A review of research on Ayubia National Park, Khyber Pakhtunkhwa, Pakistan

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Abstract. National parks belong to one of the six categories of Protected Areas identified by the World Conservation Union. National parks play an important role in the conservation of biodiversity, scenic beauty or landscape and promotion of ecotourism. The Khyber Pakhtunkhwa (KPK) Province, Pakistan, has six National Parks. Ayubia National Park, District Abbottabad, KPK, holds a pivotal position in terms of its ecological and tourism value. We aimed to provide a synthesis of research conducted to date on this National Park, identify major gaps and suggest future research and management options. We searched available published literature on biodiversity and ecotourism of the National Park using internet search engines and other online sources by spending 4400 minutes. We downloaded a total of 65 articles, reports, and theses and retained 45 for this review. We extracted our required data from each selected article by thoroughly reading its objectives and results. We created a spreadsheet to make an overview chart of the extracted data. The available literature shows that mammals and flora have remained main focus of research on biodiversity. Likewise, work on the food habits and human-wildlife conflict has also been centered on mammals. Studies conducted to date report 22 species of mammals, 116 birds, 2 amphibians, 101 lepidopterans and 298 plants. The National Park attracted 120,000 visitors per year in early 2000s which rose to > 150,000 visitors per year in 2019. The studies so far on the aspects mentioned show following gaps: short duration, limited sampling, misidentification, and others.

Keywords: protected areas, chir pine, blue pine, sub-alpine meadows, carnivores, *Gentiana kurroo*, *Manis crassicaudata*.

Introduction

Protected Areas (PAs) are established to conserve nature and reduce biodiversity loss. These areas are helpful in the conservation of endangered species by providing a suitable habitat (Maxwell et al. 2020). They cover one-sixth of the world's terrestrial land (Geldmann et al. 2019). Protected areas limit the excessive use of land and forests and remove many threats (Adams et al. 2015, Halstead et al. 2022). The World Conservation Union (IUCN) has identified six major types of protected areas (Hirons et al. 2022). National parks belong to Category II of IUCN Protected Areas (Dudley et al. 2010). National parks are pivotal in conserving biodiversity, scenic beauty, or landscape and promoting ecotourism (Burns et al. 2003, Naughton-Treves et al. 2005). Each national park has a unique species assemblage and landscape (Vukomanovic & Randall 2021, Halstead et al. 2022).

Establishing a network of Protected Areas in Pakistan started in the early 1970s under the provincial wildlife Acts / Ordinances. The federal cabinet approved the Wildlife Enquiry Committee on 2 October 1968, which was mandated to draft model wildlife law, manage wildlife on a scientific basis, and establish a network of protected areas. Since wildlife is a provincial subject, the provincial wildlife departments notified and managed these areas. Initially, three categories of PAs were established in Pakistan: National Park (NP), Wildlife Sanctuary (WLS), and Game Reserve (GR) on public land. However, recently, Khyber Pakhtunkhwa (KP), Azad Jammu and Kashmir (AJ&K) and Baluchistan has revised wildlife legislation and included additional categories such as Private Game Reserve,

Community Conservation / Managed Area, Biodiversity Reserve, Wildlife Refuge, Wildlife Park, Biosphere Reserve, Site of Special Scientific Interest, National Natural Heritage Site, Sacred Protected Site and Marine Conservation Area (Anwar 2019).

The Khyber Pakhtunkhwa Province, Pakistan, has six National Parks: Chitral Gol National Park, Sheikh Badin National Park, Saiful Maluk National Park, Lulosar Dodipat National Park, Broghil Valley National Park and Ayubia National Park (Anwar 2019). Ayubia National Park (34.0642˚N, 73.4062˚E) is an important National Park of the province because of its ecological and tourism value. The park is located in Abbottabad District on the right bank of Jhelum River. It is situated at an elevation of 2300-3000 meters above sea level and covers an area of about 3,122 ha. This park was established under the Khyber Pakhtunkhwa Wildlife Act 1975 in 1984 for the protection and conservation of fauna and flora of the region (Khan & Naqvi 2000, Shaker et al. 2020, Shafique & Barkati 2010, Shah et al. 2016). The area's climate is temperate (Beck et al. 2018), with a mean maximum temperature of 19.2 °C and annual precipitation of 1412 mm. The park has three types of forest: Sub-tropical Chir Pine Forest, Himalayan Moist Temperate Forest, and Sub-alpine Meadows (Lodhi 2007).

Materials and methods

We followed Ward et al. (2008) to acquire information about studies conducted on Ayubia National Park (Fig. 1). We searched available published literature using internet search engines and other online sources: Google Chrome, Firefox, Google Scholar, ResearchGate, Elsevier, SpringerLink, Pakistan Journal of Forestry, Pakistan Journal

of Zoology and Academia.edu. We used key words "Ayubia National Park", "National Parks", "Wetland", "KPK", "Pakistan", "Fauna", "Flora", "Wildlife", "Wildlife conservation", "Management", "Tourism", "Ecotourism", "Abbottabad", "Margalla Hills National Park", "Murree Kotli Sattian Kahuta National Park". While searching the articles and published literature, we used these key terms separately and combinations of these terms. The total time spent searching and collecting the data was about 4400 minutes. For this review, we downloaded 65 articles, reports, and theses. Of the downloaded literature items, 45 were retained for this review.

We extracted our required data from each selected article by thoroughly reading its objectives and results. We created a spreadsheet to make an overview chart of the extracted data. We recorded the following information after the study: author names, area of study, year of study, wildlife flora of Ayubia National Park, wildlife fauna of Ayubia National Park, IUCN status of species, species distribution, species, major findings, and research gaps or shortcomings left in the study.
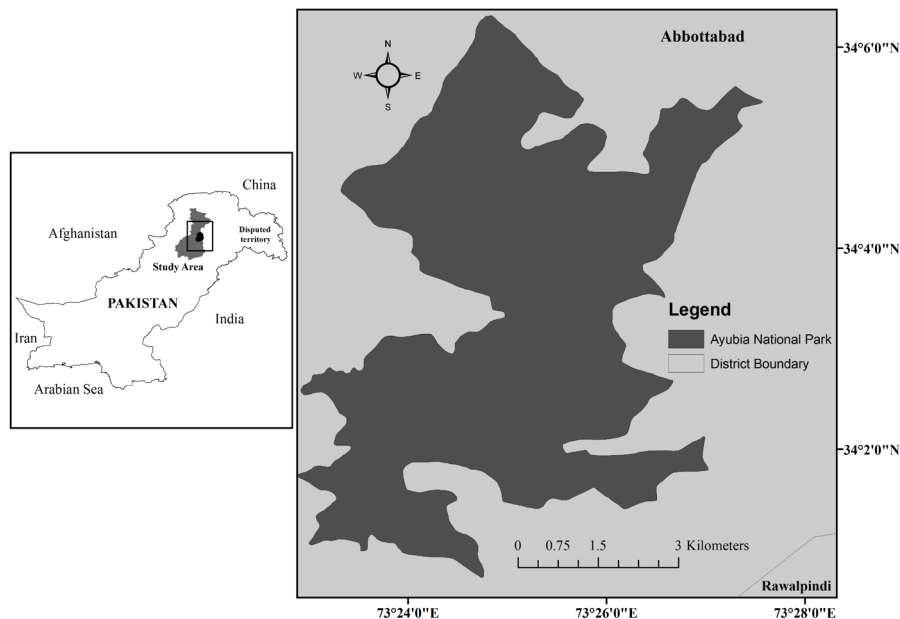

Figure 1. Map of Ayubia National Park, Abbottabad, Khyber Pakhtunkhwa, Pakistan.

Results

The biodiversity of the Ayubia National Park has been subjected to many scientific studies on mammals (Oshida et al. 2004, Shafique et al. 2006, Lodhi 2007, Shafique et al. 2009, Shafique & Barkati 2010, Farooque 2011, Shafique & Barkati 2011, Shehzad et al. 2012, 2014, Awan et al. 2020, Bashir et al. 2021, Rafaqat et al. 2021, Bashir et al. 2023), birds (Roberts 1992, Shafique & Barkati 2011, Afza 2016, Bashir et al. 2021, Bashir et al. 2023), amphibians (Saeed et al. 2021, Saeed et al. 2022a,b), invertebrates (Shafique & Barkati 2011, Bajwa & Waseem 2013) and plants (Aumeeruddy-Thomas et al. 2004, Khanum & Gilani 2005, Gilani et al. 2006, Ahmad & Javed 2007, Nasim et al. 2008, Saima et al. 2009, Afshan et al. 2010, Shinwari 2010, Ahmad 2011, Ahmad 2012, Ali et al. 2015a,b, Afza et al. 2016, Shah et al. 2016, Afza et al. 2018, Nazakat et al. 2021, Ali et al. 2022, Razzaq et al. 2022).

Studies conducted to date report 22 species of mammals (Shafique & Barkati 2010), 116 birds (Bashir et al. 2023), two amphibians (Saeed et al. 2021, Saeed et al. 2022a, b), 101 lepidopterans (Bajwa & Waseem 2013) and 298 plants (Nazakat et al. 2021). Documentation of mammalian species was carried out by Bashir et al. (2023) and Shafique & Barkati (2010), of birds by Bashir et al. (2023) and Roberts (1992). General work on animal diversity (mammals, birds, and invertebrates) was conducted by Khan (2013), Khan & Naqvi (2000), Shafique & Barkati (2011), and Bashir et al.

(2021). Oshida et al. (2004) studied the two flying squirrel species - the Red Giant Flying Squirrel (*Petaurista petaurista albiventer*) and the Small Kashmir Flying Squirrel (*Eoglaucomys fimbriatus*) of the National Park. Saeed (2008) concluded that Black Bear (*Selenarctos thibetanus*), Musk Deer (*Moschus moschiferus*), Grey Goral (*Naemorhedus goral*), Barking Deer (*Muntiacus muntjak*), and Monal Pheasant (*Lophophorus impejanus*) went extinct from the National Park, for the species had not been sighted in past 40-50 years. Afza (2016) concluded that Koklass Pheasant preferred *Pinus wallichiana*, *Abies pindrow*, *Acer caesium*, *Prunus padus*, *Rhamnus purpurea*, *Cornus macrophylla*, and *Aesculus indica* (trees); *Vibernum mullah*, *Vibernum grandiflorum*, *Rosa chinensis*, and *Skimmia laureola* (shrubs) and *Fragaria nubicola*, *Dryopteris stewartii*, *Adiantum venustum*, *Bromus hordeaceus*, *Valeriana jatamonsii*, and *Thalictrum cultratum* (herbs) for nesting while Kalij Pheasant preferred *Acer caesium*, *Pinus wallichiana*, *Parrotiopsis jacquemontiana*, *Prunus padus*, and *Abies pindrow* (trees); *Viburnum grandiflorum*, *Viburnum mullaha*, *Rubus pedunclosus*, and *Rosa chinensis* (shrubs); *Adiantum venustum*, *Dryopteris ramosa*, *Thalictrum cultratum*, *Geum elatum*, *Sinopodophyllum hexandrum*, *Polygonatum multiflorum, and Senecio analogus* (herbs). Saeed et al. (2021) and Saeed et al. (2022a, b) modeled the occupancy of Hazara Frog and Murree Hills Frog regarding site and survey covariates. The detection of these two species was influenced by the study year and temperature, while occupancy was

influenced by elevation and year (for the visual encounter survey). The detection of these two species was uninfluenced by any studied parameter, while occupancy was influenced by elevation, year, and wetland type (for environmental DNA detection) (Saeed et al. 2022a).

Common Leopard of the National Park has remained the focus of many scientific studies and posed management issues. Shehzad et al. (2014) reported that 95% of the prey items of Common Leopard were domestic animals. Lodhi (2007) reported 12 human deaths and 142 depredations of livestock due to Common Leopard, while 40 leopards were killed by humans from 1989 to 2007. Awan et al. (2020) concluded that Human-leopard conflict increased in the National Park. About 22 human deaths were reported, and 35 leopards were killed from 2005 to 2017. Another data document includes 805 depredation cases, 67 killings of Common Leopard, and about 20 injuries/causalities from 1986 to 2011 (Farooque 2011).

Studies on the ecology and food habits of mammalian species of the National Park are available (Shafique et al. 2006, Shehzad et al. 2012, Shehzad et al. 2014, Rafaqat et al. 2021). Shafique et al. (2006) reported that the diet of flying squirrels is affected by their body size. The diet of the Red Giant Flying squirrel comprised items from 27 tree species, while the Small Kashmir Flying Squirrel comprised items from 28 tree species. Shehzad et al. (2012) recorded House Rat, Kashmir Flying Squirrel, Himalayan Wood Mouse, House Mouse, Koklass Pheasant, Chukar Partridge, Red Junglefowl, Babblers, Jungle Crow, Murree Vole, Asiatic White Toothed Shrew, Kalij Pheasant, Woodpecker, Murree Hill Frog and Catfish from the diet of Leopard Cat (*Prionailurus bengalensis*). Rafaqat et al. (2021) documented Red Himalayan Giant Flying Squirrel, Cape Hare, Himalayan Palm Civet, House Mouse, Domestic Sheep, Donkey, House Sparrow, Katchmach, Chirata, Kala Amlok, and Chonkaath from the diet of Red Fox (*Vulpes vulpes griffithii*).

The flora (vegetation) (Khan & Naqvi 2000, Khanum & Gilani 2005, Saeed 2008, Saima et al. 2009, Ahmad 2011, Ahmad 2012, Afza et al. 2016, Shah et al. 2016, Afza et al. 2018, Bashir et al. 2021, Ali et al. 2022) and fungal diversity (Nasim et al. 2008, Afshan et al. 2010, Ali et al. 2015a, b, Razzaq et al. 2022) of the National Park is also well documented. Further, the medical significance of the vegetation of the National Park has been explored (Aumeeruddy-Thomas et al. 2004, Gilani et al. 2006, Ahmad & Javed 2007, Shinwari 2010, Nazakat et al. 2021). The local community use *Quercus incana*, *Quercus dilatata*, *Dalbergia sissoo*, *Robinia pseudoacacia*, *Abies pindrow*, *Pinus wallichiana*, *Taxus wallichiana* for fuelwood; *Aesculus indica*, *Taxus wallichiana*, *Quercus dilatata*, *Ulmus wallichiana*, *Prunus padus*, *Poa pratensis*, *Agrostis nervosa*, *Bromus spp*, *Chrysopogon gryllus*, *Arthraxon prionoides*, and *Festuca gigantea* for fodder and *Morchella esculenta*, *Dryopteris stewartii*, *Nepeta laevigata*, *Dryopteris blanfordii*, *Solanum nigra*, and *Dipsacus inermis* for human consumption and Malabar Nut (*Adhatoda vasica*), Redstem Wormwood (*Artemisia scoparia*), Cleavers (*Galium aparine*), Green Amaranth (*Amaranthus viridis*), Himalayan Ivy (*Hedera nepalensis*), Stinging Nettle (*Urtica dioica*), *Pinus wallichiana*, *Abies pindrow*, *Quercus dilatata*, *Aesculus indica*, *Ulmus wallichiana*, and *Prunus padus* for various remedies. This poses issues such as unsustainable harvesting of resources. Likewise, the use of non-standard methods puts such vegetation under threat.

The Ayubia National Park is of immense ecotourism value in the region commonly referred to as Galiat (Northern Murree, Punjab, and Southern Abbottabad, KPK). The National Park attracted 120,000 visitors per year (Waseem et al. 2004), which rose to > 150,000 visitors per year in 2019 (Rauf et al. 2022). This, however, creates a serious issue of solid waste, especially from hotels and restaurants (Waseem et al. 2004). The higher number of vehicles and automotive transportation is another problem of tourist activity (Shaker et al. 2020).

Discussion

Many studies on mammalian and avifauna of the park are available. However, studies on reptiles, fish, and invertebrates (excluding lepidopterans) are lacking. The species list of mammals (Shafique & Barkati 2010), 116 birds (Bashir et al. 2023), two amphibians (Saeed et al. 2021, Saeed et al. 2022a, b), 101 lepidopteran (Bajwa & Waseem 2013) and 298 plants (Nazakat et al. 2021) may be expanded. New records could be found through detailed and systematic surveys combining modern field and lab methods. The extinction records provided by Saeed (2008) are valid since these species were not sighted in any recent studies. The cases of human-leopard conflict have been increasing (Lodhi 2007, Awan et al. 2020, Farooque 2011), requiring scientific intervention for effective management. Studies (Oshida et al. 2004, Shafique et al. 2006, Shehzad et al. 2012, Shehzad et al. 2014, Afza 2016, Rafaqat et al. 2021, Saeed et al. 2021, Saeed et al. 2022a, b) on ecology such as habitat, diet, and distribution are also scarce and focuses mainly on carnivores or pheasant with very little information on groups such as rodents (except flying squirrels), forest birds, passerine birds, raptors, amphibians and reptiles.

The Ayubia National Park has two other national parks: Margalla Hills National Park (MHNP) (33.7481°N, 73.0051°E), Islamabad Capital Territory and Murree-Kotli Sattian-Kahuta National Park (MKSKNP) (33.6986 °N, 73.5195 °E), Punjab, Pakistan, situated to its south. The former features sub-tropical broad-leaf forest or scrub forest in most parts (Rais et al. 2021), while the latter features sub-tropical broad-leaf forest, sub-tropical chir pine forest, and moist temperate coniferous forest with oak and deciduous broad-leaved trees (Siddiqui et al. 2010, Khatoon et al. 2022). These national parks share most of their flora and fauna and, therefore, are subjected to similar studies, especially on mammals (carnivores) (Asad et al. 2019, Aslam & Yasmeen 2021, Fatima et al. 2021, Shafique & Barkati 2010, Mahmood et al. 2013, Khatoon et al. 2019a, b), birds by Hadi et al. (2022) and herpetofauna by Rais et al. (2021) amphibians by Akram et al. (2022) and Saeed et al. (2022a).

The studies on the aspects mentioned in the preceding sections show the following gaps: short duration, limited sampling, misidentification, and conventional methods (Table 1).

Table 1. Summary of work conducted on biodiversity of Ayubia National Park, Abbottabad, Khyber Pakhtunkhwa, Pakistan (Short Duration: The study was conducted for a short time period, fewer number of months >12; Limited Sampling: The samples were collected, observed, measured or recorded from only a part of the National Park not representative of the habitat type of the National Park; Misidentification: Species might have been misidentified for no photographic evidence or molecular data was provided; Conventional methods: The study lacked use of modern and advanced methods.)

Source	Scope	Mammals	Birds	Reptiles	Amphibians	Fish	Plants	Invertebrates	Short duration	Limited sampling	Misidentification	Conventional methods
Roberts 1992	Birds / Avian fauna of Pakistan	-	33	-	-	-	-	-		✓	✓	✓
Khan & Naqvi 2000	Biodiversity of park	10	11	1	-	-	35	1	✓	✓	✓	✓
Aumeeruddy-Thomas et al. 2004	Ethnobotany	-	2	-	-	-	23	-		✓	✓	✓
Oshida et al. 2004	Genetic diversity of Red giant flying squirrel & small Kashmir flying squirrel	2	-	-	-	-	5	-		✓		
Waseem et al. 2004	Ecotourism	31	203	19	3	-	757	-	✓	✓	✓	
Khanum & Gilani 2005	Conservation status of plant seedlings	-	-	-	-	-	10	-	✓	✓	✓	✓
Gilani et al. 2006	Ethnobotany	-	-	-	-	-	21	-	✓	✓	✓	✓
Khan 2006	Herpetofauna of Pakistan	-	-	8	4	-	-	-		✓	✓	✓
Shafique et al. 2006	Diet analysis of Red giant flying squirrel & small Kashmir flying squirrel	2	-	-	-	-	28	-		✓	✓	✓
Ahmad & Javed 2007	Ethnobotany	-	-	-	-	-	6	-	✓	✓		✓
Lodhi 2007	Conservation and Human-Leopard Conflict)	31	200	16	3	-	-	650	✓	✓		✓
Nasim et al. 2008	Diversity of fungi	-	-	-	-	-	8	-	✓	✓		✓
Saeed 2008	Boundary delineation of Park	7	7	1	-	-	3	-	✓	✓	✓	
Saima et al. 2009	Floristic composition	-	-	-	-	-	142	-	✓	✓	✓	
Shafique et al. 2009	Comparison of nest trees of Red giant flying squirrel & small Kashmir flying squirrel	2	-	-	-	-	16	-	✓	✓	✓	
Afshan et al. 2010	Diversity of fungi	-	-	-	-	-	3	-		✓		
Shafique & Barkati 2010	Diversity of mammals in the park	22	-	-	-	-	-	-	✓	✓	✓	✓
Shinwari 2010	Ethnobotany	-	-	-	-	-	6	-	✓	✓	✓	
Ahmad 2011	Vegetation classification in the park	-	-	-	-	-	59	-	✓	✓	✓	✓
Farooque 2011	Human-Leopard Conflict	31	203	16	3	-	757	650		✓	✓	✓
Shafique & Barkati 2011	Nesting habitats of mammals, birds & invertebrates in the park	5	29	-	-	-	17	5		✓	✓	
Ahmad 2012	Plants' response to environmental variables	-	-	-	-	-	59	-	✓	✓	✓	
Shehzad et al. 2012	Diet analysis of Leopard Cat	7	7	-	1	1	-	-	✓	✓	✓	
Bajwa & Waseem 2013	Documentation of Lepidopteran fauna	-	-	-	-	-	-	101	✓	✓	✓	
Khan 2013	Recreational amenities	8	9	-	-	-	-	-	✓	✓	✓	✓
Khan et al. 2013	Land cover changes & Soil properties	-	-	-	-	-	-	-	✓		✓	
Shehzad et al. 2014	Diet analysis of Common Leopard	4	1	-	-	1	-	-	✓	✓		
Ali et al. 2015a	Diversity of fungi	-	-	-	-	-	11	-	✓	✓		
Ali et al. 2015b	Diversity of fungi	-	-	-	-	-	9	-	✓	✓		✓
Afza 2016	Habitat analysis of birds	-	2	-	-	-	757	-		✓		
Afza et al. 2016	Phytodiversity in park	-	-	-	-	-	250	-			✓	
Shah et al. 2016	Conifers in park	8	9	-	-	-	5	-	✓	✓	✓	
Afza et al. 2018	Vascular plants of park	1	1	-	-	-	250	-			✓	
Awan et al. 2020	Human-Leopard Conflict	1	-	-	-	-	-	-	✓	✓	✓	
Shaker et al. 2020	Impact of transport network changes on tourism in the park	-	-	-	-	-	-	-	✓		✓	
Bashir et al. 2021	Ethnomedicinal uses of mammals and birds in the park	8	30	8	4	-	9	45	✓	✓	✓	
Nazakat et al. 2021	Ethnobotany	-	-	-	-	-	298	-		✓	✓	
Rafaqat et al. 2021	Diet analysis of red fox	4	1	-	-	-	4	-		✓		
Saeed et al. 2021	Temperature effects on amphibians	-	-	-	2	-	-	-		✓		
Ali et al. 2022	Conifers in park	-	-	-	-	-	4	-	✓			
Rauf et al. 2022	Tourism's effect on park	-	-	-	-	-	-	-	✓	✓	✓	
Razzaq et al. 2022	Diversity of fungi	-	-	-	-	-	2	-	✓	✓	✓	
Saeed et al. 2022a	Amphibians (eDNA protocol)	-	-	-	2	-	-	-				
Saeed et al. 2022b	Amphibians (Lab protocol & climate change)	-	-	-	2	-	-	-				
Bashir et al. 2023	Ethnopharmacological applications of mammalian and bird fauna	20	116	-	-	-	-	-	✓			

Given the importance of its location, connecting Provinces Punjab and Khyber Pakhtunkhwa and proximity to the federal capital city of Islamabad, Ayubia National Park requires more serious efforts to promote ecotourism and scientific research. The biodiversity of the National Park should be studied systematically by dividing each of the three habitat types into grids, performing sampling for the presence of a species, and recording its habitat/ landscape variables for species distribution or occupancy modeling. Some groups, such as fish, amphibians, and reptiles, require detailed studies. This would also help document and update the conservation status of the species. However, modern scientific tools such as molecular taxonomy or eDNA can be used, or the species can be photographed for species identification. Further, using an automated or hand-held sound recorder would not only help identify a species but could also enable the estimation of the population and establishment of a population monitoring baseline or estimation. Finally, an atlas and digital maps of distribution records of all species could be made. Human-wildlife conflict must be studied and managed beyond merely reporting deaths, injuries, and cases. Lastly, the National Park should be studied in connection with adjoining national parks, Margalla Hills National Park, for instance, to examine any change in the forest cover or climate, home ranges of avian and mammalian species, particularly threatened species (Table 2) and spread of invasive species.

Table 2. Threatened and Near Threatened biodiversity of Ayubia National Park, Abbottabad, Khyber Pakhtunkhwa, Pakistan

Common Name	Scientific Name	Family	Order	IUCN Status	Reference
Common Leopard	*Panthera pardus*	Felidae	Carnivora	Vulnerable	Shafique & Barkati 2010
Indian Pangolin	*Manis crassicaudata*	Manidae	Pholidota	Endangered	Bashir et al. 2023
Himalayan Griffon	*Gyps himalayensis*	Accipitridae	Accipitriformes	Near Threatened	Bashir et al. 2023
Mountain Hawk-eagle	*Nisaetus nipalensis*	Accipitridae	Accipitriformes	Near Threatened	Bashir et al. 2023
Western tragopan	*Tragopan melanocephalus*	Phasianidae	Galliformes	Vulnerable	Afza 2016
Cheer pheasant	*Catreus wallichii*	Phasianidae	Galliformes	Vulnerable	Afza 2016
Saker falcon	*Falco cherrug*	Falconidae	Falconiformes	Endangered	Bashir et al. 2023
Egyptian vulture	*Neophron percnopterus*	Accipitridae	Accipitriformes	Endangered	Bashir et al. 2023
Red Sand Boa	*Eryx johnii*	Boidae	Squamata	Near Threatened	Khan 2006
Central Asian cobra	*Naja oxiana*	Elapidae	Squamata	Near Threatened	Khan 2006
Himalayan elm	*Ulmus wallichiana*	Ulmaceae	Rosales	Vulnerable	Afza et al. 2016
East Himalayan Yew	*Taxus wallichiana*	Taxaceae	Cupressales	Endangered	Khanum & Gilani 2005
Atish	*Aconitum heterophyllum*	Ranunculaceae	Ranunculales	Endangered	Khan & Naqvi 2000
Golden thread herb	*Coptis teeta*	Ranunculaceae	Ranunculales	Endangered	Khan & Naqvi 2000
Gentiana Kurroo	*Gentiana kurroo*	Gentianaceae	Gentianales	Critically Endangered	Gilani et al. 2006

References

Adams, V.M., Setterfield, S.A., Douglas, M.M., Kennard, M.J., Ferdinands, K. (2015): Measuring benefits of protected area management: trends across realms and research gaps for freshwater systems. Philosophical Transactions of the Royal Society B: Biological Sciences 370(1681): 20140274.

Afshan, N.S., Khalid, A.N., Niazi, A.R. (2010): Three new species of rust fungi from Pakistan. Mycological progress 9: 485-490.

Afza, R. (2016): Phytosociological indicators for pheasant's habitat use and occurrence in Ayubia National Park. Unpublished dissertation, Hazara University, Mansehra, Pakistan.

Afza, R., Ahmad, H., Saqib, Z., Ali, N., Khan, J. (2016): Phytodiversity of Ayubia National Park Pakistan: Conservation and Management issues. Journal of Biodiversity and Environmental Sciences 8(2): 327-336.

Afza, R., Ahmad, H., Saqib, Z., Marwat, K.B., Khan, J. (2018): Spatial analysis of vascular flora of Ayubia national park, KPK, Pakistan: a classical example of moist temperate Himalaya. Pakistan Journal of Botany 50(4): 1499-1508.

Ahmad, S.S., Javed, S. (2007): Exploring the economic value of underutilized plant species in Ayubia National Park. Pakistan Journal of Botany 39(5): 1435-1442.

Ahmad, S.S. (2011): Vegetation classification in Ayubia National Park, Pakistan using ordination methods. Pakistan Journal of Botany 43(5): 2315-2321.

Ahmad, S.S. (2012): Species response to environmental variables in Ayubia National Park, Pakistan using multivariate analysis. Pakistan Journal of Botany 44(4): 1225-1228.

Ali, M., Haider, A., Aslam, H. (2015a): Resilience of the genus Agaricus to climatic variability in and around Ayubia National Park, Pakistan. Journal of Environment and Earth Science 5(1): 25-28.

Ali, M., Shahid, A.A., Asif, M., Azam, M. (2015b): A Contribution to the Previous Study for Genus Agaricus in and around Ayubia National Park, Pakistan. Journal of Biology, Agriculture and Healthcare 5(9): 96-98.

Ali, A., Muhammad, S., Nawaz, H., Tayyab, M., Awan, U.F., Rasool, K., Khan, Z. (2022): Growth response of four dominant conifer species in moist temperate region of Pakistan (Ayubia National Park). Notulae Botanicae Horti Agrobotanici Cluj-Napoca 50(2):12674.

Akram, A., Rais, M., Saeed, M., Ahmed, W., Gill, S., Haider, J. (2022): Movement Paradigm for Hazara Torrent Frog *Allopaa hazarensis* and Murree Hills Frog *Nanorana vicina* (Anura: Dicroglossidae). Biodiversity Data Journal 10: e84365.

Anwar, M. (2019): Review of protected areas system of Pakistan to include new categories as provided by IUCN. A report prepared for Green Pakistan Programme, Ministry of Climate Change, Government of Pakistan. Islamabad.

Asad, M., Waseem, M., Ross, J.G., Paterson, A.M. (2019): The un-common leopard: Presence, distribution and abundance in Gallies and Murree Forest Division, Northern Pakistan. Nature Conservation 37: 53–80.

Aslam, I., Yasmeen, R. (2021): Vertebrate diversity at Margalla Hills National Park, Pakistan. Arxius de Miscellània Zoològica 19: 237–247.

Aumeeruddy-Thomas, Y., Shinwari, Z.K., Abdullah, A., Khan, A.A. (2004): Ethnobotany and the management of fodder and fuelwood at Ayubia National Park, North West Frontier Province, Pakistan. People and Plants. WWF, Godalming, UK. 13.

Awan, M.N., Yaqub, A., Kamran, M. (2020): Survey of human-leopard (*Panthera pardus*) conflict in Ayubia National Park, Pakistan. Journal of Bioresource Management 7(2): 1-5.

Bajwa, G.A., Waseem, M. (2013): Climate change and its impacts on Lepidopterous fauna in Ayubia National Park, Abbottabad. Pakistan Journal of Forestry 61(2):33-46.

Bashir, S.M., Altaf, M., Umair, M., Zahoor, S., Amjad, M.S., Abbasi, A.M. (2021): Ethnomedicinal Uses of Animals in Vicinity of Ayubia National Park, Khyber Pakhtunkhwa-Pakistan. Ethnobiology of Mountain Communities in Asia 221-243.

Bashir, S.M., Altaf, M., Hussain, T., Umair, M., Majeed, M., Mangrio, W.M., Khan, A.M., Gulshan, A.B., Hamed, M.H., Ashraf, S. (2023): Vernacular Taxonomy, Cultural and Ethnopharmacological Applications of Avian and Mammalian Species in the Vicinity of Ayubia National Park, Himalayan Region. Biology 12(4): 609.

Beck, H.E., Zimmermann, N.E., McVicar, T.R., Vergopolan, N., Berg, A., Wood, E.F. (2018): Present and future Köppen-Geiger climate classification maps at 1-km resolution. Scientific Data 5(1): 1-12.

Burns, C.E., Johnston, K.M., Schmitz, O.J. (2003): Global climate change and mammalian species diversity in US national parks. Proceedings of the National Academy of Sciences 100(20): 11474-11477.

Dudley, N., Parrish, J.D., Redford, K.H., Stolton, S. (2010): The revised IUCN

protected area management categories: the debate and ways forward. Oryx 44(4): 485-490.

Farooque, M. (2011): Transforming theory and practice of environmental governance–A case study of Ayubia National Park, Pakistan. Unpublished dissertation, University of Waterloo, Canada.

Fatima, H., Mahmood, T., Hennelly, L.M., Farooq, M., Akrim, F., Nadeem, M.S. (2021): Spatial Distribution and Dietary Niche Breadth of Leopard Cats (*Prionailurus bengalensis*) Inhabiting Margalla Hills National Park, Pakistan. Zoological Studies 60(34): 1-12.

Geldmann, J., Manica, A., Burgess, N.D., Coad, L., Balmford, A. (2019): A global-level assessment of the effectiveness of protected areas at resisting anthropogenic pressures. Proceedings of the National Academy of Sciences 116(46): 23209-23215.

Gilani, S.A., Qureshi, R.A., Gilani, S.J. (2006): Indigenous uses of some important ethnomedicinal herbs of Ayubia National Park, Abbottabad, Pakistan. Ethnobotanical Leaflets 2006(10): 285-293.

Hadi, A., Rais, M., Muddassir, I., Tasib, A., Zafar, M., Gill, S. (2022): Avian Assemblage, Monitoring and Bioassessment of Margalla Hills National Park, Islamabad Capital Territory, Pakistan. Pakistan Journal of Zoology 55(4): 1917-1926.

Halstead, B.J., Ray, A.M., Muths, E., Grant, E.H.C., Grasso, R., Adams, M.J., Delaney, K.S., Carlson, J., Hossack, B.R. (2022): Looking ahead, guided by the past: The role of US national parks in amphibian research and conservation. Ecological Indicators 136: 108631.

Hirons, S., Collins, C.M., Singh, M. (2022): Assessing variation in the effectiveness of IUCN protected area categorisation. What remotely sensed forest integrity and human modification reveals across the major tropical forest biomes. Ecological Indicators 143: 109337.

Khan, S.R., Naqvi, A. (2000): Indigenous Rights and Biodiversity Conservation: A Case Study of Ayubia National Park. SDPI Working Paper Series 52: 11-15.

Khan, M.S. (2006): Amphibians and reptiles of Pakistan. Krieger Publishing Company, Malabar, Florida, USA.

Khan, H. (2013): Demand elasticities of recreational amenities from environmental resources: empirical evidence from Ayubia National Park, Pakistan. Environmental Economics 4(1): 09-14.

Khan, S., Khan, A., Zia, M., Irshad, S., Aurangzeb, N., Fawad, M., Shah, W. (2013): Impacts of land cover changes on soil physical properties in Galliyat, Pakistan. International Journal of Recent Scientific Research 4(3): 216-220.

Khanum, R., Gilani, S.A. (2005): Conservational status of plant seedlings in Ayubia National Park, Pakistan. Lyonia: A Journal of Ecology and Application 8(1): 51-60.

Khatoon, R., Anwar, M., Habiba, U., Mustafa, N., Khalil, S., Eggert, L.S., Gompper, M.E. (2019a): Diet of common leopard and leopard cat in Murree, Kotli Sattian and Kahuta National Park, Pakistan: contrasting patterns of domestic animal and wild carnivore consumption. International Journal of Biosciences 15(1): 321-330

Khatoon, R., Mehmood, T., Anwar, M., Habiba, U., Eggert, L.S., Gompper, M.E. (2019b): A field and laboratory-based assessment of the distribution of large- and meso-carnivore species in the newly established Murree, Kotli Sattian, and Kahuta National Park, Pakistan. Mammal Research 64: 411-422.

Khatoon, R., Anwar, A., Khalil, S., Habiba, U. (2022): Distribution and diet composition of two sympatric mongoose species in Murree Kahuta Kotli Sattian National Park, Pakistan. Journal of Animal & Plant Sciences 32(5): 1469-1477.

Lodhi, A. (2007): Conservation of leopards in Ayubia National Park, Pakistan. Master Thesis, University of Montana, USA.

Mahmood, T., Niazi, F., Nadeem, M. (2013): Diet composition of Asiatic Jackal (*Canis aureus*) in Margallah Hills National Park, Islamabad, Pakistan. The Journal of Animal and Plant Sciences 23(2): 444-456.

Maxwell, S.L., Cazalis, V., Dudley, N., Hoffmann, M., Rodrigues, A.S., Stolton, S., Visconti, P., Woodley, S., Kingston, N., Lewis, E. (2020): Area-based conservation in the twenty-first century. Nature 586(7828): 217-227.

Nasim, G., Ali, M., Shabbir, A. (2008): A study of genus Ramaria from Ayubia national park, Pakistan. Mycopath 6(2): 43-46.

Naughton-Treves, L., Holland, B.M., Brandon, K. (2005): The role of protected areas in conserving biodiversity and sustainable development. Annual Review of Environmental Resources 30: 219-252.

Nazakat, S., Khan, S.M., Noor, R., Zaman, I.U., Arif, M., Khalid, N., Ahmad, Z. (2021): Floral composition, sustainable utilization, and conservation of important medicinal plants in the Ayubia National Park, Abbottabad, Khyber Pakhtunkhwa, Pakistan. pp. 103-123. In: Abbasi, A.M., Bussmann, R.W. (eds.), Ethnobiology of Mountain Communities in Asia.

Oshida, T., Shafique, C.M., Barkati, S., Masuda, R. (2004): A preliminary study on the genetic diversity of small populations of two flying squirrel species from Pakistan (*Hylopetes fimbriatus* and *Petaurista petaurista albiventer*), based on mitochondrial DNA control region sequences. Mammal Study 29(1): 21-26.

Rafaqat, I., Mahmood, T., Hennelly, L., Akrim, F., Zaman, I., Fatima, H., Andleeb, S., Muhammad, G., Abbas, Y., Farooq, M. (2021): Phylogenetic status and diet of red fox (*Vulpes vulpes griffithii*) inhabiting Ayubia National Park, Pakistan. Brazilian Journal of Biology 84: e252991.

Rais, M., Ahmed, J., Naveed, A., Batool, A., Shahzad, A., Bibi, R., Sajjad, A. (2021): Field surveys along habitat gradients revealed differences in herpetofauna assemblage in Margalla Hills National Park, Islamabad, Pakistan. Biodiversity Data Journal 9: e61541.

Rauf, T., Khan, N., Ali, D., Tuyen, T.T., Alam, M., Imlaq, M., Salam, M. (2022): Assessment of tourism industry effects on environmental sustainability: case of Ayubia National Park, Pakistan. GeoJournal 87: 5133–5147.

Razzaq, F., Saba, M., Niazi, A.R., Khalid, A.N. (2022): Two New Records of Genus *Lepiota* (Agaricaceae) from Pakistan. Biology Bulletin 49(5): 458-465.

Roberts, T.J. (1992): The Birds of Pakistan. Oxford University Press, Karachi.

Saeed, U. (2008): Boundary delineation of Ayubia National Park. pp. 5-14. In: Boundary demarcation and renotification of protected areas project. GIS Laboratory, WWF-Pakistan, Lahore.

Saeed, M., Rais, M., Gray, R.J., Ahmed, W., Akram, A., Gill, S., Fareed, G. (2021): Rise in temperature causes decreased fitness and higher extinction risks in endemic frogs at high altitude forested wetlands in northern Pakistan. Journal of Thermal Biology 95: 102809.

Saeed, M., Rais, M., Akram, A., Williams, M.R., Kellner, K.F., Hashsham, S.A., Davis, D.R. (2022a): Development and validation of an eDNA protocol for monitoring endemic Asian spiny frogs in the Himalayan region of Pakistan. Scientific Reports 12(1): 5624.

Saeed, M., Rais, M., Ali, S.M., Khosa, D.N., Akram, A., Ahmed, W., Gill, S. (2022b): Lab protocol for investigating impacts of climate change on frogs. MethodsX 9: 101767.

Saima, S., Dasti, A.A., Hussain, F., Wazir, S.M., Malik, S.A. (2009): Floristic compositions along an 18-km long transect in Ayubia National Park district Abbottabad, Pakistan. Pakistan Journal of Botany 41(5): 2115-2127.

Shafique, C.M., Barkati, S., Oshida, T., Ando, M. (2006): Comparison of diets between two sympatric flying squirrel species in northern Pakistan. Journal of Mammalogy 87(4): 784-789.

Shafique, C.M., Barkati, S., Oshida, T., Ando, M. (2009): Comparison of nest trees of two sympatric flying squirrel species in northern Pakistan. Mammalian Biology 74: 240-244.

Shafique, C.M., Barkati, S. (2010): Mammalian fauna of Ayubia National Park district Abbottabad Khyber-Pukhtoonkhwa province Pakistan. International Journal of Biology and Biotechnology 7(4): 455-461.

Shafique, C.M., Barkati, S. (2011): Some bio-ecological studies on cavity nesters in Ayubia National Park, district Abbottabad, Khyber-Pukhtoon Khwa province, Pakistan. International Journal of Biology and Biotechnology 8(2): 299-303.

Shah, S.A.A., S., Shah, W., Rahman, A. (2016): Impact of Terrain Slopes and Aspect on the Natural Regeneration of the Coniferous Forest in the Northern Pakistan-A Case Study of Ayubia National Park: Natural Regeneration of the Coniferous Forest in the Northern Pakistan. Proceedings of the Pakistan Academy of Sciences: B. Life and Environmental Sciences 53(1): 57-64.

Shaker, M., Adnan, M., Hermans, E., Yasar, A., Wets, G. (2020): Impact of transport network changes on tourism in protected areas: A case study of Ayubia National Park, Pakistan. Journal of Transportation Technologies 10(4): 325.

Shehzad, W., Riaz, T., Nawaz, M.A., Miquel, C., Poillot, C., Shah, S.A., Pompanon, F., Coissac, E., Taberlet, P. (2012): Carnivore diet analysis based on next-generation sequencing: Application to the leopard cat (*Prionailurus bengalensis*) in Pakistan. Molecular Ecology 21(8): 1951-1965.

Shehzad, W., Nawaz, M.A., Pompanon, F., Coissac, E., Riaz, T., Shah, S.A., Taberlet, P. (2014): Forest without prey: livestock sustain a leopard *Panthera pardus* population in Pakistan. Oryx 49(2): 248-253.

Shinwari, Z.K. (2010): Medicinal plants research in Pakistan. Journal of Medicinal Plants Research 4(3): 161-176.

Siddiqui, M., Moinuddin, A., Nasrullah, K., Khan, I. (2010): A quantitative description of moist temperate conifer forests of Himalayan region of Pakistan and Azad Kashmir. International Journal of Biology and Biotechnology 7(3): 175-185.

Vukomanovic, J., Randall, J. (2021): Research trends in US national parks, the world's "living laboratories". Conservation Science and Practice 3(6): e414.

Ward, R., Stevens, C., Brentnall, P., Briddon, J. (2008): The attitudes of health care staff to information technology: a comprehensive review of the research literature. Health Information & Libraries Journal 25(2): 81-97.

Waseem, M., Mohammad, I., Khan, S., Haider, S., Hussain, S.K. (2004): Tourism and solid waste problem in Ayubia National Park, Pakistan (a case study, 2003–2004). Peshawar, Pakistan: WWF–P Nathiagali office.