



Ecosystem Services of Rema-Kalenga Wildlife Sanctuary, Habiganj, Sylhet, Bangladesh

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Article History

Received: 28.08.2024

Accepted: 19.09.2024

Published: 08.10.2024

Abstract: Bangladesh, as a developing country, is widely focused on its immense development projects without considering the environment and ecosystem. The natural ecosystem provides services to living organisms and contributes to maintaining a balance in the environmental equilibrium. In Bangladesh, Rema Kalenga Wildlife Sanctuary (RKWS) is the largest reserve forest after the Sundarbans, inhabiting a huge number of species, both floral and faunal. This study identifies the products and services (ecosystem services) that the RKWS generates to the population. A total of 212 provisioning services (fruit, fish, vegetables, medicine, flowers, crafts), a huge variety of ecosystem functions as regulating services, 84 cultural services (recreation and relaxation, spiritual and ritual practices, social relations, economic opportunities, academics and research, and different local beliefs), 150 plant species (46% tree, 22.66% shrub, 25.33% herb and 5.33% climber), 37 animal species (7 endangered and 3 vulnerable), 27 fish species (3 vulnerable) and 43 bird species (1 vulnerable and 1 critically endangered) has been identified at RKWS. The study provides an understanding of the huge importance of natural environment and ecosystem. Decision-makers and the government should look at it to consider the environment as an integral component of sustainable development. Also, further research and policy are required to manage not only the forests but also all the open green spaces in a way that is socially equitable and environmentally comprehensive.

Keywords: Ecosystem services, Wildlife sanctuary, Flora, Fauna, Avifauna.

Cite this article:

Rahman, S. M. M., Atia, S. K., Rahman, F., Nibras, M. S., Shahriar, T., Mowry, M. T., Joy, H. I., Dina, M. H., Minhaz, S. I. and Pasha, A. B. M. K., (2024). Ecosystem Services of Rema-Kalenga Wildlife Sanctuary, Habiganj, Sylhet, Bangladesh. *ISAR Journal of Science and Technology*, 2(10), 33-45.

1. Introduction

Ecosystem service (ES) means “What people are receiving from their surrounding ecosystem directly and indirectly that provides benefits to them” (Mengist and Soromessa, 2019). These services provide both material and non-material wellbeing to the people (Englund et al., 2017; Vizzarri et al., 2015). It is defined as “the goods or the essential needs of human being which are produced by the surrounding environmental or ecosystem functions (photosynthesis, pollination, transpiration, etc.) through the natural resources are known as the ecosystem services (fruit, fuel, oxygen, etc.) (Rezwan et al., 2022). ES is categorized into four (04) diverse categories: provisioning, regulating, cultural and supporting ecosystem services (Millennium Ecosystem Assessment, 2005). Provisioning services are defined as the tangible products and goods (fish, fresh water, genes, etc.) that are obtained directly from the ecosystem and which have an economic value (Costanza et al., 1998; Nelson et al., 2009). Regulating services are the benefits that

provided through the regulation of any ecosystem processes (temperature regulation, pollination, air quality regulation, etc.) (Flood et al., 2020; Wallace, 2007). Cultural services are the intangible and non-material benefits that people attain from the ecosystem through experiencing aesthetic and scenic beauty, recreation, spiritual enhancement, gaining knowledge, etc. (Finisdore et al., 2020; Fisher et al., 2009). Supporting services are the ultimate functions (nutrient cycling, soil formation, habitat formation for species, etc.) of the ecosystem through which all other services are generated and everything maintains a balance for the survival on this Earth (De Groot et al., 2002; Rezwan et al., 2022). Hence, the supply of ecosystem services regulates the level of human welfare that is linked with the structure, composition and function of the ecosystem (Cruz-Garcia et al., 2016; Vizzarri et al., 2015).

Globally, the concept of the ES became familiar and famous when it was introduced as a political agenda at (Millennium Ecosystem Assessment, 2005). After that policy inclusion, the ES

are considered the natural capital assets that provide benefits and services for the wellbeing of human. In addition, the fact of the impact of human beings' action on the ecosystem started to raise concern and discussion worldwide as a matter of alarm (Ojea et al., 2012). Before all those incidents, the concept began as a field of study after the publication of the work by Costanza et al. (1998) and Daily (1997) (Aznar-Sánchez et al., 2018).

In Bangladesh, Rema-Kalenga Wildlife Sanctuary (RKWS) is a forest. Which is the second largest reserve forest after the Sundarbans mangrove forest (Nishat et al., 2002). This forest ecosystem consists a massive variety of floral and faunal diversity. A lot of ecosystem processes and functions are regulated here with the existence of huge vegetation cover and a number of different water sources. The local community is highly dependent on the forest as it provides many benefits to them (Chowdhury and Koike, 2010; Rahmatullah et al., 2017; Rana et al., 2010). Urbanization is taking place all over the country and immense development projects towards at uplifting the least developed countries are hugely compressing the green and open spaces of the country. People are losing their opportunities for relaxation and recreation (Rezwan et al., 2022). Therefore, everyone including people and policymakers needs to know and understand the importance of a particular ecosystem from a broader perspective. On that note, ecosystem services are the vital factors upon which human beings often depends for survival, and without a functional, healthy

ecosystem there is no chance of generating any ecosystem services. Yet, RKWS is an untouched forest ecosystem which is a huge natural capital asset for the community and country. Besides, the forest has immense conservation value as more than 80% (approximately) of the forest is still in its natural state (Hossain and Numata, 2021; Reddy et al., 2016). So, the objective of the study is to identify and assess the ecosystem services thoroughly to let everyone know what and how many kinds of ecosystem services a functional and healthy ecosystem like RKWS can provide for which everyone should aware of protecting every single ecosystem around their surroundings and exploit them wisely.

2. Methodology

2.1 Study Area

RWKS (24°05' - 24°13' N; 91°34' - 91°40' E) is located in the Chunarughat Sub-district of Habiganj District, Sylhet, Bangladesh (Figure 1). The forest is a hilly area falls under the Sylhet Hilly Region and the RKWS area known as Rema-Kalenga Forest Range (RKFR) (Fox et al., 2013; Subroto et al., 2017). In this present scenario of the world where climate change induced hazard, disasters are posing extreme threat, and anthropogenic pressures are increasing with time, RKWS is a trace patch of tropical hill forest, In Bangladesh.

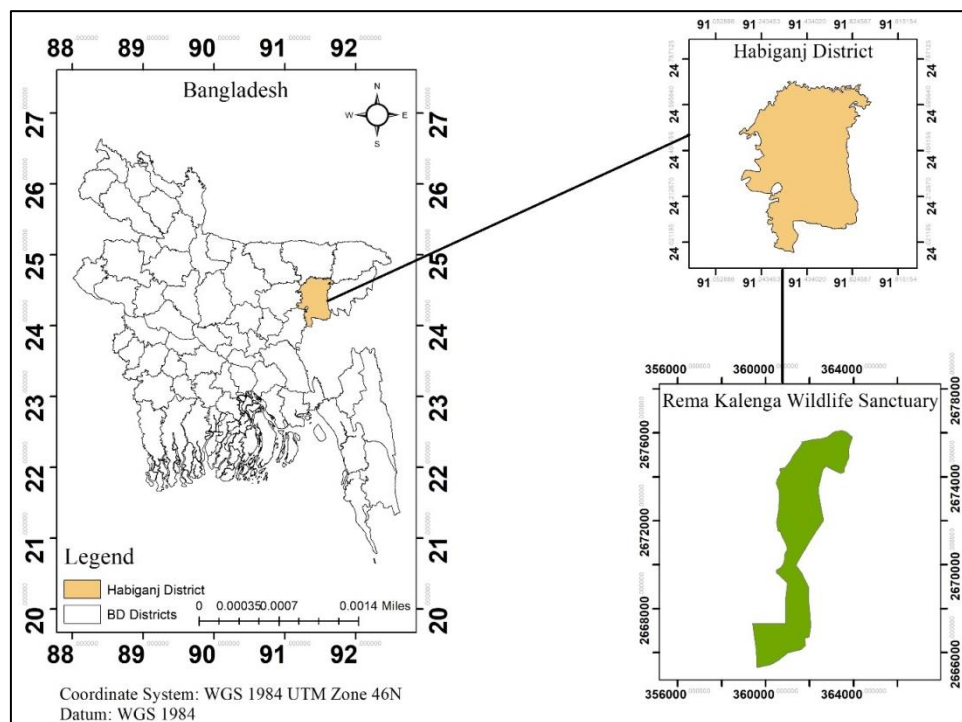


Figure 1. The study area (Rema Kalenga Wildlife Sanctuary - RKWS).

As the RKWS is a large forest, it is divided into three small administrative unit (each unit is a beat), titled as the Rema, Kalenga and Chanbari Beat (Hossain and Numata, 2021; Rahman and Alam, 2016). RKWS is a forest consisting a total area of 6232 ha. In 1996, following the IUCN (International Union for Conservation of Nature) guideline, the Government of Bangladesh designated an area of 1795.54 ha at RKWS as a wildlife sanctuary to control the overexploitation of the natural resources and protect different floral and faunal species (Ministry of Agriculture, 1999; Rana and Akhter, 2010).

2.2 Conceptual Framework of the Study

The study was designed largely based on the primary data collection at RKWS through a four (04) day long extensive field visit of ten (10) individuals from 30th of December 2022 to 2nd of January 2023. The required structured tabulation (data collection) sheet was provided to the

individuals. Each day, from morning (08.00 am) to the afternoon (03.00 pm), all individuals trailed within the deep forest with the help of two (02) guide, combined as a working group. The group observed every little detail of the forest profoundly, took support from the guide where required and discussed everything extensively with all during the walk. Then, the data and every single fact of anything recorded precisely at the tabulation sheet. Each day, at the end of the day in the evening, the group was set for two (02) particular discussion session. First one is within the working group and a key-informant (local forest guide) to clarify any sorts of confusion, misconception of things through discussion and cross-check each data by the key informant. Second one is within the group and a bunch of local people (the FGD group) to get more insight into the collected data and cross-check them. The FGD group was formed with seven (07) members: two (02) aged individuals (> 60 years), two (02) individuals who were involved directly with the RKWS management (headman or member of the forest management group), two (02) individuals from the tribe community who lived inside the RKWS and one (01) forest guide. The FGD groups consisted of at least two (02) women among the seven (07) individuals. Finishing the two-discussion session, the working group documented all the cross-checked data in a designated data format and unidentified data in a different designated data format for further analysis.

On the last day of the field visit, the two (02) evening sessions conducted in a more intense manner. The sessions include all four (04) key-informants (forest guides), all the individuals from the four (04) FGD groups, and the working group to extract any missing issue or fact that was overlooked in the previous days, extract every bit of information's about the collected data facts, and cross-check everything twice. Finally, the working group prepared a detailed presentation on the findings of the field visit and presented it in front of all the individuals from the local community who helped and supported the working group in almost everything through their involvement with this work. At the end of the presentation, they provided their feedback and missing resources with such care to the working group (Figure 2).

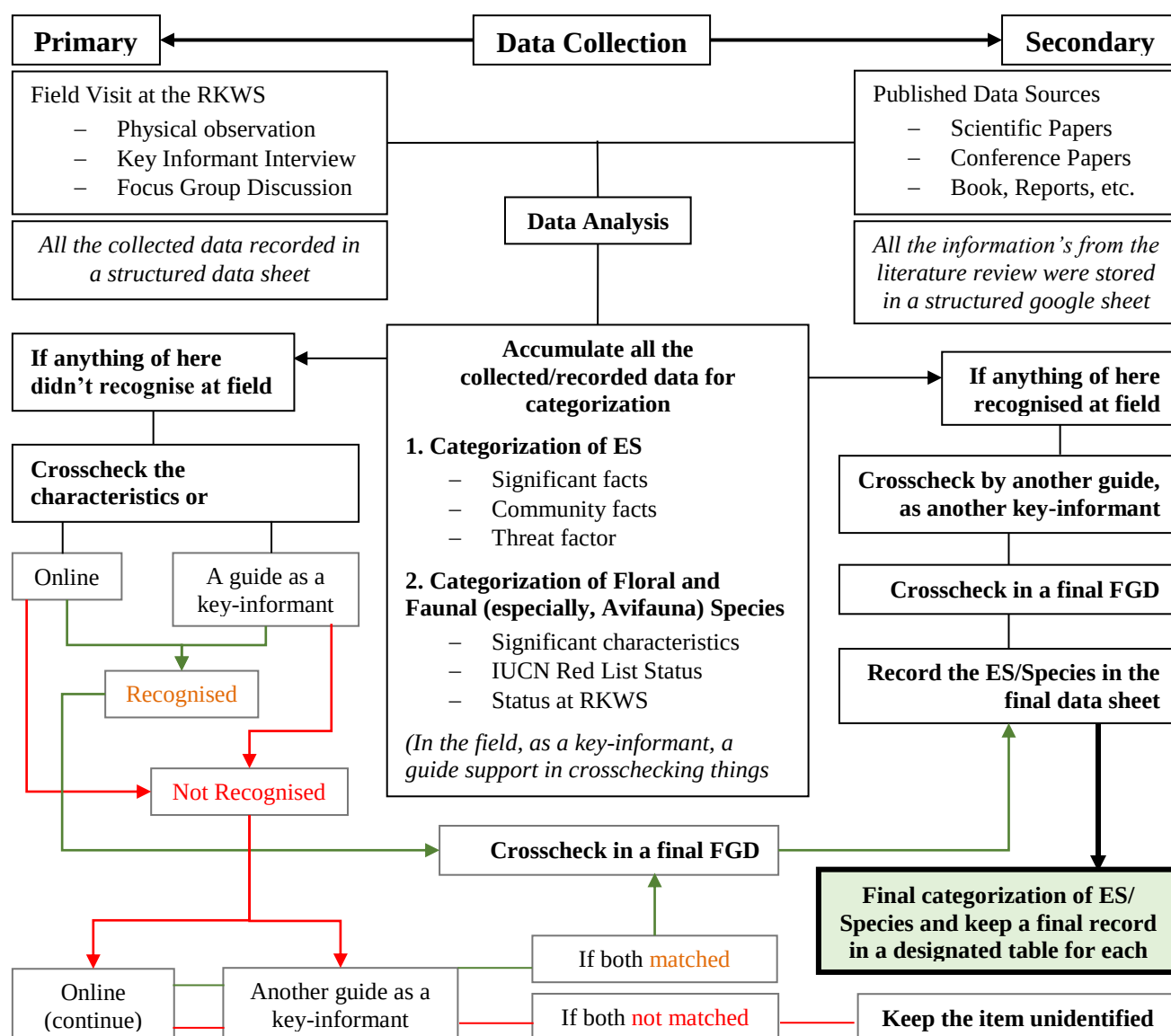


Figure 2. Conceptual framework of the study (from data collection to data analysis).

2.3 Instrumentation

In this study, to identify the avifaunal species (bird), the working groups used BirdNET, which is an artificial intelligence (AI) powered bird sound recognition application/software or tool (a research tool/platform) by Cornell Lab of Ornithology. The tool detects and classify a bird

sound using machine learning to support researchers (Kahl et al., 2021; Wood et al., 2021). PlantNet is a software application that used to detect different plants by capturing the plant's image. It is a research tool that helps researchers and explorers to detect plants with images (Joly et al., 2014). Other faunal species that were unfamiliar to the team was detected through iNaturalist. It is a crowdsourced species identification system and a recording tool of species occurrence (Heberling and Isaac, 2018; López-Guillén et al., 2024; Ueda, 2024). ArcGIS 10.8 software were used for mapping purpose and GPS Device (GARMIN eTrex® 10) were used for navigation, point marking, the waypoint determination, etc. at RKWS. IUCN red list status was detected through the secondary data retrieved from the IUCN (International Union for Conservation of Nature) red list database based on the red list categories and criteria (Table 1).

Table 1. IUCN Red List Categories.

Category	Full Form	Category	Full Form
EX	Extinct	NT	Near Threatened
EW	Extinct in Wild	LC	Least Concern
CR	Critically Endangered	DD	Data Deficient
EN	Endangered	NE	Not Evaluated
VU	Vulnerable	T	Threatened (CR + EN + VU = T)

References: (Betts et al., 2020; IUCN, 2024, 2001)

3. Result and Discussion

3.1 Provisioning Ecosystem Services (PES)

Apart from being a haven for wildlife, RKWS provides a diverse range of provisioning ecosystem services to the local communities. Two hundred and twelve (212) provisioning ecosystem services (PES) were identified during the data collection in the RKWS, which belong to six (06) different categories (fruit, fish, medicine, flowers/ornaments, craft products, energy and other). Among them eighty-four (84) were food products/goods from trees, tribe house farming and water bodies, where thirty-three (33) were fruit, twenty-seven (27) were fishes and twenty-four (24) were vegetables (Table 2). Almost all the identified plant species have some sort of medicinal characteristics, among them twenty-one (21) medicinal plant species were identified that used for medicinal purposes directly. The people from the local community rely on these plants for their healthcare (Chowdhury and Koike, 2010; Rahmatullah et al., 2017). The local communities use these plants to treat various ailments such as fever, cold, cough, skin diseases, etc. Twenty (20) flower and ornamental species found were at RKWS. The local communities (especially the tribe communities) use these plants for their home decoration, religious rituals, festivals, and wedding ceremonies, for medicinal purposes. Craftwork by local communities, especially by women's is one of the PES that is very important for the locality and local people as their livelihoods are dependent on it. Nine (09) different floral species found which used for the making of different craft products (basket, mat, etc.). RKWS is a dry and evergreen forest with rich organic matter in its topsoil (Hossain and Numata, 2021; Rahman and Alam, 2016). Fallen dry leaves, trees, twigs, other parts of the tree benefit from its fuel and energy pool. The local communities use these resources for cooking, heating, and lighting purposes. Kitta leaf, a kind of giant and hard leaf that local people used to wrap or pack parcels from the kitchen market instead of polythene. Local people and beekeepers collect around five to six (5-6) tons of honey per year from the forest.

Table 2. Identified floral species and things as provisioning ecosystem services (fruit, fish, vegetables, medicinal plants, craft products, fuels, etc) in RKWS.

Section: Fruits	Species Scientific Name (IUCN Global Extinction Status)	
<i>Psidium guajava</i> (LC)	<i>Calamus gibbsianus</i> (-)	<i>Aphanamixis polystachya</i> (LC)
<i>Musa acuminata</i> (LC)	<i>Annona reticulata</i> (LC)	<i>Syzygium samarangense</i> (LC)
<i>Aegle marmelos</i> (NT)	<i>Mangifera indica</i> (DD)	<i>Artocarpus heterophyllies</i> (-)
<i>Carissa carandas</i> (-)	<i>Cordyla Africana</i> (LC)	<i>Baccaurea motleyana</i> (LC)
<i>Ziziphus jujube</i> (LC)	<i>Punica granatum</i> (LC)	<i>Phyllanthus emblica</i> (LC)
<i>Cocos nucifera</i> (LC)	<i>Eleocharis dulcis</i> (LC)	<i>Terminalia bellirica</i> (LC)
<i>Dillenia indica</i> (LC)	<i>Syzygium jambos</i> (LC)	<i>Erythrina variegata</i> (LC)
<i>Citrus maxima</i> (LC)	<i>Syzygium cumini</i> (LC)	<i>Elaeocarpus serratus</i> (-)
<i>Areca catechu</i> (DD)	<i>Artocarpus chama</i> (-)	<i>Tamarindus indica</i> (LC)
<i>Ananas comosus</i> (-)	<i>Abroma augustum</i> (LC)	<i>Averrhoa carambola</i> (-)
<i>Ficus carica</i> (-)	<i>Litchi chinensis</i> (-)	<i>Ficus racemosa</i> (LC)
Section: Fish	Species Scientific Name (IUCN Global Extinction Status)	
<i>Labeo calbasu</i> (LC)	<i>Litopenaeus setiferus</i> (-)	<i>Oreochromis mossambicus</i> (VU)

<i>Puntius sophore</i> (-)	<i>Clarias batrachus</i> (LC)	<i>Metapenaeus monoceros</i> (-)
<i>Wallago attu</i> (VU)	<i>Channa punctata</i> (LC)	<i>Neotropius atherinoides</i> (LC)
<i>Nandus nandus</i> (LC)	<i>Batasio tengana</i> (LC)	<i>Heteropneustes fossilis</i> (LC)
<i>Labeo rohita</i> (LC)	<i>Corica soborna</i> (LC)	<i>Platycephalus indicus</i> (DD)
<i>Puntius sarana</i> (-)	<i>Channa striata</i> (LC)	<i>Anguilla bengalensis</i> (NT)
<i>Catla catla</i> (LC)	<i>Barilius barila</i> (LC)	<i>Anabas testudineus</i> (LC)
<i>Puntius chola</i> (LC)	<i>Cirrhinus cirrhosus</i> (VU)	<i>Systemus sarana</i> (LC)
<i>Labeo catla</i> (LC)	<i>Batasio batasio</i> (LC)	<i>Lepidocephalichthys guntea</i> (LC)
Section: Vegetables	Species Scientific Name (IUCN Global Extinction Status)	
<i>Vigna unguiculata</i> (-)	<i>Momordica charantia</i> (-)	<i>Psophocarpus tetragonolobus</i> (-)
<i>Cucurbita mixta</i> (LC)	<i>Ipomoea aquatica</i> (LC)	<i>Momordica cochinchinensis</i> (-)
<i>Plantago major</i> (LC)	<i>Solanum melongena</i> (-)	<i>Amorphophallus bulbifer</i> (-)
<i>Carica Papaya</i> (DD)	<i>Lagenaria siceraria</i> (-)	<i>Diplazium esculentum</i> (LC)
<i>Raphanus sativus</i> (-)	<i>Moringa oleifera</i> (T)	<i>Lycopersicon tuberosum</i> (-)
<i>Luffa aegyptiaca</i> (-)	<i>Centella asiatica</i> (LC)	<i>Amaranthus gangeticus</i> (-)
<i>Dioscorea alata</i> (-)	<i>Citrus aurantifolia</i> (-)	<i>Alocasia macrorrhizos</i> (-)
<i>Basella alba</i> (-)	<i>Benincasa hispida</i> (-)	<i>Amaranthus oleraceus</i> (-)
Section: Medicine	Species Scientific Name (IUCN Global Extinction Status)	
<i>Kalanchoe pinnata</i> (LC)	<i>Abroma augustum</i> (LC)	<i>Peltophorum pterocarpum</i> (-)
<i>Terminalia arjuna</i> (VU)	<i>Justicia adhatoda</i> (LC)	<i>Clerodendrum viscosum</i> (LC)
<i>Cynodon dactylon</i> (-)	<i>Achyranthes aspera</i> (-)	<i>Asclepias curassavica</i> (LC)
<i>Hyptis suaveolens</i> (-)	<i>Cassia abbreviata</i> (LC)	<i>Terminalia bellirica</i> (LC)
<i>Ocimum sanctum</i> (-)	<i>Kyllinga nemoralis</i> (-)	<i>Terminalia chebula</i> (LC)
<i>Ficus sycomorus</i> (-)	<i>Aristolochia indica</i> (-)	<i>Rauvolfia serpentina</i> (-)
<i>Cassia fistula</i> (LC)	<i>Aegle marmelos</i> (NT)	<i>Alstonia scholaris</i> (LC)
Section: Flowers	Species Scientific Name (IUCN Global Extinction Status)	
<i>Mimusops elengi</i> (LC)	<i>Ziziphus mauritiana</i> (LC)	<i>Melastoma malabathricum</i> (-)
<i>Jasminum sambac</i> (-)	<i>Nymphaea nouchali</i> (LC)	<i>Nyctanthes arbor-tristis</i> (LC)
<i>Albizia chinensis</i> (-)	<i>Gardenia jasminoides</i> (-)	<i>Anthocephalus chinensis</i> (-)
<i>Bombax ceiba</i> (LC)	<i>Michelia champaca</i> (LC)	<i>Lagerstroemia speciosa</i> (LC)
<i>Ipomoea carnea</i> (-)	<i>Catharanthus roseus</i> (-)	<i>Zephyranthes atamasco</i> (-)
<i>Delonix regia</i> (LC)	<i>Rhynchosyilis retusa</i> (-)	<i>Hibiscus rosa-sinensis</i> (-)
<i>Tagetes erecta</i> (-)	<i>Murraya paniculata</i> (-)	
Section: Crafts	Species Scientific Name (IUCN Global Extinction Status)	
<i>Areca catechu</i> (DD)	<i>Rhynchosyilis retusa</i> (-)	<i>Schumannianthus dichotomus</i> (-)
<i>Cassia fistula</i> (LC)	<i>Celosia argentea</i> (LC)	<i>Diplazium esculentum</i> (LC)
<i>Calamus tenuis</i> (-)	<i>Bambusa bambos</i> (-)	<i>Pandanus fascicularis</i> (-)
Other Special Mentionable Goods Used by the Locals		
Kittapata, Or Kitta Leaf (Kind of Leaf)		Honey from Forest

References: (Ahmed et al., 2007; Al-Sagheer, 2021; Ansari et al., 2021; Bhalerao and Teli, 2016; Brown et al., 2017; Darwis and Iswanto, 2018; Geetha et al., 2013; Guruge et al., 2017; HABIB and ISLAM, 2020; Hasan et al., 2018; Islam and Hossain, 2017; Khan et al., 2021; Malik et al., 2021; Pasha and Uddin, 2019; Perera et al., 2021; Prasad et al., 2020; Radloff et al., 2010; Raut et al., 2017; Tanjina Hasnat et al., 2016; Yin and Liu, 2018)

3.2 Regulating Ecosystem Services (RES)

Carbon-di-oxide (CO₂) is a greenhouse gas (GHG) that was converted into a pollutant from an important air constituent and became transboundary pollution (Chandrappa and Chandra Kulshrestha, 2016; Manteghi et al., 2015). RKWS consists of a huge vegetation cover that stores a huge amount of CO₂ and leads to flawless photosynthesis. As Bangladesh is a member state of the Copenhagen accord, UN Framework Convention on Climate Change (UNFCCC), the stored carbon at the RKWS can be sell at a rate of 5-15 US\$ per ton (Aziz and Paul, 2015). Plant stores the CO₂ through uptake and release oxygen (O₂) as the by-product of photosynthesis (Ainsworth et al., 2020; Mitra et al., 2017; Ramanan et al., 2021; Yolasıgımaz and Keles, 2009). The production of O₂ maintains an impressive quality of air at RKWS. On the other hand, the transfer of pollen from a male part of the plant to the female part is defined as the pollination and transport of plant seeds from one place to another considered as the seed-dispersal (Carvalho et al., 2021; Neuschulz et al., 2016). As RKWS consists of a huge floral and faunal diversity, active pollination and vigorous seed-dispersal are the two go-to ecosystem functions in the forest. Birds, monkeys, squirrels and entellus are the key agents for the process. Besides, all other faunal organisms, winds and humans also play a big role in the process.

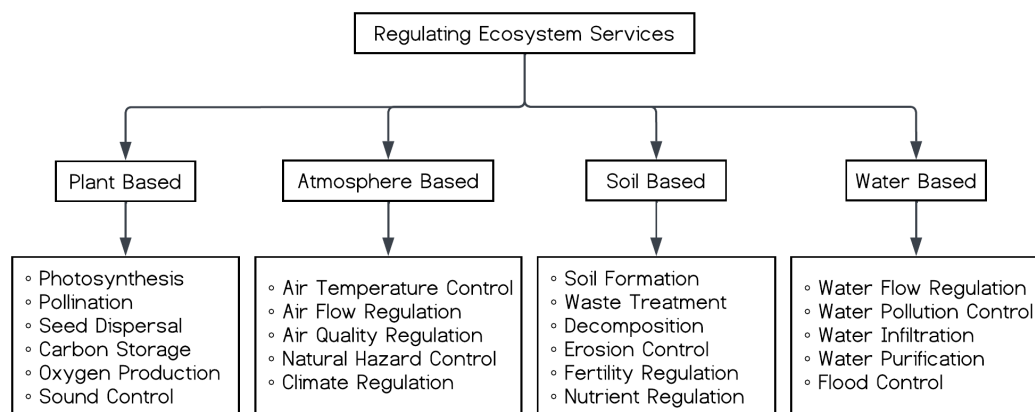


Figure 3. Possible regulating ecosystem services in RKWS.

The fluent existence of a wide variety of birds, animals and microorganisms contributed to the decomposition and regulates the waste treatment as well in the RKWS. The forest is very calm and a zone of acoustic comfort. Huge vegetative area in and out of the forest is the reason for that comfort widely. Because vegetation reduces noise through reflecting, absorbing, scattering and refracting (Aylor, 1972; Fan et al., 2010; Fang and Ling, 2003; Ow and Ghosh, 2017). Shading by the vegetation cover restricts the excessive heating of the local environment by controlling the air temperature and provides shelter to the people from the direct thermal exposure (Doick and Hutchings, 2013; Emmanuel, 2005). Huge vegetation covers provide sufficient shading not only for the people but also for the different faunal species at the RKWS. It also plays a crucial role in regulating the air temperature in the surrounding. The roots of the plants at RKWS protect the soil by holding it in place and stabilize the area by making it less susceptible to erosion. Besides, water absorption breaks down the impact of raindrops, slows down the runoff and disperses the overland runoff flow, hence reduce runoff erosion (Lowdermilk, 1934; Sandercock et al., 2017). Precipitation infiltrates and contributes to the water cycle efficiently through groundwater storage. That effective water flow is contributing to nutrient regulation and maintaining a standard soil fertility as well (Figure 3).

3.3 Cultural Ecosystem Services (CES)

RKWS plays a significant role in the cultural ecosystem of the region. There are a total of eighty-four (84) types of CES that were identified. Identified CES is categorized into six (06) divisions. These services include recreation and relaxation, spiritual and ritual practices, social relations, economic opportunities, academics and research, and different local beliefs.

According to the community people, there are different types of sports that have been played by the children's which is rare in urban culture. Young people play different types of games and sports (e.g., Bon Prishti) using different materials from the forest services (such as fruits and seeds of different plants used as the sports materials). People often went there to track and trail through the deep forest with guides who know the forest well and went for camping there as well at night. People organize different recreational camps at the forest for recreation, relaxation and mental health enrichment by getting the feel of the aesthetics of the forest through different arrangements (picnic, get-together, friends and family tour, etc.). Many people come around to enjoy the calm environment and the aesthetic appeal that the forest offers. Local people walk through the forest in the morning and evening as their physical exercise to keep their mental and physical health in a good state (Hossain and Numata, 2021; Wood et al., 2021).

The local community holds a wide variety of beliefs, rituals and spiritual facts, such as that the Muslim community occasionally catches and eats rabbits whose legs are similar to goat's legs and avoids eating those whose legs are similar to cats. People believe that the indication of good luck and bad luck depends on the calling of *Gekko gekko* (Takshak). The yellow bird's head, bones, wings and fur are used as talisman (protection from jaundice). Keeping two leaves in the yard before entering into the home is considered as the indicator of good luck; if someone forgets to keep the leaves, it is considered to bring bad luck. It means, two leaves are kept in the yard before entering the home to keep away bad luck and things. Local and indigenous people collect flowers from the forest for different pujas or worship and make crafts using forest materials for weddings and different ceremonies. A mosque for the Muslim community and a temple for the Hindu community are the two places where local people go to worship and pray to their respective gods. Local people don't kill snakes, though the snakes invade their homes. Because they

believe the snakes won't harm the people. Also, some local tribes worship of the snakes (Islam and Chuenpagdee, 2013; Islam and Hossain, 2017; Rahman and Alam, 2016).

Local communities are engaged with forest management through different projects (e.g., Sustainable Forest and Livelihood – SUFAL Project) by the government. All the communities, together, protect and conserve the forest. At the end, they will get the ultimate benefit from it. Different business facilities have been initiated by the local community based on the tourism potential of the forest, such as eco-cottages, camping facilities, small restaurants, craft markets, etc. These initiatives are decreasing the community's reliance on the forest. As tourism is expanding, local people are getting interested to working as tourist guide. These tourist guides are like a library of the forest, who know almost everything about the forest and forest things. So, tourists are also shown their interest in hiring them to learn more interesting facts about the forest. Local people collect different parts from the plant species in the forest and process them into different essential medicines. People sell flowers, honey, different forest fruits (Betel Nuts, Coconuts, Guavas, etc.), cottons and everything else collected from the forest. Nine (09) indigenous communities – Tripura, Santal, Urang, Kharia, Kurmi, Goala, Munda, Telugu and Bunargi, - lived there for many years in harmony. “Bamboo” is a significant part of this forest that carries different cultural service value such as making “Hookahs” by the Tripura communities and different craft products by all the local communities (Rana and Akhter, 2010; Rezwan et al., 2022; Subroto et al., 2017).

Different academic institutions (Shahjalal University of Science and Technology, Jahangirnagar University, Chattogram University, Daffodil International University, North South University, etc.) conduct their research at RKWS on different issues. Academicians and students often visit RKWS for research, specimen/sample collection and field purpose with their research team. Institution visits RKWS with their teachers and students to grow interest among the students about the environment and its protection. Also to provide a hand-in experience to get to know about different forest organisms (flora, fauna). The forest, forest management, everything is controlled by the local communities with the help of Bangladesh Forest Department, Government of Bangladesh (GoB). To climb in a small hill, where Tripura community live, they do not cut stairs. Instead of stairs, they keep a smooth slope which decrease the soil erosion and eliminate the difficulties for the disable and aged individuals to climb (Ahmed et al., 2007; Tanjina Hasnat et al., 2016).

Such practices demonstrate the strong cultural ties that the local community has with the forest and how they incorporate their beliefs into their daily lives. RKWS provides a range of cultural ecosystem services that contribute to the well-being of local communities and sustain the forest ecosystem. These services are crucial for maintaining the social, economic, spiritual, and cultural values of the forest.

3.4 Supporting Ecosystem Services (SES)

3.4.1 Floral diversity

In RKWS, according to the forest information graphs, there are 638 floral species. The study was able to find a total of one hundred and fifty (150) plant species in RKWS. Among them sixty-nine (69) were trees, thirty-four (34) were shrubs, thirty-eight (38) were herbs, eight (8) were climbers, and one (1) were epiphyte types of plant (Table 3). According to the IUCN global extinction status, ninety-eight (98) were least concerned (LC), twelve (12) were threatened (T), five (5) were data deficient (DD), three (3) were vulnerable (VU), two (2) were critically endangered (CR), two (2) were nearly threatened (NT), and one (01) were endangered (EN) species. Also, thirty-one (31) were without any specified conservation status (-).

In RKWS, the study was able to find some unique plant species with unique characteristics besides the one hundred and fifty (150) that was unidentified. Those plants are widely known among the local communities but not to the people who went there to visit them. Among them, the local name of one species was “Ghon Rui,” which was so rare that only two (02) of them existed during the field visit. People use this plant as a snake repellent. The local name of another species was “Kitta Pata,” rarely found nowadays, which was used in local bazars (kitchen market, groceries, etc.) to pack market products instead of polythene. Generation after generation, the indigenous peoples of RKWS have been using all these plants for various medicinal purposes, where certain plant species often emerge as veritable life-savers. Common name; Sada basak (*Justicia adhatoda*) has been used as a magical solution for treating respiratory complexities like Asthma and Bronchitis (Dhankhar et al., 2011; Singh and Huidrom, 2013). Nakful (*Sida acuta*), a flowering plant works like a tonic and can heal Ulcers, neurological disorders, diabetes, and tuberculosis (Donkor et al., 2023; Karou et al., 2007).

Table 3. Identified floral species in RKWS.

Floral Species	Scientific Name (IUCN Global Extinction Status) Plant Type	
<i>Psidium guajava</i> (LC) T	<i>Calamus gibbsianus</i> (-) S	<i>Aphanamixis polystachya</i> (LC) T
<i>Musa acuminata</i> (LC) H	<i>Annona reticulata</i> (LC) T	<i>Syzygium samarangense</i> (LC) T
<i>Aegle marmelos</i> (NT) T	<i>Mangifera indica</i> (DD) T	<i>Artocarpus heterophyllus</i> (-) T
<i>Carissa carandas</i> (-) S	<i>Cordyla Africana</i> (LC) T	<i>Baccaurea motleyana</i> (LC) T
<i>Ziziphus jujuba</i> (LC) T	<i>Punica granatum</i> (LC) S	<i>Phyllanthus emblica</i> (LC) T
<i>Cocos nucifera</i> (LC) S	<i>Eleocharis dulcis</i> (LC) H	<i>Terminalia bellirica</i> (LC) T
<i>Dillenia indica</i> (LC) T	<i>Syzygium jambos</i> (LC) T	<i>Erythrina variegata</i> (LC) T
<i>Citrus maxima</i> (LC) T	<i>Syzygium cumini</i> (LC) T	<i>Elaeocarpus serratus</i> (-) T
<i>Shorea robusta</i> (LC) T	<i>Artocarpus chama</i> (-) T	<i>Tamarindus indica</i> (LC) T

<i>Ananas comosus</i> (-) H	<i>Abroma augustum</i> (-) S	<i>Averrhoa carambola</i> (-) T
<i>Ficus carica</i> (-) S	<i>Litchi chinensis</i> (-) T	<i>Ficus racemosa</i> (LC) T
<i>Vigna unguiculata</i> (-) H	<i>Momordica charantia</i> (-) H	<i>Psophocarpus tetragonolobus</i> (-) H
<i>Cucurbita mixta</i> (LC) H	<i>Ipomoea aquatica</i> (LC) H	<i>Momordica cochinchinensis</i> (-) C
<i>Plantago major</i> (LC) H	<i>Solanum melongena</i> (-) S	<i>Amorphophallus bulbifer</i> (-) H
<i>Carica Papaya</i> (DD) S	<i>Lagenaria siceraria</i> (-) C	<i>Diplazium esculentum</i> (LC) H
<i>Raphanus sativus</i> (-) H	<i>Moringa oleifera</i> (T) T	<i>Lycopersicon tuberosum</i> (-) H
<i>Luffa aegyptiaca</i> (-) C	<i>Centella asiatica</i> (LC) H	<i>Amaranthus gangeticus</i> (-) S
<i>Dioscorea alata</i> (-) C	<i>Citrus aurantifolia</i> (-) S	<i>Alocasia macrorrhizos</i> (-) S
<i>Basella alba</i> (-) H	<i>Benincasa hispida</i> (-) C	<i>Amaranthus oleraceus</i> (-) S
<i>Kalanchoe pinnata</i> (LC) S	<i>Solanum nigrum</i> (-) H	<i>Peltophorum pterocarpum</i> (-) T
<i>Terminalia arjuna</i> (VU) T	<i>Justicia adhatoda</i> (LC) S	<i>Clerodendrum viscosum</i> (LC) S
<i>Cynodon dactylon</i> (-) H	<i>Achyranthes aspera</i> (-) H	<i>Asclepias curassavica</i> (LC) S
<i>Hyptis suaveolens</i> (-) H	<i>Cassia abbreviata</i> (LC) T	<i>Terminalia bellirica</i> (LC) T
<i>Ocimum sanctum</i> (-) H	<i>Kyllinga nemoralis</i> (-) H	<i>Terminalia chebula</i> (LC) T
<i>Ficus sycomorus</i> (-) T	<i>Aristolochia indica</i> (-) S	<i>Rauvolfia serpentina</i> (-) S
<i>Cassia fistula</i> (LC) T	<i>Aegle marmelos</i> (NT) T	<i>Alstonia scholaris</i> (LC) T
<i>Mimusops elengi</i> (LC) T	<i>Ziziphus mauritiana</i> (LC) T	<i>Melastoma malabathricum</i> (-) S
<i>Jasminum sambac</i> (LC) C	<i>Nymphaea nouchali</i> (LC) H	<i>Nyctanthes arbor-tristis</i> (LC) S
<i>Albizia chinensis</i> (-) T	<i>Gardenia jasminoides</i> (LC) S	<i>Anthocephalus chinensis</i> (-) T
<i>Bombax ceiba</i> (LC) T	<i>Michelia champaca</i> (LC) T	<i>Lagerstroemia speciosa</i> (LC) T
<i>Ipomoea carnea</i> (-) S	<i>Catharanthus roseus</i> (-) H	<i>Zephyranthes atamasco</i> (-) H
<i>Delonix regia</i> (LC) T	<i>Rhynchosyris retusa</i> (LC) E	<i>Hibiscus rosa-sinensis</i> (-) S
<i>Tagetes erecta</i> (-) H	<i>Murraya paniculata</i> (CR) T	<i>Schumannianthus dichotomus</i> (-) S
<i>Areca catechu</i> (DD) S	<i>Chickrassia tabularis</i> (LC) T	<i>Diplazium esculentum</i> (LC) H
<i>Albizia lebbek</i> (LC) T	<i>Celosia argentea</i> (LC) H	<i>Pandanus fascicularis</i> (-) S
<i>Calamus tenuis</i> (-) H	<i>Bambusa bambos</i> (-) H	<i>Tectona grandis</i> (EN) T
<i>Streblus asper</i> (LC) T	<i>Bambusa polymorpha</i> (-) H	<i>Mesosphaerum suaveolens</i> (LC) S
<i>Garcinia cowa</i> (T) T	<i>Willughbeia edulis</i> (VU) C	<i>Ageratum conyzoides</i> (LC) H
<i>Dillenia pentagyna</i> (LC) T	<i>Heliconia rostrata</i> (T) H	<i>Cinnamomum pachyphyllum</i> (-) T
<i>Schima wallichii</i> (LC) T	<i>Xanthium strumarium</i> (LC) H	<i>Antidesma ghaesembilla</i> (LC) S
<i>Walsura robusta</i> (T) T	<i>Schizostachyum dullooa</i> (T) S	<i>Steudnera colocasoides</i> (-) S
<i>Aristolochia tagala</i> (LC) H	<i>Syzygium fruticosum</i> (T) T	<i>Swietenia mahagoni</i> (NT) T
<i>Bambusa tulda</i> (-) S	<i>Hydnocarpus kurzii</i> (DD) T	<i>Artocarpus lacucha</i> (LC) T
<i>Xylia xylocarpa</i> (LC) T	<i>Maesa ramentacea</i> (LC) S	<i>Acacia auriculiformis</i> (LC) T
<i>Syzygium grande</i> (LC) T	<i>Zanthoxylum rhetsa</i> (LC) T	<i>Stereospermum tetragonum</i> (LC) T
<i>Bombax insigne</i> (CR) T	<i>Ficus benjamina</i> (LC) T	<i>Gigantochloa andamanica</i> (T) H
<i>Ziziphus rugosa</i> (-) S	<i>Amomum subulatum</i> (DD) H	<i>Barringtonia acutangula</i> (LC) T
<i>Pothos scandens</i> (LC) C	<i>Cinnamomum iners</i> (LC) T	<i>Colocasia esculenta</i> (LC) H
<i>Trapa natans</i> (LC) H	<i>Aquilaria agallocha</i> (CR) T	<i>Sida acuta</i> (-) S
<i>Spondias pinnata</i> (-) T	<i>Oroxylum indicum</i> (-) T	<i>Litsea glutinosa</i> (LC) T
E = Epiphyte (01), C = Climber (08), H = Herb (38), S = Shrub (34), T= Tree (69)		

References: (Ahmed et al., 2007; Al-Sagheer, 2021; Ansari et al., 2021; Bhalerao and Teli, 2016; Darwis and Iswanto, 2018; Fox et al., 2013; Geetha et al., 2013; Guruge et al., 2017; Hasan et al., 2018; Hossain and Numata, 2021; Islam and Hossain, 2017; Khan et al., 2021; Malik et al., 2021; Pasha and Uddin, 2019; Perera et al., 2021; Prasad et al., 2020; Radloff et al., 2010; Rahman and Alam, 2016; Rana et al., 2010; Raut et al., 2017; Rezwan et al., 2022; Subroto et al., 2017; Tanjina Hasnat et al., 2016; Wood et al., 2021; Yin and Liu, 2018)

3.4.2 Faunal diversity

As RKWS is a dry and evergreen forest with rich organic matter in its topsoil (Hossain and Numata, 2021; Rahman and Alam, 2016), it is rich in rare animal, fish and bird species. In RKWS, the study was able to identify a total of thirty-seven (37) animal species, twenty-seven (27) fish species and forty-three (43) birds' species. Among the animals, eighteen (18) were least concerned (LC), seven (07) were endangered (EN), five (05) were nearly threatened (NT), three (03) were vulnerable (VU) and four (04) were unspecified (-). Among the fishes, eighteen (18) were least concerned (LC), four (04) were unspecified (-), three (03) were vulnerable (VU), one (01) was data deficient (DD) and one (01) was nearly threatened (NT). Among the birds, thirty-nine (39) was least concerned (LC), two (02) was nearly threatened (NT), one (01) was vulnerable (VU) and one (01) was critically endangered (CR) (Table 4).

In Bangladesh, the black giant squirrel (*Ratufa bicolor*) is only found in this forest. RKWS is the habitat for around two hundred (200) deer. According to the guides and local communities, two (02) pythons have been seen; one is seventeen (17) feet and another is around forty (40) feet in length. There are also fishing cats (*Prionailurus viverrinus*) which are the most ignorant or carefree type of animal in the forest. Some rare bird species include the Red Junglefowl (*Gallus gallus*), the little Green Sunbird (*Anthreptes seimundi*), the Black-Bellied Malkoha (*Phaenicophaeus diardi*), the Black Headed Munia (*Lonchura atricapilla*) etc. There is a unique bird called the Black-hooded Oriole (*Oriolus xanthornus*) which is used as medicine for the treatment of Jaundice within the local community. In RKWS, Hornbills tend to stay in the upper part of the forest. In winter season the Indian Spot-Billed Duck (*Anas poecilorhyncha*) comes into the forest as migratory bird. Alexandrine Parakeet (*Palaeornis eupatria*) is known as the 'Forest Assistant' for its role in seed dispersal as they roam and collect their feed from the forest. The forest authority claimed that there were two hundred and fifteen (215) of bird species. But, now, the forest consists of around one hundred and sixty-five (165) bird species where the rest of the birds have become extinct.

Table 4. Identified faunal species in RKWS.

Section: Fauna	Species Scientific Name (IUCN Global Extinction Status)	
Animals		
<i>Pan troglodytes</i> (EN)	<i>Macaca nemestrina</i> (EN)	<i>Trachypithecus phayrei</i> (EN)
<i>Canis aureus</i> (LC)	<i>Bungarus fasciatus</i> (LC)	<i>Chlorocebus sabaeus</i> (LC)
<i>Felis silvestris</i> (LC)	<i>Macaca assamensis</i> (NT)	<i>Prionailurus viverrinus</i> (VU)
<i>Gekko gecko</i> (LC)	<i>Herpestes edwardsii</i> (LC)	<i>Varanus bengalensis</i> (-)
<i>Crocota crocuta</i> (LC)	<i>Fowlea piscator</i> (LC)	<i>Paradoxurus hermaphroditus</i> (LC)
<i>Ahaetulla nasuta</i> (LC)	<i>Muntiacus muntjak</i> (LC)	<i>Coelognathus radiates</i> (LC)
<i>Sus scrofa</i> (LC)	<i>Zamenis longissimus</i> (LC)	<i>Nycticebus bengalensis</i> (EN)
<i>Naja naja</i> (LC)	<i>Python molurus</i> (NT)	<i>Oryctolagus cuniculus</i> (EN)
<i>Cuon alpinus</i> (EN)	<i>Gecarcoidea natalis</i> (-)	<i>Boleophthalmus boddarti</i> (LC)
<i>Scylla serrata</i> (-)	<i>Macaca leonina</i> (VU)	<i>Trachypithecus pileatus</i> (VU)
<i>Ratufa bicolor</i> (NT)	<i>Arctonyx collaris</i> (-)	<i>Prionailurus bengalensis</i> (LC)
<i>Macaca mulatta</i> (LC)	<i>Hoolock hoolock</i> (EN)	<i>Catopuma temminckii</i> (NT)
		<i>Panthera pardus fusca</i> (NT)
Fishes (Pisces)		
<i>Labeo calbasu</i> (LC)	<i>Litopenaeus setiferus</i> (-)	<i>Oreochromis mossambicus</i> (VU)
<i>Puntius sophore</i> (-)	<i>Clarias batrachus</i> (LC)	<i>Metapenaeus monoceros</i> (-)
<i>Wallago attu</i> (VU)	<i>Channa punctata</i> (LC)	<i>Neotropius atherinoides</i> (LC)
<i>Nandus nandus</i> (LC)	<i>Batasio tengana</i> (LC)	<i>Heteropneustes fossilis</i> (LC)
<i>Labeo rohita</i> (LC)	<i>Corica soborna</i> (LC)	<i>Platycephalus indicus</i> (DD)
<i>Puntius sarana</i> (-)	<i>Channa striata</i> (LC)	<i>Anguilla bengalensis</i> (NT)
<i>Catla catla</i> (LC)	<i>Barilius barila</i> (LC)	<i>Anabas testudineus</i> (LC)
<i>Puntius chola</i> (LC)	<i>Cirrhinus cirrhosus</i> (VU)	<i>Systemus sarana</i> (LC)
<i>Labeo catla</i> (LC)	<i>Batasio batasio</i> (LC)	<i>Lepidocephalichthys quntea</i> (LC)

Birds (Avifauna)		
<i>Cuculus canorus</i> (LC)	<i>Pycnonotus jocosus</i> (LC)	<i>Aethopyga siparaja</i> (LC)
<i>Ceyx azureus</i> (LC)	<i>Acridotheres tristis</i> (LC)	<i>Copsychus malabaricus</i> (LC)
<i>Corvus corax</i> (LC)	<i>Vespertilio murinus</i> (LC)	<i>Dicrurus macrocercus</i> (LC)
<i>Cygnus olor</i> (LC)	<i>Hylatomus pileatus</i> (LC)	<i>Orthotomus sutorius</i> (LC)
<i>Strix uralensis</i> (LC)	<i>Oriolus xanthornus</i> (LC)	<i>Anas poecilorhyncha</i> (LC)
<i>Columba oenas</i> (LC)	<i>Copsychus saularis</i> (LC)	<i>Anthobaphes violacea</i> (LC)
<i>Ardea cinerea</i> (LC)	<i>Lonchura atricapilla</i> (LC)	<i>Phaenicophaeus diardi</i> (NT)
<i>Ardeola grayii</i> (LC)	<i>Passer domesticus</i> (LC)	<i>Leptocoma zeylonica</i> (LC)
<i>Falco subbuteo</i> (LC)	<i>Cuculus micropterus</i> (LC)	<i>Dicrurus paradiseus</i> (LC)
<i>Buceros bicornis</i> (VU)	<i>Palaeornis eupatria</i> (NT)	<i>Alophoixus flaveolus</i> (LC)
<i>Vanellus indicus</i> (LC)	<i>Gyps bengalensis</i> (CR)	<i>Rubigula flaviventris</i> (LC)
<i>Aquila chrysaetos</i> (LC)	<i>Anthreptes seimundi</i> (LC)	<i>Anthracoceros albirostris</i> (LC)
<i>Sturnus vulgaris</i> (LC)	<i>Pellorneum ruficeps</i> (LC)	<i>Amaurornis phoenicurus</i> (LC)
<i>Gracula religiosa</i> (LC)	<i>Garrulax leucolophus</i> (LC)	<i>Harpactes erythrocephalus</i> (LC)
<i>Gallus gallus</i> (LC)		

References: (Ahmad et al., 2020; Devi and Ali, 2015; Duckworth et al., 2016; Hoffmann et al., 2018; Humle et al., 2016; IUCN Bangladesh, 2015; Ruppert et al., 2022; Striata and Murrel, 2019; Stuart et al., 2013, 2021)

4. Conclusion

Immense development project encroaching on the natural spaces around the country in Bangladesh. The RKWS demands a shift in governance structure, focusing on restoring biological diversity and fostering economic diversity in response to a fast-changing socio-ecological setting. To restrict the level of effort, the optimum harvest limitations for each commercially viable species must be identified (e.g., maximum economic output and maximum sustainable production). Interventions are needed to generate alternative economic prospects in the region in order to relieve the strain. Through the study, an understanding of the importance of the natural environment and ecosystem has been provided for decision makers and the government should consider natural environment as an integral component of their development, which eventually ensures sustainable development. Further research is required on the extinction of birds, birds' conservation, valuation of ecosystem services and sustainable forest management. There are a few species which is anonymous yet and requires intensive research. Also, carbon measurement could be a vast area to work on at RKWS.

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