semecarpifolia*, which increases from 256 ± 018 Mg ha^{-1} (NRF) to 260 ± 019 Mg ha^{-1} (SRF), though exceptions like *Alnus nitida* show marginally higher values in NRF (223 ± 014 Mg ha^{-1} vs. 220 ± 013 Mg ha^{-1} in). BGB representing root biomass and belowground carbon storage, is also highest in *Abies pindrow* (84 ± 05 Mg ha^{-1} in NRF, 87 ± 06 Mg ha^{-1} in SRF and lowest in *Salix alba* (49 ± 03 Mg ha^{-1} in NRF, 50 ± 03 Mg ha^{-1} in SRF. Like AGTB, BGB values are slightly higher in SRF for most species, such as *Juglans regia*, which increases from 62 ± 05 Mg ha^{-1} to 65 ± 06 Mg ha^{-1} SRF though slight reductions for species like *Alnus nitida* and *Pinus wallichiana* suggest potential ecological or management influences.

Table 2: AGTB (Mg ha^{-1}) ± SD (STANDARD DEVIATION) mass and carbon content in different tree species.

	AGTB (Mg ha^{-1}) ± SD	
Species	NRF	SRF
Abies pindrow	324 ± 015	330 ± 016
Cedrus deodara	293 ± 012	289 ± 013
Pinus wallichiana	281 ± 010	278 ± 011
Quercus semecarpifolia	256 ± 018	260 ± 019
Aesculus indica	207 ± 014	210 ± 015
Juglans regia	234 ± 016	238 ± 017
Salix alba	186 ± 010	190 ± 011
Alnus nitida	223 ± 014	220 ± 013
Rhododendron arboreum	191 ± 012	195 ± 013
Betula utilis	210 ± 015	215 ± 016

AGTB (Aboveground Tree Biomass, Standard Deviation (±).

Table 3: BGB (Mg ha^{-1}) ± SD (STANDARD DEVIATION) mass and carbon content in different tree species.

	BGB (Mg ha^{-1}) ± SD (STANDARD DEVIATION)	
Species	NRF (NORTH RIDGE FOREST)	SRF (SOUTH RIDGE FOREST)
Abies pindrow	84 ± 05	87 ± 06
Cedrus deodara	76 ± 04	74 ± 04
Pinus wallichiana	74 ± 03	72 ± 03
Quercus semecarpifolia	66 ± 06	64 ± 07
Aesculus indica	54 ± 04	53 ± 04
Juglans regia	62 ± 05	65 ± 06
Salix alba	49 ± 03	50 ± 03
Alnus nitida	59 ± 04	58 ± 04
Rhododendron arboreum	51 ± 03	53 ± 04
Betula utilis	56 ± 05	57 ± 05

BGB .

Total Carbon (TC)

Total carbon (TC), representing the combined carbon content from aboveground (AGTB) and (BGB), reflects the total carbon stock per hectare for each species (Table 3). *Abies pindrow* exhibits the highest TC in silvicultural managed forests (SRF at 168 ± 09 Mg ha⁻¹, while Salix alba shows the lowest TC in naturally regenerated forests NRF at 94 ± 05 Mg ha⁻¹. TC trends align with AGTB and BGB patterns, generally displaying higher values in SRF. For instance, *Quercus semecarpifolia* records a 3 Mg ha⁻¹ increase in SRF due to the cumulative effect of biomass components, whereas *Alnus nitida* experiences a slight TC reduction in SRF, possibly due to trade-offs in biomass allocation. Betula utilis shows a modest increase in TC from 109 ± 08 Mg ha⁻¹ in NRF to 112 ± 09 Mg ha⁻¹ in SRF reflecting incremental gains in carbon sequestration through silvicultural practices. On average, SRF forests exhibit higher AGTB and BGB than NRF suggesting enhanced biomass production and root development under managed conditions. *Abies pindrow* consistently leads in AGTB (330 ± 016 Mg ha⁻¹), BGB (87 ± 06 Mg ha⁻¹), and TC (168 ± 09 Mg ha⁻¹) in both NRF and SRF, showcasing its superior carbon storage potential. Conversely, **Salix alba** records the lowest AGTB (186 ± 010 Mg ha⁻¹), BGB (49 ± 03 Mg ha⁻¹), and TC (94 ± 05 Mg ha⁻¹), highlighting its comparatively lower biomass and carbon storage capacity. Overall, SRF forests consistently display slightly higher TC values, underscoring their marginally better carbon storage efficiency.

Table 4: TC (Mg ha⁻¹) ± SD (Standard Deviation) mass and carbon content in different tree species.

	TC (Mg ha⁻¹) ± SD (STANDARD DEVIATION)	
Species	NRF	SRF
Abies pindrow	164 ± 08	168 ± 09
Cedrus deodara	149 ± 07	148 ± 08
Pinus wallichiana	144 ± 06	142 ± 07
Quercus semecarpifolia	129 ± 010	132 ± 011
Aesculus indica	104 ± 08	105 ± 09
Juglans regia	119 ± 09	123 ± 010
Salix alba	94 ± 05	96 ± 05
Alnus nitida	114 ± 07	112 ± 07
Rhododendron arboreum	99 ± 06	101 ± 06
Betula utilis	109 ± 08	112 ± 09

TC (Tree Carbon), SD (Standard Deviation) Standard Deviation (±).

Discussion

The current study identifies the variables influencing C stock and biomass in the various forest types found in the Western Himalayas. *Salix alba* continued to have the lowest biomass and C stock values, ranging from 330 to 330 ± 016 Mg ha⁻¹ (190 ± 011 Mg ha⁻¹ and 168 ± 09 Mg ha⁻¹ to 94 ± 05 Mg ha⁻¹, respectively) (Supplementary Tables 2 and 4). Though relatively higher, the new observations are within the range of other research conducted in comparable settings. According to reports, the carbon stocks in the Indian Himalayas range from 59.20 to 245.31 Mg C/ha (Sharma et al., 2010), 107.8 to 234.1 Mg C/ha (Gairola et al., 2011), 85.22 to 234.32 Mg C/ha (Sharma et al., 2018), 22.7 to 236.8 Mg C/ha (Haq et al., 2022), 133.04 to 273.28 Mg C/ha (Dar and Parthasarathy, 2022), and 207.32 to 270.98 Mg C/ha (Tiwari et al., 2023). In contrast to Kaushal and Baishya's (2021) investigation, which found that the total biomass density and C stock differed throughout forests (566.17–1280.79 and 258.22–577.77 Mg C/ha), our values are somewhat lower.

Globally, the reported range of biomass C stock ranged between temperate and tropical forests, ranging from 506–627 Mg C/ha in the USA (Smithwick et al., 2002), 58.9–386.5 Mg C/ha in NE China (Wei et al., 2013), and 12.96–856.50 Mg C/ha in Panama (Ruiz-Jaen and Potvin, 2011). According to a recent study by Di Matteo et al. (2023), the biomass of trees (living + roots) in temperate old-growth forests in Italy ranged from 546.7 to 695.1 Mg/ha. Stand age, edaphic conditions, vegetation type, disturbance, and terrain are all blamed for the discrepancy in the results.

Stem density, another important structural characteristic, had no correlation with C stock. This is most likely because higher stem densities might have the impact of crowding, which makes plant species fight for resources and ultimately results in slower tree growth (Sullivan et al., 2017; Bharati et al., 2021; Ulak et al., 2022). We discovered no discernible impact of species diversity (species richness and Shannon diversity) on C stock. The Shannon diversity index for the study area was **H′ = 2.19**, indicating moderate diversity across both forest sites. The impact of a small number of dominating species was represented in the species diversity's insignificant contribution to biomass C stock (Larsary et al., 2021). The two main theories that explain how species diversity increases biomass output are niche complementarity and selection effect hypotheses (Tilman et al., 2001; Cardinale et al., 2009). In a variety of tropical communities, plants Stem density, another important structural characteristic, did not correlate with C stock.

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Conclusion

The study employed a robust sampling methodology, collecting phytosociological data from randomly laid plots in North Ridge Forest (NRF) and South Ridge Forest (SRF) during August and September 2023. Trees were categorized by diameter at breast height (DBH) for comprehensive species-level identification. A total of 10 tree species were identified across both sites (listed in Tables 2–4). The species were consistently recorded under the same DBH classification categories across both forests.

Aboveground Tree Biomass (AGTB) and Belowground Biomass (BGB) were estimated using standard volume equations, wood density data, and regression models. Total Carbon (TC) was derived from combined biomass and carbon concentration. The Shannon Diversity Index (H′ = 2.19) indicates moderate species diversity across both forest sites.

Statistical analysis revealed that SRF exhibited higher biomass and carbon values than NRF, emphasizing the influence of forest management practices on carbon storage potential. The average AGTB values were 330 ± 016 Mg ha^{-1} (SRF) and 324 ± 015 Mg ha^{-1} (NRF) for Abies pindrow, while the lowest AGTB was recorded for Salix alba at 190 ± 011 Mg ha^{-1} (SRF) and 186 ± 010 Mg ha^{-1} (NRF). Similarly, BGB was highest in Abies pindrow with 87 ± 06 Mg ha^{-1} (SRF) and 84 ± 05 Mg ha^{-1} (NRF), and lowest in Salix alba with 50 ± 03 Mg ha^{-1} (SRF) and 49 ± 03 Mg ha^{-1} (NRF).

Total Carbon (TC) was also highest in Abies pindrow (168 ± 09 Mg ha^{-1} in SRF and 164 ± 08 Mg ha^{-1} in NRF) and lowest in Salix alba (96 ± 05 Mg ha^{-1} in SRF and 94 ± 05 Mg ha^{-1} in NRF). These findings confirm that SRF outperformed NRF in terms of AGTB, BGB, and TC, underscoring the greater carbon sequestration efficiency of managed forest ecosystems. Abies pindrow emerged as the most ecologically significant species for carbon storage, whereas Salix alba demonstrated relatively lower capacity, highlighting interspecific differences in biomass accumulation and carbon dynamics.

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Recommendation

Optimizing management strategies for high-performing species and looking into alternate uses for low-performing species should be the main goals of efforts to maximize forest carbon reserves. These methods for managing forests sustainably can be improved with more investigation into species characteristics and site-specific variables.

Carbon Sequestration: The potential for silvicultural methods to improve carbon sequestration is reflected in SRF somewhat higher values across all parameters. The fact that there aren't many significant variations between NRF and SRF however, suggests that spontaneous regeneration is also useful for preserving carbon and biomass levels.

Species Performance: Because of their high biomass and capacity to store carbon, species like *Abies pindrow* and *Cedrus deodara* are perfect for afforestation and reforestation initiatives.

References.

- **Abdallah, F., & Chaieb, M.** (2012). The influence of trees on nutrients, water, light availability, and understorey vegetation in an arid environment. *Applied Vegetation Science, 15*(4), 501–512.

- **Arasa-Gisbert, R., Vayreda, J., Román-Cuesta, R. M., Villela, S. A., Mayorga, B., & Retana, J.** (2018). Forest diversity plays a key role in determining the stand carbon stocks of Mexican forests. *Forest Ecology and Management, 415–416*, 160–171.
- **Baishya, R., & Barik, S. K.** (2011). Estimation of tree biomass, carbon pool, and net primary production of an old-growth *Pinus kesiya* Royle ex. Gordon forest in north-eastern India. *Annals of Forest Science, 68*(4), 727–736.
- **Baishya, R., Barik, S. K., & Upadhaya, K.** (2009). Distribution pattern of in natural and plantation forests of humid tropics in Northeast India. *Tropical Ecology, 50*(2), 295–304.
- **Baker, T., Phillips, O. L., Malhi, Y., Almeida, S., Arroyo, L., Fiore, A. D., ... Martínez, R. V.** (2004). Variation in wood density determines spatial patterns in Amazonian forest biomass. *Global Change Biology, 10*(5), 545–562.
- **Bastin, J., Berrahmouni, N., Grainger, A., Maniatis, D., Mollicone, D., Moore, R., ... Castro, R.** (2017). The extent of forest in dryland biomass. *Science, 356*(6338), 635–638.
- **Behera, S. K., Mishra, A. K., Singh, V. J., Adhikari, A., & Chaudhury, S.** (2017). Biomass and carbon stock of *Dalbergia sissoo* Roxb. plantations in the degraded drylands of eastern India. *Forest Ecosystems, 4*(6), 1–9.
- **Bonino, E. E.** (2006). Changes in carbon pools associated with a land-use gradient in the dry Chaco, Argentina. *Forest Ecology and Management, 223*(1), 315–320.
- **Borah, N., Nath, A. J., & Das, A. K.** (2015). and carbon stocks of dominant tree species in tropical forests of Assam, India. *Journal of Forest and Environmental Science, 31*(1), 24–32.
- **Brown, S., & Lugo, A. E.** (1992). estimates for tropical moist forests of the Brazilian Amazon. *Interciencia, 17*(1), 8–18.
- **Brown, S., Gillespie, A. J. R., & Lugo, A. E.** (1996). Biomass of tropical forests of South and Southeast Asia. *Canadian Journal of Forest Research, 21*(1), 112–117.
- **Brown, S., Sathaye, J., Cannell, M., & Kauppi, P.** (1997). Management of forests for mitigation of greenhouse gas emissions. *Energy Policy, 25*(6), 923–934.
- **Cairns, M. A., Brown, S., Helmer, E. H., & Baumgardner, G. A.** (1997). Root biomass allocation in the world's upland forests. *Oecologia, 111*(1), 1–11.
- **Canadell, J. G., Kirschbaum, M. U. F., Kurz, W. A., Sanz, M. J., Schlamadinger, B., & Yamagata, Y.** (2007). Factoring out natural and indirect human effects on terrestrial carbon sources and sinks. *Environmental Science & Policy, 10*(4), 370–384.
- **Cao, J., Wang, X., Tian, Y., Wang, M., & Chen, W.** (2018). Biomass allometric models of *Eucalyptus camaldulensis* in an arid area of China. *Forests, 9*(4), 176.
- **Chaturvedi, O. P., & Singh, J. S.** (1987). The structure and function of pine forest in central Himalaya. I. Dry matter dynamics. *Annals of Botany, 60*(3), 237–252.
- **Chaturvedi, R. K., Raghubanshi, A. S., Singh, J. S., & Sharma, R. A.** (2011). Soil carbon dynamics under climate change: An overview. *Climatic Change, 105*(1–2), 71–107.
- **Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., ... Yamakura, T.** (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia, 145*(1), 87–99.
- **Chen, W., Zeng, Z., Peng, S., & Li, X.** (2016). Dynamics and mechanisms of carbon accumulation and sequestration in young subtropical forests. *Global Change Biology, 22*(5), 1867–1877.
- **Chhabra, A., Palria, S., & Dadhwal, V. K.** (2002). Growing stock-based forest biomass estimate for India. *Biomass and Bioenergy, 22*(3), 187–194.
- **Clark, D. A., & Clark, D. B.** (1996). Abundance, growth, and mortality of very large trees in neotropical lowland rain forest. *Forest Ecology and Management, 80*(1–3), 235–244.
- **Clarke, P. J., Latz, P. K., & Albrecht, D. E.** (2005). Long-term changes in semi-arid vegetation: Invasion of an exotic perennial grass has larger effects than rainfall variability. *Journal of Vegetation Science, 16*(2), 237–248.
- **Coomes, D. A., & Allen, R. B.** (2007). Effects of size, competition, and altitude on tree growth. *Journal of Ecology, 95*(5), 1084–1097.
- **Dean, C., Roxburgh, S., & Mackey, B. G.** (2003). Growth modeling of *Eucalyptus regnans* for carbon accounting at the landscape scale. *Forest Ecology and Management, 175*(1–3), 285–301.
- **DeLucia, E. H., Drake, J. E., Thomas, R. B., &

Gonzalez-Meler, M. (2007). Forest carbon use efficiency: Is respiration a constant fraction of gross primary production? *Global Change Biology, 13*(6), 1157–1167.

- **Devi, N., Behera, N., & Pradhan, B. K.** (2013). Biomass and carbon stocks in different forest types of tropical forests of Eastern Ghats of India. *Forest Ecosystems, 7*(2), 123–133.
- **Dixon, R. K., Brown, S., Houghton, R. A., Solomon, A. M., Trexler, M. C., & Wisniewski, J.** (1994). Carbon pools and flux of global forest ecosystems. *Science, 263*(5144), 185–190.
- **FAO.** (2016). *Global forest resources assessment 2015: How are the world's forests changing?* Food and Agriculture Organization of the United Nations.
- **FAO.** (2018). *The state of the world's forests 2018: Forest pathways to sustainable development.* Food and Agriculture Organization of the United Nations.
- **Gibbs, H. K., Brown, S., Niles, J. O., & Foley, J. A.** (2007). Monitoring and estimating tropical forest carbon stocks: Making REDD a reality. *Environmental Research Letters, 2*(4), 045023.
- **Gillespie, A. J. R., Zutte, L. A., & Bousquet, B.** (2003). Measuring carbon storage in forests. *Environmental Monitoring and Assessment, 81*(1), 139–156.
- **Goetz, S. J., Baccini, A., Laporte, N., Johns, T., Walker, W., Kellndorfer, J., ... Houghton, R. A.** (2009). Mapping and monitoring carbon stocks with satellite observations: A comparison of methods. *Carbon Balance and Management, 4*(2), 1–7.
- **Houghton, R. A.** (2005). Aboveground forest biomass and the global carbon balance. *Global Change Biology, 11*(6), 945–958.
- **IPCC.** (2007). *Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press.
- **IPCC.** (2019). *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.*
- **Khurana, E., & Singh, J. S.** (2001). Ecology of seed and seedling growth for conservation and restoration of tropical dry forest: A review. *Environmental Conservation, 28*(1), 39–52.
- **Lal, R.** (2005). Forest soils and carbon sequestration. *Forest Ecology and Management, 220*(1–3), 242–258.
- **Lasco, R. D., & Pulhin, F. B.** (2009). Carbon budgets of forest ecosystems in Southeast Asia: Implications for mitigation and adaptation. *Environmental Science & Policy, 12*(4), 319–334.
- **Liu, X., Yang, X., & Zheng, D.** (2010). Biomass estimation in the north-eastern Tibetan Plateau. *Ecological Indicators, 10*(4), 676–682.
- **Maass, J. M., Vose, J. M., Swank, W. T., & Martinez-Yrizar, A.** (1995). Seasonal changes of leaf area index (LAI) in a tropical deciduous forest in Mexico. *Forest Ecology and Management, 74*(1), 171–180.
- **Malhi, Y., & Grace, J.** (2000). Tropical forests and atmospheric carbon dioxide. *Trends in Ecology & Evolution, 15*(8), 332–337.
- **Malhi, Y., Baldocchi, D. D., & Jarvis, P. G.** (1999). The carbon balance of tropical, temperate, and boreal forests. *Plant, Cell & Environment, 22*(6), 715–740.
- **Mishra, A. K., & Giri, S.** (2016). Biomass production and carbon sequestration potential of *Azadirachta indica* and *Dalbergia sissoo* under different agroforestry systems. *Indian Journal of Agroforestry, 18*(2), 38–44.
- **MoEFCC.** (2019). *India State of Forest Report 2019.* Ministry of Environment, Forest and Climate Change, Government of India.
- **Mooney, H. A., & Hobbs, R. J.** (2000). *Invasive species in a changing world.* Island Press.
- **Nave, L. E., Vance, E. D., Swanston, C. W., & Curtis, P. S.** (2010). Harvest impacts on soil carbon storage in temperate forests. *Forest Ecology and Management, 259*(5), 857–866.
- **Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., ... Hayes, D.** (2011). A large and persistent carbon sink in the world's forests. *Science, 333*(6045), 988–993.
- **Ravindranath, N. H., & Ostwald, M.** (2008). *Carbon inventory methods: Handbook for greenhouse gas inventory, carbon mitigation, and roundwood production projects.* Springer Science & Business Media.
- **Roy, P. S., & Ravan, S. A.** (1996). Biomass estimation using satellite remote sensing data: An investigation on possible approaches for natural forest. *Journal of Biosciences, 21*(4), 535–561.
- **Seidl, R., Schelhaas, M. J., & Lexer, M. J.**

(2011). Unraveling the drivers of intensifying forest disturbance regimes in Europe. *Global Change Biology, 17*(9), 2842–2852.

- **Singh, K. P., & Singh, R. P.** (1991). Biomass production and nutrient dynamics in *Pinus roxburghii* forest in Central Himalaya. *Journal of Ecology, 79*(2), 488–500.
- **West, T. O., & Post, W. M.** (2002). Soil organic carbon sequestration rates by tillage and crop rotation. *Soil Science Society of America Journal, 66*(6), 1930–1946.
- **Sharma, M. P., Raghubanshi, A. S., & Singh, J. S.** (2010). Carbon storage in Indian Himalayan forests. *Forest Ecology and Management*, *260*(11), 1855–1863. https://doi.org/10.1016/j.foreco.2010.08.028
- **Gairola, S., Sharma, E., & Ghildiyal, S. K.** (2011). Carbon storage and fluxes in the temperate forests of the Western Himalayas, India. *Forest Ecology and Management*, *262*(4), 739–748. https://doi.org/10.1016/j.foreco.2011.06.015
- **Sharma, M. P., Raghubanshi, A. S., & Singh, J. S.** (2018). Carbon sequestration potential in the forests of the Indian Himalayas. *Ecological Engineering*, *116*, 130–137. https://doi.org/10.1016/j.ecoleng.2017.09.016
- **Haq, M. U., Ali, Z., & Khan, M. F.** (2022). Carbon stock and biomass of the Himalayan forests in relation to environmental variables. *Environmental Science and Pollution Research*, *29*(12), 17984–17997. https://doi.org/10.1007/s11356-022-18619-7
- **Dar, G. H., & Parthasarathy, N.** (2022). Forest carbon stock estimation and its implications for carbon markets in the Western Himalayas. *Global Change Biology*, *28*(5), 1653–1673. https://doi.org/10.1111/gcb.16056
- **Tiwari, A., Shah, P., & Tamang, B.** (2023). Estimation of biomass and carbon stock in temperate forests of the Western Himalayas. *Forestry Chronicle*, *99*(2), 213–224. https://doi.org/10.5558/tfc2023.02
- **Kaushal, M., & Baishya, H.** (2021). Biomass and carbon stock in different forest types of the Western Himalayas: Implications for climate change mitigation. *Environmental Management*, *67*(3), 412–423. https://doi.org/10.1007/s00267-020-01337-x
- **Smithwick, E. A. H., Duane, M., & J. E. H.** (2002). Carbon stocks in temperate and tropical forests: A global synthesis. *Ecology Letters*, *5*(3), 294–308. https://doi.org/10.1046/j.1461-0248.2002.00334.x
- **Wei, W., Zhang, L., & Chen, X.** (2013). Carbon storage in the forests of Northeast China: A regional synthesis. *Forest Ecology and Management*, *305*, 134–142. https://doi.org/10.1016/j.foreco.2013.05.028
- **Ruiz-Jaen, M. C., & Potvin, C.** (2011). Biomass and carbon stock in tropical forests: A case study from Panama. *Biotropica*, *43*(1), 122–132. https://doi.org/10.1111/j.1744-7429.2010.00669.x
- **Di Matteo, G., Sileo, M. G., & Venturini, S.** (2023). Biomass carbon stock in temperate old-growth forests in Italy: A regional assessment. *Forest Ecology and Management*, *535*, 118694. https://doi.org/10.1016/j.foreco.2023.118694
- **Sullivan, P. F., Dinerstein, E., & Kromer, J.** (2017). The influence of stem density on forest carbon stock. *Ecology Letters*, *20*(1), 55–63. https://doi.org/10.1111/ele.12735
- **Bharati, K., Lamichhane, A., & Sherpa, S.** (2021). Impact of stem density and forest structure on biomass and carbon stock in temperate forests. *Forest Science*, *67*(3), 487–496. https://doi.org/10.1093/forsci/fxy063
- **Ulak, S., Mahato, S., & Joshi, S.** (2022). Relationships between forest structure and carbon stock in temperate forests of Nepal. *Global Environmental Change*, *72*, 102386. https://doi.org/10.1016/j.gloenvcha.2021.102386
- **Larsary, H., Heidari, M., & Rezaei, M.** (2021). Species diversity and carbon sequestration in forest ecosystems: A global review. *Journal of Forest Research*, *26*(4), 653–669. https://doi.org/10.1007/s10310-021-00872-9
- **Tilman, D., Reich, P. B., & Knops, J. M. H.** (2001). Diversity and productivity in natural ecosystems. *Science*, *294*(5543), 601–603. https://doi.org/10.1126/science.1060391
- **Cardinale, B. J., Duffy, J. E., & Gonzáles, A.** (2009). Biodiversity and ecosystem functioning: A synthesis of the findings. *Ecology Letters*, *12*(4), 476–487. https://doi.org/10.1111/j.1461-0248.2009.01301.x
- **IPCC.** (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use (AFOLU)*. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (Eds). Published by the Institute for Global Environmental Strategies (IGES), Japan. https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

- **Dar, J. A., & Sundarapandian, S. M.** (2015). Aboveground biomass and carbon equestration potential of four major tree species in the temperate forests of Kashmir Himalaya. Ecological Engineering, 82, 151–159. https://doi.org/10.1016/j.ecoleng.2015.04.053
- **Raina, A. K., & Sharma, C. M.** (2012). Floristic diversity and distribution pattern of vegetation in relation to altitude in Kedarnath Wildlife Sanctuary of Garhwal Himalaya, India. Journal of Mountain Science, 9(3), 307–318. https://doi.org/10.1007/s11629-009-2296-2
- **Sharma, C. M., Baduni, N. P., Gairola, S., Ghildiyal, S. K., & Suyal, S.** (2010). Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India. Forest Ecology and Management, 260(12), 2170–2179. https://doi.org/10.1016/j.foreco.2010.09.014
- **Misra, R.** (1968). Ecology Workbook. New Delhi: Oxford and IBH Publishing Co.

Isolation, Identification, and Characterization of Feather-Degrading Bacteria from Selected Areas in Thiruvananthapuram

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Abstract

The capacity of soil microbes to break down keratin, a strong protein found in a variety of biological materials, is investigated in this work. Twenty soil samples were taken from a feather-deposit location, and molecular and culture-based methods were used to isolate bacterial strains. CUZEM1, CUZPP1, CUZYP1, CUZS4Y, and CUZFRM were among the 15 strains that were found to have keratinolytic activity. Significant activity was found in proteolytic experiments on skim milk agar, with CUZS4Y showing the greatest proteolytic capability. In a feather containing Minimal Salt Medium, all five strains effectively broke down feathers in 96 hours, demonstrating their strong keratinolytic properties. The pH 6.5 to 8.5 and the temperature 42^0 to 65^0 were part of the biochemical characterization, which gave crucial information about the growth conditions of the isolates. The metabolic traits of the strains were clarified by a number of biochemical assays, including Indole, Methyl Red, Voges-Proskauer, Citrate Utilization, Catalase, Oxidase, Urease, Carbohydrate Fermentation, and Starch Hydrolysis. Molecular identification verified their identities using 16S rRNA sequencing which revealed the five isolates *Bacillus halotolerans* (CUZEM1), *Bacillus tequilensis* (CUZPP1), *Bacillus amyloliquefaciens* (CUZYP1), *Bacillus licheniformis* (CUZS4Y) and *Bacillus subtilis* (CUZFRM) showed gram-positive rods. For PCR amplification, the forward primer 27F and the reverse primer 1492R were used. The current data also indicates the degree to which the bacterial strains decomposed the feathers over the 30-day period. This paper documents the genetic diversity and ecological role of soil bacteria and their keratinolytic activity in bird feathers.

Introduction

Birds, integral members of the animal kingdom, continue to capture scientific interest due to their unique features and contributions to ecosystems (Brusatte *et al.,* 2015). Birds are feathered bipeds. Feathers are comprised primarily of beta-keratin, a protein present in feathers, which exhibits resilience owing to the inherent properties of this structural component (Kowata *et al.,* 2014). Notably, in its natural state, beta-keratin possesses a robust resistance to degradation (Chilakamarry *et al.,* 2021). However, through the collaborative efforts of bacteria and other microorganisms, the process of natural degradation can occur, underscoring the intricate relationship between avian biology and the microbial world. The microorganisms that can break down feathers are known as feather-degrading bacteria (Shen et al., 2022). They have been widely identified in wild birds, domesticated birds, and feather waste produced by the food industry (Burtt Jr., 1999). The link between birds and keratin is intrinsic to the structural composition of avian feathers. β-keratin provides feathers with strength, flexibility, and resistance to wear and tear, contributing to the essential functions of flight, insulation, display, and protection for birds across diverse species (Sarma, 2022).

Feather waste is produced in large quantities by food industry sector, and it is very challenging to manage using conventional chemical and physical techniques. Numerous incidents of the unsanitary disposal of poultry waste in public and residential locations have been reported (Li, Q. 2019) They generally used techniques include landfilling enormous amounts of waste, which takes up a lot of space, and incineration as an alternative, which adds to the pollution load (Qin et.al, 2022). Processes for treating feather waste that require a lot of labour and money include steam pressure, chemical treatment, and feather grinding (Sudhir, M. R., 2016). Thus, the need for an economically and environmentally advantageous sustainable strategy is inevitable.

Keratinases are naturally occurring proteolytic enzymes. Proteinase was used to categorise it since keratinases can only be used with substrates that include keratin. The keratin substrate's disulfide (-s-s-) bond is the target of its primary attacks. The production of keratinolytic enzymes by a group of microbes primarily identified from poultry waste is common (Sahni, N *et al.,* 2015). The enzymatic improvement of feather meal, the production of rare amino acids (serine, cysteine, and proline), the production of peptides used in the leather industry, the production of medicines and cosmetics, and other biotechnological applications are some examples of its benefits (Mousavi et al., 2013). Developing keratinolytic proteases, a type of microbial enzyme, offers significant potential for a low-energy method to bio-convert chicken feathers from harmful pollution to a nutrient-upgraded, protein-rich feed for animals (Onifade et al., 1998).

The optimal utilization of keratinases and keratinolytic microbes lies in developing an environmentally friendly, economically feasible, and nutrient-rich feather meal for poultry. The presence of keratin protein in chicken feathers positions them as a promising reservoir for producing high-quality nitrogen fertilizer. Properly managed, poultry feather waste can serve as an organic fertilizer with elevated nitrogen content, offering a sustainable solid waste management solution that is environmentally favourable (Joardar., 2018). Beyond their conventional industrial applications in the production of detergents, pharmaceuticals, cosmetics, leather, and feed, these enzymes and microbes showcase their versatility in contributing to sustainable agricultural practices (A Brandelli,2008). The current investigation was conducted with the goals of isolating and identifying keratinolytic bacteria from a soil sample collected from chicken waste disposal site and a Zoological Park (with the permission of the Director of the Trivandrum Zoological Park for the collection of the samples) and evaluating keratinase activity to establish an inexpensive, environmentally friendly strategy for managing feather waste, which can be improved by the identification of possible isolates.

Materials and Methods

The soil samples were collected from feather dumping sites at Thiruvananthapuram Zoological Park and the poultry farms of Thiruvananthapuram, Kerala, India. Areas where feathers were dumped, containing partially degraded feathers and soils, were selected for the study (Sudhir, 2016). The samples were collected 30cm below the soil surface. Feathers from *Dromaius novaehollandiae* and *Pelecanus philippensis* were collected from the Zoological Park, while poultry feather was sourced from selected poultry farms. Fifteen soil samples containing feathers were collected into the sterile polythene bags using a sterile spatula, and analyses was done in the microbiology lab. The bacterial strains were isolated by serial dilution and plating on nutrient agar media (NAM). Primary screening of keratinolytic bacteria was determined using sterile Skimmed Milk agar (Patil & Jadhav, 2017). Secondary screening of keratinolytic bacteria was done by procuring the feathers of Pelicans and Emu from Zoological Park and chicken feathers from a dumping site of a poultry shop and treating them (De Azeredo *et al*., 2004; Mazzoto *et al.,* 2010). Enrichment of soil samples was carried out in a Minimal Salts Medium (MSM) Keratinolytic strain that completely broke down feathers in the medium was selected for further study. The measure of Proteolytic Activity on skim milk agar plate was conducted, the zone of casein hydrolysis and diameter of growth was measured, and relative enzyme activity (REA) was calculated (Jain et al., 2009) (REA = Diameter of zone of casein hydrolysis/ Diameter of colony in mm). Based on REA, organisms were categorized into three groups showing excellent (REA>5), good (REA>2.0 to 5.0) and poor (REA<2) producers of protease. Keratinolytic activity assay was done using a spectrophotometer (Riffel & Brandelli, 2006). Effect of pH and effect of temperature were also noted. Bergey's Manual of Systematic Bacteriology was used to identify the isolates based on their morphological, biochemical, and molecular properties (Kandler and Weiss, 1986). Specific biochemical tests and gram staining were performed on each isolate. Molecular identification of bacteria using ORIGIN Bacterial Genomic DNA Isolation Kit as per manufacturer's instruction. Agarose gel electrophoresis was used for the confirmation of the presence of DNA. The amplification reaction was performed by a DNA thermal cycle. The Primer used for the 16s rRNA gene amplification was the forward primer 27F 5'-AGAGTTTGGATCMTGGCTCAG-3' and reverse primer 1492R 5'- CGGTTACCTTGTTACGACTT -3' (Weisburg et al., 1991). DNA amplification was done, and Agarose Gel Electrophoresis was conducted.

Sequencing of PCR product was done by Sanger's dideoxy chain termination sequencing method at SciGenom Labs Private Ltd., Cochin, with ABI 3730XL Automated Sequencer and further analysed using the Clustal Omega tool of MEGA11 software. The final sequences were searched for similarity using the BLAST programme of NCBI (www.ncbi.nlm.nih.gov). Identical 16s rRNA sequences were recognized by analysis of phylogenetic trees and manual comparisons, and these sequences were used for further phylogenetic analysis as an Operational Taxonomic Unit (OTU). All sequences were submitted to GenBank for preliminary analysis using the program BLAST (http://www.ncbi.nlm.nih.gov/BLAST) to identify putative close phylogenetic relatives. Distance-based evolutionary trees were constructed using the neighbour joining algorithm.

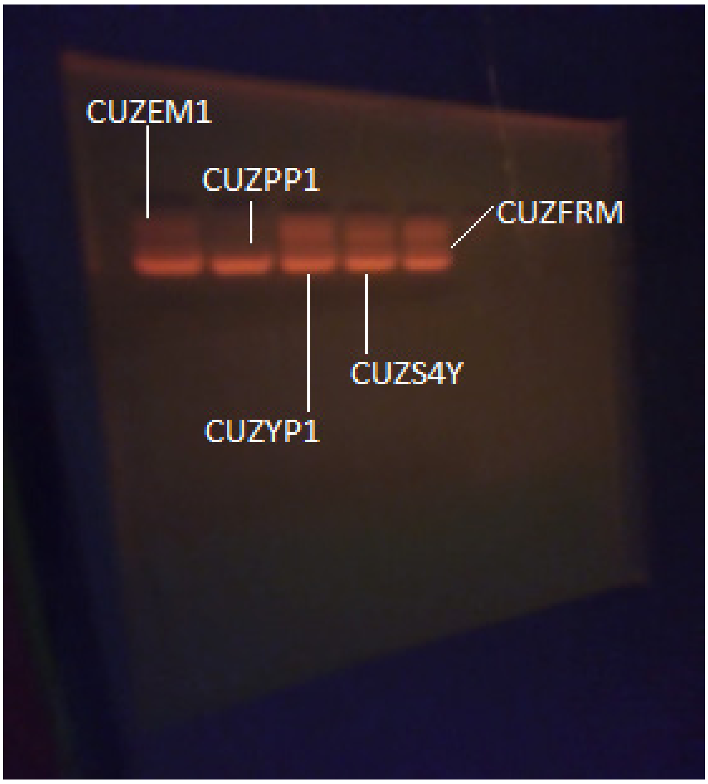

Figure 2.1: Agarose Gel electrophoresis of PCR amplified products in 16S rDNA extraction and sequencing

Microbial degradation of feathers under laboratory conditions

Determination of Weight Loss

From the data collected, weight loss of the feather was calculated.

$$\text{Weight loss \%} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \text{x100}$$

Statistics

SPSS V.27.0 was used for the statistical analysis.

Result

In this study, a total of 20 soil samples were gathered to isolate and identify bacterial strains. After processing

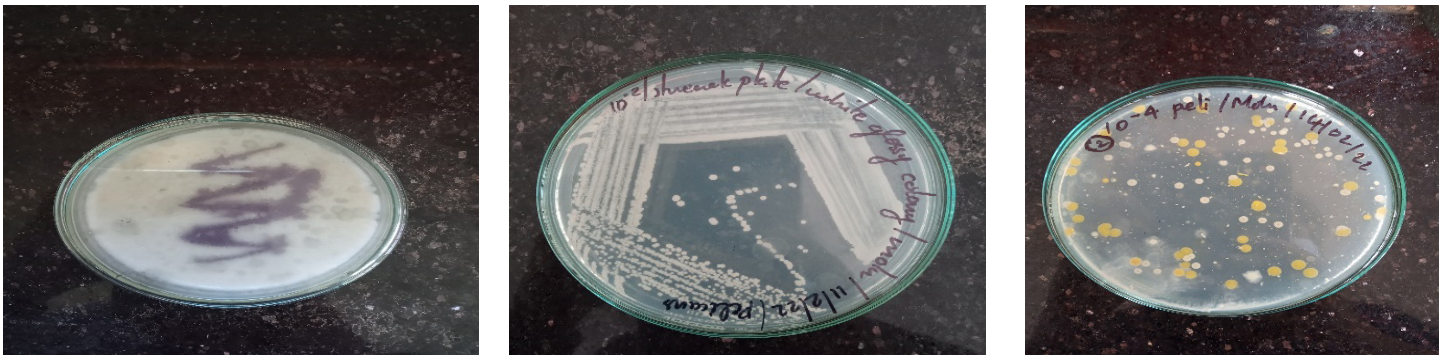

Figure 2.2: showing spread plate, streak plate and protease activity

the soil samples, 15 different bacterial strains (Table 3.1) were successfully isolated and identified. Out of these 15 strains, 5 were found to exhibit keratinolytic activity. The five of them are gram positive bacteria.

Isolation of bacteria with protease activity of selected strains was done using skim milk agar medium. Five potent isolates noted as CUZEM1, CUZPP1, CUZYP1, CUZS4Y, and CUZFRM, showed a zone of casein hydrolysis around their colonies. All five strains degraded the feathers in the medium, showing their efficiency in keratinolytic activity. CUZFRM exhibited the highest proteolytic activity with a clear zoned diameter of 35mm, followed by CUZS4Y with a clear zone of 33mm, CUZYP1 with a zone diameter of 28mm, CUZEM1 (27mm) and CUZPP1 (26mm).

Table 3.2: Keratinolytic Activity Assay

Concentration	Test Value = 0		
	t	df	Sig. (2-tailed)
10	1.491	5	.00196
20	1.857	5	.00123
30	1.799	5	.00132

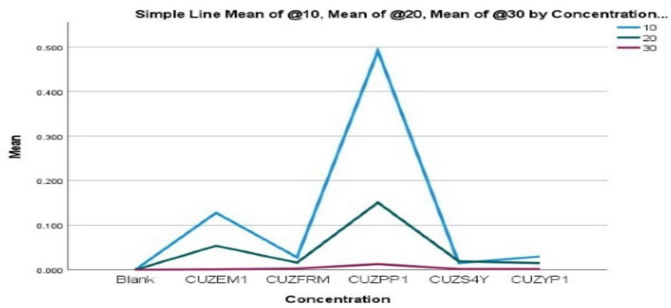

Figure 3.1: Graph Showing Keratinolytic Activity

Table 3.1: Colony Characters of Selected Strains:

Isolate	Shape	Size	Opacity	Colour
CUZS4Y	Small	Irregular	Opaque	White
CUZYP1	Medium	Irregular	Opaque	Off white
CUZPP1	Large	Regular	Opaque	White
CUZFRM6	Large	Regular	Translucent	White
CUZFRM3	Small	Regular	Opaque	Yellow
CUZFRM2	Medium	Irregular	Opaque	White
CUZS1P	Medium	Irregular	Opaque	Light pink
CUZS5W	Small	Irregular	Opaque	Off white
CUZS3P	Medium	Irregular	Opaque	Pink
CUZS2W	Medium	Regular	Translucent	White
CUZS1Y	Small	Irregular	Opaque	Yellow
CUZFRM	Large	Regular	Opaque	Yellow
CUZJM1	Small	Regular	Opaque	Violet
CUZMM1	Medium	Regular	Opaque	Orange
CUZEM1	Medium	Regular	Opaque	Off white

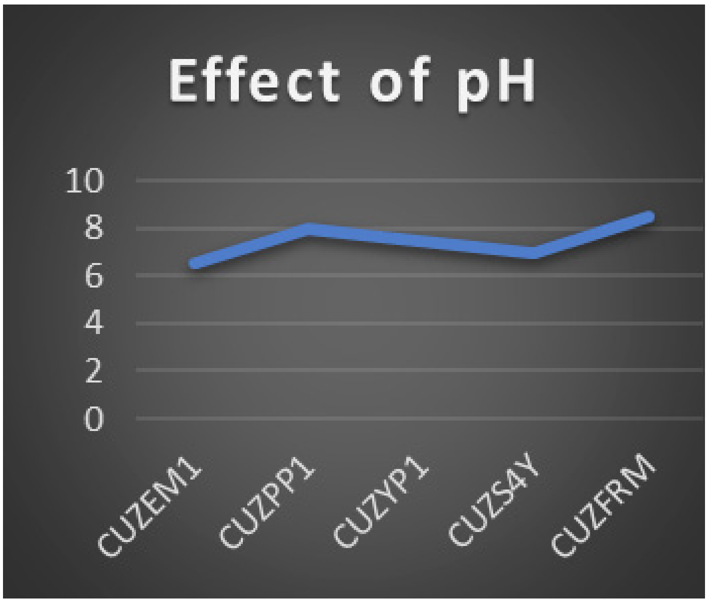

Figure 3.2: Effect of pH

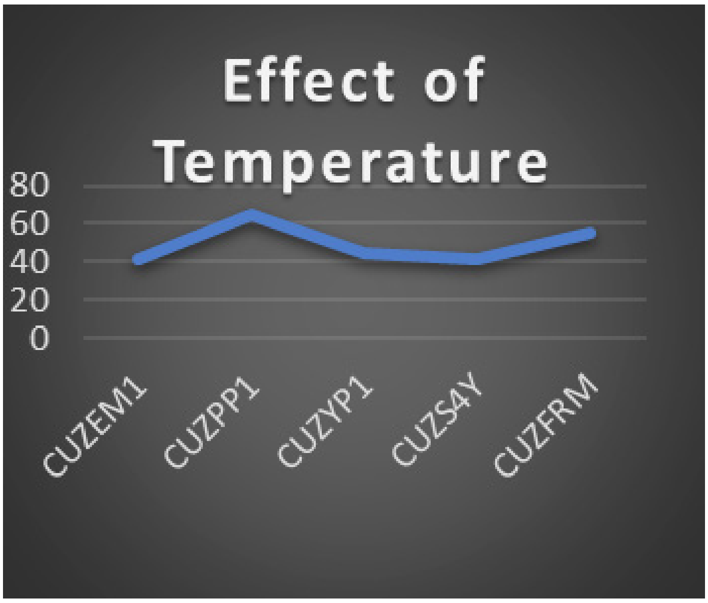

Figure 3.3: Effect of Temperature

Understanding the optimum pH and temperature for bacterial isolates (Ashfaq et al., 2022) is crucial in various fields, such as microbiology and environmental science, as it helps researchers and practitioners create suitable conditions for the growth and study of these bacteria. All the feathers were treated together for getting the keratinolytic activity of the various bacteria present in the soil samples. No difference between the types of feathers were investigated.

Table 3.3: Various Strains and Vouchers

Sl. No.	Voucher Name	Accession No.	Basepair Length
1	CUZEM1	*Bacillus halotolerans* OP848151	1412bp
2	CUZPP1	*Bacillus tequilensis* OP851351	1403bp
3	CUZYP1	*Bacillus amloliquefaciens* OP852327	1410bp
4	CUZS4Y	*Bacillus licheniformis* OP847748	1399bp
5	CUZFRM	*Bacillus subtilis* OP854666	1404bp

3.1 Morphological Characterization

The five isolates CUZEM1, CUZPP1, CUZYP1, CUZS4Y and CUZFRM showed gram-positive rods and motile nature.

Table 3.4: Biochemical tests

Characteristics	CUZEM1	CUZPP1	CUZYP1	CUZS4Y	CUZFRM
Indole test	-	+	-	-	-
Methyl red test	-	+	+	+	+
Voges-Proskauer test	+	+	+	+	+
Citrate utilization test	+	+	+	+	+
Catalase test	+	+	+	+	+
Oxidase test	+	+	+	+	-
Urease test	-	-	-	-	-
Carbohydrate fermentation	-	+	+	+	+
Starch hydrolysis	+	+	+	+	+

3.2 Molecular Identification

Molecular identification of the given isolates was done using the technique of 16S rRNA sequencing. The amplified PCR product from agarose gel electrophoresis was eluted out and sequenced. The data was subjected to BLAST analysis and subsequently to phylogenic analysis which identified the isolates to be *Bacillus halotolerans* (CUZEM1), *Bacillus tequilensis* (CUZPP1), *Bacillus amyloliquefaciens* (CUZYP1), *Bacillus licheniformis* (CUZS4Y) and *Bacillus subtilis* (CUZFRM).

3.3 Divergence

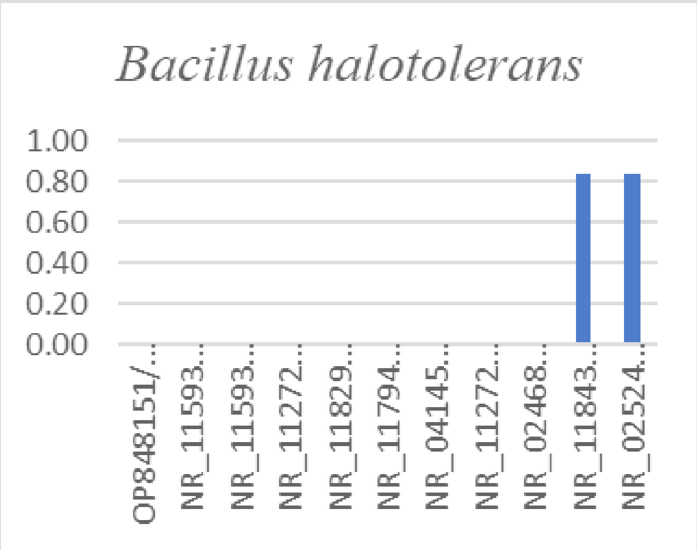

Figure 3.4 : Divergence of *Bacillus halotolerans*

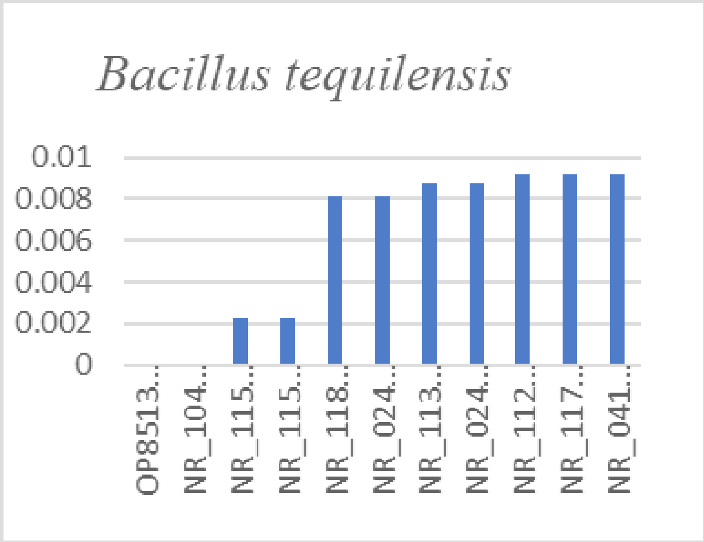

Figure 3.5 : Divergence of *Bacillus tequilensis*

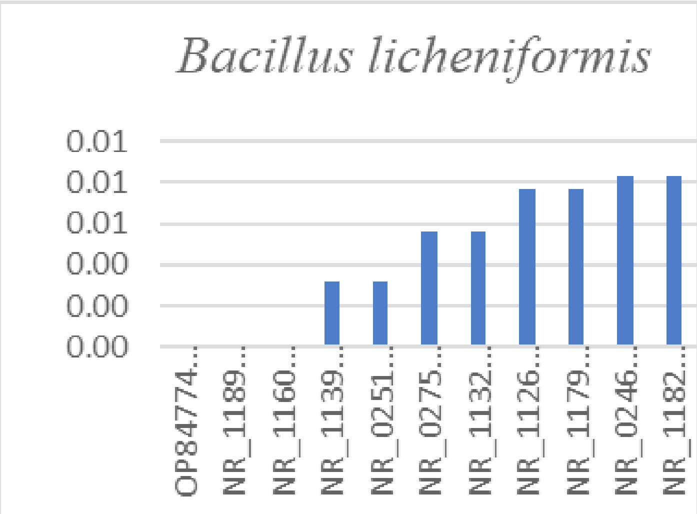

Figure 3.6 : Divergence of *Bacillus licheniformis*

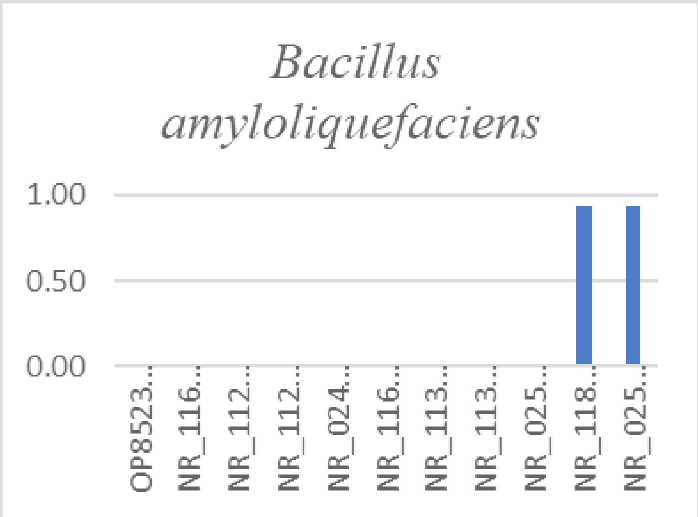

Figure 3.7 : Divergence of *Bacillus amyloliquefaciens*

Table 3.5: the weight of the feather waste after keratinolytic activity by the bacteria. (No investigation was conducted to compare the keratinolytic activity by bacteria on different types of feathers from two sites.)

Sl. No.	Name of the isolate (feather)	Initial weight (mg)	Final weight (mg)	Weight loss/ month (in %)	Paired t-test	Sig.
1	CUZEM1	0.18mg	0.06	66.6%	4.6	0.001
2	CUZPP1	0.18mg	0.08	55.5%	7.8	0.004
3	CUZYP1	0.18mg	0.04	77.7%	5.6	0.000
4	CUZS4Y	0.18mg	0.05	72.2%	4.2	0.002
5	CUZFRM	0.18mg	0.02	88.8%	3.1	0.003

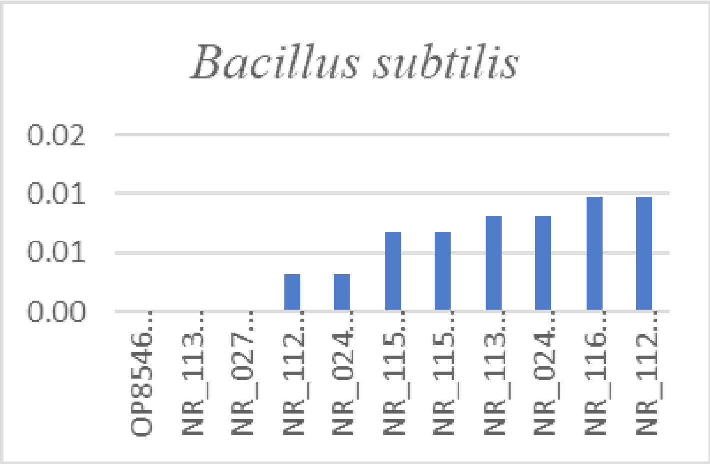

Figure 3.8: Divergence of *Bacillus subtilis*

Discussion

Similar to the results of (Vigneshwaran et al., 2010; Femi-Ola et al., 2015), wherein two of the five bacterial isolates were recognized as *Bacillus* spp., the five isolates collected in this study displayed gram-positive rods and were classified as *Bacillus* species. In contrast to our investigation, several studies have documented keratinolytic activity by gram-negative bacteria, although all of the bacterial isolates were gram-positive (Kulkarni and Jadhav, 2014). *B.licheniformis* had the highest bioconversion of feather waste (80%) and the highest production of keratinase among the 14 bacterial isolates. The results of this study, indicate that *B. Tequilensis* had the highest keratinolytic activity and maximum bioconversion of feather waste, these results highlighted the potential of microorganisms for industrial applications and waste control (Singh & Masih, 2015). This difference emphasizes the presence of the particular gram-positive bacteria in the collected soil samples with maximum keratinolytic activity. The variation in their activity can be a result of soil content.

Most researchers discovered that the best starting point for the synthesis of keratinase from various *Bacillus* species was an alkaline or neutral pH (Okoroma et al, 2012, Chaisemsaeng., et al, 2017, Ire & Onyenama, 2017). In the leather industry and for feather degradation, there are definite advantages to employing an enzyme that functions best at an alkaline pH. Similar results for numerous *Bacillus* sp. keratinases have been reported. *B. subtilis* KD-N2 and *B. licheniformis* K-19 keratinase, for example, demonstrated their highest activity at pH 8.5 (Cai et al. 2008) and pH 7.5–8.0 (Xu et al. 2009). The same outcomes were obtained by the bacterial strains that were shown to be the most active in alkaline environments. Compared to other *Bacillus,* keratinases which require a temperature of 50–55°C for optimal activity, *Bacillus* sp. MKR5 required 70°C (Lin et al. 1999; Cai et al. 2008). This enzyme's thermostability makes it a viable choice for biotechnological techniques. *Bacillus* sp. MKR5 has the potential to be used in commercial biotechnological processes since it can grow rapidly on a commonly available and inexpensive substrate, like feathers, throughout a wide variety of pH and temperature settings (Bernal et al. 2003).

In the current investigation, all the strains *Bacillus halotolerans* (CUZEM1), *Bacillus tequilensis* (CUZPP1), *Bacillus amyloliquefaciens* (CUZYP1), *Bacillus licheniformis* (CUZS4Y) and *Bacillus subtilis* (CUZFRM) exhibits an indistinguishable temperature range (42–65°C) for optimal activity. The same outcomes were obtained by the bacterial strains that were shown to be the most active in alkaline environments. Compared to other *Bacillus keratinases*, which require a temperature of 50–55°C for optimal activity, Bacillus sp. MKR5 required 70°C (Lin et al. 1999; Cai et al. 2008). This enzyme's thermostability makes it a viable choice for biotechnological techniques. Bacillus sp. MKR5 has the potential to be used in commercial biotechnological processes since it can grow rapidly on a commonly available and inexpensive substrate, like feathers, throughout a wide variety of pH and temperature settings (Bernal et al. 2003). In the current investigation, this strain likewise exhibits an indistinguishable temperature range (42–65°C) for optimal activity.

In a recent experiment conducted by Vema., 2022 feathers underwent a dramatic change in which Out of 64, 17 isolates showed proteolytic activity and keratinolytic activity on feather basal medium. This test showed degradation process taking place entirely in just 15 days. The current data present in our study indicates the degree to which the bacterial strains decomposed the feathers over the 30-day period.

Conclusion

This study shows how soil microorganisms, especially the five isolated strains *Bacillus halotolerans* (CUZEM1), *Bacillus tequilensis* (CUZPP1), *Bacillus amyloliquefaciens* (CUZYP1), *Bacillus licheniformis* (CUZS4Y) and *Bacillus subtilis* (CUZFRM) have significant keratinolytic potential. It can be utilized to solve waste management issues, and the microbes isolated in this study have biotechnological applications. Keratinase's thermotolerant character with optimum activity at alkaline pH has a clear benefit, therefore boosting the adaptability and the application possibilities. Based on the present study microbial degradation of feathers shows significant promise for transforming them into several products including animal feeds and bio-fertilizer.

References

- **Ashfaq, M. Y., Da'na, D. A., & Al-Ghouti, M. A.** (2022). Application of MALDI-TOF MS for identification of environmental bacteria: A review. *Journal of Environmental Management*, *305*, 114359.
- **Bernal, C., Vidal, L., Valdivieso, E., &Coello, N.** (2003). Keratinolytic activity of Kocuriarosea. *World journal of microbiology and biotechnology*, *19*, 255-261.
- **Brandelli, A.** (2008). Bacterial keratinases: useful enzymes for bioprocessing agroindustrial wastes and beyond. *Food and Bioprocess Technology*, *1*, 105-116.
- **Brusatte, S. L., O'Connor, J. K., & Jarvis, E. D.** (2015). The origin and diversification of birds. *Current Biology*, *25*(19), R888-R898.
- **Burtt Jr, E. H., & Ichida, J. M.** (1999). Occurrence of feather-degrading bacilli in the plumage of birds. *The Auk*, *116*(2), 364-372.
- **Cai, C., Chen, J., Qi, J., Yin, Y., & Zheng, X.** (2008). Purification and characterization of keratinase from a new Bacillus subtilis strain. *Journal of Zhejiang University-SCIENCE B*, *9*(9), 713–720.
- **Chaisemsaeng, P.** (2017). Feather Degradation and Keratinase Production by Bacillus Sp. and Lactobacillus Sp. *International Journal of Bio-technology and Research*, *7*(3), 29–36.
- **Chilakamarry, C. R., Mahmood, S., Saffe, S. N. B. M., Arifin, M. A. B., Gupta, A., Sikkandar, M. Y., ... & Narasaiah, B.** (2021). Extraction and application of keratin from natural resources: a review. *3 Biotech*, *11*, 1-12.
- **De AzevedoNeto, A. D., Prisco, J. T., Enéas-Filho, J., De Lacerda, C. F., Silva, J. V., Costa, P., & Gomes-Filho, E.** (2004). Effects of salt stress on plant growth, stomatal response and solute accumulation of different maize genotypes. *Brazilian Journal of Plant Physiology*, *16*(1), 31–38.
- **Femi-Ola, T. O., Akinbobola, O. S., &Oluwaniyi, T. T.** (2015). Isolation and characterization of feather degrading bacteria from poultry soil. *Agriculture and Biology Journal of North America*, *6*(5), 146-154.
- **Ire, F. S., &Onyenama, A. C.** (2017). Effects of Some Cultural Conditions on Keratinase Production by Bacillus licheniformis Strain NBRC 14206. *Journal of Advances in Biology & Biotechnology*, *13*(1), 1–13.
- **Jain, R., Agrawal, S. C., & Jain, P. C.** (20009). Proteolytic actinomycetes from Indian habitats.
- **Joardar, J. C., & Rahman, M. M.** (2018). Poultry feather waste management and effects on plant growth. *International Journal of Recycling of Organic Waste in Agriculture*, *7*, 183-188.
- **Kandler O, Weiss N** (1986). Microbiology of mesu, a traditional fermented bamboo shoot product, In: Bergey's Manual of Systematic Bacteriol. Sneath PHA, Mair NS, Sharpe ME, Holt JG (Eds). Baltimore: Williams, Wilkins 2: 1209 -1234.
- **Kowata, K., Nakaoka, M., Nishio, K., Fukao, A., Satoh, A., Ogoshi, M., ... & Takeuchi, S.** (2014). Identification of a feather β-keratin gene exclusively expressed in pennaceous barbule cells of contour feathers in chicken. *Gene*, *542*(1), 23-28.
- **Kulkarni, S. A., & Jadhav, A. R.** (2014). Isolation and characterization of keratinolytic bacteria from poultry farm soils. *International Research Journal of Biological Sciences*, *3*(7), 29-33.
- **Li, Q.** (2019). Progress in microbial degradation of feather waste. *Frontiers in Microbiology*, *10*, 2717.
- **Lin, X., Inglis, G. D., Yanke, L. J., & Cheng, K. J.** (1999). Selection and characterization of feather-degrading bacteria from canola meal compost. *Journal of Industrial Microbiology and Biotechnology*, *23*(2), 149-153.
- **Mazotto, A. M., De Melo, A. C. N., Macrae, A., Rosado, A. S., Peixoto, R. S., Cedrola, S. M. L., Couri, S., Zingali, R. B., Villa, A. L. V., Rabinovitch, L., Chaves, J. Q., &Vermelho, A. B.** (2010). Biodegradation of feather waste by extracellular keratinases and gelatinases from Bacillus spp. *World Journal of Microbiology & Biotechnology*, 27(6), 1355–1365.
- **Mousavi, S., Salouti, M., Shapoury, R., &Heidari, Z.** (2013). Optimization of keratinase production for feather degradation by Bacillus subtilis. *Jundishapur Journal of Microbiology*, 6(8).
- **Okoroma, E., Garelick, H., Abiola, O., & Purchase, D.** (2012). Identification and characterisation of a Bacillus licheniformis strain with profound keratinase activity for degradation of melanised feather. *International Biodeterioration& Biodegradation*, *74*, 54–60.
- **Onifade, A. A., Al-Sanè, N. A., Al-Musallam, A. A., & Al-Zarban, S. S.** (1998). A review: Potentials for biotechnological applications of keratin-degrading

microorganisms and their enzymes for nutritional improvement of feathers and other keratins as livestock feed resources. *Bioresource Technology*, 66(1), 1–11.

- **Patil, R. C., &Jadhav, B. L.** (2017). Isolation and characterization of protease producing Bacillus species from soil of dairy industry. Int. J. Curr. Microbiol. App. Sci, 6(6), 853-860.
- **Qin, X., Xu, X., Guo, Y., Shen, Q., Liu, J., Yang, C., & Zhang, C.** (2022). A sustainable and efficient recycling strategy of feather waste into keratin peptides with antimicrobial activity. *Waste Management*, *144*, 421-430.
- **Riffel, A., &Brandelli, A.** (2006). Keratinolytic bacteria isolated from feather waste. *Brazilian Journal of Microbiology*, 37(3), 395–399.
- **Sahni, N., Sahota, P. P., &Phutela, U. G.** (2015). Bacterial keratinases and their prospective applications: a review. *Int J CurrMicrobiol App Sci*, *4*(6), 768-783.
- **Sarma, A.** (2022). Biological importance and pharmaceutical significance of keratin: a review. *International Journal of Biological Macromolecules*, 219, 395-413.
- **Shen, N., Yang, M., Xie, C., Pan, J., Pang, K., Zhang, H., & Jiang, M.** (2022). Isolation and identification of a feather degrading Bacillus tropicus strain Gxun-17 from marine environment and its enzyme characteristics. BMC biotechnology, 22(1), 11.
- **Singh, S., &Masih, H.** (2015). Isolation of keratinolytic bacteria from soil for the bioconversion of the poultry feather waste. *Journal of Pure and Applied Microbiology*, 9(3), 2281-2284.
- **Sudhir, M. R.** (2016). Isolation and identification of feather degrading bacteria from poultry farm soil and characterization of enzyme.
- **Vema, R.** (2022). Isolation and characterization of keratinolytic bacteria from poultry waste soils of Himachal Pradesh. Journal of Applied Biology and Biotechnology.
- **Vigneshwaran, C., Shanmugam, S., & Kumar, T. S.** (2010). Screening and characterization of keratinase from Bacillus licheniformis isolated from Namakkal poultry farm. *Researcher*, *2*(4), 89-96.
- **Weisburg, W. G., Barns, S. M., Pelletier, D. A., & Lane, D.** (1991). 16S ribosomal DNA amplification for phylogenetic study. *Journal of Bacteriology*, *173*(2), 697–703.
- **Xu, B., Zhong, Q., Tang, X., Yang, Y., & Huang, Z.** (2009). Isolation and characterization of a new keratinolytic bacterium that exhibits significant feather-degrading capability. *African Journal of Biotechnology*, *8*(18).

An avifaunal checklist of the wetland in Ayanchery, Kozhikode, Kerala

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Abstract

Ayanchery wetland is situated in the rural part of where resident and migratory birds are found. The study was conducted from December 2023 to April 2024. A total 61 species of birds and a total of 525 birds under 33 families were observed in the study area during the study period. Of these 22 species were exclusively water birds and 39 species used both wetland and upland habitats. Among 61 bird species recorded, a total of 59 species were Least Concern and two were Near Threatened, *Threskiornis melanocephalus* (Black-headed Ibis) and *Ciconia episcopus* (Woolly-necked Stork), The present study was carried out to document the avifaunal diversity of Ayanchery wetland.

Keywords – Wetland; Near Threatened; Avifauna; Habitat status; Biodiversity.

Introduction

An estimated 1,353 bird species are found in India, accounting for 12.40% of the global avian diversity. 78 (5%) out of the 1,353 bird species, are native to our country (Sharma 1982; Bhattacharjee and Hazarika 1985). Wetland birds live in or are dependent on wetlands, either directly or indirectly, for roosting, breeding, feeding, or nesting. Because of their aesthetic, economic values wetland birds are highly significant. Wetland bird monitoring is an excellent approach to gather information on the ecological health and state of wetlands and an effective way to raise awareness about the importance of wetlands and its conservation. Wetlands perform a variety of activities, including stabilizing shorelines, storing surface water, storing carbon, retaining pollutants, recharging groundwater, retaining stormwater, and controlling flooding. Like any other natural environment, wetlands play a crucial role for maintaining the diversity of species. Wetlands serve as a significant breeding ground for wildlife and as a refuge for migratory bird population, mammals, fish, frogs, insects and plants (Buckton 2007). Wetlands in India, as elsewhere, are facing tremendous anthropogenic pressures (Prasad et al. 2002), which can greatly influence the structure of bird community (Kler 2002; Verma et al. 2004; Reginald et al. 2007).

Kerala wetlands may be the least ornithologically studied ecosystems (Nameer 1998). Kozhikode district contains several wetland habitats, including Kadalundi, Mavoor, Kottooly, Cherandathoor Chira, Avalapandi, Ayanchery, etc. (Aarif et al. 2015). By recording the diversity of bird populations, conservationists can prioritize areas that need protection or restoration. The major objective of the Ramsar Convention is to conserve the global degradation of wetlands through sensible use and sustainable management (Roy et al. 2022). High diversity areas might be targeted for conservation, while areas with declining diversity might be investigated for underlying problems. The main objective of the study is to analyse the avifaunal diversity and status in the wetland of Ayanchery, Kozhikode.

Material And Methods

Study Area

The study was conducted in the wetland area of Ayanchery village in Kozhikode district, Kerala. The study site is situated at 11062160N and 75068938E, approximately 1.84 km from Ayanchery town. It has a surface area of roughly 25 acres. The primary subject of this study is the birds of Poluthuruthi, a small island that is home to no human habitation and a small temple nearby called "Poluthuruthi Sree Bhagavathi Temple." Beside this marsh, there's a canal that provides year-round water and was refurbished by the district panchayat as part of the Rice Cultivation Development Project. Aavalapaandi and other kole lands of Velam panchayath are located in addition to this wetland.

The study was carried out from December 2023 to April 2024. Direct observation and point count method was employed for this study. Observations were made in the morning hours (7.00AM-11.00AM) from a distance of 50- 200 m without interfering with bird activities. Point count method (Bibby, 2000) was used for this study with 100m distance. Five-point counts were placed in the study area. Each point was 200m away

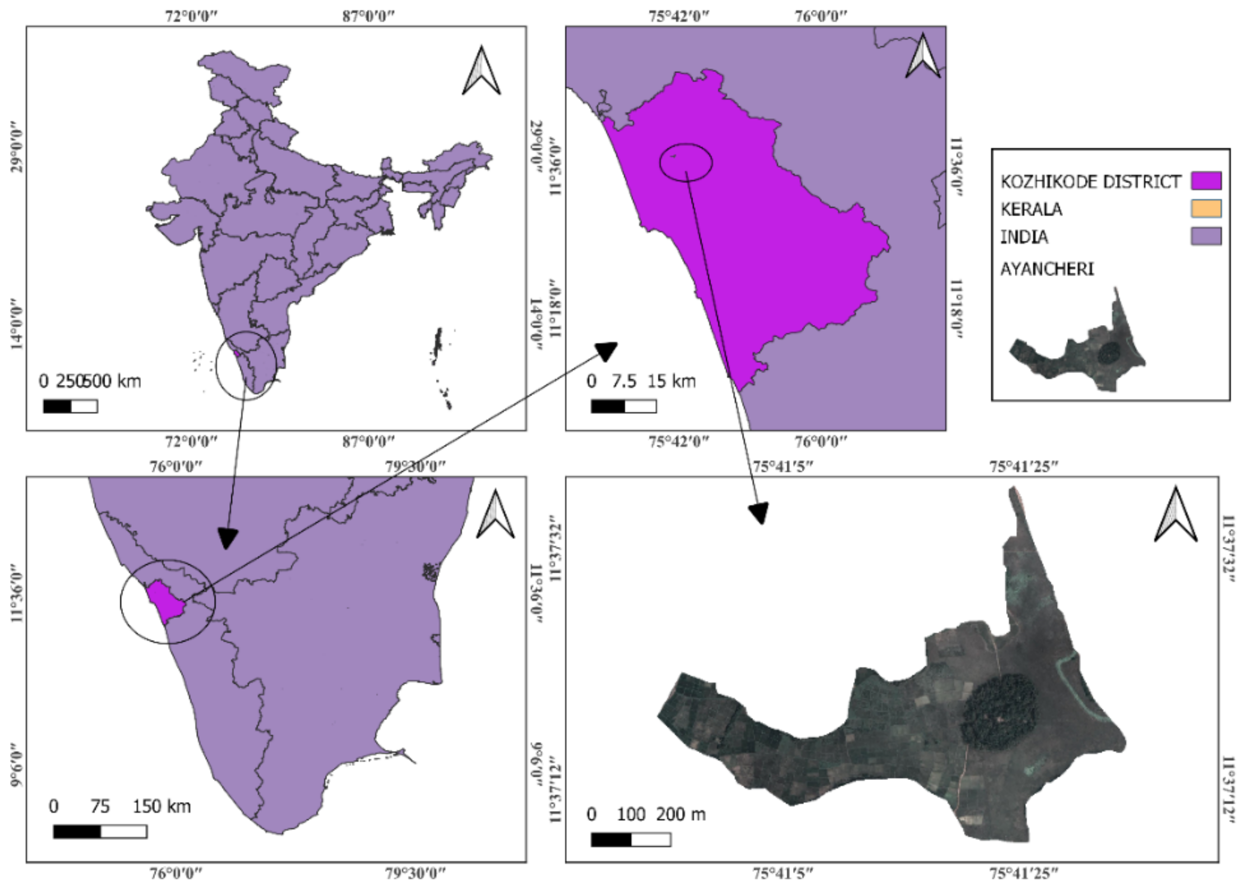
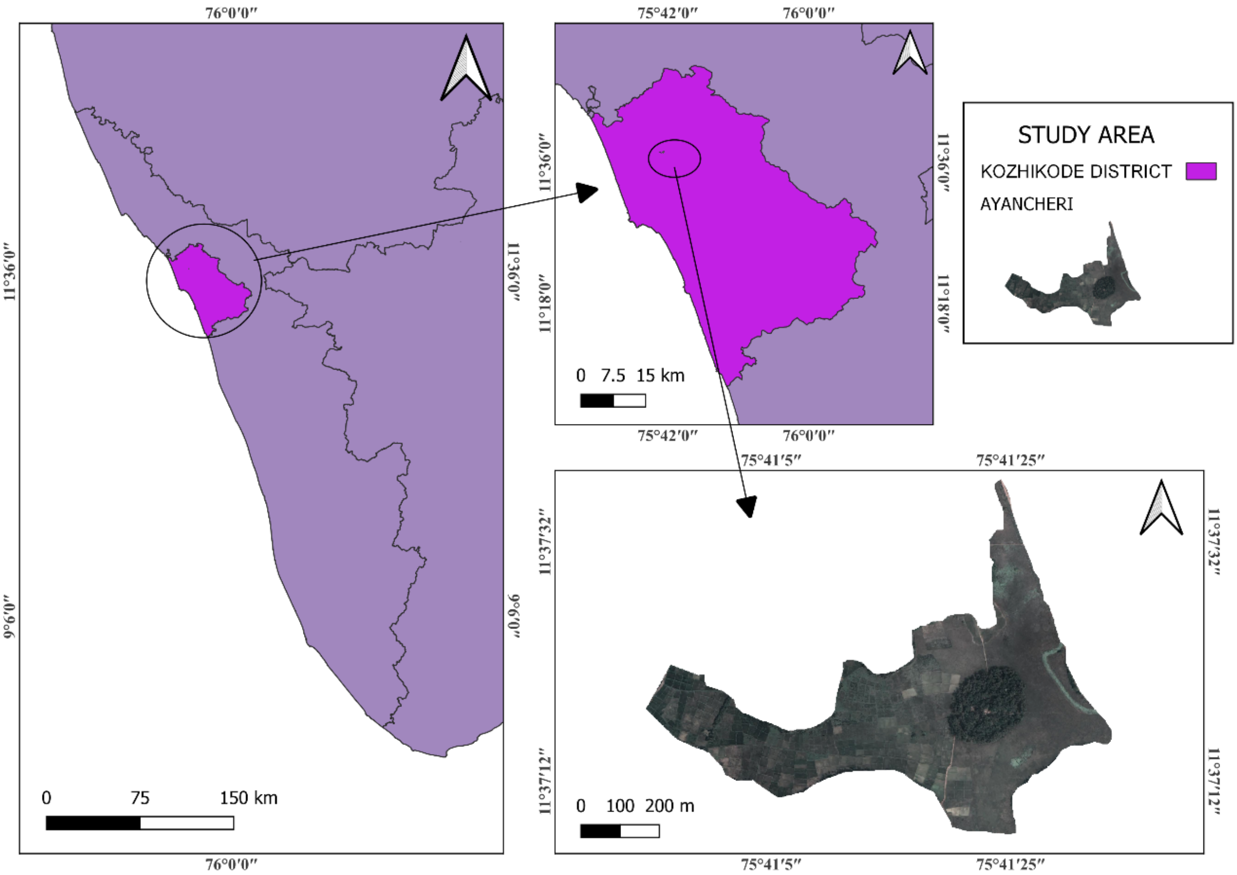


Figure 1. Map of Ayanchery showing the study site



from the other point. The time for sampling in each point was twenty minutes. Another 20 minutes were necessary for the moving between one point to another. Observation was done using binocular (Nikon 10x42) and photographs of birds were taken using Canon EOS50 Camera. Later the birds were identified by using reference books such as Birds of the Indian Subcontinent by Grimmet et al. 2015, The Book of Indian Birds by Salim Ali 2002 and experts. A detailed checklist was prepared indicating IUCN status (IUCN, 2022), WLPA schedule (Praveen, 2015) and feeding habit. Relative diversity (RDi) of family was determined. The Relative $RDi = \frac{\text{No.of species in a family}}{\text{Total No.of species}} \times 100$ was calculated by (La Torre-Cuadros et al, 2007). Species richness was estimated by recording the number of bird species encountered in the study area. Along with that Species diversity was calculated using the Shannon Diversity index (Shannon and Weaver, 1949) and Simpson Index (Simpson, 1949). Evenness index (E) (Maisyaroh et al. 2021) and dominance index (Maisyaroh et al. 2021) (Formulas are showing the table 1) were used to calculate the diversity of birds using Simpson index. (shown in table 1) All the data analysis had been done using PAST software.

Table 1. Data Analysis used in the study

Indices	Formula
Simpson's Index of Diversity, 1-D (Simpson, 1949)	$1 - D = 1 - \frac{\Sigma[ni(ni-1)]}{N(N-1)}$ ni= number of individuals of i[th] species, N= total number of individuals
Shannon's Diversity index, H` (Shannon and Weaver, 1949)	H`= - Σpi ln pi P_i= proportion of individuals of i[th] species
Evenness Index, E (Maisyaroh et al. 2021)	E= H' / ln S H' = Shannon-Wiener's diversity index S =Species richness.
Dominance Index, D (Maisyaroh et al. 2021)	$D = \frac{S}{T} \times 100$ S= No. of species in the sample T= No. of species in the population

Results And Discussion

The current study was carried out to examine the diversity, feeding guild, and conservation status of wetland birds. A total 61 species of birds under 33 families including water birds and terrestrial birds were recorded from the study site. Of these 22 species were exclusively water birds and the remaining 39 species used both wetland and upland habitats.

The observed birds belong to 13 orders (Fig. 4), namely Anseriformes(1), Columbiformes(2), Cuculiformes(3), Gruiformes(2), Pelicaniformes (9), Ciconiiformes(2), Suliformes(2), Charadriiformes(6), Acciptriformes(2), Piciformes(2), Coraciiformes(5), Psittaciformes(1) and Passeriformes(24).

Based on the analysis of relative diversity of family, Ardeidae was the most diverse family in the study area (7 species, RDi=11.4754), followed by Dicruridae (4 species, RDi=6.5574). Moreover, 5 families- Cuculidae, Alcedinidae, Corvidae, Hirundinidae and Sturnidae were represented in the study area with 3 species in each (RDi=4.9180). (Relative Diversity index) Relative diversity index (RDi) refers to the proportion of different bird families present in a specific area compared to the total bird species diversity in that region. The Relative $RDi = \frac{\text{No.of species in a family}}{\text{Total No.of species}} \times 100$ was calculated by (La Torre-Cuadros et al, 2007).

The 9 families namely Columbidae, Rallidae, Threskiornithidae, Ciconiidae, Phalacrocoracidae, Charadriidae, Scolopacidae, Accipitridae and Estrildidae were represented with 2 species in each (RDi=3.2787). The remaining 17 families – Anatidae, Recurvirostridae, Jacanidae, Picidae, Megalaimidae, Meropidae, Coraciidae, Psittaculidae, Oriolidae, 55 Artamidae, Monarchidae, Nectarinidae, Motacillidae, Pycnonotidae, Leiothrichidae, Muscicapidae and Turdidae were represented with only single species in each (RDi=1.6393)

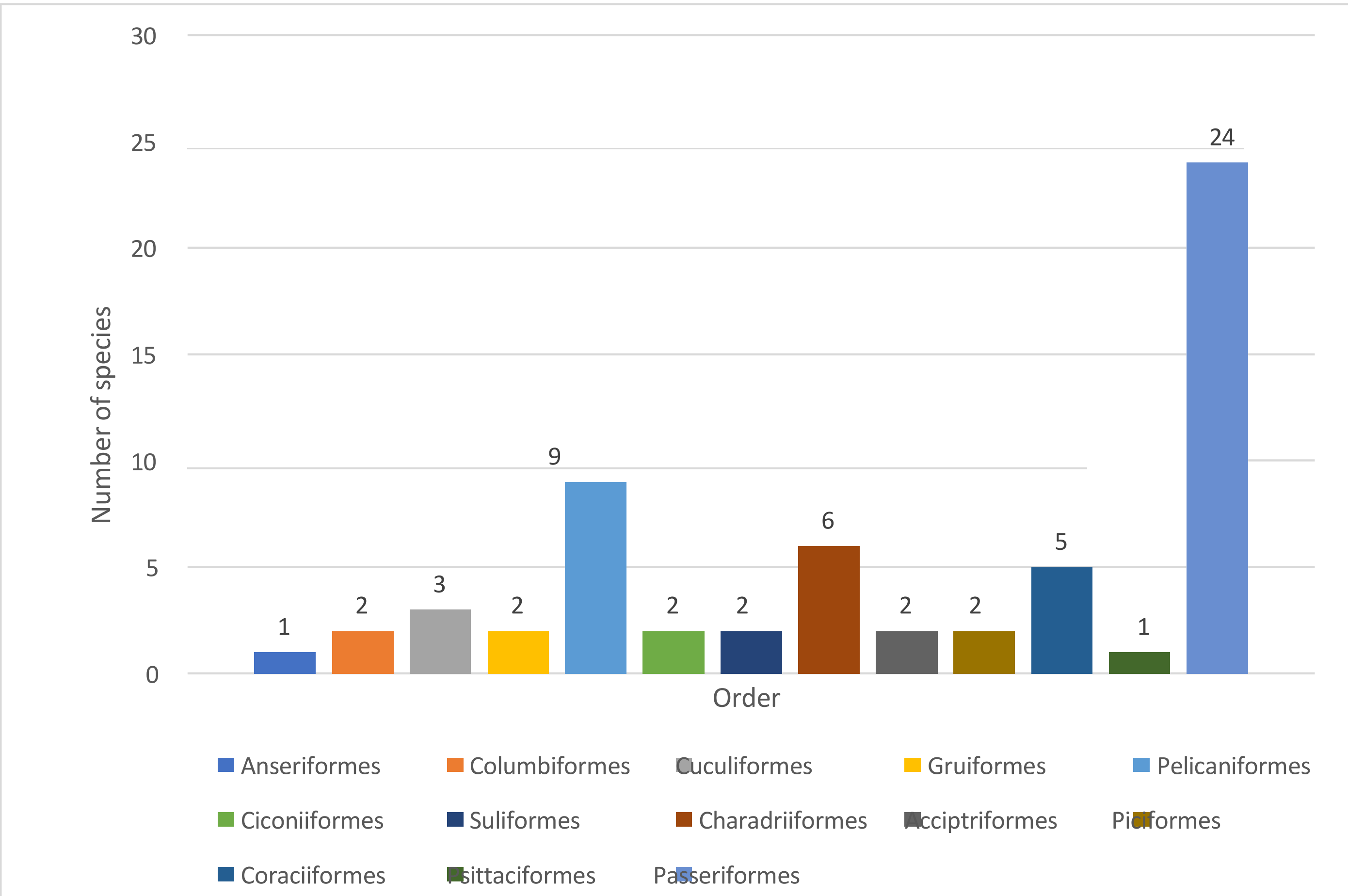


Figure 2. Avian Species Composition based on Order

Table 2. Relative Diversity index (RDi) of Bird Families in the Ayanchery wetland

No.	Family	Relative Diversity
1	Anatidae	1.6393
2	Columbidae	3.2787
3	Cuculidae	4.9180
4	Rallidae	3.2787
5	Ardeidae	11.4754
6	Threskiornithidae	3.2787
7	Ciconiidae	3.2787
8	Phalacrocoracidae	3.2787
9	Recurvirostridae	1.6393
10	Charadriidae	3.2787
11	Jacanidae	1.6393
12	Scolopacidae	3.2787
13	Accipitridae	3.2787
14	Picidae	1.6393
15	Megalaimidae	1.6393
16	Meropidae	1.6393
17	Coraciidae	1.6393
18	Alcedinidae	4.9180
19	Psittaculidae	1.6393
20	Oriolidae	1.6393
21	Artamidae	1.6393
22	Dicruridae	6.5574
23	Corvidae	4.9180
24	Monarchidae	1.6393
25	Nectarinidae	1.6393
26	Estrildidae	3.2787
27	Motacillidae	1.6393
28	Hirundinidae	4.9180
29	Pycnonotidae	1.6393
30	Leiothrichidae	1.6393
31	Sturnidae	4.9180
32	Muscicapidae	1.6393
33	Turdidae	1.6393

Number of species varied in different months and highest (45 species) were recorded during February and April 2024 and the lowest (34 species) during January 2024 (Table 2). Species richness increased during the migratory season. The species richness of birds observed in the present study showed moderately high values in this minor (small) wetland area. Total number of birds varied from 207 to 525 during the study period. The highest number of birds (525) was recorded during February 2024 which showed the influx of birds due to migration and the lowest (207) during March 2024 due to the low availability of food and water.

The highest diversity index H` was recorded in the month of March (3.344) followed by April (3.08), January (3.052), December (3,024) and the lowest H` value (2.828) (Due to the dominance of Glossy Ibis, in the wetland area during the month of February the diversity of birds becomes less. And also, human interference was observed due to the onset of paddy cultivation in this area). (Checked) was in the month of February. The highest diversity index (**Simpson Index (1-D))** 1-D was noted in the month of March (0.9531) followed by January (0.9389), December (0.9334), April (0.9215) and the lowest value (0.8808) was in the month of February. (Checked) Shannon Index and Simpson Index obtained for the area during the month of March were significantly more than the other months. Evenness indices of bird community recorded in different months are given in Table. 2. High evenness values were obtained during March (0.6749) and February (0.376) that shows the conservation value of the wetland. Out of 61 bird species observed in this area, the month of February showed the highest dominance (0.1192) and the least during the month of March (0.04689). As reported earlier from the Western Ghats, highest number of birds was recorded during winter and there was a reduction in population size during the monsoon (Daniels 1996).

Analysing the feeding guild of observed birds shows 6 categories, namely omnivores, carnivores, insectivores, granivores, frugivores and nectarivores. Among 61 species, 39% (24 species) were Omnivores, 36% (22 species) were carnivores, 15% (9 species) were insectivores, 5% (3 species) were granivores, 3% (2 species) were frugivores and 2% (a single species) were nectarivores. Guild structure is a pattern of resource utilization among bird species occurring in a habitat (Holmes and Recher 1986). The Ayanchery wetland was dominated by omnivorous species (n=56) The omnivorous species represented 6 orders and 15 families. They had both carnivorous and vegetarian type of foods that consist of fish, molluscs, crustaceans, insects, frogs, toads, plant shoots, seeds and grains.

Table 3. Showing the values of data analysis (The table showing the month wise number of species, number of individuals, and the diversity indices of the avifauna in the study area)

	December	January	February	March	April
Species	38	34	45	42	45
Individuals	496	228	525	207	430
Dominance (D)	0.06657	0.06106	0.1192	0.04689	0.07847
Simpson Index (1-D)	0.9334	0.9389	0.8808	0.9531	0.9215
Shannon Index (H')	3.024	3.052	2.828	3.344	3.08
Evenness (E)	0.5412	0.661	0.376	0.6749	0.4834

Highest number of species was from Dicruridae family and the lowest from the families such as Anatidae, Charadriidae, Scolopacidae, Picidae, Oriolidae, Estrildidae, Pycnonotidae, Leiothrichidae and Turdidae. The carnivorous species represented 6 orders and 10 families. The dominant family was Ardeidae and the lowest species were seen in the families such as Recurvirostridae, Charadriidae, Scolopacidae and Coraciidae. They fed majorly on fishes, crustaceans, molluscs, frogs, toads and snakes. The insectivorous species represented 7 families and 3 orders. The dominant family was Hirundinidae. They played an important role in controlling the pest in the field. Their diet included dragonflies, worms, larvae, caterpillars, water insects, cicadas, bees and grasshoppers. The granivorous species represented 2 families and 2 orders. The dominant family was Columbidae. They were abundant during the harvest and post-harvest periods, feeding on the grains in the fields. The frugivorous species belonged to 2 families and 2 orders. They preferred fruits which were easily available in the trees adjoining the wetland. Both the Megalaimidae and Psittaculidae families showed the dominance. The nectarivorous species belonged to the single family Nectariniidae from the order Passeriformes which feed on the nectars from the less available flowering plants.

Of these 61 species recorded two of them are listed as near threatened by IUCN, they are *Threskiornis melanocephalus* (Black-headed Ibis) and *Ciconia episcopus* (Woollynecked Stork), and the others are recorded as least concern that denotes the healthy nature of the wetland environment.

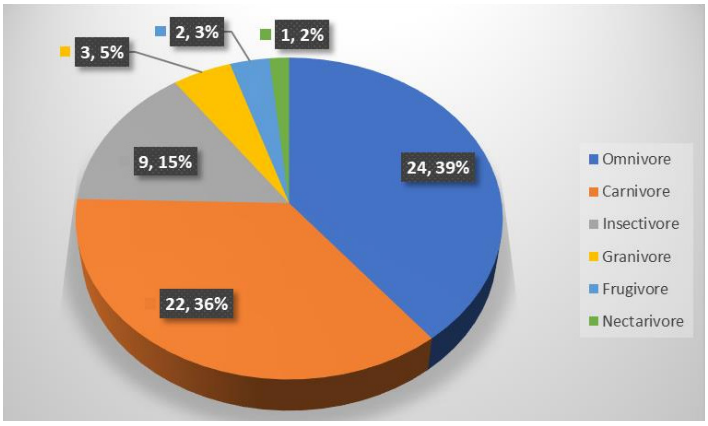


Figure 3. Feeding guild of birds recorded from the Wetland

Conclusion

During the study, 61 species of birds were reported and a total of 525 birds were counted. Most of the bird species reported were common wetland birds and among them, 2 Near Threatened birds were observed which indicates the importance of protecting the wetland in Ayanchery, Kozhikode. Fluctuation in the populations was seen during the study period because of the effect of a combination of several factors such as food availability, anthropogenic activities during the study period. The observed bird species in the study are heterogeneous in their feeding habitats that may be a reason for the diversity of avifauna in the study site.

The present study was carried out to increase the information and knowledge about the available avifauna and habitat status of. The occurrence of 61 species of birds in Ayanchery wetland during five months is remarkable, which shows the importance of this region for migratory species. Consequently, a conservation plan is required to protect this wetland ecosystem.

References

- **Aarif, K. M., Prasadan, P. K., Basheer, M. and Hameed, A.S.V.** (2015). Population trend of wintering gulls in the Kadalundi-Vallikkunnnu Community Reserve, Southern India. *Journal of Environmental Biology*.36 (4): 597-600.
- **Ali, S,** (2002). The Book of Indian Birds. Oxford University Press.
- **Bhattacharjee, P.C., and B.C. Hazarika** (1985). Roosting sites and roosting birds at Gauhati Municipal area. *In Second international symposium on life sciences*. November, 14-16, 1985. NEHU Shillong.
- **Bibby, C. J.** (2000). Bird census techniques. *Elsevier*.
- Buckton, S. (2007). Managing wetlands for sustainable livelihoods at Koshi Tappu. Danphe. 16(1): 12-13.
- **Daniels, R.J.R.** (1996). Landscape ecology and conservation of birds in the Western Ghats, Southern India. Ibis. 138: 64-69
- **Grimmet, R., Inskipp, C. and Inskipp, T.** (2015). *Birds of the Indian Subcontinent*. Second Edition. Oxford University Press.
- **Holmes, R. T., and Recher, H. F.** (1986). Determinants of guild structure in forest bird communities: an intercontinental comparison. *The Condor*. 88(4): 427-439.
- **IUCN** (2022). The IUCN Red List of Threatened Species. Version 2021– 23. www.iucnredlist.org. Accessed on 23-March-2023
- **Kler, T.K.** (2002). Bird species in Kanjali wetland. *Tiger Paper*. 39(1): 29-32.
- **La Torre-Cuadros, M.D.L.Á. Herrando-Pérez, S. and Young, K.R.** (2007). Diversity and structural patterns for tropical montane and premontane forests of central Peru, with an assessment of the use of higher-taxon surrogacy. *Biodiversity and Conservation*, 16: 2965-2988.
- **Maisyaroh, W., Hakim, L., and Batoro, J.** (2021, November). Bird diversity in the Gumuk ecosystem in Jember. In *IOP Conference Series: Earth and Environmental Science* (Vol. 886, No. 1, p. 012046). IOP Publishing.
- **Mohan, S. K., Anjitha, R., & Rodrigues, K. M.** (2023). The avian diversity of Chemmattamvayal Wetlands and adjacent areas of Kasaragod District, Kerala, India. *Journal of Threatened Taxa*. 15(4): 23047-23060.
- **Nameer, P.O.** (1998). An overview of wetlands of Kerala and their conservation. *Proceeding of the Tenth Kerala science congress*. 376-378p.
- **Prasad, S.N., T.V. Ramachandra, N. Ahalya, T. Sengupta, A. Kumar, A.K. Tiwari, V.S. Vijayan and L. Vijayan** (2002). Conservation of wetlands of India- A review. *Tropical Ecology*. 43(1): 173-186.
- **Praveen, J.** (2015). A checklist of birds of Kerala, India. *Journal of Threatened Taxa*, *7*(13), 7983-8009.
- **Reginald, L.J., C. Mahendran, S.S. Kumar and P. Pramod** (2007). Birds of Singanallur Lake, Coimbture, Tamilnadu. *Zoos' Print Journal*. 22(12): 2944-2948.
- **Roy, M.B., S. Nag, S. Halder & P.K. Roy** (2022). Assessment of wetland potential and bibliometric review: a critical analysis of the Ramsar sites of India. *Bulletin of the National Research Centre* 46: 59. https://doi.org/10.1186/s42269-022-00740-0
- **Salim Ali,** (2002). *The Book of Indian Birds*. Oxford University Press.
- **Shannon, C.E. and Weaver, W.** (1949). The Mathematical Theory of Communication. Urbana: University of Illinois Press.
- **Sharma, I.K.** (1982). Adverse effects of air, water and soil pollutions on flora and fauna of towns and villages of Western Rajasthan. *In Symposium on environment consciousness, problems of pollution and conservation in Rajasthan*. October 1-3, 1982.
- **Simpson, E.H.** (1949). Measurement of Diversity. *Nature*. 163.
- **Verma, A., S. Balachandran, N. Chaturvedi and V. Patil** (2004). A preliminary survey on the biodiversity of Mahul Creek, Mumbai, India. *Zoos' Print Journal*. 19(9): 1599-1605.

Table 4: Checklist of Birds in the wetland of Ayanchery

No	Common Name	Scientific Name	IUCN Status	WLPA Schedule	Feeding guild
1	Lesser Whistling Duck	*Dendrocygna javanica*	LC	Sch II	O
2	Rock Pigeon	*Columba livia*	LC	Sch IV	G
3	Spotted Dove	*Spilopelia chinensis*	LC	Sch II	G
4	Greater Coucal	*Centropus sinensis*	LC	Sch II	O
5	Pied Cuckoo	*Clamator jacobinus*	LC	Sch II	I
6	Asian Koel	*Eudynamys scolopaceus*	LC	Sch II	O
7	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	Sch II	O
8	Purple Swamphen	*Porphyrio poliocephalus*	LC	Sch II	O
9	Indian Pond Heron	*Ardeola grayii*	LC	Sch II	C
10	Grey Heron	*Ardea cinerea*	LC	Sch II	C
11	Purple Heron	*Ardea purpurea*	LC	Sch II	C
12	Cattle Egret	*Bubulcus ibis*	LC	Sch II	C
13	Great Egret	*Ardea alba*	LC	Sch II	C
14	Intermediate Egret	*Ardea intermedia*	LC	Sch II	C
15	Little Egret	*Egretta garzetta*	LC	Sch II	C
16	Black-headed Ibis	*Threskiornis melanocephalus*	NT	Sch II	C
17	Glossy Ibis	*Plegadis falcinellus*	LC	Sch II	C
18	Asian Openbill	*Anastomus oscitans*	LC	Sch II	C
19	Woolly-necked Stork	*Ciconia episcopus*	NT	Sch II	C
20	Little Cormorant	*Microcarbo niger*	LC	Sch II	C
21	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	Sch II	C
22	Black-winged Stilt	*Himantopus himantopus*	LC	Sch II	C
23	Little Ringed Plover	*Charadrius dubius*	LC	Sch II	C
24	Red-wattled Lapwing	*Vanellus indicus*	LC	Sch II	O
25	Bronze-winged Jacana	*Metopidius indicus*	LC	Sch II	O
26	Wood Sandpiper	*Tringa glareola*	LC	Sch II	C
27	Common Snipe	*Gallinago gallinago*	LC	Sch II	O
28	Brahminy Kite	*Haliastur indus*	LC	Sch II	C
29	Black Kite	*Milvus migrans*	LC	Sch II	C
30	Black-rumped Flameback	*Dinopium benghalense*	LC	Sch II	O
31	White-cheeked Barbet	*Psilopogon viridis*	LC	Sch II	F
32	Blue-tailed Bee-eater	*Merops philippinus*	LC	Sch II	I
33	Indian Roller	*Coracias benghalensis*	LC	Sch II	C

No	Common Name	Scientific Name	IUCN Status	WLPA Schedule	Feeding guild
34	Common Kingfisher	*Alcedo atthis*	LC	Sch II	C
35	Stork-billed Kingfisher	*Pelargopsis capensis*	LC	Sch II	C
36	White-throated Kingfisher	*Halcyon smyrnensis*	LC	Sch II	C
37	Rose-ringed Parakeet	*Psittacula krameri*	LC	Sch II	F
38	Indian Golden Oriole	*Oriolus kundoo*	LC	Sch II	O
39	Ashy Woodswallow	*Artamus fuscus*	LC	Sch II	I
40	Black Drongo	*Dicrurus macrocercus*	LC	Sch II	O
41	White-bellied Drongo	*Dicrurus caerulescens*	LC	Sch II	O
42	Bronzed Drongo	*Dicrurus aeneus*	LC	Sch II	O
43	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	LC	Sch II	O
44	Rufous Treepie	*Dendrocitta vagabunda*	LC	Sch II	O
45	House Crow	*Corvus splendens*	LC	Sch II	O
46	Large-billed Crow	*Corvus macrorhynchos*	LC	Sch II	O
47	Indian Paradise-flycatcher	*Terpsiphone paradisi*	LC	Sch II	I
48	Purple Sunbird	*Cinnyris asiaticus*	LC	Sch II	N
49	White-rumped Munia	*Lonchura striata*	LC	Sch II	G
50	Black-throated Munia	*Lonchura kelaarti*	LC	Sch II	O
51	Paddyfield Pipit	*Anthus rufulus*	LC	Sch II	I
52	Striated Swallow	*Cecropis striolata*	LC	Sch II	I
53	Wire-tailed Swallow	*Hirundo smithii*	LC	Sch II	I
54	Barn Swallow	*Hirundo rustica*	LC	Sch II	I
55	Red-whiskered Bulbul	*Pycnonotus jocosus*	LC	Sch II	O
56	Yellow-billed Babbler	*Argya affinis*	LC	Sch II	O
57	Chestnut-tailed Starling	*Sturnia malabarica*	LC	Sch II	O
58	Common Myna	*Acridotheres tristis*	LC	Sch II	O
59	Jungle Myna	*Acridotheres fuscus*	LC	Sch II	O
60	Oriental Magpie Robin	*Copsychus saularis*	LC	Sch II	O
61	Orange-headed Thrush	*Geokichla citrina*	LC	Sch II	O

O – Omnivore; C – Carnivore; I – Insectivore; G – Granivore; F – Frugivore; N – Nectarivore; LC – Least Concern; NT – Near Threatened.

Two Near Threatened species was observed in the study area.

Threskiornis melanocephalus **(Black-headed Ibis)**

Ciconia episcopus **(Woolly-necked Stork)**

Study site – Ayanchery wetland, Kozhikode District

Table 3: Checklist of Birds in the Ayanchery wetland

No	Common Name	Scientific Name	IUCN Status	WLPA Schedule	Feeding guild
I	**Order: Anseriformes**				
	Family: Anatidae				
1	Lesser Whistling Duck	*Dendrocygna javanica*	LC	Sch II	O
II	**Order: Columbiformes**				
	Family: Columbidae				
2	Rock Pigeon	*Columba livia*	LC	Sch IV	G
3	Spotted Dove	*Spilopelia chinensis*	LC	Sch II	G
III	**Order: Cuculiformes**				
	Family: Cuculidae				
4	Greater Coucal	*Centropus sinensis*	LC	Sch II	O
5	Pied Cuckoo	*Clamator jacobinus*	LC	Sch II	I
6	Asian Koel	*Eudynamys scolopaceus*	LC	Sch II	O
IV	**Order: Gruiformes**				
	Family: Rallidae				
7	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	Sch II	O
8	Purple Swamphen	*Porphyrio poliocephalus*	LC	Sch II	O
V	**Order: Pelicaniformes**				
	Family: Ardeidae				
9	Indian Pond Heron	*Ardeola grayii*	LC	Sch II	C
10	Grey Heron	*Ardea cinerea*	LC	Sch II	C
11	Purple Heron	*Ardea purpurea*	LC	Sch II	C
12	Cattle Egret	*Bubulcus ibis*	LC	Sch II	C
13	Great Egret	*Ardea alba*	LC	Sch II	C
14	Intermediate Egret	*Ardea intermedia*	LC	Sch II	C
15	Little Egret	*Egretta garzetta*	LC	Sch II	C
	Family: Threskiornithidae				
16	Black-headed Ibis	*Threskiornis melanocephalus*	NT	Sch II	C
17	Glossy Ibis	*Plegadis falcinellus*	LC	Sch II	C
VI	**Order: Ciconiiformes**				

	Family: Ciconiidae				
18	Asian Openbill	*Anastomus oscitans*	LC	Sch II	C
19	Woolly-necked Stork	*Ciconia episcopus*	NT	Sch II	C
VII	**Order: Suliformes**				
	Family: Phalacrocoracidae				
20	Little Cormorant	*Microcarbo niger*	LC	Sch II	C
21	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	Sch II	C
VIII	**Order: Charadriiformes**				
	Family: Recurvirostridae				
22	Black-winged Stilt	*Himantopus himantopus*	LC	Sch II	C
	Family: Charadriidae				
23	Little Ringed Plover	*Charadrius dubius*	LC	Sch II	C
24	Red-wattled Lapwing	*Vanellus indicus*	LC	Sch II	O
	Family: Jacanidae				
25	Bronze-winged Jacana	*Metopidius indicus*	LC	Sch II	O
	Family: Scolopacidae				
26	Wood Sandpiper	*Tringa glareola*	LC	Sch II	C
27	Common Snipe	*Gallinago gallinago*	LC	Sch II	O
IX	**Order: Accipitriformes**				
	Family: Accipitridae				
28	Brahminy Kite	*Haliastur indus*	LC	Sch I	C
29	Black Kite	*Milvus migrans*	LC	Sch II	C
X	**Order: Piciformes**				
	Family: Picidae				
30	Black-rumped Flameback	*Dinopium benghalense*	LC	Sch II	O
	Family: Megalaimidae				
31	White-cheeked Barbet	*Psilopogon viridis*	LC	Sch II	F
XI	**Order: Coraciiformes**				
	Family: Meropidae				
32	Blue-tailed Bee-eater	*Merops philippinus*	LC	Sch II	I
	Family: Coraciidae				
33	Indian Roller	*Coracias benghalensis*	LC	Sch II	C

	Family: Alcedinidae				
34	Common Kingfisher	*Alcedo atthis*	LC	Sch II	C
35	Stork-billed Kingfisher	*Pelargopsis capensis*	LC	Sch II	C
36	White-throated Kingfisher	*Halcyon smyrnensis*	LC	Sch II	C
XII	**Order: Psittaciformes**				
	Family: Psittaculidae				
37	Rose-ringed Parakeet	*Psittacula krameri*	LC	Sch II	F
XIII	**Order: Passeriformes**				
	Family: Oriolidae				
38	Indian Golden Oriole	*Oriolus kundoo*	LC	Sch II	O
	Family: Artamidae				
39	Ashy Woodswallow	*Artamus fuscus*	LC	Sch II	I
	Family: Dicruridae				
40	Black Drongo	*Dicrurus macrocercus*	LC	Sch II	O
41	White-bellied Drongo	*Dicrurus caerulescens*	LC	Sch II	O
42	Bronzed Drongo	*Dicrurus aeneus*	LC	Sch II	O
43	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	LC	Sch II	O
	Family: Corvidae				
44	Rufous Treepie	*Dendrocitta vagabunda*	LC	Sch II	O
45	House Crow	*Corvus splendens*	LC	Sch V	O
46	Large-billed Crow	*Corvus macrorhynchos*	LC	Sch II	O
	Family: Monarchidae				
47	Indian Paradise-flycatcher	*Terpsiphone paradisi*	LC	Sch II	I
	Family: Nectariniidae				
48	Purple Sunbird	*Cinnyris asiaticus*	LC	Sch II	N
	Family: Estrildidae				
49	White-rumped Munia	*Lonchura striata*	LC	Sch II	G
50	Black-throated Munia	*Lonchura kelaarti*	LC	Sch II	O
	Family: Motacillidae				
51	Paddyfield Pipit	*Anthus rufulus*	LC	Sch II	I

	Family: Hirundinidae				
52	Striated Swallow	*Cecropis striolata*	LC	-	I
53	Wire-tailed Swallow	*Hirundo smithii*	LC	Sch II	I
54	Barn Swallow	*Hirundo rustica*	LC	Sch II	I
	Family: Pycnonotidae				
55	Red-whiskered Bulbul	*Pycnonotus jocosus*	LC	Sch II	O
	Family: Leiothrichidae				
56	Yellow-billed Babbler	*Argya affinis*	LC	Sch II	O
	Family: Sturnidae				
57	Chestnut-tailed Starling	*Sturnia malabarica*	LC	Sch II	O
58	Common Myna	*Acridotheres tristis*	LC	Sch II	O
59	Jungle Myna	*Acridotheres fuscus*	LC	Sch II	O
	Family: Muscicapidae				
60	Oriental Magpie Robin	*Copsychus saularis*	LC	Sch II	I
	Family: Turdidae				
61	Orange-headed Thrush	*Geokichla citrina*	LC	Sch II	O

O - Omnivore; C - Carnivore; I - Insectivore; G - Granivore; F - Frugivore; N - Nectarivore; LC - Least Concern; NT - Nearly Threatened.

List Of Figures And Tables

A note on Sikkim's first Ramsar Site: Sacred Khecheopalri Lake Where Biodiversity, Spirituality and Culture Converge

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Abstract

This paper is an attempt to summarize all the scientific works undertaken in the Sacred Kcheopalri Lake of Sikkim Himalaya till date. It not only reviews past research works but also include authors' personal field observations and comments based on the frequent field visits during the year 2023-2024.

Introduction:

The Sacred Khecheopalri Lake [27°20'52.80"N to 27°21'6.04" N latitude and 88°11'11.50"E to 88°11'22.78"E longitude] situated in the West District of Sikkim at an altitude of 1820m above sea level is one of the most important and highly revered lakes in Sikkim (Fig. 1). It is approximately 34 km away from the District Headquarter, Gyalshing and 150 km from the capital city, Gangtok. The lake is surrounded by forested Ramam Watershed (named after Ramam Mountain) which covers an area of 12 km^2. However, only 91 hectares area actually drains directly into the lake and forms the lake watershed. This watershed is surrounded by a spectacular Khecheopalri Reserve Forest which falls under the forest type: 18B/C_1 *i.e.* East Himalayan Sub-tropical Wet Hill Forest (Champion and Seth 1968) dominated by Broadleaved Mixed Forest. Bisecting this Broadleaved Mixed Forest is a conspicuous vertical patch of *Alnus nepalensis* Forest (10-15m wide) running from top of the hill downwards eventually joining the Bog and Swamp Forest of the lake (Fig. 2). This pattern of vegetation is an outcome of *Alnus nepalensis,* a pioneer tree species in the Eastern Himalayas that had colonized landslips which occurred way back in the year 30th August, 1998. The lower foothill also witnessed interspersed fully-grown plantation of *Cryptomaria japonica* and *Cupressus cashmeriania* by the State Forest Department during 1780s. The ridges and fringe areas of the watershed supports human settlements under Yoksum administrative block further subdivided two revenue wards namely 'Gumpa Lamathang' and 'Chojo' comprising of 103 households with 349 populations. Our survey data from the household's questionnaire survey suggested that Lepchas community comprises of 90% of the total population while the others being Bhutias and Nepalese. Local people live in ethnic style wooden houses with main source of revenue from traditional agriculture, livestock rearing and recently some households are involved in eco-tourism.

Geography:

Khecheopalri lake was formerly a part of the revered landscape of "Demazong" a valley of rice and is more than 3500 years old (Jain 2000) and the real name of the lake is "Sho Dzo Sho" which means "Oh lady, Sit Here"; the lake's shape if viewed from the Tara Devi Cave, located on the top of the Dhuphuk hill resembles the impression of a left foot (Biate and Agrawala 2017). Local Buddhist belief that this is foot step of the goddess Tara Jetsun Dolma (the Buddha's mother) while the Hindus believe it to be Lord Shiva's footprint. However, scientific report points out that the lake represents the original neve region of the ancient hanging glacier, the depression being formed by the scooping action of the glacier (Raina 1966). This particular lake holds immense ecological, religious, spiritual and recreational significance to the people of Sikkim and hence had been declared as Protected Lake by the Government of Sikkim in the year 2001 (Notification no.701/Home/2001/ dated 20-09-2001).

Flora and Fauna:

The surrounding forests intercept precipitation, facilitates infiltration, enhance sub-surface water flow and provide continuous water to the lake. The upstream water also serves as a source for drinking water to the villages nearby. Two perennial and five seasonal streams drain into the lake from the watershed while only one outlet drains water out of the lake and finally joins another stream downward to form Khangchendzonga Waterfall - another tourist destination. The area is famous for its plethora of biodiversity. A total of 112 plant species, 17 mammalian species, 02 reptilian species, 07 fishes, 02 amphibians and 15 bird species were reported from the area (Jain, 2000). Lake and its bog vegetation (marsh) provide congenial site for resting to Trans-Himalayan migratory birds. A total of 07 migratory water birds were reported to visit particularly during winter season (November to March). The most common ones were *Anas crecca*, *Mergus merganser orientalis* and *Athya ferina* (Jain 2000). This result also corroborates with our field visits and their sightings (Fig. 3). Another scientific report titled inventorisation of flora of Khecheopalri lake and its surrounding forest was made that had documented 387 plant species distributed to 113 families and 278 genera which comprise of 185 shrubs/ herbs, 69 tree/small tree, 29 epiphytes/climbers, 54 species of ferns and its allies, 19 fungi and 30 orchids species (Biate and Agrawala 2017). They also reported 66 algal taxa belonging to 40 genera from different habitats of the lake and include 02 taxa of Cyanophyta/Cyanoprokaryota, 46 taxa of Chlorophyta and 18 taxa of Heterokontophyta. Latest documentation on floristic composition of aboveground vegetation and of the soil seed bank were undertaken in the lake watershed (91 ha) and in human settlement areas (Meena and Rai, 2021). This updated report documented 401 plant species (woody & non-woody) belonging to 234 genera and 111 families in the above-ground vegetation of which 160 plant species belonging to 132 genera and 65 families were able to form potential soil seed bank. Few extracts from previous studies pertaining to checklist of flora and fauna of the study area are presented (Table 1-3).

Mythology:

There is a strong belief among people that whosoever makes prayer and wishes at the lake, their wishes are fulfilled and hence earned the name "Wish fulfilling lake". The lake water is considered sacred which is used for various rites and rituals by people belonging to both the Hindu and Buddhist communities (Uprety and Sharma 2012). Regular rituals and prayers are performed by the monks and especially by local communities during the full moon day and new moon day. The lake hosts two main festivals "Chho-Tsho" and "Bhum-chu". "Chho-Tsho" festival falls in October every year as a thanksgiving festival to the presiding deity of the lake for protection and bestowing food to the local inhabitants where villagers collect money, perform rituals, and feast together; and "Bhum-chu" which takes place on the full moon of the first Buddhist month in February-March is a festival to worship the lake goddess to prevail peace and harmony throughout the Demazong area. During the Bhum-chu, idols (tormas) of gods made from flour, colors and butter are displayed, and monks and locals perform rituals for three days. Pilgrims place prayer flags around the lake. These traditions have been followed for generations and pilgrims from all districts of Sikkim, Darjeeling districts of West Bengal, Bhutan and Nepal visit the lake to perform puja and offering during Bhum-chu.

Ecotourism:

Blessed with stunning landscape, age-old monasteries, rich biodiversity, cultural heritage and sacred belief associated with it, Khecheopalri is rightly loved by travellers as large number of national and international tourists visit this pristine lake throughout the year for both pilgrimages and recreation thereby supporting tourism activity and contributing to local economy. An economic valuation of ecotourism of this sacred lake was carried out and reported 18,713 tourists to have visited the lake in 1998. Travel Cost Method (TCM) using local pilgrims' response put the sacredness value at US$ 30,186. The Contingent Valuation Method (CVM) estimation for all tourists gave US $ 46,940 for the maintenance and preservation of the lake (Maharana et al. 2000). Some visitors also go on trekking to nearby areas such as Dhuphok/Tara Devi cave, Melarapa cave and the Ekku cave for prayers and meditation purposes.

Threats:

However, over the years the longevity of the lake, its aquatic biodiversity and surrounding forest are under severe threat due to unregulated tourist inflow which had increased manifold. Moreover, the villagers derive and exploit the forest for meeting their firewood, fodder, small poles, vegetables and other medicinal plants requirements thereby exert pressure and create disturbances which in turn results in degradation and loss of biodiversity (Fig. 4 & 5). During peak tourist season, traffic jams outside the entrance gate, its associated noise pollution and litter nuisances are very high (Fig. 6). Inappropriate agricultural use and expansion of settlements in the catchment areas has increased sediment inflow, resulting in the shrinkage of lake from what is believed to be at least twice its current size a few decades back (Jain 2000). Some charismatic fauna found in the watershed includes the Himalayan Black bear (*Ursus thibetanus laniger*), barking deer (*Mountiacus muntjak*), yellow throated marten (*Martes flavigula*), Red panda (*Ailurus fulgens*), Goral (*Naemorhedus goral*) and Himalayan tahr (*Hemitragus jemlahicus*). As per our interviews, the villagers stated that sighting of these animals have become almost rare nowadays. They further indicated that sightings of bird species such as Sikkim's wedge-billed babbler locally called Bhakur (*Stachyris humei*), Himalayan Monal or Danphe (*Lophophorus impejanus*), Spiny babbler (*Turdoides nipalensis*) had become almost rare. Their absence may be attributed to the degradation and disturbances of forest in the watershed that might have led to the migration of these species further upwards where no disturbances exist. However, it is strongly believed that with the banning of transitional livestock rearing (Ghoat) in the forest by the forest department, especially the above birds' species frequently depended on the ticks, louses and bugs of livestock has dwindled in population and has moved upward in the higher elevation where such rearing system is still in practice.

Conservation:

In order to tackle these threats and improve the biodiversity of the Khecheopalri Lake, Khecheopalri Pokhri Sanrakshan Samiti (KPSS) was established in 2007 with the help of the district administration and the forest department. The Samiti's main functions are to protect the lake, control waste and to collect entry fees. Half of this revenue is used for carrying out its maintenance functions, and half goes to the Forest Department. Ecotourism is now being encouraged and promoted widely. Other measures like garbage management, visitor guidance and spreading environmental awareness, afforestation of the forest areas; prayers and offerings in the monastery instead of the lake; discouraging grazing in the catchment areas; implementation of proper management with involvement of local populace were also taken up. Recognizing its socio-ecological importance, the state government of Sikkim in 2004 had proposed this Khecheopari Lake and other two wetlands complex (The Tsomgo-Kupup and Gnathang Complex in East Sikkim and Tso Lhamu-Guru Dongmar-Gyam Tso-na Complex in North Sikkim) for their inclusion in the Ramsar list of international importance. However, this proposal was rejected citing insufficient data and expertise. Nevertheless, local government actively worked to meet Ramsar requirements, documenting historical ecology, cultural significance, and formally delineating these wetlands to highlight its importance at international level. As a result of collaborative efforts of the state Forest Department and other stakeholders, this lake has been designated as a Ramsar Wetland of International Importance on World Wetland Day, 2025 (https://www.indiatodayne.in/sikkim). This marks a significant milestone as the first Ramsar site in Sikkim, highlighting the state's commitment to environmental conservation. This Ramsar status will bring global attention and support, fostering sustainable management and enhanced conservation efforts.

Table 1: List of plants documented in the Khecheopalri lake watershed (Source: Jain, 2000)

Sl. No.	Name of Species	Family	Habit
1	*Acer campbellii* Hook.f. & Th.	Aceraceae	Tree
2	*Acer oblongum* Wall.	Aceraceae	Tree
3	*Achyranthes aspera* Linn.	Amaranthaceae	Herb
4	*Aconogonum molle* (D. Don) Hara	Polygonaceae	Under shrub
5	*Agapetes serpens* (Wight) Sleumer	Vacciniaceae	Under shrub
6	*Ageratum conyzoides* Linn.	Asteraceae	Herb
7	*Alnus nepalensis* D. Don	Betulaceae	Tree
8	*Alocasia sp.*	Araceae	Herb
9	*Anaphalis contorta* Hook.f.	Asteraceae	Herb
10	*Andromeda elliptica* Sieb. & Zucc.	Ericaceae	Tree
11	*Aporosa dioica* Muell. Arg	Euphorbiaceae	Tree
12	*Arisaema intermedium* Blume.	Araceae	Herb
13	*Artocarpus lakoocha* Roxb.	Moraceae	Tree
14	*Beilschmiedia sikkimensis* King.	Lauraceae	Tree
15	*Bidens pilosa* Linn.	Asteraceae	Herb
16	*Brachiaria eruciformis* Griseb	Poaceae	Herb
17	*Brassaiopsis mitis* C.B. Clarke	Araliaceae	Shrub
18	*Bryonia laciniosa* Linn.	Cucurbitaceae	Climber
19	*Castanopsis hystrix* A. DC.	Fagaceae	Tree
20	*Castanopsis tribuloides* A. DC.	Fagaceae	Tree
21	*Cedrela toona* Roxb.	Meliaceae	Tree
22	*Centella asiatica* (Linn) Urb.	Apiaceae	Herb
23	*Cinnamomum obtusifolium* Nees.	Lauraceae	Tree
24	*Cissus repanda* Vahl.	Vitaceae	Climber
25	*Citrullus colocynthis* Schrad.	Cucurbitaceae	Climber
26	*Colocasia sp.*	Araceae	Herb
27	*Commelina paludosa* Blume	Commelinaceae	Herb
28	*Cryptomeria japonica* (L.f.) D. Don	Taxodiaceae	Tree
29	*Cyanotis vaga* Schultes & Schultes f	Commelinaceae	Herb
30	*Cynodon dactylon* Linn.	Poaceae	Herb
31	*Cynoglossum glochidiatum* Wall.	Boraginaceae	Under shrub
32	*Cyperus rotundus* Miq.	Cyperaceae	Herb
33	*Cyperus sp.*	Cyperaceae	Herb
34	*Daphne involucrata* Wall.	Thymeliaceae	Under shrubs
35	*Dichroa febrifuga* Lour.	Hydrangiaceae	Shrub
36	*Diplazium umbrosum* Willd.	Athyriaceae	Herb
37	*Drymaria cordata* Willd.	Caryophyllaceae	Herb
38	*Dryopteris sp.*	Dryopteridaceae	Herb
39	*Edgeworthia gardneri* Meissn	Thymeliaceae	Tree
40	*Elatostema platyphyllum* Wedd.	Urticaceae	Herb
41	*Engelhardtia spicata* Bl.	Malpighiaceae	Tree
42	*Eupatorium cannabinum* Linn.	Asteraceae	Herb

Sl. No.	Name of Species	Family	Habit
43	*Eurya acuminata* Royle	Theaceae	Tree
44	*Evodia fraxinifolia* Hk. f	Rutaceae	Tree
45	*Ficus nemoralis* Wall.	Moraceae	Tree
46	*Fragaria nubicola* Lindley ex Lacaita	Rosaceae	Herb
47	*Galium sp.*	Rubiaceae	Herb
48	*Girardinia dicursifolia* (Link) Fris.	Ut1icaceae	Under shrub
49	*Gleichenia volubilis* Jungh.	Gleicheniaceae	Under shrub
50	*Gnaphalium hypoleucum* DC.	Asteraceae	Herb
51	*Gynura nepalensis* DC.	Asteraceae	Herb
52	*Hedychium ellipticum* Smith.	Zingiberaceae	Herb
53	*Hemiphragma heterophyllum* Wall.	Scrophulariaceae	Herb
54	*Hodgsonia heteroclita* Hook. f. & Th.	Cucurbitaceae	Climber
55	*Hydrangea aspera* D. Don	Hydrangiaceae	Shrub
56	*Hydrocotyle javanica* Thunb.	Apiaceae	Herb
57	*Impatiens stenantha* Hook. f.	Balsam inaceae	Herb
58	*Juglans regia* Linn.	Juglandaceae	Tree
59	*Laportea axillaris* Wight.	Urticaceae	Under shrubs
60	*Lecanthus peduncularis* (Royle)Wedd	Urticaceae	Herb
61	*Lindenbergia sp.*	Scroph u lariaceae	Herb
62	*Lycopodium sp.*	Lycopodiaceae	Herb
63	*Macaranga pustulata* King.	Euphorbiaceae	Tree
64	*Machilus edulis* King.	Lauraceae	Tree
65	*Machilus odoratissima* Kosterm .	Lauraceae	Tree
66	*Machilus sp.*	Lauraceae	Tree
67	*Maesa rugosa* Clarke	Myrsinaceae	Shrub
68	*Magnolia campbellii* Hk. f. & Th.	Magnoliaceae	Tree
69	*Mazus surculo*sus D.Don	Scrophulariaceae	Herb
70	*Melastoma normale* D. Don	Melasromataceae	Under shrub
71	*Michelia champaca* Linn.	Magnoliaceae	Tree
72	*Michelia lanuginosa* Wall.	Magnoliaceae	Tree
73	*Morus laevigata* Wall.	Moraceae	Tree
74	*Mussaenda frondosa* Wall.	Rubiaceae	Shrub
75	*Nasturtium officinale* R. Br.	Brassicaceae	Herb
76	*Oenanthe thomsoni* Clarke	Apiaceae	Herb
77	*Osbeckia stellata* Buch. Ham ex. D. Don	Melastomataceae	Herb
78	*Oxalis corniculata* Linn.	Oxalidaceae	Herb
79	*Pathos scandens* Linn.	Araceae	Climber
80	*Persicaria capitata* Gross.	Polygonaceae	Herb
81	*Pilea scripta* Wedd.	Urticaceae	Herb
82	*Pilea umbrosa* Wedd.	Urticaceae	Herb
83	*Piper boehmeriaejolia* Wall.	Piperaceae	Climber
84	*Piper longum* Linn.	Piperaceae	Climber
85	*Plantago erosa* Wall.	Plantaginaceae	Herb

Sl. No.	Name of Species	Family	Habit
86	*Plantago major* Linn.	Plantaginaceae	Herb
87	*Polygonum plebejum* Br.	Polygonaceae	Herb
88	*Polygonum sp.*	Polygonaceae	Herb
89	*Potentilla peduncularis* D. Don	Rosaceae	Herb
90	*Prunus cerasoides* D. Don	Rosaceae	Tree
91	*Quercus lamellosa* Smith.	Fagaceae	Tree
92	*Rhaphidophora glauca* Schott	Araceae	Climber
93	*Rhododendron arboreum* Sm.	Ericaceae	Tree
94	*Rhus succedanea* Linn.	Anacardiaceae	Tree
95	*Rubus ellipticus* Sm.	Rubiaceae	Under shrub
96	*Rubus paniculatus* Sm.	Rubiaceae	Under shrub
97	*Rumex nepalensis* Spreng	Pol ygonaceae	Herb
98	*Sambucus adnata* Wallich ex. DC.	Sambucaceae	Shrub
99	*Schima wallichii* Chois	Theaceae	Tree
100	*Selaginella sp.*	Selaginellaceae	Herb
101	*Smilax aspera* Linn.	Smilacaceae	Climber
102	*Spondias axillaris* Roxb.	Anacardiaceae	Tree
103	*Symingtonia populnea* R. Br.	Hamamelidaceae	Tree
104	*Symplocos theifolia* Don.	Symplocaceae	Tree
105	*Trevesia palmata* Vis.	Araliaceae	Tree
106	*Tupistra nutans* Wall.	Liliaceae	Herb
107	*Urtica dioica* Linn.	Urticaceae	Herb
108	*Vaccinium nummularia* C.B. Clarke	Ericaceae	Under shrub
109	*Vaccinium vacciniaceum* Sleumer	Ericaceae	Epiphyte
110	*Viburnum cordifolium* Wall.	Sambucaceae	Tree
111	*Viola canescens* Wall.	Violaceae	Herb
112	*Zanthoxylum acanthopodium* DC.	Ruraceae	Tree

Table 2: Faunal composition of the Khecheopalri lake watershed (Jain, 2000)

Sl. No.	Scientific name	Family	Common/local name
Avifauna			
1	*Gypaetus barbatus*	Accipitridae	Lanmergeier
2	*Megalaima franklinii*	Megalaimidae	Golden throated Barbet
3	*Cissa chinensis*	Corvidae	Common Green Magpie
4	*Cissa erythrorhyncha*	Corvidae	Red-billed Magpie
5	*Cissa fuvirostis*	Corvidae	Yellow-billed blue Magpie
6	*Dendrocitta formosae*	Corvidae	Himalayan treepie
7	*Dicrurus adsimilis*	Dicruridae	Fork-tailed Drongo
8	*Myophonus caeruleus*	Muscicapidae	Blue whistling thrush
9	*Ficedula westermanni*	Muscicpidae	Little pied flycatcher
10	*Actinodura strigula*	Leiothrichidae	Bar-throated Siva
11	*Heterophasia annectens*	Leiothrichidae	Sikkim chestnut trump sibea

Sl. No.	Scientific name	Family	Common/local name
12	*Picus flavinucha*	Picidae	Large yellow naped woodpecker
13	*Dendrocopos cathpharius*	Picidae	Crimson-breasted pied woodpecker
14	*Dendrocarpus dinopium shril*	Picidae	Goldenbacked three toed woodpecker
15	*Blythipicus pyrrhotis*	Picidae	Red earned woodpecker
Migratory birds			
1	*Anas crecca*	Anatidae	Common teal
2	*Aythya baeri*	Anatidae	Baer's pochard
3	*Mergus merganser orieantalis*	Anatidae	Eastern goosander
4	*Anser indicus*	Anatidae	Barheaded goose
5	*Phalacrocoxas fuscicollis*	Phalacrocoracidae	Indian Cormorant
6	*Todorna ferruginea*	Anatidae	Brahmini duck
7	*Aythya ferina*	Anatidae	Common pochard
Reptiles			
1	*Hemidactylus flaviviridis*	Gekkonidae	House gecko
2	*Calotes versicolor*	Agamidae	Common garden lizard
Mammals			
1	*Ailurus fulgens*	Ailuridae	Red panda
2	*Canis aureus*	Canidae	Jackal (Siyal)
3	*Vulpes vulpes*	Canidae	Red fox
4	*Macaca silenus*	Cercopithecidae	Lion tailed macaque (Suhukabu)
5	*Macaca assamensis*	Cercopithecidae	Assamese macaque (Suhu)
6	*Mountiacus muntjak*	Cervidae	Barking deer
7	*Hystrix indica*	Erethizontidae	Indian porcupine (Dumshi)
8	*Felis marmorata*	Felidae	Jungle cat (Sikmar)
9	*Felis bengalensis*	Felidae	Leopard cat
10	*Paradoxorus hermaphroditus*	Felidae	Common palm civet
11	*Herpestes vitticolis*	Herpistidae	Stripe necked mangoose
12	*Martes flavigula*	Musletidae	Yellow throated martin (Malsapra)
13	*Ratufa indica*	Sciuridae	Indian giant squirrel (Lotharkay)
14	*Ratufa bicolor*	Sciuridae	Malayan gaint squirrel
15	*Funambulus pennanti*	Sciuridae	Five striped palm squirrel
16	*Suncus marinus*	Soricidae	Grey musk shrew (Timzing)
17	*Viverra zibetha*	Viverridae	Large Indian civet

Table 3: Flora of Khecheopalri lake and its surrounding forest (Source: Biate and Agrawala, 2017)

Sl. No.	Name of the species	Family	Life form/Habit
1	*Acer campbellii* Hook.f. & Thomson ex Hiern	Sapindaceae	Tree
2	*Acer sikkimense* Miq.	Sapindaceae	Tree
3	*Achyranthes bidentata* Blume	Amaranthaceae	Herb
4	*Aconogonon molle* (D.Don) H. Hara	Polygonaceae	Shrub
5	*Acorus calamus* L.	Acoraceae	Herb
6	*Acrocarpus fraxinifolius*Wight & Arn.	Fabaceae	Tree

Sl. No.	Name of the species	Family	Life form/Habit
7	*Adiantum incisum* Forssk.	Adiantaceae	Fern
8	*Aeschynanthus hookeri* C.B.Clarke	Gesneriaceae	Epiphyte
9	*Aeschynanthus micranthus* C.B.Clarke	Gesneriaceae	Epiphyte
10	*Aeschynanthus* sp.	Gesneriaceae	Epiphyte
11	*Agapetes hookeri* (C.B.Clarke) Sleumer	Ericaceae	Shrub
12	*Agrimonia pilosa* Ledeb.	Rosaceae	Herb
13	*Agrostis triaristata* (Hook.f.) Bo	Poaceae	Herb
14	*Agrostophyllum callosum* Rchb.f.	Orchidaceae	Epiphyte
15	*Ainsliea latifolia* Kuntze	Asteraceae	Herb
16	*Ajuga macrosperma* Wall. ex Benth.	Lamiaceae	Herb
17	*Alcimandra cathcartii* (Hook.f. & Thomson) Dandy	Magnoliaceae	Tree
18	*Alnus nepalensis* D.Don	Betulaceae	Tree
19	*Anaphalis contorta* (D.Don) Hook.f.	Asteraceae	Herb
20	*Anthogonium gracile* Wall. ex Lindl.	Orchidaceae	Terrestrial
21	*Arachniodes coniifolia* (T Moore) Ching	Dryopteridaceae	Fern
22	*Ardisia macrophylla* Reinw. ex Blume	Myrsinaceae	Shrub
23	*Arisaema concinnum* Schott	Araceae	Herb
24	*Artemisia nigricans* Filatova & Ladygina	Asteraceae	Undershrub
25	*Arthromeris lachmanii* (Mett.) Ching	Polypodiaceae	Fern
26	*Arthromeris wallichiana* (Spreng.) Ching	Polypodiaceae	Fern
27	*Asplenium gueinzianum* Mett.ex. Kuhn	Aspleniaceae	Fern
28	*Asplenium pellucidum* Lam	Aspleniaceae	Fern
29	*Aspleniumn normale* D. Don	Aspleniaceae	Fern
30	*Athyrium himalaicum* Ching ex Mehra & Bir.	Athyriaceae	Fern
31	*Bauhinia vahlii* Wight & Am	Leguminosae	Shrubby climber
32	*Begonia cathcartii* Hook.f. & Thomson	Begoniaceae	Herb
33	*Belvisia henryi* (Hieron. & C.Chr.) Raym.	Polypodiaceae	Fern
34	*Belvisia spicata* (L.f.) Mirb. ex Saff	Polypodiaceae	Fern
35	*Berberis asiatica* Roxb. ex DC.	Berberidaceae	Shrub
36	*Berberis insignis* Hook.f. & Thoms.	Berberidaceae	Shrub
37	*Betula alnoides* Buch.-Ham.	Betulaceae	Tree
38	*Bidens biternata* (Lour.) Merr. & Sherff	Asteraceae	Herb
39	*Bidens pilosa* L.	Asteraccae	Herb
40	*Boehmeria clidemioides* Miq.	Urticaceae	Herb
41	*Boenninghausenia albiflora* (Hook.) Rchb. ex Meisn.	Rutaceae	Herb
42	*Bolelellus* sp.	Boletaceae	Mushroom
43	*Botrychium virginianum* (L.) Sw.	Ophioglossaceae	Fern
44	*Brassaiopsis hainla* (Buch.-Ham.) Seem.	Araliaceae	Tree
45	*Bridelia* sp.	Euphorbiaceae	Shrub
46	*Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Bercht. & J.Presl	Solanaceae	Shrub
47	*Bulbophyllum cauliflorum* Hook.f	Orchidaceae	Epiphyte
48	*Bulbophyllum leopardinum* (Wall.) Lindl.	Orchidaceae	Epiphyte

Sl. No.	Name of the species	Family	Life form/Habit
49	*Bulbophyllum reptans* Lindl.	Orchidaceae	Epiphyte
50	*Calanthe alismifolia* Lindl.	Orchidaceae	Terrestrial
51	*Calanthe puberula* Lindl.	Orchidaceae	Terrestrial
52	*Camellia kissi* Wall.	Theaceae	Shrub
53	*Camellia sinenis* (L.) Kuntze	Theaeene	Small tree
54	*Cantpylandra aurantiaca* Baker	Liliaceae	Herb
55	*Carex eleusinoides* Turcz. ex Kunth	Cyperaceae	Herb
56	*Carex filicina* Nees	Cyperaceae	Herb
57	*Carex insignis* Boott.	Cyperaceae	Herb
58	*Carlemannia congesta* Hook C	Carlemanniaceae	Herb
59	*Carpesium cernuum* L.	Asteraceae	Herb
60	*Castanopsis hystrix* Hook.f. & Thomson ex A. DC.	Fagaceae	Tree
61	*Cautleya gracilis* (Sm.) Dandy	Zingiberaceae	Herb
62	*Centella asiatica* (L.) Urb.	Apiaceae	Herb
63	*Cestrum fasciculatum* (Schltdl.) Miers	Solanaceae	Shrub
64	*Cestrum nocturnum* L.	Solanaceae	Shrub
65	*Chamabainia cuspidata* Wight	Urticaceae	Herb
66	*Chassalia curviflora* (Wall.) Thwaites	Rubiaceae	Shrub
67	*Chirita pumila* D.Don	Gesneriaceae	Herb
68	*Chirita urticifolia* Buch.-Ham. ex D.Don	Gesneriaceae	Herb
69	*Chrysosplenium nepalense* D.Don	Saxifragaceae	Herb
70	*Cinnamomum impressinervium* Meisn.	Lauraceae	Tree
71	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Lauraceae	Tree
72	*Cinnantonlum bejolghota* (Buch.-Ham.) Sweet	Lauraceae	Tree
73	*Cissampelos pareira* L.	Menispermaceae	Climber/Vines
74	*Clinopodium umbrosum* (M.Bieb.) Kuntze	Lamiaceae	Herb
75	*Coelogvne cristata* Lindl.	Orchidaceae	Epiphyte
76	*Coelogyne corymbosa* Lindl.	Orchidaceae	Epiphyte
77	*Commelina paludosa* Blume	Commelinaceae	Herb
78	*Coniogramme procera* Fée	Pteridaceae	Fern
79	*Conyza canadensis* (L.) Crong.	Asteraceae	Herb
80	*Coprinellus disseminalus* (Pers.) J.E. Lange	Psathyrellaceae	Mushroom
81	*Coprinellus* sp.	Psathyrellaceae	Mushroom
82	*Cortinarius* sp.	Cortinariaceae	Mushroom
83	*Crassocephalum crepidioides* (Benth.) S.Moore	Asteraceae	Herb
84	*Cryptochilus lutells* Lindl.	Orchidaceae	Epiphyte
85	*Cryptomeria japonica* (Thunb. ex L.f.) D.Don	Cupressaceae	Tree
86	*Cyanotis vaga* (Lour.) Schult. & Schult.f.	Commelinaceae	Herb
87	*Cyathea spinulosa* Wall. ex Hook.	Cyatheaceae	Tree fern
88	*Cymbidium longifolium* D. Don	Orchidaceae	Epiphyte
89	*Cynodon dactylon* (L.) Pers.	Poaceae	Herb
90	*Cynoglossum zeylanicum* (Vahl) Brand	Boraginaceae	Herb
91	*Cymbidium devonian* Paxton	Orchidaceae	Epiphyte

Sl. No.	Name of the species	Family	Life form/Habit
92	*Daldinia concentrica* (Bolton) Ces. & De Not.	Hypoxylaceae	Mushroom
93	*Dendrobium hookerianum* Lindl.	Orchidaceae	Epiphyte
94	*Dendrobium longicornu* Lindl.	Orchidaceae	Epiphyte
95	*Dendrobium ochreatum* Lindl.	Orchidaceae	Epiphyte
96	*Dennstaedtia scabra* (Wall.ex Hook.) Moore	Dennstaedtiaceae	Fern
97	*Desmodium multiflorum* DC.	Fabaceae	Shrub
98	*Desmodium podocarpum* DC.	Leguminosae	Undershrub
99	*Dicentra scandens* (D.Don) Walp.	Papavaraceae	Climber
100	*Dichroa febrifuga* Lour.	Hydrangeaceae	Shrub
101	*Dichrocephala integrifolia* (L.f.) Kuntze	Compositae	Herb
102	*Didymocarpus hookeri* C.B.Clarke	Gesneriaceae	Herb
103	*Digitaria cruciata* (Nees) A.Camus	Poaceae	Herb
104	*Diplazium doerleinii* (Luerss) Mark	Athyriaceae	Fern
105	*Diplazium javanicum* (Blume.) Makine	Athyriaceae	Fern
106	*Dircranopteris taiwansis* Ching & P. S. Chin	Gleicheniaeeae	Fern
107	*Duchesnea indica* (Jacks.) Focke	Rosaceae	Herb
108	*Dufrenoya granulata* (Hook.f. & Thomson ex A.DC.) Stauffer	Santalaceae	Shrub
109	*Dymaria villosa* Schltdl. & Cham.	Caryophyllaceae	Herb
110	*Edgeworthia gardneri* (Wall.) Meisn.	Thymeliaceae	Undershrub
111	*Ehretia wallichiana* Hook.f. & Thomson ex C.B.Clarke	Boraginaceae	Tree
112	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae	Tree
113	*Elaphoglossum marginatum* (Wall. Ex Fee) T. Moore	Dryopteridaceae	Fern
114	*Elatostema reticulatum* Wedd.	Urticaeae	Herb
115	*Elatostema sessile* J.R.Forst. & G.Forst.	Urticaeae	Herb
116	*Elatostema platyphyllum* Wedd.	Urticaeae	Herb
117	*Engelhardtia spicata* Lechen ex Blume	Juglandaceae	Tree
118	*Equisetum diffusum* D. Don	Equisetaceae	Fern
119	*Eragrostis nutans* (Retz.) Nees ex Steud.	Poaceae	Herb
120	*Eranthemum indicum* (Nees) C.B.Clarke	Acanthaceae	Shrub
121	*Eria coronaria* (Lindl.) Rchb.f.	Orchidaceae	Epiphyte
122	*Eria excavata* Lindl.	Orchidaceae	Epiphyte
123	*Eria spicata* (D.Don) Hand.-Mazz.	Orchidaceae	Epiphyte
124	*Erigeron karvinskianus* DC.	Asteraceae	Herb
125	*Eupatorium adenophorum* Hort.Berol. ex Kunth	Asteraceae	Shrub
126	*Eurya acuminata* DC.	Theaceae	Small tree
127	*Eurya cerasifolia* (D.Don) Kobuski	Theaceae	Tree
128	*Eurya japonica* Thunb.	Theaceae	Tree
129	*Evodia fraxinifolia* (Hook.) Benth.	Rutaceae	Tree
130	*Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br.	Hamamelidaceae	Tree
131	*Fagopyrum dibotrys* (D.Don) H.Hara	Polygonaceae	Herb
132	*Fagopyrum esculentum* Merr.	Polygonaceae	Herb
133	*Ficus neriifolia* Sm.	Moraceae	Tree

Sl. No.	Name of the species	Family	Life form/Habit
134	*Ficus roxhurghii* Steud.	Moraceae	Tree
135	*Flammulina velutipes* (Curtis) Singer	Physalacriaceae	Mushroom
136	*Fragaria indica* Andr.	Rosaceae	Herb
137	*Galeola lindleyana* (Hook.f. & Thomson) Rchb.f.	Orchidaceae	Saprophytic
138	*Galium asprellum* Michx.	Rubiaceae	Herb
139	*Galium elegans* Wall.	Rubiaceae	Herb
140	*Ganlinsoga parviflora* Cav.	Asteraceae	Herb
141	*Garuga floribunda* Decne.	Burseraceae	Tree
142	*Geranium nepalense* Sweel	Geraniaceae	Herb
143	*Girardinia diversifolia* (Link) Friis	Urticaceae	Herb
144	*Gleichenia gigantea* Wall. ex Hook.	Gleicheniaceae	Fern
145	*Gleichenia longissima* Blume	Gleicheniaceae	Fern
146	*Glochidion khasicum* Hook.f.	Euphorbiaceae	Small Tree
147	*Gnaphalium* sp.	Asteraceae	Herb
148	*Gonatanlhus pumilus* (D.Don) Engl. & K.Krause	Araceae	Herb
149	*Goodyera foliosa* (Lindl.) Benth. ex C.B.Clarke	Orchidaceae	Terrestrial
150	*Goodyera schlechtendaliana* Rchb.f.	Orchidaceae	Terrestrial
151	*Gymnopetalum chinense* (Lour.) Merr.	Cucurbitaceae	Climber
152	*Halenia elliptica* D.Don	Gentianaccae	Herb
153	*Hedychium gracile* Roxb.	Zingiberaceae	Epiphyte
154	*Hedyotis hispida* Retz.	Rubiaceae	Herb
155	*Helvetia elastica* Bull.	Helvellaceae	Mushroom
156	*Hemiphragma heterophyllum*Wall.	Scrophulariaceae	Herb
157	*Holboellia latifolia* Wall.	Lardinbalaceae	Climber
158	*Hoya fusca* Wall.	Asclepiadaceae	Subshrub
159	*Hoya linearis* Wall. ex D.Don	Asclepidiaceae	Herb
160	*Hydrangea aspera* D.Don	Hydrangiaceae	Small Tree
161	*Hydrangea heteromalla* D. Don	Saxifragaceae	Shrub
162	*Hydrangea macrophylla* (Thunb.) Ser,	Hydrangeaceae	Herb
163	*Hydrocotyle javanica* Thunb.	Apiaceae	Herb
164	*Hymenodictyon flaccidum* Wall.	Rubiaceae	Tree
165	*Hymenodictyon sp.*	Rubiaceae	Tree
166	*Hymenophyllum badium* Hook.f.	Hymenophyllaceae	Fern
167	*Hymenopogon parasiticus* Wall.	Rubiaceae	Shrub
168	*Hypericum dyeri* Render	Hypericaceae	Herb
169	*Hypericum filicaule* (Dyer) N.Robson	Polygonaceae	Herb
170	*Hypericum hookerianum* Wight & Arnott.	Hypricaceae	Herb
171	*Hypericum japonicum* Thunb.	Hypericaceae	Herb
172	*Hypolepis punctata* (Thunb.) Mett. ex Kuhn.	Hypolepidaceae	Fern
173	*Hypoxis aurea* Lour.	Hypoxidaceae	Herb
174	*Impatiens arguta* Hook.f. & Thomson	Balsam inncaene	Herb
175	*Impatiens drepanophora* Hook.f.	Balsaminaceae	Herb
176	*Impatiens radiata* Hook.f.	Balsaminaceae	Herb

Sl. No.	Name of the species	Family	Life form/Habit
177	*Indigofera dosua* Buch.-Hem. Ex D.Don	Fabaceae	Shrub
178	*Indigofera tomentosa* Eckl. & Zeyh.	Leguminosae	Shrub
179	*Isachne albens* Trin.	Poaceae	Herb
180	*Ixora athroantha* Bremek.	Rubiaceae	Tree
181	*Jasminum dispermum* Wall,	Oleaceae	Shrub
182	*Juglans regia* L.	Juglandaceae	Tree
183	*Juncus inflexus* L.	Juncaceae	Herb
184	*Knoxia sumatrensis* (Retz.) DC.	Rubiaceae	Subshrub
185	*Kuehneromyces mutabilis* (Schaeff.) Singer & A.H. Sm.	Strophariaceae	Mushroom
186	*Kyllinga brevifolia* Rottb.	Cyperaceae	Herb
187	*Lactifluus piperatus* (L.) Roussel	Russulaceae	Mushroom
188	*Lactifluus dissitus* Van de Putte, K. Das & Verbeken	Russulaceae	Mushroom
189	*Laportea ternlinalis* Wight	Urticaeae	Herb
190	*Lasianthus biermannii* King ex I-look.f.	Rubiaceae	Shrub
191	*Lecanthus peduncularis* (Wall. ex Royle) Wedd.	Urticaceae	Herb
192	*Lepidogrammitis subrostrata* Ching	Polypodiaceae	Fern
193	*Lepisorous loriforms* (Wall. ex Mett.) Ching	Polypodiaceae	Fern
194	*Lepisorus scolopendrium* (Ham.-ex D.Don) Mehra & Bis	Polypodiaceae	Fern
195	*Lepisorus sublinearis* (Baker ex Takeda) Ching	Polypodiaceae	Fern
196	*Leynmaphyllum rostratum* (Burm. f) Tagawa	Polypodiaceae	Fern
197	*Lindsaea odorata* Roxb.	Lindsaeaceae	Fern
198	*Liparis bootanensis* Griff.	Orchidaceae	Epiphyte
199	*Liparis resupinata* Ridl.	Orchidaceae	Epiphyte
200	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	Fagaceae	Tree
201	*Lithocarpus pachyphyllus* (Kurz) Rehder	Fagaccae	Tree
202	*Litsea citrata* Blume	Rutaceae	Tree
203	*Lobelia angulata* G.Forst.	Lobeliaceae	Herb
204	*Lonicera glabrata* Wall.	Caprifoliaceae	Shrub
205	*Lonicera magnibracteata* M.P.Naya & Giri	Caprifoliaceae	Shrub
206	*Lycoperdon perlutum* Pers.	Agaricaceae	Mushroom
207	*Lycopodium japonicum* Thunb.	Lycopodiaceae	Fern
208	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	Tree
209	*Lysimachia dubia* Aiton	Primulaceae	Herb
210	*Lysimachia laxa* Baudo	Primulaceae	Herb
211	*Lysimachia ramosa* Wall.ex Duby	Primulaceae	Herb
212	*Machilus edulis* King ex Hook.f.	Lauraceae	Tree
213	*Maesa chisia* Buch.-Ham. ex D. Don	Primulaceae	Shrub
214	*Maesa rugosa* C.B. Clarke	Primulaceae	Shrub
215	*Magnolia camphellii* Hook.f. & Thomson	Magnoliaceae	Tree
216	*Mallotus phillipinensis* (Lam.) Mull. Arg.	Euphorbiaceae	Tree
217	*Mazus surculosus* D.Don	Mazaceae	Herb
218	*Medinilla rubicunda* (Jack) Blume	Melastomataceae	Epiphyte
219	*Melissa axillaris* (Benth.) Bakh.f.	Lamiaceae	Herb

Sl. No.	Name of the species	Family	Life form/Habit
220	*Michelia doltsopa* Buch.-Ham. ex DC.	Magnoliaceae	Tree
221	*Microsorum membranaceum* (D.Don) Ching	Polypodiaceae	Fern
222	*Monachosorum henryi* H. Christ	Dennstaedtiaceae	Fern
223	*Monachosorum subdigitatum* (Blume) Kuhn	Dennstaedtiaceae	Fern
224	*Morus indica* L.	Moraceae	Tree
225	*Mucidula mucida* (Schrad.) Pat.	Physalacriaceae	Mushroom
226	*Mussaenda macrophylla* Wall.	Rubiaceae	Shrub
227	*Nasturtium officinale* R.Br.	Brassiceae	Herb
228	*Neanotis gracilis* (Hook. f.) Lewis	Rubiaceae	Herb
229	*Neillia rubiflora* D.Don	Rosaceae	Shrub
230	*Neillia thrysiflora* D.Don	Rosaceae	Shrub
231	*Nephrolepis cordifolia* (L.) C. Presl	Nephrolepidaceae	Fern
232	*Nicandra physalodes* (L.) Gaertn.	Solanaceae	Herb
233	*Notochaete hamosa* Benth.	Lamiaceae	Herb
234	*Nyssa javanica* (Blume) Wangerin	Nyssaceae	Tree
235	*Odontosoria chinensis* (L.) J. Sm.	Lindsaeaceae	Fern
236	*Oenanthe thomsonii* C.B. Clarke	Apiaceae	Herb
237	*Oleandra wallichii* (Hook.) C. Presl	Oleandraceae	Fern
238	*Onychium cryptogrammoides* Christ.	Pteridaceae	Fern
239	*Ophiorrhiza fasciculata* D.Don	Rubiaceae	Herb
240	*Ophiorrhiza heterostyla* Dunn.	Rubiaceae	Herb
241	*Ophiorrhiza rugosa* Wall.	Rubiaceae	Herb
242	*Ophiorrhiza treutleri* Hook.f.	Rubiaceae	Herb
243	*Ophiorrhiza fasiculata* D.Don	Rubiaceae	Herb
244	*Oplismenus compositus* (L.) P.Beauv.	Poaceae	Herb
245	*Osbeckia stellata* Buch.-Ham. ex Ker Gawl.	Melastomataceae	Shrub
246	*Oudemansiella mucida* (Schrad.) Hohn.	Physalacriaceae	Mushroom
247	*Oxalis corniculata* L.	Oxiladaceae	Herb
248	*Oxyspora paniculata* (D. Don) DC.	Melastomataceae	Shrub
249	*Paris formosana* Hayata	Melanthiaceae	Herb
250	*Parthenocissus himalayana* (Royle) Planch.	Vitaceae	Climber
251	*Passiflora edulis* Sims	Passifloracea	Climber
252	*Paxillus sp.*	Paxillaceae	Mushroom
253	*Pentapanax fragrans* (D.Don) Ha	Araliaceae	Tree
254	*Peperomia reflexa* Kunth	Piperaceae	Herb
255	*Peranema cyatheoides* D.Don	Dryopteridaceae	Fern
256	*Persea fructifera* Kosterm.	Lauraceae	Tree
257	*Persicaria capitata* (Buch.-Ham. ex D.Don) H.Gross	Polygonaceae	Herb
258	*Persicaria dolichopoda* (Ohki) Nakai	Polygonaceae	Herb
259	*Persicaria hydropiper* (L.) Delarbre	Polygonaceae	Herb
260	*Persicaria nepalensis* (Meisn.) Miyabe	Polygonaceae	Herb
261	*Persicaria polystachya* Opiz.	Polygonaceae	Herb

Sl. No.	Name of the species	Family	Life form/Habit
262	*Persicaria protermissa* (Hook.f.)	Polygonaceae	Herb
263	*Persicaria rumemata* (Buch.-Ham. ex D.Don) H.Gross	Polygonacene	Herb
264	*Persicaria runcinata* (Buch.-Ham. ex D. Don) H. Gross	Polygonaceae	Herb
265	*Persicaria tenella* (Blume) H. Hara	Polygonaceae	Herb
266	*Phaelaenopsis taenialis* (Hook.f.) Christenson & Pradhan	Orchidaceae	Epiphyte
267	*Phaius tankervilleae* (Banks) Blume	Orchidaceae	Terrestrial
268	*Phlomoides hamosa* (Benth.) Mathiesen	Lamiaceae	Herb
269	*Pholidota pallida* Lindl.	Orchidaceae	Epiphyte
270	*Photinia integrifolia* Lindl.	Rosaceae	Shrub/Epiphyte
271	*Pilea anisophylla* (Hook. f.) Wedd.	Urticaceae	Herb
272	*Pilea scripta* (Buch.-Ham. Ex D. Don) Wedd.	Urticaeae	Herb
273	*Pilea symmeris* Wedd.	Urticaeae	Herb
274	*Pilea umbrosa* Blume	Urticaeae	Herb
275	*Piper hamiltonii* C.D.C.	Piperaceae	Climber
276	*Piper mullesua* Buch.-Ham.	Piperaceae	Climber
277	*Piper suipigua* Buch.-Ham. ex D. Don	Piperaceae	Climber
278	*Plagiogyria pycnophylla* (Kunze) Mett.	Plagiogyriaceae	Fern
279	*Plantago erosa* Wall.	Plantaginaceae	Herb
280	*Plantago major* L.	Plantaginaceae	Herb
281	*Plectranthus mollis* (Aiton.) Spreng	Lamiaceae	Herb
282	*Pleione praecox* (Sm.) D. Don	Orchidaceae	Epiphyte
283	*Poa annua*	Poaceae	Herb
284	*Polygala arillata* Buch.-Ham ex D.Don	Polygonaceae	Shrub
285	*Polypodales amoena* (Wall. Ex Mett.) Ching P.S.Chin	Polypodiaceae	Fern
286	*Polypodiodes hendersonii* S.G. Lu	Polypodiaceae	Fern
287	*Polypodiodes lachnopus* (Wall. Ex Hook) Ching	Polypodiaceae	Fern
288	*Polystichum lactum* C.Pres	Dryopteridaceae	Fern
289	*Polystichum lentum* (D. Don) T. Moore	Dryopteridaceae	Fern
290	*Polygonatum oppositifolium* (Wall.) Royle	Liliaceae	Epiphyte
291	*Potentilla lineata* Trev.	Rosaceae	Herb
292	*Potentilla mooniana* Wight	Rosaceae	Herb
293	*Potentilla peduncularis* D.Don	Rosaceae	Herb
294	*Potentilla polyphylla* Wall. Ex Lehm.	Rosaceae	Herb
295	*Potentilla sundaica* (Blume) Kuntz	Rosaceae	Herb
296	*Pouzolzia hirta* Blume ex Hassk.	Urticaeae	Herb
297	*Pouzolzia sanguinea* (Blume) Merr	Urticaceae	Herb
298	*Prenanthes sp.*	Asteraceae	Herb
299	*Procris cernata* C.B.Robinson	Urticaceae	Herb
300	*Prunus cerasoides* D.Don	Rosaceae	Tree
301	*Prunus nepalensis* Hook.f.	Rosaceae	Tree
302	*Pseudophegopteris aurita* (Hook.) Ching	Thelypteridaceae	Fern
303	*Pteris biaurita* L.	Pteridaceae	Fern

Sl. No.	Name of the species	Family	Life form/Habit
304	*Pteris scabirigens* Frs. Jenk.	Polypodiaceae	Fern
305	*Pteris spinescens* C.Presl.	Polypodiaceae	Fern
306	*Pteris vittata* L.	Selaginelaceae	Fern
307	*Pyrrosia heteractis* (Mett. Ex Kuhn) Ching	Polypodiaceae	Fern
308	*Pyrrosia lingua* (Thumb.) Farwell.	Polypodiacene	Fern
309	*Pyrularia edulis* (Wall.) A. DC.	Santalaceae	Tree
310	*Quercus lineata* Blume	Fagaeeae	Tree
311	*Ranunculus diffusus* DC.	Ranunculaceae	Herb
312	*Rhaphidophora decursiva* (Roxb.) Schott	Araceae	Epiphyte
313	*Rhaphidophora glauca* (Wall.) Schott	Araceae	Climber
314	*Rhododendron arboreum* Sm.	Ericaceae	Tree
315	*Rhododendron dalhousieae* Hook. f.	Ericaceae	Epiphytic/Shrub
316	*Rhododendron griffithianum* Wight	Ericaceae	Small tree
317	*Rhus chinensis* Miller.	Ancardiaceaae	Small tree
318	*Rhus hookeri* K.C. Sahni & Bahadur	Anacardiaceae	Tree
319	*Rhus semiliata* Murray	Anacardiaceae	Tree
320	*Rhus succedanea* L.	Anacardiaceae	Tree
321	*Rubus ellipticus* Sm.	Rosaceae	Shrub
322	*Rubia manjith* Roxb. ex Fleming	Rubiaceae	Climber
323	*Rubus paniculatus* Sm.	Rosaceae	Shrub
324	*Rubus rugosa* Smith.	Rosaceae	Shrub
325	*Rubus indotibetanus* Koidz.	Rosaceae	Shrub
326	*Rumex nepalensis* Spreng.	Polygonaceae	Herb
327	*Russula albonigra* (Krombh.) Fr.	Russulaceae	Mushroom
328	*Russula dubdiana* K. Das, Atri & Buyck	Russulaceae	Mushroom
329	*Russula nigricans* Fr.	Russulaceae	Mushroom
330	*Russula senecis* S.Imai	Russulaceae	Mushroom
331	*Sabia campanulata* Wallich ex Roxb.	Sabiaceae	Climber
332	*Sambucus adnata* Wall. ex DC.	Adoxaceae	Small tree
333	*Sambucus canadensis* L.	Adoxaceae	Small tree
334	*Sambucus wighliana* Wall. ex Wight & Arn.	Adoxnceae	Small tree
335	*Sanicula elata* Buch.-Ham.	Apiaceae	Herb
336	*Sarcopyramis napalensis* Wall.	Melastomataceae	Herb
337	*Saurauia napaulensis* DC.	Saurariaceae	Tree
338	*Schima wallichii* Choisy	Theaceae	Tree
339	*Scurrula parasitica* L.	Loranthaceae	Shrub
340	*Selaginella monospora* Spring	Selaginellaceae	Fern
341	*Setaria palmifolia* (J.Koenig) Stapf	Urticaceae	Herb
342	*Setaria pumila* (Poir.) Roem. & Schult.	Poaceae	Herb
343	*Smilax perfoliata* Lour.	Smilacaceae	Climber
344	*Smilax rigida* Wall. Ex Kunth.	Smilaceae	Climber
345	*Solanum americanum* var. *nodiflorum* (Jacq.) Edmonds	Solanaceae	Herb
346	*Solanum viarum* L.	Solanaceae	Herb

Sl. No.	Name of the species	Family	Life form/Habit
347	*Sphenomeris chinensis* (L.) Maxon	Lindsaeaceae	Fern
348	*Spiranthes sinensis* (Pers.) Ames	Orchidaceae	Terrestrial
349	*Sporoholus diandrus* (Retz.) P.Bcauv.	Poaceace	Herb
350	*Stephania elegans* Hook.f. & Th.	Menispermaceae	Climber
351	*Stephania glabra* (Roxb.) Miers	Menispermaceae	Climber
352	*Streptopus simplex* D.Don	Liliaceae	Herb
353	*Strobilanthes sp.*	Acanthaceae	Herb
354	*Swertia bimaculata* (Siebold & Zucc.) Hook. f. & Thomson ex C.B. Clarke	Gentianaceae	Herb
355	*Swertia chirita* (Flem.) Karst	Gentianaceae	Herb
356	*Symoplocos dryophila* C.B. Clarke	Symplocaceae	Tree
357	*Symplocos caudata* Wall. ex G. Don	Symplocaceae	Tree
358	*Symplocos glomerata* King ex C.B. Clarke	Symplocaceae	Tree
359	*Symplocos lucida* (Thunb.) Siebold & Zucc.	Symplocaceae	Tree
360	*Synotis cappa* (Buch.-Ham. ex D.Don) C.Jeffrey & Y.L.Chen	Asteraceae	Shrub
361	*Tainia minor* Hook.f.	Orchidaceae	Epiphyte
362	*Tetradium fraxinifolium* (Hook. f.) T.G. Hartley	Rutaceae	Tree
363	*Tetrastigma bractolatum* (Wall.) Planchen	Vitaceae	Climber
364	*Tetrastigma rumicispermum* (M.A. Lawson) Planch.	Vitaceae	Climber
365	*Tetrastigma serrulatum* (Roxb.) Planch.	Vitaceae	Climber
366	*Thelephora* sp.	Thelephoraceae	Mushroom
367	*Thelypteris flaccida* (Blume) Ching	Thelypteridaceae	Fern
368	*Thunbergia lutea* T. Anderson	Acanthaceae	Epiphyte
369	*Toona ciliata* M.Roem.	Meliaceae	Tree
370	*Torenia violacea* (Azoala ex Blaneo) Penell	Scrophulariaceae	Herb
371	*Trichocoma paradoxa* Jungh.	Trichocomaceae	Mushroom
372	*Trichosanthes lepiniana* (Naudin) Cogn.	Cucurbitaceae	Climber
373	*Tupistra nutans* Wall. ex Lindl.	Liliaceae	Herb
374	*Vaccinium dunalianum* Wight	Ericaceae	Shrub
375	*Vaccinium nummularia* Hook. f. & Thomson ex C.B. Clarke	Ericaeae	Shrub
376	*Vaccinium vacciniaceum* (Roxb.) Sleumer	Ericaceae	Epiphyte
377	*Vandopsis undulata* (Lindl.) J.J. Sm.	Orchidaceae	Epiphyte
378	*Viburnum cylindricum* D. Don.	Caprifoliaceae	Shrubs/Small Tree
379	*Viburnum erubescens* Wall.	Adoxaceae	Small tree
380	*Vicia hirsuta* (L.) Gray	Fabaceae	Herb
381	*Viola hamiltoniana* D. Don	Violaceae	Herb
382	*Vittaria elongata* Sw	Pteridaceae	Fern
383	*Vittaria flexuosa* Fee	Pteridaceae	Fern
384	*Wightia speciosissima* (D. Don) Merrill	Scrophulariaceae	Tree
385	*Zanthoxylum acanthopodium* DC.	Rutaceae	Shrub
386	*Zanthoxylum oxyphyllum* Edgew.	Rutaceae	Shrub
387	*Zephyranthes carinata* Herb.	Amaryllidaceae	Herb

Some Field Photographs of the Study Site

Fig.1: A view of Khecheopalri Lake showing the surrounding forest with prayer flags.

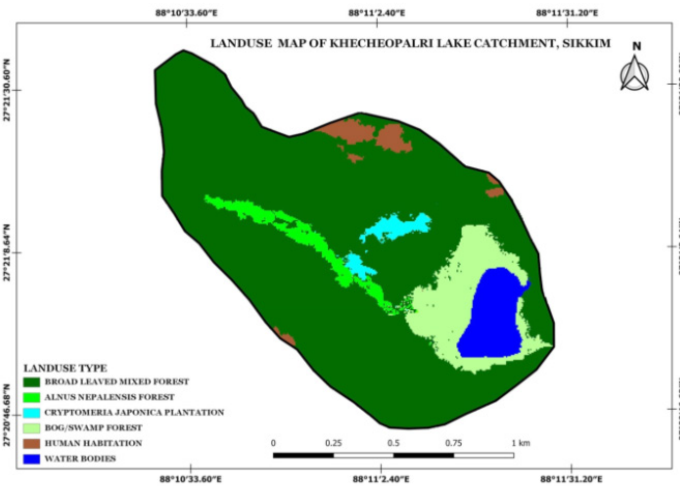

Fig. 2: Map showing watershed of Sacred Khecheopalri Lake and other land use land cover.

Fig. 3: Migratory bird (*Mergus merganser*)

Fig. 4: Livestock grazing inside the forest.

Fig. 5: Extraction of small poles from the forest.

Fig. 6: Entrance gate with tourists and monastery behind.

REFERENCES

- **Biate, D.L. and Agrawala, D.K.** (2017) Inventorisation of flora of Khecheopalri Lake and its surrounding forest. A Scientific Report by Forest, Environment & Wildlife Management, Government of Sikkim and Botanical Survey of India, Sikkim Himalayan Regional Center, Gangtok,36p.
- **Jain, Alka** (2000). Study of sacred Khecheopalri Lake ecosystem in the Sikkim Himalaya. PhD. thesis. University of North Bengal, Raja Rammohanpur, P.O. North Bengal University, West Bengal-734430, India, 212pp.
- **Maharana, I., Rai, S.C., and Sharma, E.** (2000) Valuing ecotourism in a Sacred Lake of Sikkim Himalaya, India. *Environmental Conservation* 27(3): 269-277.
- **Meena, D.K. and Rai, P.** (2021) Studies on natural regeneration, diversity and distribution of soil seed banks and their relationship with above-ground vegetation in watershed of Sacred Khecheopalri Lake of Sikkim. NMHS-Fellowship Project. ICFRE-Rain Forest Research Institute, Jorhat-Assam, 145p.
- **Raina, K.V.,** Geological mapping in the western part of Sikkim. Geological Survey of India, Eastern Region, Calcutta, 1966, pp. 14.
- **Uprety, I.M. and Sharma, G.** (2012) Cultural attributes, economic valuation and community conservation in holy Kchecheopalri Lake of Sikkim in the Eastern Himalaya. In Cultural landscapes- The basis for linking biodiversity conservation with the sustainable development (eds. Ramakrishnan, P.S., Saxena, K.G., Rao, K.S. and Sharma, G.), UNESCO, New Delhi, India, 202p.
- https://www.indiatodayne.in/sikkim/story/sikkims-khecheopalri-lake-declared-ramsar-wetland-of-international-importance-1164645-2025-02-02

Management of a fracture of pterygopalatine bone in Indian Spectacled Cobra (*Naja naja*): A Case Report

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Introduction:

CARE guidelines were used for drafting this case report. Snake human interaction poses an important yet challenging issue worldwide. Snakebite causes over 125,000 deaths and 400,000 permanent disabilities worldwide every year. India alone accounts for an average of approximately 58,000 annual snakebite related deaths (Salim et al, 2024). Anthropocentric causes like human encroachment and intrusion of snake dwellings are causing untoward interactions (Vidhya et al, 2023). Snake rescuers spread across urban and sub-urban areas work with no incentive most of the times; thereby causing inconsistent work or lack of reporting of snake injuries. There are various causes of traumatic injuries in snakes like road traffic accidents, human inflicted trauma due to scare, dog bites or even excavation work related injuries (Nithin, 2022). The Indian Spectacled Cobra (*Naja naja*) is widely distributed across India and is one of the 'Big 4' venomous species of snakes. It is seen near rice and other fields which have plenty of rats and niches for inhabitation. Cobras are hunted for skin and killed out of fear. The Indian Wildlife (Protection) Act 1972 has safeguarded the cobra under Schedule II.

Our case shows an injury inflicted by humans. The cobra was hit on its head with a stick while the snake was seen in a household. The household later contacted a snake rescuer who rescued the cobra and brought it to Ela Foundation and Maharashtra Forest Department's Villoo C Poonawalla Hospital for Wildlife or Ela Transit Treatment Center (TTC).

Patient information:

Before getting the cobra to ETTC on 4th August 2022, the snake rescuer had it under observation hoping for a recovery and speedy release. But refusal of the cobra to accept food and bleeding from the mouth prompted the rescuer to bring it to ETTC. On admission the cobra showed no external injuries or abnormalities. However, we observed intra-oral bleeding when the cobra spread its hood. The snake rescuer had not undertaken any intervention prior to the admission.

Clinical findings and Diagnostic assessment:

There are several ways of restraining venomous reptiles (Antonio, 2015). Amongst them we employed tube restraint. Pilstrom tong was used to harness control over the head. Manual restrain (pinning behind the head or three finger grip) was employed for head from tube. But this was done in addition to tube restraint on account of being unsafe owing to accidental movement and thereby envenomation. The restrain was done by a trained handler. Fergusson- Ackland mouth gag was used for keeping mouth open. Anti- puncture gloves were worn through the entire procedure.

Intra-oral clinical examination revealed a bony fragment jutting from the roof of the mouth through an ulcer which was the cause of recurrent bleeding. Another small laceration was seen on the floor of the mouth. Intra-oral radiography was employed to diagnose the jaw fracture. We used Vattech Size 0 sensor and Allerio Neo Handheld Portable X-ray machine for radiography. Radiograph revealed a fracture of pterygopalatine bone with a partially displaced sharp end of the fragment jutting out from the roof of the mouth.

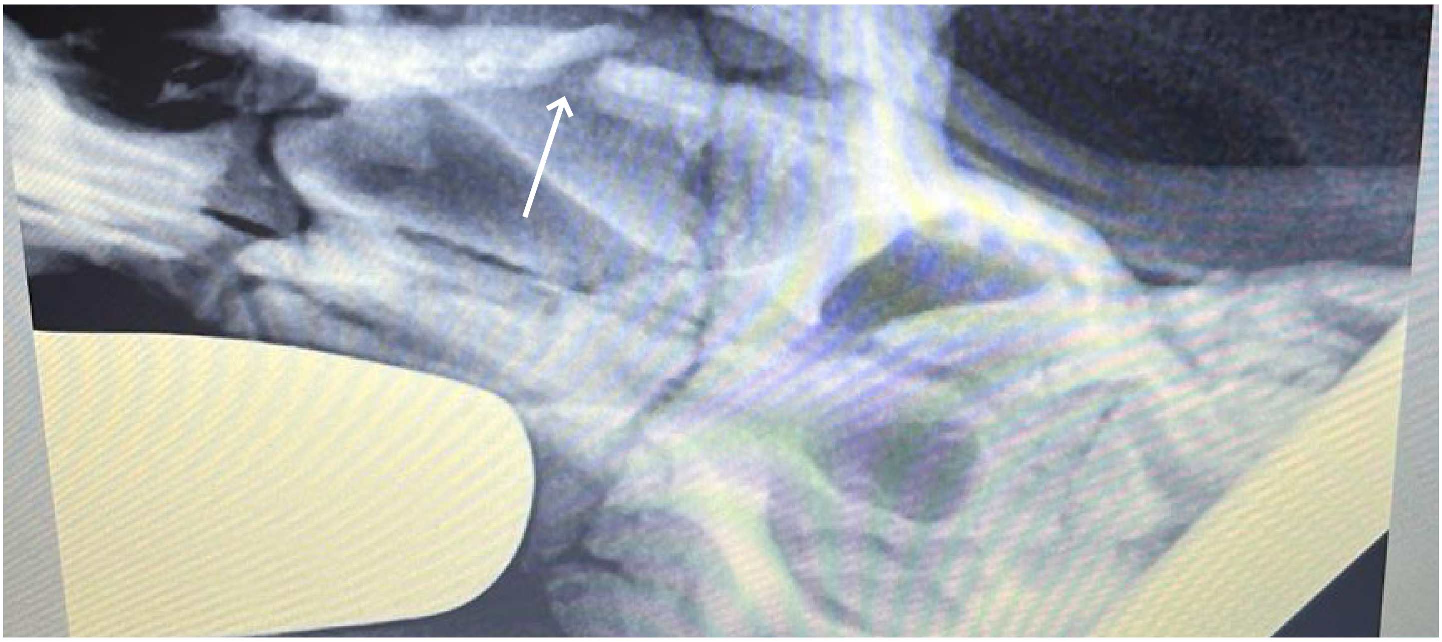
Therapeutic interventions:

After ascertaining pterygopalatine bone fracture and ruling out any other injury, we decided to trim the projecting segment. 2% Lignocaine was used as infiltration local anesthesia. A bone rongeur was used to sever small projecting segment. The fragment was reduced. No other fixation or wiring was possible owing to the very small size of jaw bones. Secondary healing and callous formation were expected. The proximate and correct cause of intra-oral bleeding was addressed and treated with this procedure. A post operative analgesia with local infiltration was administered. No antibiotics were used. Analgesia in reptiles still remains to be an enigma hence was not considered. (Sladky and mans, 2012). However, Inj. Meloxicam 0.2 mg/kg IM was administered for

Rescued Indian Spectacled Cobra *(Naja naja).*

Injury to the roof of the mouth with fracture fragment jutting out.

analgesia (Maders and Divers, 2005). The entire procedure was completed quickly. No feed was given on the immediate post-operative day. Boiled eggs were started as feed from the second post-operative day until release after 15 days. No intra-oral bleeding was noted after the post op 1st day. Cobra started feeding and had uneventful recovery. Cobra was successfully re-wilded in the same natural and regional habitat from where it was rescued and it swiftly disappeared in the habitat.



X-Ray of palate showing fracture of Pterygopalatine bone.

Discussion:

No previous reports of successful treatment of a fracture of the skull bone of *Naja naja* were found. Previous records describe surgical management of luxated mandible and lacerated jaw in an Indian Rock Python (*Python molurus molurus*) (Sarangom et al, 2022). Modified mini plates for spine fractures of snakes have been used (Nithin, 2022). Terminal tail fracture management by tail amputation is also documented (Jadhav, 2007). The present case could be the first report of diagnosis and successful treatment of a fracture of pterygopalatine bone in an Indian Spectacled Cobra.

References:

- **Salim A, Williams J, Almeida JR, Chandrasekharuni G, Williams HF, Vaiyapuri R, Vaiyapuri M, Viswanath R, Annamalai T, Patel K, Thirumalaikolundusubramanian P.** (2024). Challenges in rescuing snakes to protect human lives and promote snake conservation in Tamil Nadu, India. PLOS Neglected Tropical Diseases. Sep 17;18(9):e0012516.
- **Vidhya VJ, Sarangom SB, Mathai VM, Dharamshaw CA, Dominic S.** (2023). Snake-human conflict: rise in presentation of injured snakes at the Referral Veterinary Hospital in Kannur, Kerala, India. ZOO'S PRINT. Oct 21;38(10):03-8.
- **Sarangom SB, Nair SL, KS S, Mathai VM, PA A, Varghese R, NC S, Sundaran S.** (2022). Surgical management of luxated mandible and lacerated jaw in an Indian rock python (Python molurus molurus). Journal of Indian Veterinary Association. Dec 1;20(3).
- **Nithin K.** Surgical Management Of Traumatic Spinal Injuries In Snakes Using Modified Microplate Spinal Fixation Technique (Doctoral Dissertation, Kerala Veterinary And Animal Sciences University).
- **Antonio FB.** (2014). Venomous reptile restraint and handling. Zoo Animal and Wildlife Immobilization and Anesthesia. Aug 25:337-50.
- **Sladky KK, Mans C.** (2012). Clinical analgesia in reptiles. Journal of Exotic Pet Medicine. Apr 1;21(2):158-67.
- **Jadhav SS, Disale DS, Mukherjee S.** (2007). Tail amputation in Indian Spectacled Cobra (Naja naja)-A case study. ZOOS'PRINT JOURNAL. Dec 21;22(12):2950-.
- **Divers SJ, Mader DR.** (2005). Reptile Medicine and Surgery-E-Book: Reptile Medicine and Surgery-E-Book. Elsevier Health Sciences; Dec 13.

A Sighting Record of a Western Indian Leopard Gecko *(Eublepharis fuscus)* from Pingori, District Pune, Maharashtra, India

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- **Name of Species:-** Western Indian Leopard Gecko
- **Scientific Name**:- *Eublepharis fuscus*
- **Status: -** Resident to India, and generally found in Northern Western Ghats (Pande, S. et al., 2019). Least Concern as per the IUCN Red List of Threatened Species. However; the current population trend is unknown (Srinivasulu, C. & Srinivasulu, B, 2013), and scarce data are available about its ecology.
- **Date of sighting:-** 06 June 2018
- **Time of sightings:-** 07.58 pm
- **Weather parameters: -** Rain showers
- **Number of times sighted: -** Once
- **Number of animals:-** 1
- **Locality:** - Pingori, District-Pune, Maharashtra (18°14'13.7"N 74°08'35.2"E)
- **Habitat description: -**: Hilly tracts
- **Distance from human habitation: -** Approximately 0.5 km.
- **Animal Behaviour: -** Active and probably foraging, crossing the road
- **Threats to the habitat: -** Habitat modification due to anthropogenic activities
- **Photographs: -** Attached.
- **Previous records: -** None from the study site.

References:

- **Pande S., Vishwasrao V., Pandit R., and Barbhai U.;** (2019). Reptiles of Northern Western Ghats (Including Maharashtra and Goa), Ela Foundation, Pune.
- **Srinivasulu, C. & Srinivasulu, B.** (2013). Eublepharis fuscus. The IUCN Red List of Threatened Species 2013: e.T172683A1366357. https://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T172683A1366357.en. Downloaded on 18 March 2025.

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