



Conservation challenges and hope: A study on herpeto-fauna in the Totalai Game Reserve (District Buner) in Khyber Pakhtunkhwa's Pakistan

Aziz Ullah^{1*}, Muhammad Sajid Nadeem¹, Waseem Ahmad¹, Shahid Rehan²

¹Department of Zoology Faculty Science, PMAS Arid Agriculture University Rawalpindi, Pakistan

²Department of Zoology Faculty Science Hazara University Pakistan

*Email: uaziz7003@email.com

Received: 16 June 2024 / Revised: 01 September 2024 / Accepted: 02 September 2024 / Published online: 02 September 2024.

How to cite: Ullah, A., Nadeem, M. S., Ahmad, W. & Rehan, S. (2024). Conservation challenges and hope: A study on herpeto-fauna in the Totalai Game Reserve (District Buner) in Khyber Pakhtunkhwa's Pakistan. *Sustainability and Biodiversity Conservation*, 3(3): 1-11. **DOI:** <https://doi.org/10.5281/zenodo>.

Abstract

About one-third of amphibians (40.7%) and one in five reptile species (21%) are threatened with extinction. We conducted the present study to examine the diversity, richness, and abundance of herpetofauna in the Totalai game reserve (District Buner) in Khyber Pakhtunkhwa's Pakistan. We gathered data from June 2021 to July 2023 in selected sampling sites of the study area using standard methods. We detected only 19 herpetofauna species, with six amphibians, seven lizards, and six snake species belonging to 11 families. Our results indicated that the Rocky and Human settlement areas exhibited higher diversity (Shannon $H = 2.298$) and more even distribution ($e^{H/S} = 0.5241$) of species compared to the Agricultural area ($e^{H/S} = 1.835$) and Water bodies ($e^{H/S} = 2.286$). Additionally, the Rocky area and Human settlement showed a greater abundance ($D = 0.1374$) of species, indicating a more diverse array of species in these habitats (Table II). Examination of individual species' distribution revealed all four habitats displayed a relatively even spread. The entire study region had a moderate species diversity Index (H') = 1.095. The major threats are believed to be water pollution due to inadequate sewage systems and the scarcity of water bodies. Additionally, the lack of awareness among the local communities and the officials of the Wildlife Department of KPK has led to the neglect of amphibian and reptile conservation efforts.

Keywords: Protected areas, diversity, Richness, Buner

Introduction

About one-third of amphibians (40.7%) and one in five reptile species (21%) are threatened with extinction (Luedtke et al., 2023; Cox et al., 2022). Species of herpeto-fauna play a crucial role as bio-indicators that reflect ecosystem health. They contribute to energy flow between aquatic and terrestrial ecosystems and are involved in biological pest eradication, pollination, and seed dispersion (Luedtke et al., 2023). Additionally, these species help maintain ecological balance, serve as a food source for many carnivores, act as natural pest control, and some reptiles are kept as pets (Azevedo et al., 2021). Furthermore, the economic significance of these species extends to the use of their skins for leather goods (Rhoman et al., 2020; Cortés-Gomez et al., 2015; Connelly et al., 2011).

Pakistan's unique natural and altitudinal variations have led to complex Zoogeographic patterns, resulting in remarkable biodiversity. Climate and geographic location influence the diversity and distribution of amphibians and reptiles in the region (Khan, 2006). The country has a diverse reptilian fauna including Testudines, Lizards, Snakes, and Crocodiles. Pakistan's herpetofauna consists of 25 families, 77 genera, and 199 species, with 40 species being endemic (Khan, 2006). Of the 21 amphibian species (Rais et al., 2021) nine are endemic, whereas 13 reptile species are endemic to the country (Ali et al., 2018). Species diversity estimates and related measures are pivotal in understanding the dynamics of ecological communities, linking ecosystem services with key species. These parameters also contribute to insights into ecosystem function, ecological monitoring, and spatial community patterns over time (Iknayan et al., 2014). In research evaluating herpetofauna, particularly their condition, abundance and distribution, habitats, and conservation priorities, detection investigations and diversity assessments have grown in importance (Kumar et al., 2022; Wilson & Gownaris, 2022).

Species checklist and herpetofauna inventories of various areas of Pakistan are available in scientific literature (Ullah et al., 2022; Hamid et al., 2021; Ali et al., 2021; Khalid et al., 2019; Jamal et al., 2018; Balouch et al., 2016; Rais et al., 2015, 2021a, 2021b, 2023; Masroor, 2011; Baig et al., 2006, 2008), but many geographical areas of the country have still not been explored. The present study aims to fill this gap for the first time and report the herpeto-fauna of Northern Khyber Pakhtunkhwa, Totalia Game Reserve (District Buner). Our findings will enhance existing knowledge of the herpetofauna of the country and could be used to prepare a species atlas of the country in the future. Additionally, this information will benefit wildlife managers to devise

improved conservation management strategies.

Martial and methods

Study area

Totlai Game Reserve (TGR) (Fig. 1) is located between latitudes $34^{\circ} 25' 29.14''\text{N}$ and $34^{\circ} 39' 56.83''\text{N}$ and longitudes $72^{\circ} 25' 37.42''\text{E}$ and $72^{\circ}39' 56.83''\text{E}$, having a total area of 17000 ha with an elevation of 1105 m (a.s.l). It is situated south of District Buner, Khyber Pakhtunkhwa, Pakistan, and is close to District Swabi. The average temperature ranges from -2°C in January to 44°C in June, with an annual precipitation of approximately 30 inches (Khan et al., (2019). The area features mainly Dry Temperate Semi-Evergreen Scrub Forest, along with dominant vegetation that includes *Pinus roxburghii*, *Quercus incanna*, *Dodonaea viscosa*, *Rhodendron arboretum*, and various grasses (Ali et al., (2015).

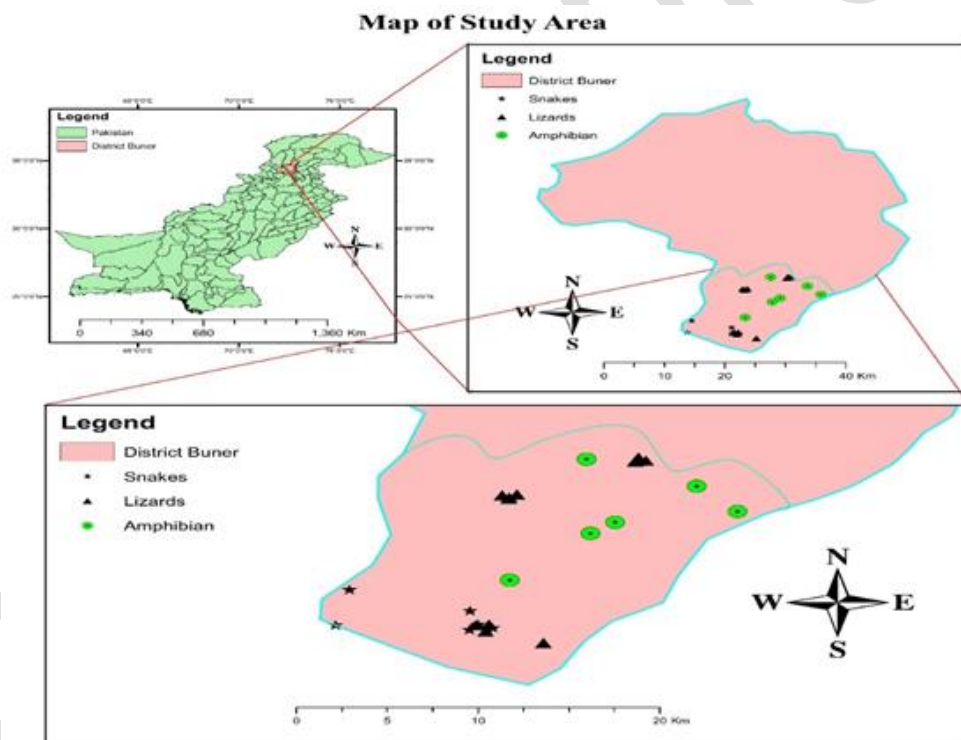


Figure 1. Map showing locations of sampling sites Totalai Game Reserve, District Buner, Khyber Pakhtunkhwa, Pakistan.

Twenty-four sites were randomly selected from TGR. We visited each site from June 2021 to July 2023 to gather (1) presence-only data on each herpetofauna species and (2) species abundance among the four habitats. The study area was stratified into four main habitats: (1) Agricultural

area; (2) Water bodies, including both permanent and seasonal ponds; (3) Rocky area, comprising crags, rocky boulders, and scree; and (4) Human settlements (Fig 2.) Surveys were conducted at each site during Spring (February-March), Summer (May-June), and monsoon seasons (July-August). We used the standard time-constrained visual encounter surveys method (VES) (Heyer et al., 1994; Greater et al., 2013) and the rock flipping method (McDiarmid, 2012). Observers actively and thoroughly searched the sampling locations for a predefined time (~60–120 min.). We recorded the species, life stage (egg, larval, juvenile, or adult), sex (if known), substrate, detection method, GPS coordinates, and encounter rates, i.e., common (that are abundant in numbers and have a widespread geographic distribution) and uncommon (have small populations and restricted geographic ranges) (Chapman et al., 2018). Voucher photos for identity confirmation were preferred, rather than gathering herpetofauna for museum depositions and following the guidelines (Glorioso et al., 2022). To reduce stress on animals, specimens were collected with dip nets for examination and identification following descriptive identification by (Khan, 2006) and Rais et al. (2021) and then released back in their habitat.



Figure 2. Major habitats of the study area: (A) Agricultural lands, (B) Water Bodies, (C) Rocky areas, and (D) Human settlements.

Statistical Analysis

We used Shannon Weiner's diversity index formula to estimate the diversity of herpetofauna.

$$H' = -\sum P_i \cdot \ln P_i$$

The p_i = proportional frequency of the i th species; Evenness Index (E) = $H' / \ln(S)$ where H' is the Shannon-Weiner Diversity Index and S is the number of species. The species richness was determined using the Margalef index 1951 by the given formula.

$$\text{Species richness} = (S - 1) / \log n$$

Analyses were performed in SPSS 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0.; Armonk, New York, USA).

Results

Across all the visited sites, we detected only 19 herpetofauna species, including six amphibian species, seven lizard species, and six snake species belonging to 11 families, as listed in Table 2. It was observed that the Rocky and Human settlement areas exhibited higher diversity (Shannon $H' = 2.298$) and more even distribution ($e^{H'/S} = 0.5241$) of species compared to the Agricultural area ($e^{H'/S} = 1.835$) and Water bodies ($e^{H'/S} = 2.286$). Additionally, the Rocky area and Human settlement showed a greater abundance ($D = 0.1374$) of species, indicating a more diverse array of species in these habitats (Table 1). When examining the distribution of individual species, all four habitats displayed a relatively even spread. The entire study region had a Shannon Diversity Index (H') = 1.095, indicating a moderate level of species diversity.

Table 1. The diversity indices of Amphibians and Reptiles in different area sampling sites.

Various indices	Sampling Sites			
	Agriculture area	Water bodies	Rocky area	Human settlement
<i>Taxa S</i>	10	16	19	19
<i>Individuals</i>	58	83	97	97
<i>Dominance D</i>	0.2241	0.1383	0.1374	0.1374
<i>Shannon H'</i>	1.835	2.286	2.298	2.298
<i>Evenness $e^{H'/S}$</i>	0.6268	0.6144	0.5241	0.5241
<i>Richness</i>	2.217	3.395	3.935	3.935
<i>Equitability</i>	0.7971	0.8243	0.7806	0.7806

Discussion

The information about the geographical distributions of the species at local and global sizes is poor- the Wallacean gap (Whittaker et al., 2005). There are still numerous geographical areas in Khyber Pakhtunkhwa (Ullah et al., 2022; Hamid et al., 2021; Khalid et al., 2019; Jamal et al., 2018) notwithstanding the paucity of literature on the species inventory of different regions of the province. Within the order Anura, the toads (Family Bufonidae): *Duttaphrynus bengalensis* and *D. stomaticus* were the most common frog species in the Totalai Game Reserve and predominantly utilized rice fields, both permanent and temporary water ponds, and human settlements (Khan 2006; Rais et al., 2021; 2023). The dicroglossid frogs: *Sphaerotheca maskeyi*, *Hoplobatrachus tigerinus*, and *Euphlyctis* spp were collected from all types of habitats at different elevations in the project area, except the Rocky area (Rais et al., 2021; Hamid et al., 2021), whereas the endemic frog *Allopa hazarensis* was restricted to water bodies (Ahmed et al., 2020.)

Laudakia pak auffenbergi was captured from hard cliffs stones and rocky hills of the study area. In Pakistan, this species is documented from the Waziristan mountains in Khyber Pakhtunkhwa, and the Kalabagh area in northwestern Punjab and some parts of Sindh and Balochistan (Khan, 1980 & Khan 2004).

Calotes versicolor is widespread in Pakistan, with two subspecies: *Calotes versicolor Farooqi* and *C. versicolor nigrigularis* (Khan, 2006). However, *Calotes versicolor farooqi* is restricted to the northern foothills of the Himalayas and occurs at higher altitudes (Khan, 2006). Most recently the authors nominated subspecies *C. versicolor nigrigularis* for Peninsular India (Gowande et al., 2021).

The present study found Garden Lizards at higher and lower altitudes and preferred the Rocky Mountains (Khan, 2006; Hamid et al., 2021). *Varanus bengalensis* was found in soft and clay soils, rocky hills, and near human settlements. In Pakistan, it is documented throughout the plains of Punjab and Sindh, sub-Himalayan tracts, and Waziristan (Khan, 2003). *Eutropis dissimilis* was observed from croplands mostly during the daytime. It inhabits moist open grass fields and extends into tilled land (Khan, 2006; Shezad et al., 2022). From the genus Hemidactylus, only one species was documented in this study: *Hemidactylus brookii*, which is found in southern parts of Khyber Pakhtunkhwa and westernmost parts of Sindh and Baluchistan in Pakistan (Muhammad & Khan, 2004) and commonly inhabits the bark of trees, logs, leaf litter, piles of dead branches, and other rubbish. In several locations across the study sites, during the night, *Eubeipharis macularius* was

collected from rocky terrain hills, mudflats with scant flora and bushes, and clayey soil and documented in Pakistan from lower Sindh, northern Punjab, Baluchistan, AJ & (Khan, 2006). Our results agree with the previously mentioned research. We infer that the protected areas support an excellent diversity and quantity of snake species, despite the limited direct sightings of amphibians and reptiles in Totalai Game Reserve and encounters with snake species throughout the study period. Sand boas with coarse scales were gathered from settlements and croplands. Hameed et al. (2021) recorded it from Sheikh Baddin National Park, Khyber Pakhtunkhwa. *Ptyas mucosus* is distributed all over Pakistan and is also reported from India, Sri Lanka, Afghanistan, and Andaman Island (Khan, 2006). *Bungarus caeruleus* is documented in Punjab, KPK, Azad Kashmir, Sindh, and Southern Baluchistan, While *Echis carinatus* is distributed throughout the Middle East, Russia, Iran, Afghanistan, India, Sri Lanka and Pakistan (Khan, 2006). The primary threats to the herpetofauna in the game reserve include habitat degradation from fuel wood cutting and human encroachment. Among these, another major threat is the release of waste from marble factories in the area directly into water bodies, causing severe threats like deformities, kidney problems (glomeruli having dead or ruptured cells), abnormal shapes, cytoplasmic depositions, and habitat shrinkage to the herpetofauna, especially amphibians (Mahmood et al., 2016). The local community relies on natural vegetation for fuel and fodder, and livestock is permitted to graze freely in the game reserve. Additionally, the once suitable habitat for reptiles, a barren mountain, is now endangered due to stone quarries and extraction for a nearby marble factory.

Table 2. Diversity and encounter rate of Amphibians and Reptiles of Totalai Game Reserve District Buner, Khyber Pakhtunkhwa Pakistan.

Families	Common Names	Scientific Names	Longitude	Latitude	Encounter rates
			(E)	(N)	
<i>Bufonidae</i>	Asian Toad	<i>(Duttaphrynus bengalensis)</i>	72.525920	34.173168	common
	Indus Valley Toad	<i>(Duttaphrynus stomaticus)</i>	72.525920	34.173168	common
<i>Dicroglossidae</i>	Skittering Frog	<i>(Euphlyctis cyanophlyctis)</i>	72.492221	34.196653	common
	Bull Frog	<i>(Hoplobatrachus tigerinus)</i>	72.477719	34.185659	uncommon
	Burrowing Frog	<i>(Sphaerotheca breviceps)</i>	72.492865	34.197452	uncommon
	Hazara Torrent Frog	<i>(Allopaa hazarensis)</i>	72.488165	34.190742	uncommon
<i>Agamidae</i>	Pakistani Agama	<i>(Laudakia pak auffenbergi)</i>	72.503447	34.177765	common
	Garden Lizard	<i>(Calotes versicolor farooqi)</i>	72.505916	34.172150	common

Varanidae	Bengal Monitor	(<i>Varanus bengalensis</i>)	72.505916	34.171944	uncommon
	Himalaya Ground Skink	(<i>Ablepharus himalayanus</i>)	72.507987	34.171978	uncommon
Scincidae	Striped Grass Skink	(<i>Eutropis dissimilis</i>)	72.507987	34.171978	common
	House gecko	(<i>Hemidactyla brooki</i>)	72.505916	34.171944	common
Gekkonidae	Leopard Gecko	(<i>Eublepharis macularis</i>)	72.514257	34.174897	uncommon
Eublepharidae	Brown Sand Boa	(<i>Eryx johnii</i>)	72.514252	34.174897	uncommon
Boidae	Royal Snake	(<i>Spalerosophis diadema</i>)	72.579363	34.213446	common
Colubridae	Royal Snake	(<i>Spalerosophis atriceps</i>)	72.579363	34.213446	common
	Rat Snake	(<i>Ptyas mucosa</i>)	72.594494	34.305489	common
Elapidae	Central Asian Cobra	(<i>Naja oxiana</i>)	72.579365	34.213252	uncommon
Viperidae	Saw Scales Viper	(<i>Echis carinatus</i>)	72.492221	34.196653	common

Conclusion

During the survey, we collected 19 species of amphibians and reptiles from all four habitats of the Game Reserve. High species diversity and distribution were detected in the Rocky and Human settlement areas compared to water bodies and the agricultural area.

Acknowledgments

We owe a deep sense of gratitude to Khyber Pakhtunkhwa Wildlife Department, and PMAS Arid Agriculture University Rawalpindi for providing assistance, equipment, and supplies. The department had signed a Memorandum of Understanding with the provincial wildlife department and no special permit was required to conduct surveys in the study area.

References

- Ali, S., Perveen, A., and Qaiser., M. (2015). Vegetation structure, edaphology, and ethnobotany of Mahaban and Malka (District Buner) KPK, Pakistan. *Pakistan Journal of Botany*, 47:15– 22.
- Ali, W., Javid, A., Hussain, A., and Bukhari., S. M. (2018). Diversity and habitat preferences of amphibians and reptiles in Pakistan: a review. *J. Asia. Pac. Biodiverse*, 11 (1): 173– 187.
- Azevedo, A., Guimarães, L., Ferraz, J., Whiting, M., and Magalhães-Sant’A., M. (2021). Are we meeting pet reptiles' needs? *Animals*, 11 (10): 2964. <http://dx.doi.org/10.3390/ani11102964>
- Baig, K. J., Mohammad, R.A. and Naeem, A., (2006). Ecological studies and zoogeographic affinities of the amphibians and reptiles found in Chagai desert, Balochistan, Pakistan. *Pakistan Journal of Zoology*, 38 (2):145.
- Baig, K. J., Rafaqat, M. and Arshad, M., (2008). Biodiversity and ecology of the herpetofauna of Cholistan Desert, Pakistan. *Russian Journal of Herpetology*, 15 (3): 193– 205.

- Balouch, S., Rais, M., Hussain, I. and Akram, A. (2016). Squamate diversity in different croplands of district Chakwal, Punjab, **Pakistan. J. King Saud Univ. Sci.** 28 (3): 255-260.
- Chapman, A. S., Tunnicliffe, V., & Bates, A. E. (2018). Both rare and common species make unique contributions to functional diversity in an ecosystem unaffected by human activities. *Diversity and Distributions*, 24(5), 568-578.
- Connelly, S., Pringle, C.M., Whiles, M.R., Lips, K.R., Kilham, S., Brenes, R. (2011). Do tadpoles affect leaf decomposition in neotropical streams? **Freshw. Biol.** 56 (9):1863– 1875.
- Cortés-Gomez, A. M., Ruiz-Agudelo, C. A., Valencia Aguilar, A., and Ladle, R. J. (2015). Ecological functions of neotropical amphibians and reptiles: a review. **Univ. Sci.** 20 (2): 229– 245.
- Cox, N., Young, B. E., Bowles, P., Fernandez, M., Marin, J., Rapacciuolo, G. and Xie, Y. (2022). A global reptile assessment highlights shared conservation needs of tetrapods. *Nature*, 605 (7909): 285– 290.
- Glorioso, B. M., Vanbergen, P., Pilgrim, S., Villermin, B., Vanbergen, E., Comeaux-Villermin, K., & Wood, K. D. (2022). A Citizen science herpetofaunal inventory of palmetto island state park in southwest Louisiana, USA. **Herpetol. Conserv. Biol.** 17 (1):122– 130.
- Graeter, G. J., Buhlmann, K. A., Wilkinson, L. R., and Gibbons, J., W. (2013). Inventory and monitoring: Recommended techniques for reptiles and amphibians. *Partners in Amphibian and Reptile Conservation Technical Publication United States*.
- Gowande, G., Pal, S., Jablonski, D., Masroor, R., Phansalkar, P. U., Dsouza, P., ... & Shanker, K. (2021). Molecular phylogenetics and taxonomic reassessment of the widespread agamid lizard *Calotes versicolor* (Daudin, 1802)(Squamata, Agamidae) across South Asia. *Vertebrate Zoology*, 71, 669-696.
- Hamid, H. N., Rais, M., Arif, M. and Noor., R. (2021). Amphibians and reptiles of Sheikh Baddin National Park, Khyber Pakhtunkhwa: Diversity, Threats and Conservation Prospects. *Pakistan Journal of Zoology*, 53 (3): 785. <https://dx.doi.org/10.17582/journal.pjz/20190826180828>
- Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.A.C. Hayak, and M.S. Foster (Eds.). (1994). *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. Smithsonian Institution Press, Washington, D.C. USA.
- Iknayan, K. J., Tingley, M. W., Furnas, B. J., and Beissinger, S. R. (2014). Detecting diversity: emerging methods to estimate species diversity. **Tends Ecol. Evol.** 29 (2): 97– 106. [10.1016/j.tree.2013.10.012](https://doi.org/10.1016/j.tree.2013.10.012)
- Jamal, Q., Idrees, M., Ullah, S., Adnan, M., Zaidi, F., Zaman, Q. and Rasheed, S., B. (2018). Diversity and altitudinal distribution of Squamata in two distinct ecological zones of Dir, a Himalayan sub-zone of northern Pakistan. *Pakistan Journal of Zoology*, 50 (5): 1835– 1839. <http://dx.doi.org/10.17582/journal.pjz/2018.50.5.1835.1839>.
- Khalid, S., Attaullah, M., Waris, A., Baset, A., Masroor, R., Khan, A.U. and Khan., I. (2019). Diversity and distribution of lizard fauna in tehsil Samar Bagh, Dir lower, khyber Pakhtunkhwa, Pakistan. **Int. J. Fauna Biol.** 6 (6): 20– 25. <http://www.faunajournal.com/>

- Khan, A., Shams, S., Khan, S., Khan, M. I., Khan, S., and Ali, A. (2019). Evaluation of prevalence and risk factors associated with Cryptosporidium infection in rural population of district Buner, Pakistan. *PLoS One*. 14 (1): e0209188.
- Khan, M. S. (1980). Affinities and zoogeography of herpetiles of Pakistan. *Biologia*, 26 (1-2): 113-171.
- Khan, M. S. (2003). Checklist and key to lizards of Pakistan. *Pak. J. Zoo*. 5. 1– 25.
- Khan, M. S. (2004). Annotated checklist of amphibians and reptiles of Pakistan. *Asiat. Herpetol. Res.* 10 (1): 191– 201.
- Khan, M. S. (2006). *Amphibians and reptiles of Pakistan*: Krieger Publishing Company Malabar, Florida, USA.
- Kumar, P., Dobriyal, M., Kale., A, Pandey A, Tomar, R., and Thounaojam E. (2022). Calculating forest species diversity with information-theory based indices using sentinel-2A sensors of Mahavir Swami wildlife sanctuary. *NIH. PLOS One*. 17 (5): e0268018
- Luedtke, J. A., Chanson, J., Neam, K., Hobin, L., Maciel, A. O., Catenazzi, A. and Stuart, S. N. (2023). Ongoing declines for the world's amphibians in the face of emerging threats. *Nature*, 622 (7982): 308– 314.
- Masroor, R. (2011). An annotated checklist of amphibians and reptiles of Margalla Hills National Park, Pakistan. *Pak. J. Zoo*. 43 (6): 1041– 1048.
- McDiarmid, R. W. (Ed.). (2012). *Reptile biodiversity: standard methods for inventory and monitoring*. Univ of California Press.
- Muhammad, S. and Khan, K. (2004). *Hemidactylus* geckos of Pakistan. *Natural History and Captive Breeding. Reptilia, the Euro. Herp. Magazine*. 43 (3): 1-19.
- Mahmood, T., Qadosi, I. Q., Fatima, H., Akrim, F., & Rais, M. (2016). Metal concentrations in common skittering frog (*Euphlyctis cyanophlyctis*) inhabiting Korang River, Islamabad, Pakistan. *Basic and Applied Herpetology*, 30, 25-38.
- Rais, M., Ahmed, W., Sajjad, A., Akram, A., Saeed, M., Hamid, H. N., & Abid, A. (2021a). Amphibian fauna of Pakistan with notes on future prospects of research and conservation. *ZooKeys*, 1062, 157.
- Rais, M., Ayesha, A., Syeda, M. A., Muhammad, A. A., Misbah, J., Muhammad, J. J., & Maqsood, A. (2015). Qualitative analysis of factors influencing the diversity and spatial distribution of the herpetofauna in Chakwal tehsil (Chakwal District), Punjab, *Pakistan. Herpetol. Conserv. Biol.* 10 (3): 801–810.
- Rais, M., Jamal, A., Aiman, N., Arooj, B., Aqsa, S., Razia, B. and Anum, S., (2021b). Field surveys along habitat gradients revealed differences in herpetofauna assemblage in Margalla Hills National Park, Islamabad, *Pakistan. Biodivers. Data J.* 9: e6154.1
- Rais, M., Nawaz, M. A., Gray, R. J., Qadir, W., Ali, S. M., Saeed, M. and Leston, L. (2023). Niche suitability and spatial distribution patterns of anurans in a unique Ecoregion mosaic of Northern Pakistan. *PLOS One*, 18: e0285867.

- Rohman, F., Permana, H., Akhsani, F., Wangkulangkul, S., & Priambodo, B. (2020). The amphibians diversity as bioindicator of aquatic ecosystem at Sumber Taman, Malang, East Java. AIP Conf. 2231 (1).
- Shehzad, M., Ullah, F., Khan, S. N., Majid, A., Rais, M., Khan, M. A., Ahmed, T and Khan, S. (2023). Squamate Fauna of Southern Khyber Pakhtunkhwa (Tank and Lakki Marwat Districts), Pakistan. Pak. J. Zoo. 1–7.
- Ullah, I., Saeed, K., Ullah, A., Ahmed, W., & Rais, M. (2022). First record of *Coelognathus helena* (Daudin, 1803) from Pakistan: New country record. Herpetology Notes,15: 633– 634.
- Whittaker, R. J., Araújo, M. B., Jepson, P., Ladle, R. J., Watson, J. E. & Willis, K. J. (2005). Conservation biogeography: Assessment and prospect. Diversity and Distributions 11 (1): 3–23.
- Wilson, A., Gownaris, N. (2022). Diversity indices. Libre Texts Biology. [accessed 9 May 2023].https://bio.libretexts.org/Courses/Gettysburg_College/01%3A_Ecology_for_All/22%3A_Biodiversity/22.02%3A.