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CONTENTS

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CONTENTS

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CONTENTS

COMPARATIVE STUDY ON THE OCCURRENCE AND INCIDENCE OF INSECT PESTS DUE TO CLIMATE CHANGE IN COASTAL AND HAOR RICE ECOSYSTEM

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Abstract

The survey and assessment were carried out at three coastal and three haor districts of Bangladesh to know the occurrence and incidence of insect pests of rice due to climate change in coastal and haor rice ecosystem during June 2022 to July 2023. The infestations of insect pests in rice ecosystem are changing gradually with time due to changing in climate. Sixteen (16) insect pests of rice and six (6) natural enemies were recorded on rice field of coastal and haor ecosystem. Stem borer, rice leaf roller and Brown plant hopper were one of the major insect pests in coastal and haor rice ecosystems in survey areas. Among three coastal districts, the highest number of stem borer (4.5/30 hills) followed by leaf roller (4.4/30 hills) was observed on boro rice in Khulna followed by Noakhali and the lowest number in Bhola (3.4/30 hills) on T aman rice. Among three haor districts, the highest number of stem borer (3.4/30 hills) in Habigonj followed by Sunamgonj (3.1/30 hills) and the lowest number of stem borer in Kishoregonj (2.9/30 hills). In case of leaf roller, similar trend was also observed on boro rice. Major insect pests of rice is higher in boro season than those of T aman season. Stem borer, rice leaf roller, rice bug and brown plant hopper were one of the major insect pests of rice in coastal and haor rice ecosystems in survey areas. The incidence of 4 major insect pest species of rice crop was higher in coastal rice ecosystem compared to haor rice ecosystem.

Key words: Stem borer, leaf roller, BPH, T aman, Boro

Introduction

Rice is considered as the main unique food for most of the Asian and more than 50% of the globe's populations (IRRI, 2006). It is an essential food crop and more than 90% of world production occurs in tropical and semi tropical Asia (FAOSTAT, 2012). For decades rice crops have directly or indirectly played a key role in the livelihood of several billion people. In 2010, 154 million hectares of rice were cultivated worldwide, of

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which 137 million hectares were in Asia, with 48 million hectares harvested in Southeast Asia (FAOSTAT, 2012). In Bangladesh, eighty per cent of agricultural land is dedicated to rice cultivation (DAE, 2010). More than two hundred species of insects are known to be available in rice ecosystems of Bangladesh (Islam and Catling, 2012; Ali *et al.*, 2017). Among these 20-33 species are considered as pest which cause yield losses (Ali *et al.*, 2021). These insects make a complex food web within the rice ecosystem. In the rice agroecosystem 42 insect species are considered to be pests (Srivastava *et al.*, 2004). Minor and major are recognized as status of pest insect species. These pests cause severe damage to rice crops at different growth stages. The degree of damage is dependent on the growing season and surrounding environment (Khaliq *et al.*, 2014). The behavior as well as distribution and abundance of Yellow stem borer are influenced by changing in climate in southern Asia due to increasing winter survival rates and the number of generations per year, as well as inducing an earlier appearance in the crops after winter (Patel *et al.*, 2017). Elevated winter temperature may not only reduce mortality rates for rice leaf folder and brown plant hopper, but also speed up their development, increasing their potential to accumulate and harm crops in subsequent generations (Kirtani, 1999 and 2007). Altering in climatic factors forced insect pests to move into new ecological niches for survival which is responsible for the invasion of foreign pest in the new habitat as well as threaten for food security (Skendzic *et al.*, 2021). Increasing temperature had a positive effect on growth rate of yellow stem borer and the growth rate of yellow stem borer was found to be high at relatively low temperature and abundant rainfall (Ali *et al.*, 2020). In addition, higher temperature affected the population dynamics of rice insect pests such as brown plant hopper, *Nilaparvata lugens* (Stal) and rice leaf folder, *Cnaphalocrosis medinalis* (Guen), by lowering the survival rate (Karuppaiah *et al.*, 2012). Rice agro-ecosystems have evolved over the last 5,000 years under human management; for this reason human beings are considered to be an integral component. An abundance of insect species are supported through a series of complex interactions that comprise the food web that at its base is maintained by rice (Redfern *et al.*, 2015). In this agroecosystem, the food web can serve as a tool to help improve natural ecosystem functions. However, function is dependent upon the continued propagation of predator insect species. Ecosystem function in a healthy rice agroecosystem can be improved through protecting and encouraging those insects that prey on pest species (Allara *et al.*, 2012). In conventional pest management strategies the role of predator species is minimized or even eliminated by heavy pesticide application. In China, 889 insect species that prey on pest insects have been identified. These predator insect species account for 64.74% of all naturally occurring enemies of pest species (Lou *et al.*, 2013). Increased pesticide use has led to an increase in soil, water and air pollution. These

increases have in turn had an adverse impact on human health and rice quality (Sattar *et al*., 2013). The misuse or excessive use of pesticides can harm plants, livestocks, aquatic organisms, and humans. Jacobsen and Hjelmso (2014) reported that pesticide use has a higher cost to benefit ratio with respect to yields and can have negative impacts on beneficial microbes. One hundred fifty-nine rice insect species are recorded in the rice agroecosystem (Alam, 1977). Among these species, 20–23 species have been found to be most damaging in Bangladesh (Alam, 1977). Farmers often apply pesticides at higher rates and at inappropriate times due to lacking of knowledge relating to insect pest species and insect's life cycle. Farmers are using modern high yielding rice varieties, fertilizers, pesticides, water and other technologies intensively for producing more rice which ultimately changed the ecology and accelerate pest proliferation (Parvin, 2010). A majority of farmers are not concerned with the negative impacts of pesticide use may have on fish, wildlife, humans, soil, and beneficial insect species (Jepson *et al*., 2014). For this reason, previously designated minor insect pests have attained the status of major pests and some major pests have become minor status causing minimum damage and few may be disappeared or extinct from the agro-ecosystem. Hence this study was designed to know the occurrence and incidence of insect pest in coastal and haor rice ecosystem.

Materials and Methods

Survey studies were carried out in the farmers' rice fields of three selected coastal districts such as Khulna, Bhola, Noakhali and three selected haor districts such as Kishoreganj, Habiganj, Sunamganj of Bangladesh to collect data on occurrence and incidence of insect pests of rice and to know the status of insect pests during 2022-23 growing season. Studies were conducted in two locations of each coastal and haor districts. A total 12 upazila viz., Koyra (22.3515^0N and 89.2859^0E), Paikgachha (22.5931^0N and 89.3168^0E) upazila of Khulna district, Bhola sadar (22.6855^0N and 90.6439^0E), Char Fasson (22.1860^0N and 90.7603^0E) upazila of Bhola district, Noakhali sadar (22.8653^0N and 91.0971^0E), Subarnachar (22.6756^0N and 91.1257^0E) upazila of Noakhali district, Itna (24.5278^0N and 91.0958^0E) and Mithamain (24.4196^0N and 91.0634^0E) upazila of Kishoreganj district, Ajmiriganj (24.5489^0N and 91.2362^0E) and Baniachong (24.5063^0N and 91.3566^0E) upazila of Habiganj district, Bishwamvapur (25.1209^0N and 91.3135^0E) and Tahirpur (25.0990^0N and 91.1755^0E) upazila of Sunamganj district were selected as study sites for survey. Three rice fields owned by different farmers were selected from each location. Thirty (30) hills of rice plant from each field of each upazila comprising 90 hills of rice plant were selected randomly. A

total 1080 hills of rice plant from 12 locations were observed for taking data on occurrence and incidence of rice insect pests. Data were recorded through observation of individual tillers of rice plant in each location.

Meteorological data: Simultaneously, the meteorological data such as maximum and minimum temperature, relative humidity and rainfall were collected from the meteorological office of study areas. The average minimum and maximum temperature of Sunamganj district were 18 and 31^0C, Kishoreganj district were 22 and 32^0C, Habiganj district were 17.4 and 36^0C, Noakhali district were 20.3 and 32^0C, Bhola district were 21 and 23 ^{0}C and Khulna district were 24 and 34ºC.

Statistical analyses: The data obtained were statistically analyzed by using WASP 1.0 (Web Agri Stat Package) software and means were separated by CD (critical difference) values.

Results and Discussion

Occurrence of insect pests in coastal and haor rice ecosystem: The occurrence of insect pests and natural enemies observed in coastal and haor rice ecosystem is presented in Table 1. Sixteen (16) insect pests of rice and six (6) natural enemies were recorded on rice field of coastal and haor ecosystem. Out of 16, six species were under the order Hemiptera, five species were under the order Lepidoptera, two of them were under Orthoptera, two under Diptera and one was under Thysanoptera. Among 16 insect pests, 12 insect pests were found in both coastal and haor rice ecosystem. Three insect pests viz., rice thrips, rice mealybug and whorl maggot were recorded from coastal ecosystem and rice case worm was recorded from haor rice ecosystem in T aman season.

*Incidence of major insect pests in coastal rice ecosystem***:** The mean number of four major insect pests per 30 hills on T aman and boro rice in three coastal districts is presented in Figure 1. Among three coastal districts, the highest number of stem borer (4.5/30 hills) followed by leaf roller (4.4/30 hills) was observed on boro rice in Khulna followed by Noakhali and the lowest number in Bhola (3.4/30 hills) on T aman rice. Likewise, similar trend was also observed in case of brown plant hopper (BPH) (3.1/ 30 hills) and rice bug (2.8/ 30 hills) where BPH was higher than rice bug in boro rice but in T aman, rice bug (2.6/ 30 hills) was higher than BPH (1.6/ 30 hills). From this figure it was found that major insect pests of rice is higher in boro season than those of T aman season.

Table 1. Occurrence of insect pests and natural enemies observed in coastal and haor rice ecosystem.

Rice ecosystem	Insect pests	Scientific name	Family	Order
Coastal & haor	Stem borer	*Scirpophaga incertulas*	Crambidae	Lepidoptera
Coastal & haor	Brown plant hopper	*Nilaparvata lugens*	Delphacidae	Hemiptera
Coastal & haor	Rice leaf roller	*Cnaphalocrosis medinalis*	Pyralidae	Lepidoptera
Coastal & haor	Green rice leafhopper	*Nephotettix nigropictus*	Cicadellidae	Hemiptera
		N. virescence		
		Recilia dorsalis		
Coastal & haor	Short horned grasshopper	*Oxya velox*	Acrididae	Orthoptera
		O. chinensis		
Coastal & haor	Long horned grasshopper	*Conocephalus longipennis*	Tettigoniidae	Orthoptera
Coastal & haor	Rice bug	*Leptocorisa acuta*	Coreidae	Hemiptera
Coastal & haor	White backed planthopper	*Sogatella furcifera*	Delphacidae	Hemiptera
Coastal & haor	Rice gall midge	*Orseolia oryzae*	Cecidomyiidae	Diptera
Coastal	Rice thrips	*Stenchaetothrips biformis*	Thripidae	Thysanoptera
Coastal & haor	Rice ear cutting caterpillar	*Mythimna separata*	Noctuidae	Lepidoptera
Haor	Rice caseworm	*Nymphula depunctalis*	Pyralidae	Lepidoptera
Coastal	Small brown planthopper	*Laodelphax striateltus*	Delphacidae	Hemiptera
Coastal	Rice mealybug	*Brevennia rehi*	Pseudococcidae	Hemiptera
Coastal & haor	Swarming caterpillar	*Spodoptera mauritia*	Noctuidae	Lepidoptera
Natural enemies				
Coastal & haor	Spiders	Species was not identified		
Coastal & haor	Dragonfly	Species was not identified	Libellulidae	Odonata
Coastal & haor	Carabid beetle	Species was not identified	Carabidae	Coleoptera
Coastal & haor	Mirid bug	Species was not identified	Miridae	Hemiptera
Coastal & haor	Lady bird beetle	Species was not identified	Coccinellidae	Coleoptera
Coastal & haor	Damselfly	Species was not identified	Coenagrionidae	Odonata
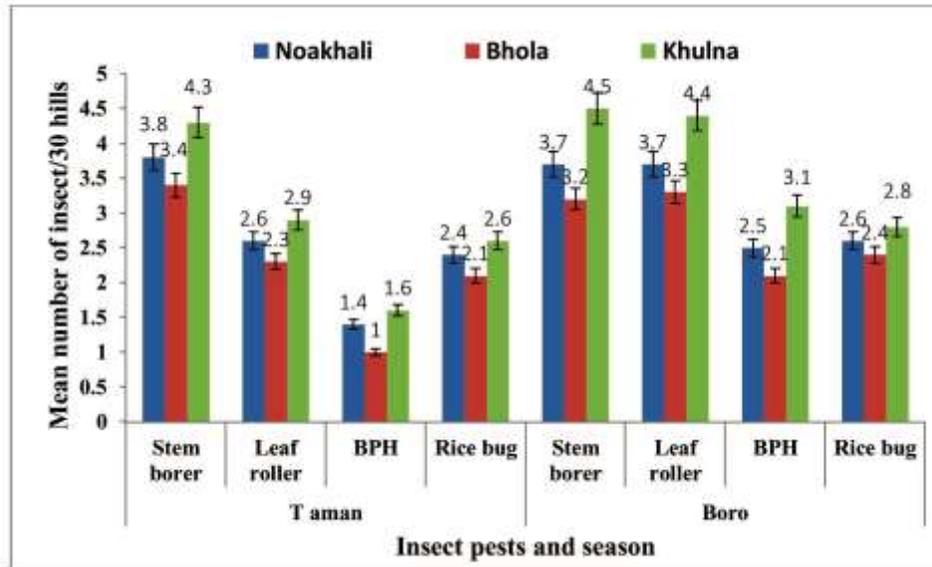
Fig. 1. Mean number of major insect pests at T aman and boro season in coastal rice ecosystem
        during July 2022 to June 2023

Incidence of major insect pests in haor rice ecosystem: The mean number of four major
insect pests per 30 hills on T aman and boro rice in three haor districts is presented in Fig.
2. Among three haor districts, the highest number of stem borer (3.4/30 hills) in Habigonj
followed by Sunamgonj (3.1/ 30 hills) and the lowest number of stem borer in
Kishoregonj (2.9/30 hills). In case of leaf roller, similar trend was also observed on boro
rice. The number of brown plant hopper (BPH) (2.4/ 30 hills) and rice bug (2.4/ 30 hills)
were identical on boro rice in Habigonj which was followed by Sunamgonj and
Kishoregonj. In T aman rice, the highest number of stem borer (2.7-3.1) was recoreded in
three coastal districts followed by leaf roller (1.9-2.4) while the lowest number of BPH
(1-1.2) was recorded in Habigonj and Sunamgonj districts followed by rice bug (1.5-2.1).
No BPH was recorded on T aman in Kishoregonj district. From this figure it was evident
that major insect pests of rice is higher in boro season than those of T aman season.

Major insect pests on T aman in haor and coastal rice ecosystem: The incidence of four
major insect pest species on T aman in haor and coastal rice ecosystem is presented in
Fig. 3. The incidence of stem borer was maximum in Khulna district followed by
Noakhali and Bhola while the lowest incidence was observed in Kishoregonj followed by
Sunamgonj and Habigong. In case of leaf roller and rice bug, similar trend was also

found. The incidence of BPH was maximum in Khulna district followed by Noakhali and Habigonj while the lowest incidence was observed in Sunamgonj followed by Habigong. No BPH was found in Kishoregonj. The incidence of 4 major insect pest species of rice crop was higher in coastal rice ecosystem compared to haor rice ecosystem.
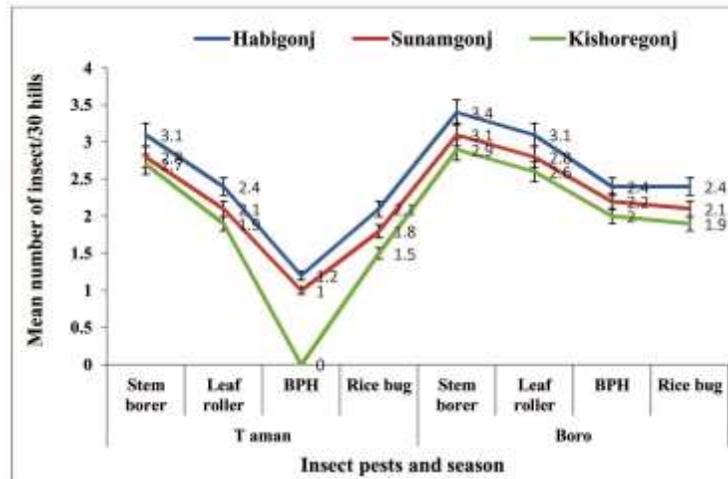
Fig. 2. Mean number of major insect pests at T aman and boro season in haor rice ecosystem during July 2022 to June 2023
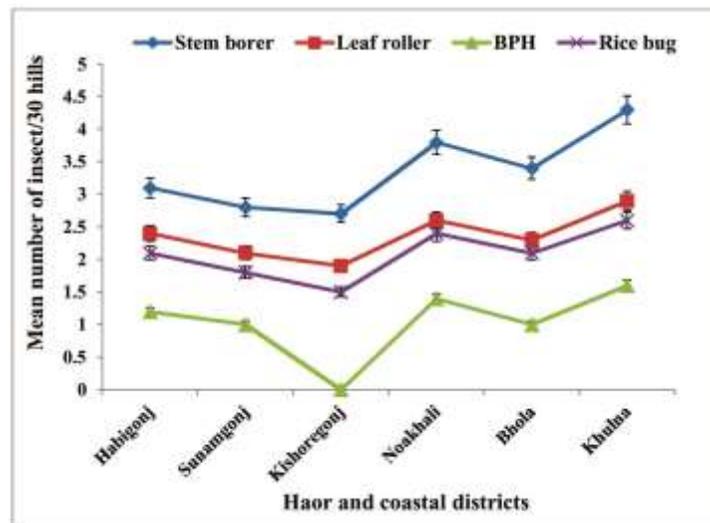
Fig. 3. Comparison of major insect pests on T aman rice in haor and coastal rice ecosystem

Major insect pests on boro in haor and coastal rice ecosystem: The incidence of four major insect pest species on boro in haor and coastal rice ecosystem is presented in Fig. 4. The incidence of stem borer and leaf roller was maximum in Khulna district followed by Noakhali and Bhola while the lowest incidence was observed in Kishoregonj followed by Sunamgonj and Habigong. In case of rice bug, similar trend was also observed. The incidence of BPH was maximum in Khulna district followed by Noakhali and Habigonj while the lowest incidence was observed in Kishoregonj followed by Bhola and Sunamgonj.
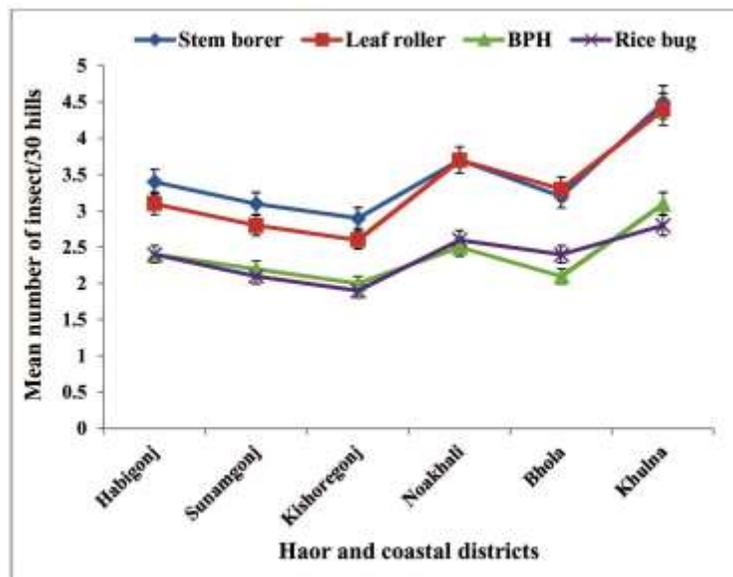
Fig. 4. Comparison of major insect pests on boro rice in haor and coastal rice ecosystem

The findings of the present study revealed that different species of insect pest were affecting the rice crop which was supported by Paramasiva *et al*. (2024) who stated that over one hundred insect pest species consume rice. Twenty of these species were significant pests that seriously harm the economy. The brown planthopper, *Nilaparvata lugens* (Stal), rice yellow stem borer *Scirpophaga incertulas* (Walker), leaf folder, *C*n*apalocrocis medinalis* (Linnaeus), gall midge (GM), *Orseolia oryzae* (Wood-Mason), panicle mite, and *Steneotarsonemus spinki* were the main insect pests of recent years that have regional significance. Among these pests, leaf folder, rice stem borer and brown

plant hopper were very important economically to cause great losses in yield of rice (Barley and Butter, 2008). BPH was a severe pest in rice crop, which was harming to rice plant with heavy damage (Madhuri *et al*., 2017). The rice leaf folder, *Cnaphalocrocis medinalis*, was shown in several lab experiments to be affected by high temperatures in terms of growth rate, reproduction rate, survival, adult longevity, population size, and sexual behavior (Liao *et al*., 2014). Though there were several possible reasons for the abundance/shifts in insect pests viz., growing varieties lacking resistance to major pests, extensive cultivation of high yielding varieties, intensified rice cultivation throughout the year providing niches for pest multiplication, imbalance use of fertilizers and indiscriminate use of insecticides, harmful cultural practices, evolution of biotypes, changes in temperatures or rainfall patterns had profound influence on pest scenario of rice crop. Majority of the researchers opined that the infestation of BPH increased due to the miss use and overuses of nitrogenous fertilizers which favours to excrete more honeydew by BPH (Rashid *et al*., 2017), the plants become more vulnerable to BPH by using more amount of nitrogen. Along with the rice production using modern rice varieties, the insects/pests attack was also increased and loss of rice was continuously going on. These attacks always demanded more care for the rice plant (Horgan *et al*., 2018). Due to the insects/ pests at the global level the rice yield has decreased (Horgan *et al*., 2007). A tropical monsoon climate of Bangladesh was characterized by wide seasonal variations in rainfall, high temperatures, and high humidity which influenced the multiplication of pest. Haq *et al.* (2008) observed a decline in the number of *S. incertulas* during the past thirty years, which could be attributed to mortality brought on by increased rainfall and temperatures. Global warming might theoretically lead to an increase in the number of generations of rice insect pests and their potential to do harm, although this isn't necessarily the case. It is undoubtedly a significant impact in the population rise, even though many other causes might also be involved (Paramasiva *et al.*, 2024).

Conclusion

Sixteen (16) insect pests of rice and six (6) natural enemies were recorded on rice field of coastal and haor ecosystem. Major insect pests of rice is higher in boro season than those of T aman season. Stem borer, rice leaf roller, rice bug and brown plant hopper were one of the major insect pests of rice in coastal and haor rice ecosystems in survey areas. The incidence of 4 major insect pest species of rice crop was higher in coastal rice ecosystem compared to haor rice ecosystem.

References

Alam, S. 1977. Check list of rice insect pests of Bangladesh. In: Literature review of insect pests and diseases of rice in Bangladesh. Director, BRRI, Gazipur-1701, Bangladesh, pp. 79-90.

Allara, M., , S. Kugbei, F. Dusunceli and G. Gbehounou. 2012. Coping with changes in cropping systems: plant pests and seeds," in Proceedings of the Joint FAO/OECD Workshop on Building Resilience for Adaptation to Climate Change in the Agriculture Sector, pp. 91–102, Rome, Italy, April 2012.

Ali, M.P., M.N. Bari, S.S. Haque, M.M.M. Kabir and J. Willer. 2017. Rice Production without Insecticide in Smallholder Farmer's Field. *Front. Environ. Sci.* **5**: 16.

Ali, M.P., M.N. Bari, S.S. Haque, M.M.M. Kabir, F. Nowrin, T.R. Choudhury, R.W. Mankin, and N. Ahmed. 2020. Response of a rice insect pest, *Scirpophaga incertulas* (Lepidoptera: Pyralidae) in warmer world. *BMC Zool*. **5**: 1-8.

Ali, M.P., B. Nessa, M.T. Khatun, M.U. Salam and M.S. Kabir. 2021. A Way Forward to Combat Insect Pest in Rice. *Bangladesh Rice J*. **25**(1): 1-22.

DAE (Department of Agriculture Extension). 2010. Retrieved from http://www .dae.gov.bd/.

FAOSTAT (Food and Agriculture Organization Stat). 2012. Retrieved from www.fao.org/statistics.

Haq, M., M.A. Taher, M.F. Rabbi and M.A. Ali. 2008. Incidence and severity of rice diseases and insect pests in relation to climate change. International symposium on climate change and food security in South Asia, Dhaka, Bangladesh.

Horgan, F.G., D.T. Quiring, A. Lagnaoui and Y. Pelletier. 2007. Variable responses of tuber moth to the leaf trichomes of wild potatoes. *Entomol. Exp. Appl.* **125**(1): 1-2.

International Rice Research Institute (IRRI). 2006. Bringing Hope, Improving Lives: Strategic Plan 2007-2015, International Rice Research Institute (IRRI), Los Banos, Laguna, Philippines.

Islam, Z. and D. Catling. 2012. Rice pest of Bangladesh. Their ecology and management. The university press limited, Dhaka, 451.

Jacobsen, C.S. and M.H. Hjelmsø. 2014. Agriculturalsoils,pesticides and microbial diversity. *Curr. Opin. Biotechnol.* **27**: 15-20.

Jepson, P.C., M. Guzy, K. Blaustein, M. Sow, M. Sarr, P. Mineau and S. Kegley. 2014. Measuring pesticide ecological and health risks in West African agriculture to establish an enabling environment for sustainable intensification. *Philos Trans R Soc Lond Ser B*. **369**(1639): 20130491.

Karuppaiah, V.G.K. 2012. Sujayanad Impact of climate change on population dynamics of insect pests. *World J. Agri. Sci*. **8** (3): 240-246.

Khaliq, A. M. Javed, M. Sohail and M. Sagheer. 2014. Environmental effects on insects and their population dynamics. *J. Entomol. Zool. Stud*. **2**(2): 1-7.

Kirtani, K. 1999. Shift of IPM strategy for rice under global warming in temperate areas. In: Zhang R, Gu D, Zhang W, Zhou C, Pang Y, editors. Integrated pest management in Rice-based ecosystem. Zhongshan University Press, Guangzhou, PRC. pp. 235-244.

Kirtani, K. 2007. The impact of global warming and land use change on the pest status of rice and fruit bugs (Heteroptera) in Japan. *Popul Ecol*. **48**: 5-12.

Liao, H.J., Q. Qian and X.D. Liu. 2014. Heat shock suppresses mating and sperm transfer in the rice leaf folder Cnaphalocrocis medinalis. *Bull Entomol Res*. **104**:383-392.

Lou, Y.G., G.R. Zhang, W.Q. Zhang, Y. Hu and J. Zhang. 2013. Bio logical control of rice insect pests in China. *Biol. Control*. **67**: 8-20.

Madhuri, G., K.K. Rout, P.C. Dash and L.K. Rath. 2017. Influence of Graded Levels of Fertilizers Against Brown Planthoppers (BPH), Nilaparvata lugens (Stal) and Green Leaf Hopper Nephotettix virescens (Distant) in Paddy. *Int. J. Pure App. Biosci*. **5**(5): 984-988.

Paramasiva, I., P. Madhusudhan, U. Vineetha and C.H. Srilakshmi. 2024. Possible impact of climate change on incidence of insect pests of rice. *Int. J. Adv. Biochem. Res*. **8**(1): 498-501.

Parvin. 2010. Rice farmers' knowledge about the effects of pesticides on environmental pollution in Bangladesh. *Bangladesh Res. Pub. J*. :1214-1227.

Patel, S. and C.P. Singh. 2017. Seasonal incidence of rice stem borer, *Scirpophaga incertulas* (Walker) on different varieties of rice in relation to weather parameters. *J. Entomol. Zool. Stud*. **5**(3): 80-83.

Rashid MM, Ahmed N, Jahan M, Islam KS, Nansen C, Willers JL, Ali MP. 2017. Higher fertilizer inputs increase fitness traits of brown plant hopper in rice. *Sci. Rep*. **7**(1):4719.

Redfern, S.K., N. Azzu and J.S. Binamira. 2015. Rice in South East Asia: facing risks and vulnerabilities to respond to climate change. Retrieved from http://www.fao.org/docrep/017/ i3084e/ i3084e18.pdf.

Sattar, M.A., M.Z. Alam and M.M. Rahaman. 2004. The farm use of pesticides and the guidelines of pesticides research in Bangladesh. *Bangladesh J. Environ. Sci*. **10**: 313-317.

Skendzic, S. Zovko, I.P. Zivkovic, V. Lesic and D. Lemic. 2021. The impact of climate change on agricultural insect pests. *Insects,* 12.

Srivastava, S.K., D.K.R. Biswas, B.K.G. Garg, N.M.M.M. Haque, P. Ijaj and S.N. Tiwari. 2004. Management of Stem Borers of Rice and Wheat in Rice-wheat System of Pakistan, Nepal, India and Bangladesh, vol.17 of Rice-Wheat Consortium Paper, Rice Wheat Consortium for the Indo-Gangetic Plains, New Delhi, India.

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TEMPORAL VARIATION AND HETEROGENEITY OF AVIFAUNA IN THE BANGLADESH NATIONAL MUSEUM PREMISES

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Abstract

The study on temporal variation and heterogeneity of avifauna was carried out in the Bangladesh national museum premises during May 2018 to April 2019 employing Strip Transect Sampling technique. A total of 46 species of birds belonging to 11 orders, 26 families and 40 genera were recorded. Of which, 21 species were passerines and 25 non-passerines, 40 were resident and 6 migratory. Family Ardeidae and Sturnidae constituted the highest number of species (n=4, 8.7% of total). Only a single species were recorded from each of the 13 families. The maximum numbers (33%) of species were locally rare. Insectivorous birds were the highest (n=18,39.13% of total) than the other type of birds (piscivorous, frugivorous, omnivorous, granivorous, scavengers, nectarivorous and carnivorous). The highest number of species were (36.22%) recorded during winter than the other two seasons and the species heterogeneity was negatively correlated with temperature ($y = -0.011x + 1.118$, $R^2 = 0.262$) and precipitation ($y = -0.000x + 0.835$, $R^2 = 0.048$) of the study area. The Euclidean distance between the recorded birds in monsoon and winter are much closer than summer. One third of the recorded birds (31.11% of total) used the tree holes, bank of the pond, tree canopies and roof top of the main building of the Bangladesh National Museum for breeding purposes. Altogether 63 tree species (n=556 individuals) of 34 families were recorded in the premises, all of which were used by birds for different purposes. Of the total species of trees, 60% of trees were used for roosting, 30% for feeding and 11% for nesting by birds.

Keywords: Bird diversity, Passerine, Non-passerine, Resident, Migratory, Birds and plant interaction

Introduction

Bird diversity is considered to be a great indicator of healthy environment and it's occupying a wide range of habitats (Islam *et al.*, 2014). It can be sensitive to environmental change and are belong to near or at the top of the food chain (Khan and Ahsan, 2015). It can, therefore, be excellent barometers of the health of the environment and of the sustainability of human progress (Khan and Ahsan, 2015).They are potentials pollinators and bio-indicators (Amat and Green, 2010). Globally about 10,500 species of

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birds are recorded of which, 13% are threatened (IUCN Bangladesh, 2015). Bangladesh is harbours about 690 species of birds, of which 337 residents, 208 winter visitors, 12 summer visitors, 14 passage visitors and 119 vagrants (Khan, 2018). But due to excessive anthropogenic activities and lack of proper conservation measures 19 species of birds have extirpated from Bangladesh (IUCN Bangladesh, 2015). At present Dhaka is being an overpopulated city with a very limited range of habitats for wildlife (Kabir *et al.*, 2010).

Every county of a country should have a list of birds, because they are important biological components of all ecosystems (Ahsan and Khanom, 2005). This research was an attempted to find out the scientific data on temporal variation and avifaunal species diversity, local status and some other aspects of birds of Bangladesh National Museum (BNM) premises. Except this area, sporadically some studies have been done on birds of the different part of the capital city of Dhaka. Chowdhury *et al.* (2014) and Banu *et al.* (2016) studied on seasonal occurrence and checklist of avifauna in Dhaka University campus. The study on avifauna of the national botanical garden of Bangladesh, Dhaka was done by Islam *et al.* (2014). Status and diversity of birds in the Ramna park, Dhaka was noted by Rajia *et al.* (2015). Mohsanin and Khan recorded the status and seasonal occurrence of the birds in Jahangirnager University Campus, Bangladesh (Mohsanin, 2009). The study on diversity of avifauna in Sher-e-Bangla Agricultural University Campus was done by Shovon *et al.* (2014). Diversity and population of avifauna of two urban sites in Dhaka city was recorded by Sarker *et al*. (2009). Capital city of Dhaka is highly diversified with bird species. Bangladesh National Museum campus is surrounding by diversified plant species of Dhaka University Campus and Ramna Park. Hence, an attempt was taken to find out the temporal variation and bird species diversity of the Bangladesh National Museum area. This study should provide baseline information to take in-depth research plan in future.

The objectives of this study were to: (1) find out the diversity of bird species, (2) know the present status with abundance of passerine, non-passerine, resident and migratory bird species, (3) find out the temporal variation and (4) to examine the interaction of birds with tree species in this area.

Materials and Methods

Study site: The study was carried out at the Bangladesh National Museum (BNM) premises, Shahbag, Dhaka, Bangladesh from May 2018 to April 2019. Bangladesh National Museum is a national institute, focused on collection, preservation, research and

interpretative display of historical documents, archaeological artefacts, decorative arts, ethnological materials and specimens of natural heritage of Bangladesh. The museum is located at Shahbag in Dhaka city (Fig. 1) occupying 8.63 acres land, with a magnificent building. The geographical position of the study area is 23°44′15″ N latitude and 90°23′40.2″E longitude.
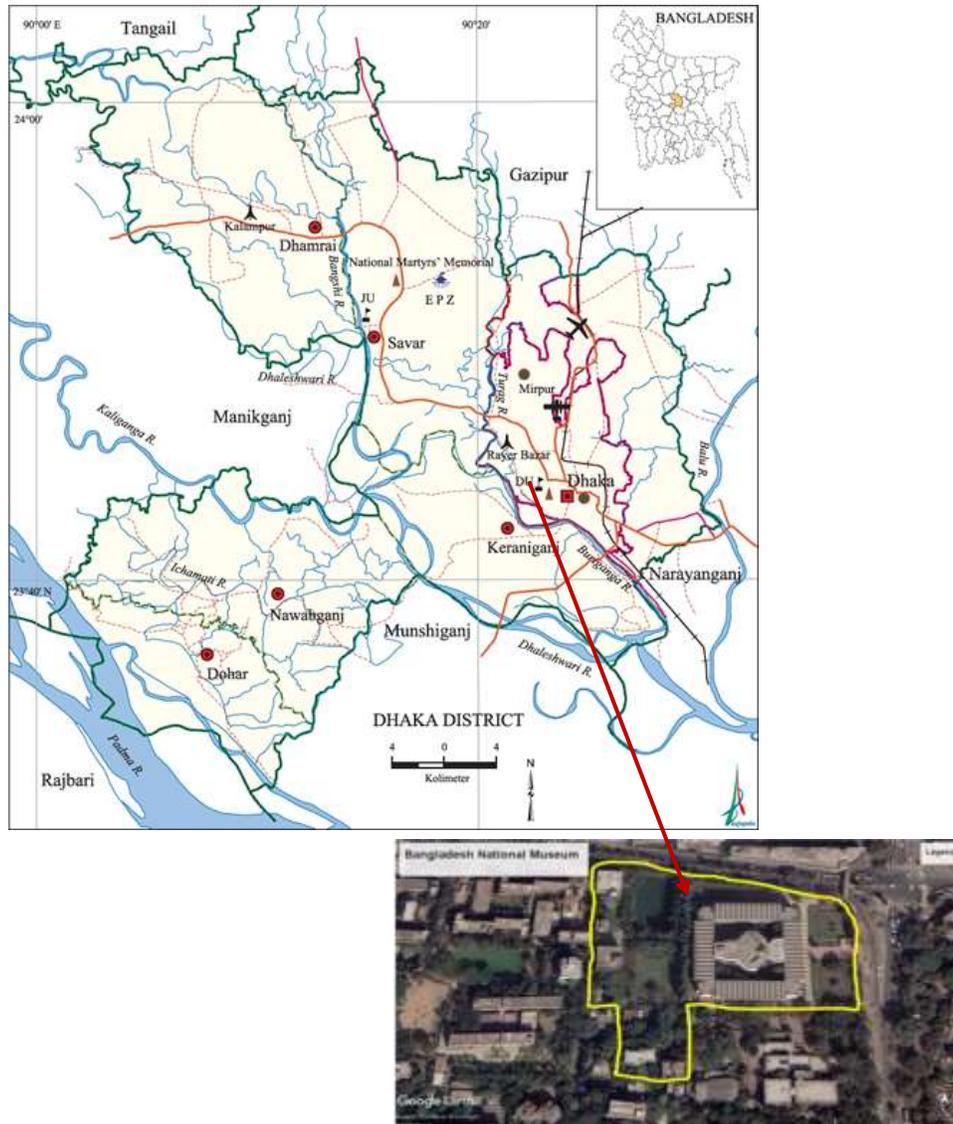
Fig. 1. Map of the study area (map source: Banglapedia 2009 and Google Earth).

PG hospital on the north and Dhaka University campus practically limit the southern and western boundaries of the study area. The Shahbag police station is on the eastern side of the national museum campus.

Dhaka experiences a hot, wet and humid tropical climate. The city has a distinct monsoonal season. The average high temperature for Dhaka ranges from 26°C in January to approximately 36.3°C in April. Similarly, the average low temperature oscillates from 15.3°C in January to 27.3°C in June (Fig. 2). Rainfall is significantly less frequent between October and April, with monthly averages not exceeding 10mm. Conversely, May to September is the wettest months, with an average of 100mm to 134mm of rain per month (Fig. 2). Cold weather is unusual in and around Dhaka.

Fig. 2.Graphs show monthlyweather averages over the year in Dhaka city
(Data source: www.weather-atlas.com).

Materials used: For clear observation of bird a pair of binoculars (Bushnell 10 x 40X) was used from a safe distance. Sometimes, telescope (Swarovski ATS 80 HD with 20 x 60X) was used on roof top of officer's building number 2 to observe the bird from a long distance. Nikon (D3200) camera with 70–300 mm lens used to take photographs of birds and tree species. Garmin (etrex 10) GPS machine used to measure the length of each transect and also to record latitude and longitude of start and end point of each transect. Weather station (Acurite 5 in 1) used to record the temperature, relative humidity and precipitation of the study area.

Data collection: The study area was inspected twice a week during day time. Sometimes night survey (from sunset to 2100 hr) was done to record nocturnal species from their sound call. A total of 96 days, 672 hours (7 hrs/day) were spent for this study. The observation was done during 0600 – 1000 hr and 1500 – 1800 hr. The time schedule was fluctuated depending on the seasonal day length variation. Most of the birds are diurnally active and data were collected through direct field observations. The survey was conducted through simple Strip Transect Sampling technique (Buckland *et al.*, 2001). In total 6 transects were used to count the bird species. Each transect was repeated 3 to 4 times in a day. The total length of transects were 1,023.9 m (Table 1). Sometimes ad libitum data were also recorded to count the bird species.

All bird species were identified following Grimmette *et al*. (1999) and Halder (2010). The local status of the bird species was assessed based on the percentage of occurrence during observations (Emrose, 2024): Very Common (VC) – a species seen during 76 to 100% of the visits; Common (C) – a species seen during 51 to 75% of the visits; Fairly Common (FC) – a species seen during 26 to 50 % of the visits; and Rare (R) – a species seen single or in small number of occasions, i.e. up to 25% of the visits.

Table 1.Transects no, length and GPS coordinate.

Transect no.	Location	Length (m)	GPS	
			Start point	End point
1	Taltala gate to BNM substation	142	23°44′13″N 90°23′43″E	23°44′13″N 90°23′37″E
2	In between Officer's building number 2 and 3 to Agrani bank gate	226	23°44′11″N 90°23′37″E	23°44′17″N 90°23′36″E
3	North – west – south side of officer's building 2	76.4	23°44′12″N 90°23′37″E	23°44′11″N 90°23′37″E
4	East – north – west side of BNM main building	292	23°44′13″N 90°23′41″E	23°44′13″N 90°23′38″E
5	Taltala gate – shahbagh foot over – Agrani bank gate	246	23°44′13″N 90°23′43″E	23°44′17″N 90°23′36″E
6	South side of pond	41.5	23°44′15″N 90°23′37″E	23°44′15″N 90°23′36″E
	Total =	**1,023.9**		

Data analysis: All data were computerized and analysedby SPSS (version 19) software. Pearson two-tailed test performed to determine the correlation coefficient between number of bird species with monthly temperature and precipitation of the area. The temporal changes were analysed by comparing seasons. The hierarchical cluster analysis was done to find out the Euclidean distance between the numbers of bird species based on their diet and also to find out the temporal variation of bird diversity.

Results and Discussion

Heterogeneity of avifauna: During the study period, a total of 46 species of birds recorded belonging to 11 orders, 26 families and 40 genera (Table 2). Among the recorded species, 21species were passerine and 25 non-passerines (Fig. 3); 40 resident and 6 migratory (Fig. 4) (Plate 1). Whereas Shome *et al.* (2022), Banu *et al.* (2016) and Chowdhury *et al.* (2014) recorded 70, 54 and 78 species, respectively from the Dhaka University campus and 65 species were reported by Islam *et al.* (2014) from the National Botanical garden. Rajia *et al*. (2015) found 50 species from Ramna park. Shovon *et al*. (2014) and Sarker *et al*. (2009) recorded 60 and 27 species from Sher-e-Bangla Agricultural University campus and Uttara (sector 7 and 9), respectively.

Plate 1. Recorded migratory bird species in BNM premises: (a) Brown Shrike, (b) Taiga Flycatcher, (c) Blyth's Leaf Warbler, (d) Clamorous Reed Warbler. (Photo credit:Author)

Table 2. Recorded avifaunal species in the Bangladesh National Museum (BNM) premises during May 2018 to April 2019.

Scientific name	English common name	Resident/ Migratory	LS	CS (IUCN Bangladesh 2015)	GS
Order: Columbiformes					
Family: Columbidae					
Columba livia	Rock Dove	R	C	LC	LC
Spilopelia chinensis	Eastern Spotted Dove	R	F C	LC	LC
Order: Caprimulgiformes					
Family: Caprimulgidae					
Caprimulgus macrurus	Large-tailed Nightjar	R	Ra	LC	LC
Family: Apodidae					
Cypsiurus balasiensis	Asian Palm Swift	R	F C	LC	LC
Apus nipalensis	House Swift	R	Ra	LC	LC
Order: Cuculiformes					
Family: Cuculidae					
Eudynamys scolopaceus	Western Koel (Asian Koel)	R	C	LC	LC
Cacomantis merulinus	Plaintive Cuckoo	R	Ra	LC	LC
Order: Pelecaniformes					
Family: Ardeidae					
Butorides striata	Green-backed (Striated) Heron	R	Ra	LC	LC
Ardeola grayii	Indian Pond Heron	R	F C	LC	LC
Egretta garzetta	Little Egret	R	Ra	LC	LC
Ixobrychus cinnamomeus	Cinnamon bittern	R	Ra	LC	LC
Order: Suliformes					
Family: Phalacrocoracidae					
Microcarbo (Phalacrocorax) niger	Little Cormorant	R	Ra	LC	LC
Order: Strigiformes					
Family: Tytonidae					
Tyto alba	Common Barn Owl	R	FC	LC	LC
Family: Strigidae					
Athene brama	Spotted Owlet	R	FC	LC	LC
Order: Accipitriformes					
Family: Accipitridae					
Milvus migrans	Black Kite	R	C	LC	LC
Order: Coraciiformes					
Family: Meropidae					
Merops orientalis	Asian Green Bea-eater	R	FC	LC	LC
Family: Alcedinidae					
Alcedo atthis	Common Kingfisher	R	C	LC	LC
Family:Dalcelonidae					
Halcyon smyrnensis	White-breasted Kingfisher	R	VC	LC	LC
Pelargopsis capensis	Stork-billed Kingfisher	R	Ra	LC	LC
Order: Piciformes					
Family: Megalaimidae					
Psilopogon haemacephalus	Coppersmith Barbet	R	VC	LC	LC

Family: Picidae					
Dinopium benghalense	Black-rumped Flameback	R	C	LC	LC
Micropternus brachyurus	Rufous Woodpecker	R	Ra	LC	LC
Dendrocopos macei	Fulvous-breasted Woodpecker	R	FC	LC	LC
Order: Psittaciformes					
Family: Psittacidae					
Psittacula krameri	Rose-ringed Parakeet	R	VC	LC	LC
Psittacula alexandri	Red-breasted Parakeet	R	Ra	LC	NT
Order: Passeriformes					
Family: Lanidae					
Lanius cristatus	Brown Shrike	M	Ra	LC	LC
Family: Oriolidae					
Oriolus xanthornus	Black-hooded Oriole	R	C	LC	LC
Family: Dicruridae					
Dicrurus macrocercus	Black Drongo	R	C	LC	LC
Family: Corvidae					
Dendrocitta vagabunda	Rufous Tree-pie	R	FC	LC	LC
Corvus splendens	House Crow	R	VC	LC	LC
Corvus levaillantii	Jungle Crow	R	C	LC	LC
Family: Pycnonotidae					
Pycnonotus cafer	Red-vented Bulbul	R	VC	LC	LC
Family: Sylvidae					
Orthotomus sutorius	Common Tailorbird	R	VC	LC	LC
Acrocephalus dumetorum	Blyth's Leaf Warbler	M	Ra	LC	LC
Acrocephalus stentoreus	Clamorous Reed Warbler	M	Ra	LC	LC
Family: Sturnidae					
Sturnus contra	Asian Pied Starling	R	VC	LC	LC
Sturnus malabaricus	Chestnut-tailed Starling	R	VC	LC	LC
Acridotheres fuscus	Jungle Myna	R	C	LC	LC
Acridotheres tristis	Common Myna	R	VC	LC	LC
Family: Muscicapidae					
Ficedula albicilla	Taiga Flycatcher	M	Ra	LC	LC
Copsychus saularis	Oriental Magpie Robin	R	VC	LC	LC
Family: Nectarinidae					
Nectarinia zeylonica	Purple-rumped Sunbird	R	C	LC	LC
Nectarinia asiatica	Purple Sunbird	R	C	LC	LC
Family: Passeridae					
Passer domesticus	House Sparrow	R	C	LC	LC
Dendronanthus indicus	Forest Wagtail	M	Ra	LC	LC
Family: Motacilidae					
Motacilla alba	White Wagtail	M	FC	LC	LC

Note: LS - Local Status, CS - Country Status, GS - Global Status, R - Resident, M - Migratory, VC - Very Common, C - Common, FC - Fairly Common, Ra - Rare, LC - Least Concern, NT - Near Threatened

Number of bird species according to the order: The significant number of species (45.7%) and generae (40%) were recorded from the Order Passeriformes and the minimum number of species (2.2%) and generae (2.5%) recorded from Suliformes and Accipitriformes, respectively.

Passerine birds: Among the Order Passeriformes, family Sturnidae comprised the highest number of species (8.7% of the total and 19.1% of the passerines). Five generae consisted (*Corvus, Acrocephalus, Sturnus, Acridotheres* and *Nectarinia*) the maximum number of species (two, i.e. 4.5% of the total and 9.5% of the passerine species). Thirteen (8 Non-passerines and 5 Passerines) of the 26 recorded families contained single species.

Non-passerine birds: In case of non-passerine, Family Ardeidae consisted of the highest number of genera (four, i.e. 10% of the total and 16.7% of the non-passerines) and species (four, i.e. 8.7% of the total and 16% of the non-passerines) (Table 2). *Psittacula* consisted of the maximum number of species (two, i.e. 4.4% of the total and 8% of the non-passerines).
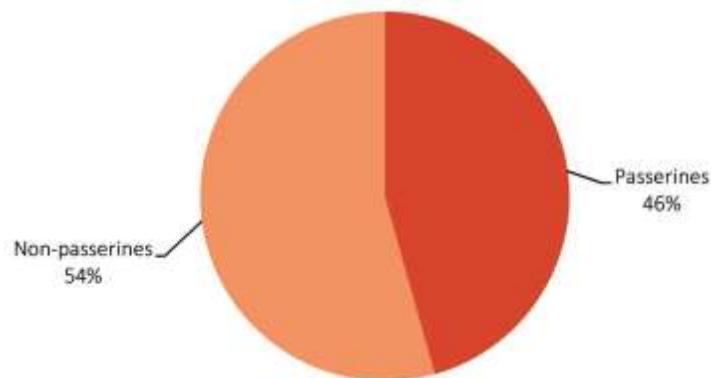
Fig. 3. Percentage of passerine and non-passerine species.
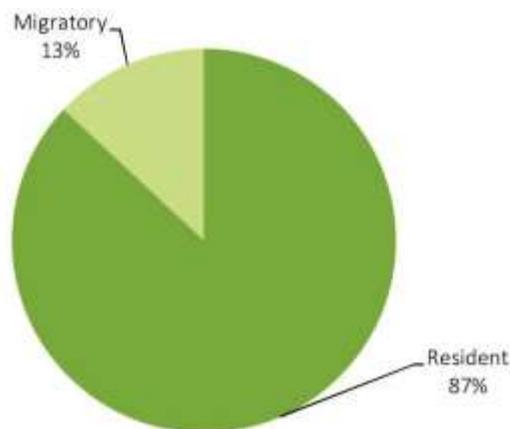
Fig. 4. Percentage of resident and migratory species.

Local status of the recorded bird species: During the study period the maximum number of species (15) were locally rare, 12 species were common, 10 very common and 9 species were fairly common (Fig. 5). Among the passerine species 7 were very common, 7 common, 5 rare and 2 fairly common and in non-passerine 10 rare, 7 fairly common, 5 common and 3 very common species recorded.
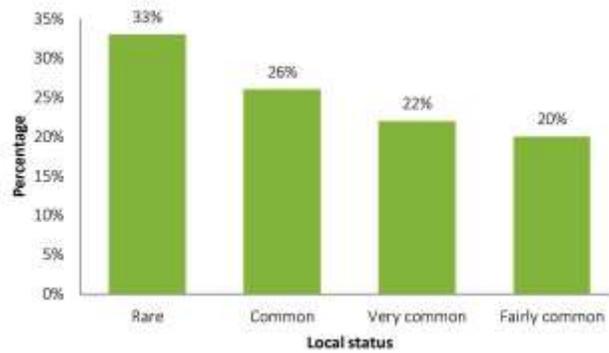
Fig. 5. Local status of the recorded species.

Bird species based on their food habit: Among the recorded species, the highest numbers of birds (18 species) were insectivorous than the other types of birds (piscivorous, frugivorous, omnivorous, granivorous, scavengers, nectarivorous and carnivorous) (Fig. 6).
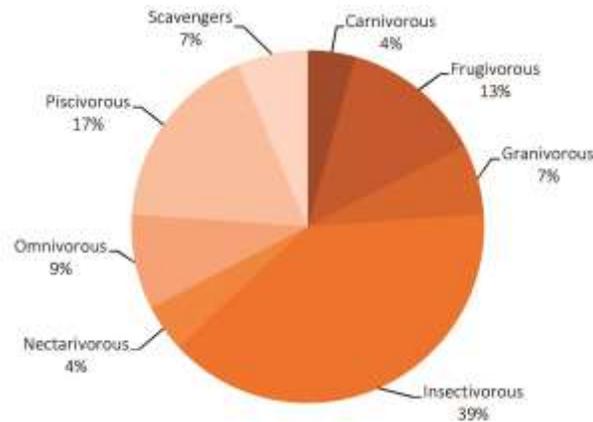
Fig. 6. Bird species based on their food habit.

Temporal variation: This study reported that the maximum numbers of bird species (36.22%) were recorded during winter due to abundance of migratory species than the other two seasons (monsoon, summer) (Fig. 7). Shome *et al.* (2022) also found the highest species diversity in winter.
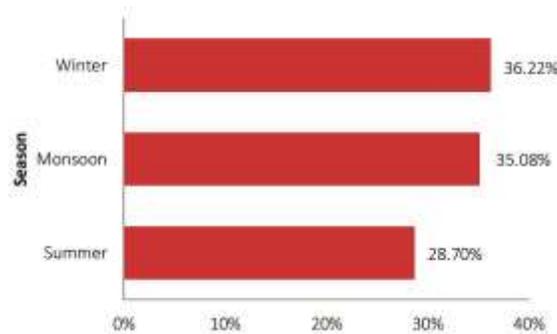
Fig. 7. Temporal variation of bird species in the BNM premises.

From hierarchical cluster analysis it is revealed that the Euclidean distance between the recorded birds in monsoon and winter are much closer than summer (Fig. 8). That means the recorded birds in winter and monsoon is more similar.
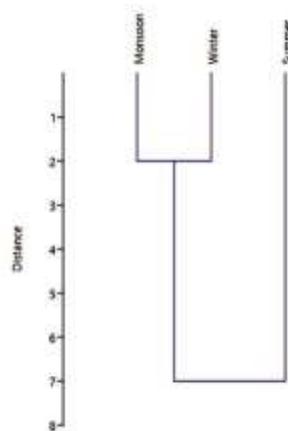
Fig. 8. Euclidean distance between the number of birds in different seasons.

Heterogeneity of birds in relation to temperature and precipitation: The bird species heterogeneity was negatively correlated with temperature (y = -0.011x + 1.118, R^2 = 0.262) and precipitation (y = -0.000x + 0.835, R^2 = 0.048) in this area (Fig. 9). That means, the highest number of species were recorded when the temperature was low and minimum precipitation recorded.
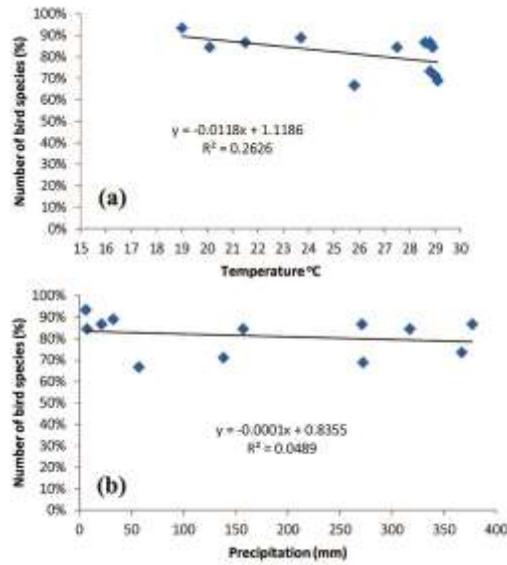
Fig. 9. Relationship of bird species diversity with temperature (a) and rainfall (b) of the study area.
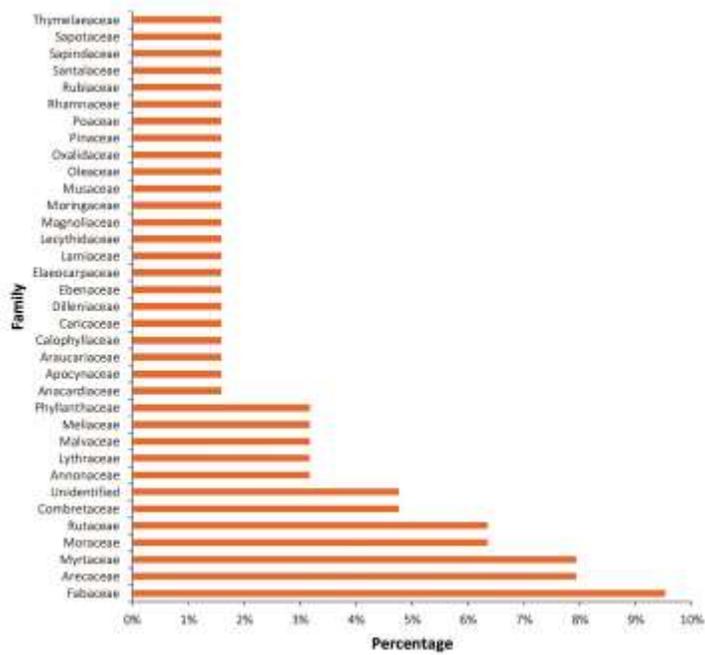
Fig. 10. Family wise tree species in the BNM premises.

Plate 2. Some breeding birds in the BNM premises (Photo credit: Author).

Breeding birds in the BNM premises: Among the total recorded species 31.11% birds (Plate 2) used the study area for breeding purposes. Tree holes, bank of the pond, tree canopies and roof top of the main building of the Bangladesh National Museum were the preferred breeding sites in this area (Plate 3).

Interaction of birds with tree species: A total of 63 tree species (556 individuals), under 34 families were recorded to be used by birds for different purposes. Family Fabaceae was dominant (9.52%) (Fig. 10). Most of the trees (59%) were used for roosting followed by feeding (30%) and nesting (11%).
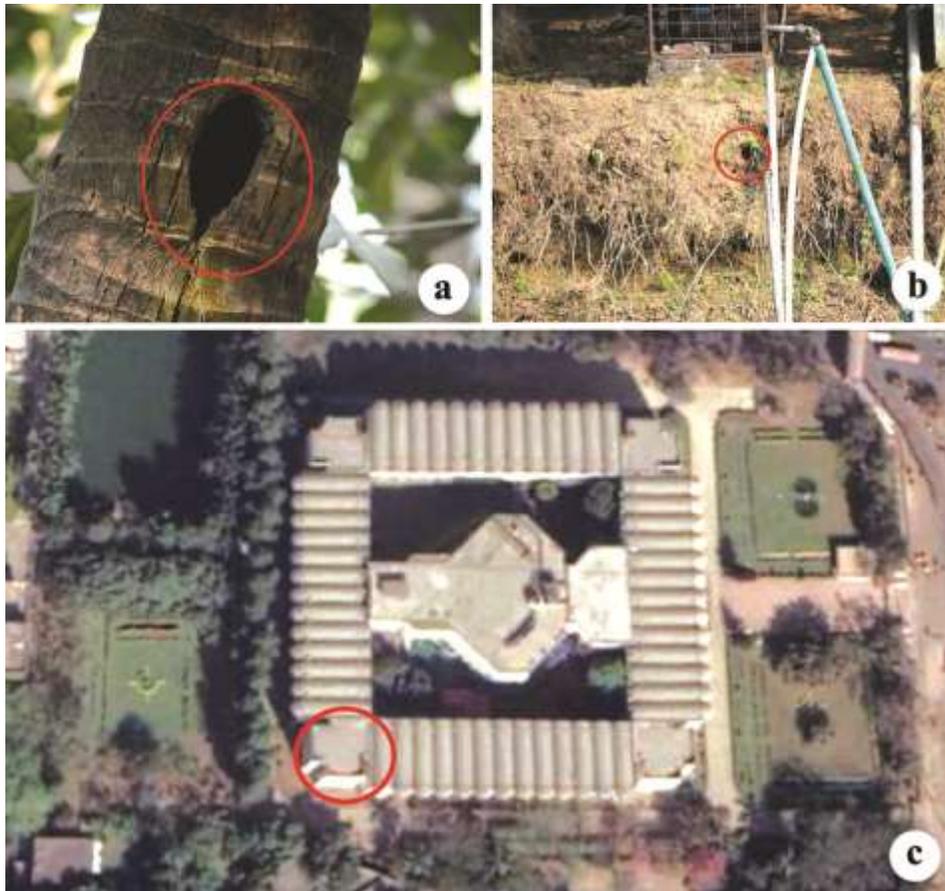
Plate 3. Some preferred bird breeding sites in the BNM premises; (a) tree hole, (b) bank of the pond and (c) roof top of the museum's building (Photo credit: Author).

Conservation values: This study revealed that the diversified habitats of BNM premises i.e.; aquatic habitat (pond), flowering, fruiting, roosting and nesting trees supports different types of bird. Different habitats shelter different species of birds, such as a large pond (0.50 acres) containing fishes and aquatic insects which supports 8 species of piscivorous birds. This habitat occupied by 30% fruit plants which provide food (fruits) for frugivorous birds (6 species).

Conclusions

Bangladesh national museum (BNM) premises are restricted and prohibited to access general people for avoiding excessive crowd, ensuring museum safety and healthy environment of avifaunal species. There is no record of anthropogenic activities in this area. Birds are enjoying this area through nesting, foraging, feeding and resting. Some of the species are living throughout the year in this area without any human disturbance. Even migratory birds are using this area as a stopover while they are flying over a thousand miles from their home country. Thus, BNM ensures a healthy and secure habitat which is rich with different foods and nesting opportunities, provides tremendous ecological benefits along with functional value to birds as well as other animals. BNM plays a great role in conservation of bird species in such an overcrowded unplanned capital city.

Acknowledgements

References

Ahsan, M.F. and N. Khanom. 2005. Birds of the Chittagong University Campus, Chittagong. *The Chittagong Uni. J. Sci.* **29**: 77–88.

Amat, J.A. and A.J. Green. 2010. Waterbirds as Bioindicators of Environmental Conditions. In: *Conservation Monitoring in Freshwater Habitats*, Hurford, C., M. Schneider and I. Cowx (eds). Springer, Dordrecht. pp. 45-52. https://doi.org/10.1007/978-1-4020-9278-7_5

Banu, M.F.A., M. Akash, G.W. Chowdhury and M.A. Hossain. 2016. Status and seasonal occurrence of birds in the Dhaka University Campus. *Dhaka Uni. J. Biol. Sci.* **25**(1): 27-37.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D. L. Borchers and L. Thomas. 2001. *Introduction to distance sampling: estimating abundance of biological populations*. Oxford University Press, Oxford, UK.pp. 448.

Chowdhury, S., U. Aich and O. Shahadat. 2014. Checklist of avifauna of Dhaka University Campus, Bangladesh. *Inter. J. Fauna and Biol. Stud.* **1**(5): 56-60.

Emrose, A., A.R. Shome, M.M. Alam, M.F. Rabbe, N. Hawlader and M.M. Jaman. 2024. Northwesterntransboundary area of Bangladesh: a key to sustaining a quarter of the country's avian species. *Ornothology Research*. **32**: 23-32.

Grimmette, R., C. Inskipp and T. Inskipp. 1999. *Pocket Guide to the bird of the Indian Subcontinent*. Oxford University Press, New Delhi. pp. 384.

Halder, R.R. 2010. *A photographic guide to birds of Bangladesh*. Baikal Teal Production, Dhaka. pp. 258.

Islam, M.S., O. Shahadat, M. M. Kabir, M. A. Rashid, H. A. Razi, M. Kamruzzaman, S.I. Alam and T. Mustafa. 2014. Avifauna of the national botanical garden of Bangladesh. *J. Taxon and Biodi. Resea.* **6**: 17-20.

IUCN Bangladesh. 2015. *Red List of Bangladesh Volume 3: Birds*. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh 2015. pp. xvi+676.

Kabir, S.M.H., E.U. Haque and M.A. Islam. 2010. Wildlife of Dhaka. *In*: Islam, M.A., S.U. Ahmed, and A.K.M.G. Rabbani, (eds). *Environment of Capital Dhaka: Plants Wildlife Gardens Parks Open Spaces Air Water Earthquake*. Asiatic Society of Bangladesh, Dhaka. pp. 83-128.

Khan, M.M.H. 2018. *Photographic Guide to the Wildlife of Bangladesh*. Arannayk Foundation, Dhaka. pp. 488.

Khan, S.I. and M.F. Ahsan. 2015. Frugivorous birds and fruit plants in a deciduous forest in Bangladesh: a case study in the Madhupur National Park. *Bangladesh J. Zoology.* **43**(2): 173-187.

Mohsanin, S. and M.M.H. Khan. 2009. Status and seasonal occurrence of the birds in Jahangirnager University Campus, Bangladesh. *Bangladesh J. Life Sci.* **21**(1): 29-37.

Rajia, S., M.M. Alam, G.W. Chowdhury, M.Akash and M.A. Islam. 2015. Status anddiversity of birds ofRamna Park, Dhaka, Bangladesh. *Bangladesh J. Zool.* **43**(2): 291-301.

Sarker, N.J., D. Sultana, M.F. Jaman and M.K. Rahman. 2009. Diversity and population of avifauna of two urban sites in Dhaka, Bangladesh. *Ecoprint.* **16**: 1-7.

Shome, A.R., M.M. Alam, M.F. Rabbe, M.M. Rahman and M.F. Jaman. 2022. Ecology and diversity of wildlife in Dhaka University Campus, Bangladesh. *Dhaka Univ. J. Biol. Sci.* **30**(3CSI): 429-442.

Shovon, S.C., M.S. Islam, J.A. Mahmud, M.S.N. Chowdhury, M.N. Alam, T. Sultana and M.M. Islam. 2014. Diversity of avifauna in Sher-e-Bangla Agricultural University Campus. *Intern. J. Bus. Soc. and Sci. Res.* **2**(1): 58-63.

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SUSTAINABLE RECOVERY OF RARE EARTH ELEMENTS FROM GRANITE: A REVIEW OF MODERN TECHNIQUES

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Abstract

The extraction of Rare Earth Elements (REEs) is important for clean energy, electronics, and high-tech materials. While minerals like monazite and bastnäsite are the main sources, granite is also being studied as a backup source because it contains REE-rich minerals such as apatite, zircon, and allanite. But extracting REEs from granite is difficult due to its hardness, low REE content, and radioactive materials, which make separation and recovery more complex. This paper reviews different extraction methods, including standard physical processes, bio-based techniques, and newer, greener methods like using ionic liquids. Additionally this study also reviews the importance of finding cleaner, more efficient ways to recover REEs from granite, focusing on better results with less harm to the environment. The findings show that pre-treatment with microwaves reduces the strength of the rock, making it easier to process, and acid leaching after this treatment improves the REE extraction rate.

Key words: Rare Earth Elements; Granite Leaching; Microwave Pre-treatment;
          Sustainable Extraction

Introduction

REEs consist of 17 elements, including 15 lanthanides, Yttrium (Y), and Scandium (Sc), with similar chemical properties (Hoshino *et al.*, 2016; Hu *et al.*, 2004). Although widely distributed in the Earth's crust, Promethium (Pm) is excluded due to its radioactive nature. REEs are critical for modern technologies, particularly in clean energy and electronics, where they are used in permanent magnets for electric vehicles (Dent, 2012), wind turbines (Per Kalvig and Machacek, 2018), and electronics (Daigle and DeCarlo, 2021). REEs also play an essential role in catalysts for petroleum refining (Nieto *et al.*, 2013), pollution control (Patel *et al.*, 2024) , medical imaging (Reddy and Pranav, 2024). The global demand for REEs continues to rise, driven by the shift toward renewable

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energy (Drobniak and Mastalerz, 2022). China dominates the REE market, holding significant reserves and leading in production (Massari and Ruberti, 2013). Due to their low concentrations, REEs are typically obtained as byproducts during the processing of other minerals (Jha *et al.*, 2016), with common minerals such as allanite, bastnaesite, and monazite being the primary sources of REEs (Lashen *et al.*, 2016). However, granite, typically composed of quartz, mica, and feldspar, has emerged as an underutilized source of REEs (Balaram and Sawant, 2022). A-type and S-type granites contain REE-rich minerals like apatite, zircon, allanite, and monazite, and weathering processes can concentrate these elements in regolith-hosted deposits, offering easier extraction options than primary ore bodies (Bucher and Seelig, 2018; Li *et al.*, 2017). Granite extraction presents unique challenges, including the presence of radioactive elements such as thorium (Th) and uranium (U), which complicate the process (Balaram, 2023a). Analytical techniques like ICP-MS, gamma spectrometry, and SEM-EDS are crucial for understanding ore composition and optimizing extraction methods (Pinto *et al.*, 2012). Eco-friendly methods such as ionic liquids and bio-extraction offer sustainable options for recovering rare earth elements (REEs). Ionic liquids allow for selective and low-impact extraction, while bio-extraction uses microorganisms to recover REEs in a cost-effective and environmentally safe way. The results show that using microwave pre-treatment weakens the rock, making it easier to break down, and that acid leaching after this step leads to better REE recovery.

Mineralogical specification of REE in granite

REEs possess unique chemical, physical, magnetic, and luminescent properties, owing to their distinctive atomic structures and electronic configurations (Dushyantha *et al.*, 2020). Analyzing REE distribution within granite is essential for developing efficient extraction methods, as highlighted in several studies.

Nature of occurrence of REEs in granite

In granite, REEs are primarily concentrated in accessory minerals like monazite, bastnäsite, and xenotime, which are often part of the igneous mineral assemblage. These minerals are important for the primary extraction of REEs from granite deposits (Ishihara *et al.*, 2008) (Table 1). Demonstrates various granite types along with their concentration of REEs and economic potential, highlighting the correlation between mineral composition and REE concentration.

Table 1. Demonstrates various granite types along with their concentration of REEs and economic potential, highlighting the correlation between mineral composition and REE concentration.

Country names	Types/classification of Granite	Concentration of REE(ppm)	Mineral composition	Reference
USA (New Mexico)	Granites (Various Types) / Peralkaline Granite	Tajo Granite: 174.9 (avg.), Sevilleta Granite: 107.1 (avg.), Gallinas Granite: 264.5 (avg.)	Monazite, zircon, apatite,feldspars,fluorite, xenotime,thorite, allanite, samarskite	(Dietz and McLemore)
China (Jiangxi Province)	Peralkaline Granites /HREE-enriched Granites	Dingnan Biotite Granite: 358, 429 ppm, Wuliting Mafic Biotite Granite: 344 ppm	Alkali feldspars, quartz, biotite, zircon, aegirine, fluorite,allanite, samarskite, xenotime	(Zhao *et al.*, 2022)
Cameroon (Biou Area)	Granites (S-type, Peraluminous) / Weathered Granites	Weathered materials: 200 to 1,400 ppm	Quartz, alkali feldspars, biotite,muscovite, plagioclase,zircon, monazite,apatite, fluorite	(Sababa *et al.*, 2021)
Egypt (W. Hawashia, North Eastern Desert)	Monzogranites / Intrusive Granites	43 ppm (average)	Plagioclase**,** quartz**,** alkali feldspars**,** biotite Accessory minerals**:** apatite**,** zircon	(Saleh *et al*., 2019)
Indonesia (Sijunjung, West Sumatra)	A-type Unggan Granite	Average REE = 860 ppm, with La and Nd as the major REE	Quartz, feldspar, mica (dark red coarse-grained granite) with significant presence of Ga, Nb, and Y, indicating A-type affinity	(Irzon *et al*., 2018)

Major and minor mineral constituents

REEs occur in various mineral classes such as oxides, phosphates, silicates, carbonates, and halides (Balaram and Sawant, 2022), but current production is primarily sourced from fewer than ten key minerals, notably bastnäsite, xenotime, and monazite (Jordens *et al.*, 2013). In granite systems, important REE-bearing minerals include apatite, allanite, xenotime, and zircon (Zhang *et al.*, 2021; Ishihara *et al*., 2008; Anitha *et al.*, 2020b). Studies from southern Jiangxi Province (China) and Skye (UK) show significant LREE enrichment in allanite and apatite (Ishihara *et al*., 2008; Anitha *et al.*, 2020a). Additionally, ion-exchangeable clays formed from the weathering of minerals such as allanite, titanite, and fluorocarbonates are major hosts for secondary REEs (Kanazawa and Kamitani, 2006; Sanematsu *et al.*, 2015). Less commonly, minerals like britholite

and thorite also contribute to REE distribution in some granite complexes (Zozulya *et al.*, 2019; Santana and Botelho, 2022).

Spectroscopic and mineralogical analysis: Characterization Method

Accurate identification and quantification of REEs require a combination of elemental, isotopic, and mineralogical techniques. ICP-MS is widely used due to its sensitivity and ability to detect low REE concentrations in rock and mineral samples (Alnour *et al.*, 2015; Navarro *et al.*, 2008). For in-situ measurements, LA-ICP-MS allows REE mapping within individual minerals without full digestion (Sindern, 2017; Jarvis and Williams, 1993). XRD and SEM-EDS are used to identify REE-hosting minerals and determine their textural relationships within the rock (Balaram, 2023b). INAA is also effective for multi-element analysis, offering high sensitivity without the need for chemical separation (El-Taher, 2007; Silachyov, 2020). For rapid, non-destructive elemental assessment, XRF is used, though with lower sensitivity for trace REEs; it performs better when combined with pre-concentration or calibration methods (Srivastava and Premadas, 1999; Sitko *et al.*, 2005). Raman spectroscopy can support the identification of REE-bearing phosphates, especially in lateritic or weathered granites (Zhukova *et al.*, 2022).

Processing techniques for rare earth element recovery from granite

REEs, due to their similar ionic sizes and stable trivalent states, are challenging and costly to separate. Efficient isolation methods have been the focus of extensive research, with fractional crystallization being an early technique that exploits slight solubility differences in REE salts.

Beneficiation techniques: Physical approaches: (Gravity and Froth flotation)

Physical separation techniques are often used as a pre-concentration step in REE extraction from granite-hosted ores, where REEs are found in minerals like monazite, xenotime, and allanite. These methods help remove gangue before applying hydrometallurgical processes. Gravity separation exploits the density contrast between REE minerals (specific gravity ~2.9–7.2) and lighter gangue (2.5–3.5) (Somani *et al.*, 2017). Devices like shaking tables, spiral concentrators, and centrifugal separators (e.g., Falcon, Knelson) are used to concentrate REE-rich particles. The Wilfley shaking table has shown effectiveness in processing granite-derived ores, as demonstrated in studies

from Wadi Abu Dob, and combined use of spirals and centrifugal methods has enhanced recovery in Eastern Siberia (Hassan, 2023; Khokhulya *et al.*, 2021). Froth flotation is widely used to separate REE-bearing minerals, particularly when associated with gangue minerals like ilmenite, rutile, quartz, and zircon. Successful separation depends on tailoring flotation parameters reagents, pH, and surface chemistry to the ore's mineralogy (Abaka-Wood *et al.*, 2016). Avazpour *et al.*, (2021) demonstrated that using a Maxblend impeller significantly improves recovery and enrichment (65% and 3.85×, respectively), while minimizing environmental impact.

Integrated metallurgical extraction methodology for REE separation

An integrated metallurgical extraction approach for the separation of REEs involves the combination of various techniques. This comprehensive methodology enhances the efficiency of REE recovery by addressing the complexities of mineral matrices, optimizing the purification process.

Pre-Treatment (Thermal)

Granite's hardness requires high energy for comminution. Pre-treatment methods like microwave heating, thermal breakage, and ultrasonic reduce energy use by weakening its structure. Microwave heating is the most energy-efficient, causing localized damage and reducing compressive strength (Somani *et al*., 2017; Pressacco *et al.*, 2023). Ji and Zhang (2021a) showed that thermal treatment at 600 °C improved REE recovery from kaolinite to 92%, compared to <20% with mechanical grinding. In further studies, thermal pre-treatment followed by acid leaching significantly boosted REE recovery from both kaolinite and phosphatic clay to over 80% (Ji and Zhang, 2021b; Ji and Zhang, 2021a).

Hydrometallurgy: Methods and Application

Physical beneficiation methods are often ineffective for REE recovery due to mineral complexity, making chemical leaching essential (Liu and Chen, 2021). Table 2 shows the summary of Hydrometallurgical REE Extraction Methods: Reagents, Advantages, and Limitations.

Enhance recovery and purification of REEs

The purification of REEs requires removal of impurities often present in processing streams. Gupta and Krishnamurthy (1992) reported methods such as vacuum melting, electrorefining, zone refining, and solid-state electrotransport to eliminate volatile,

Table 2. Summary of Hydrometallurgical REE Extraction Methods: Reagents, Advantages, and Limitations (W. Liu *et al.*, 2024) (Hazan *et al.*, 2022) (Prasastia *et al.*, 2015) (Merroune *et al.*, 2024; Xie *et al.*, 2014).

Method	Target REE Host Mineral(s)	Typical Reagent(s)/Process	Advantages	Limitations
Acid leaching	Granite-associated silicate minerals (e.g., allanite, apatite)	H_2SO_4, HCl, HNO_3 – commonly used mineral acids for silicate REE dissolution .	High LREE recovery (~85%), well-suited for granite silicates.	Less effective for monazite; acid waste generation.
Alkaline Leaching	Phosphate-rich minerals (e.g., monazite in granite)	NaOH.	Efficient breakdown of phosphate matrix; selective REE liberation.	High temperature; caustic waste handling.
Sequential Leaching	Mixed mineral phases in weathered granite	Stepwise acids/bases (e.g., acetic acid, HNO_3, NaOH) depending on mineral matrix.	Phase-specific REE targeting; improved overall recovery.	Lab-scale complexity; slower and reagent-intensive.
Solvent Extraction (SX)	Leachate from previous leaching steps (acidic or alkaline)	D2EHPA, TBP, HEHEHP, Versatic 10, Aliquat 336 – organic solvents for REE separation.	High selectivity and purity; widely used at industrial scale.	Multistage; uses hazardous organic solvents.

metallic, and interstitial impurities. SX is commonly used to purify REEs from pregnant leach solutions (PLS), utilizing kerosene as diluent and P507 as extractant, with scrubbing and stripping stages. Due to similar REE behaviors, some SX systems exceed 1500 stages (McNulty *et al.*, 2022). Precipitation methods using hydroxides, carbonates, sulfates, and oxalates are also widely applied (Han, 2020). U and Th, common in monazite and xenotime, are removed via selective precipitation, leaching, or solvent extraction (Garcia *et al.*, 2020). Combined approaches precipitation, sorption, and extraction efficiently separate radioactive impurities (Mukhachev *et al.*, 2021), while selective Th precipitation is used industrially, And ion exchange with dual resins enables >99% recovery of REEs and U [96]. Impurities such as Co, Zn, Cu, Pb, Cr, Fe, Mn, Ni, and others are typically removed via ion exchange, SX, adsorption or precipitation (Altaş *et al*., 2018). Judge and Azimi (2020) provide a detailed review on recent impurity removal advancements. Cerium purification via ceric hydroxide and manganese dioxide achieves >98% recovery and 99–99.5% purity (Abreu and Morais, 2010). REE processing involves roasting, leaching (acid/alkali), and subsequent purification by techniques such as ion exchange, SX, precipitation, bioleaching and membrane separation (Judge and Azimi, 2020).

Recent developments and innovations in REE extraction and purification

REE recovery from ores is limited to 50–80% due to process constraints (McNulty *et al*., 2022). Table 3 shows the. Comparison of Advanced Methods for REE Extraction: Biohydrometallurgy, Ionic Liquids, Polymer-Based Materials, and Membrane Separation. With rising demand, focus is shifting to alternative resources and eco-friendly methods. Clay in weathered granite shows potential for HREE extraction, though traditional methods are ineffective. Greener alternatives like in-situ leaching with ammonium salts are being explored (Azimi, 2025). Fig. 1 shows the schematic diagram depicts the bioleaching mechanisms and ionic-liquid mechanisms.

Complications in the extraction of REEs and recommendation

REE extraction from granite is challenging due to uneven distribution across ore minerals and alteration processes, such as K-silicate, sericitic, and tourmalinization, which can result in the loss of specific REEs (Alderton *et al.*, 1980). Alterations can form REE-rich minerals like cerite and bastnäsite but also cause unpredictable changes in composition. Granite's hardness complicates physical separation, requiring energy-intensive grinding. Extracting REEs from complex mixtures is time-consuming and energy-demanding, especially for high purity. The presence of radioactive elements, such as uranium and thorium, further complicates extraction and raises environmental and health concerns (Taalab *et al*., 2024). A multi-method approach is proposed for REE extraction from granite to overcome challenges related to its hardness, low REE concentrations, and environmental impact.1. Microwave-Assisted Acid Leaching**.** The use of microwave heating weakens the granite's dense structure, reducing the energy needed for grinding and improving the efficiency of subsequent acid leaching. Advantages: High recovery rates (up to 92%), cost effective by reducing grinding energy and chemical usage, environmentally sustainable, minimizing energy consumption and chemical waste, Scalable for industrial applications. 2. Ionic Liquid-Based Extraction**.** It can be customized for high selectivity of lanthanides, improving the purity of extracted materials while being environmentally friendly and recyclable. Advantages: High selectivity for REEs, improving purity, Eco-friendly due to low toxicity and recyclability, Sustainable with minimal chemical waste. Disadvantages**:** High cost and limited scalability for large-scale applications, currently in the early stages.
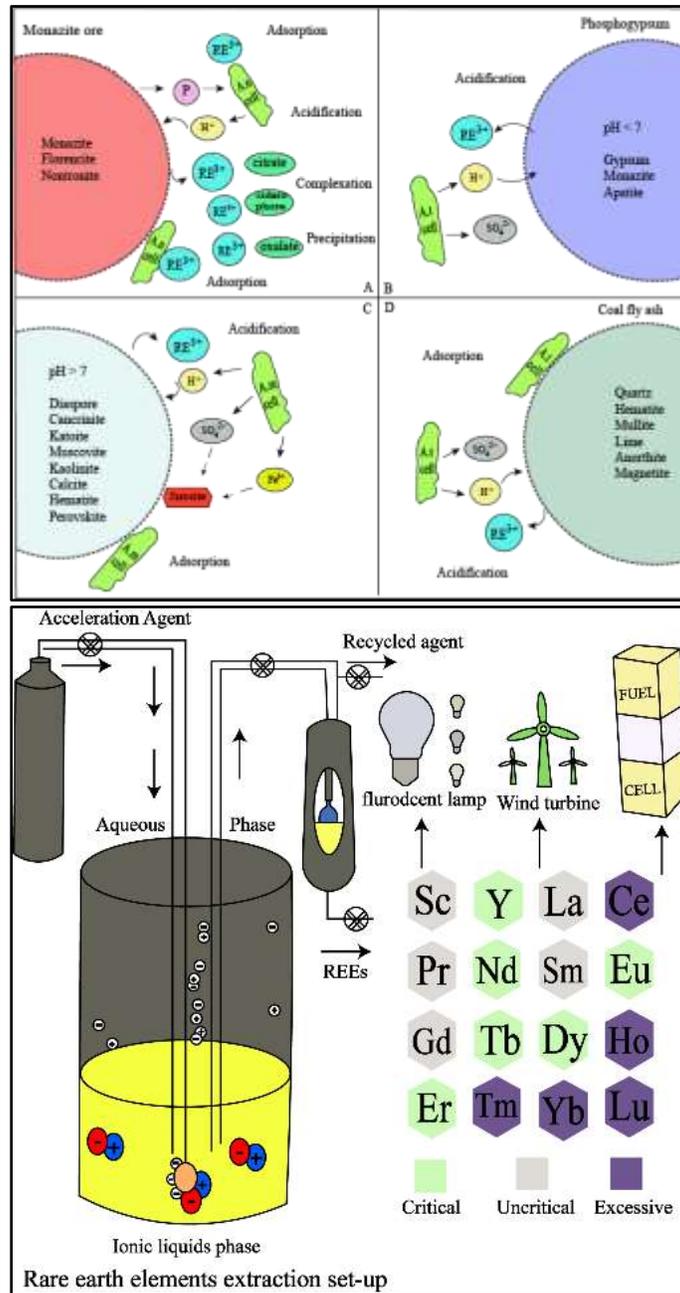
Fig. 1. The schematic diagram depicts the bioleaching mechanisms and ionic-liquid mechanisms (Arrachart *et al.*, 2021; Shi *et al.*, 2023).

Table 3. Comparison of Advanced Methods for REE Extraction: Biohydrometallurgy, Ionic Liquids, Polymer-Based Materials, and Membrane Separation (Fathollahzadeh et al., 2019; Kumar and P. R, 2020) (Y. Liu et al., 2011) (Quijada-Maldonado and Romero, 2020) (Almeida et al., 2012; H. Zhang and Gao, 2023) (Bashiri et al., 2022; Chen et al., 2017).

Method	Sub-methods	Description	Advantages	Limitations
Biohydrometallurgy	1. Bioleaching 2. Microbial Leaching 3. Bioprecipitation	Biohydrometallurgy uses microorganisms to extract REEs. Bioleaching, with microbes like Aspergillus niger and Acidithiobacillus ferrooxidans, releases REEs from ores like monazite. Biosorption concentrates REEs using microbial biomass, while bioprecipitation induces REE precipitation through microbial metabolites.	Environmentally friendly, sustainable, cost-effective, low energy consumption, can be applied to low-grade ores and waste streams.	Slow process, requires careful control of parameters (e.g., pH, temperature, microbial population), low recovery rates for some REEs.
Ionic Liquids (IL)		ILs are green solvents known for their thermal stability, low flammability, and minimal vapor pressure. They offer a sustainable, selective method for REE extraction, especially from complex mixtures. Imidazolium-based ILs are commonly used and can be tailored for specific REEs. ILs are non-volatile, customizable, and offer high selectivity for REE separation.	Environmentally friendly, high selectivity for REE separation, non-volatile, low toxicity.	Expensive, limited scalability, potential toxicity.
Polymer-based Materials	1. Ion-Imprinted Polymers (IIPs) 2. Solvent Impregnated Resins (SIRs) 3. Polymer Composite Nanoparticles	Polymer-based materials like IIPs, SIRs, and polymer composite nanoparticles provide selective REE extraction, working similarly to traditional SX methods but in a more sustainable manner. These materials are particularly useful for REE extraction from granite, as they target specific ions and provide higher selectivity.	Eco-friendly, selective for REEs, sustainable, scalable, and chemical similarity to SX methods.	Limited large-scale industrial research, complexity in fabrication, and higher cost for advanced polymer materials.
Membrane Separation	1. Hollow Fiber Supported Liquid Membrane (HFSLM) 2. Bulk Liquid Membrane (BLM) 3. Supported Liquid Membrane (SLM) 4. Emulsification Liquid Membrane (ELM)	Membrane technologies like HFSLM, BLM, and SLM offer eco-friendly, non-thermal solutions for REE separation, integrating stripping and extraction without relying on thermal processes. PIMs are a promising development for REE separation in complex systems.	Non-thermal, rapid separation, selective, scalable, no reliance on high-energy methods.	Membrane fouling, cost, limited lifetime of membranes, and requirement for pre-leaching of ores like granite.

Conclusion

Granite contains REEs, but traditional extraction methods are energy-intensive and environmentally challenging. Microwave-Assisted Acid Leaching is recommended for its ability to enhance ore reactivity, reduce energy use, and improve recovery rates, offering a cost-effective and environmentally friendly solution. Additionally, Ionic Liquid-Based Extraction provides a selective, sustainable alternative to traditional solvents, with high potential for purity and minimal waste, though it remains in the early stages of industrial use. Combining these methods optimizes REE recovery from granite, ensuring better efficiency, sustainability, and reduced environmental impact.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Abaka-Wood, G., J. Addai-Mensah and W. Skinner. 2016. *Froth flotation of monazite from mixed minerals*.

Abreu, R. D., and C. A. Morais. 2010. Purification of rare earth elements from monazite sulphuric acid leach liquor and the production of high-purity ceric oxide. *Minerals Engineering*. **23**(6): 536-540.

Alderton, D. H. M., J. A. Pearce and P. J Potts. 1980. Rare earth element mobility during granite alteration: Evidence from southwest England. *Earth and Planetary Science Letters*. **49**(1): 149-165.

Almeida, M. I., R. Cattrall and S. Kolev. 2012. Recent trends in extraction and transport of metal ions using polymer inclusion membranes (PIMs). *Journal of Membrane Science*. **415–416**: 9–23.

Alnour, I. A., H. Wagiran, N. Ibrahim, S. Hamzah, B. S. Wee and M. S. Elias. 2015. Rare earth elements determination and distribution patterns in granite rock samples by using INAA absolute method. *Journal of Radioanalytical and Nuclear Chemistry*. **303**(3): 1999-2009.

Altaş, Y., H. Tel, S. İnan, Ş. Sert, B. Çetinkaya, S. Sengül and B. Özkan. 2018. An experimental design approach for the separation of thorium from rare earth elements. *Hydrometallurgy*. **178**: 97-105.

Anitha, J. K., S. Joseph, R. G. Rejith and M. Sundararajan. 2020a. Monazite chemistry and its distribution along the coast of Neendakara–Kayamkulam belt, Kerala, India. *SN Applied Sciences*. **2**(5): 1-18.

Anitha, J. K., S. Joseph, R. G. Rejith and M. Sundararajan. 2020b. Monazite chemistry and its distribution along the coast of Neendakara–Kayamkulam belt, Kerala, India. *SN Applied Sciences*. **2**(5): 812.

Arrachart, G., J. Couturier, S. Dourdain, C. Levard and S. Pellet-Rostaing. 2021. Recovery of Rare Earth Elements (REEs) Using Ionic Solvents. *Processes*. **9**(7): 1202.

Avazpour, R., J. Chaouki and L. Fradette. 2021. A cleaner recovery of rare earth bearing minerals by Pickering emulsification: Improvement of processing conditions toward an economic operation. *Journal of Environmental Chemical Engineering*. **9**: 105449.

Azimi, G. 2025. Technological advancements in rare earth elements recovery from ionic clays: A comprehensive review. *Hydrometallurgy*. **231**: 106414.

Balaram, V. 2023a. Advances in Analytical Techniques and Applications in Exploration, Mining, Extraction, and Metallurgical Studies of Rare Earth Elements. *Minerals*. **13**(8): 1031.

Balaram, V. 2023b. Advances in analytical techniques and applications in exploration, mining, extraction, and metallurgical studies of rare earth elements. **13**(8): 1031.

Balaram, V., and S. S. Sawant. 2022. Indicator Minerals, Pathfinder Elements, and Portable Analytical Instruments in Mineral Exploration Studies. *Minerals*. **12**(4): 394.

Bashiri, A., A. Nikzad, R. Maleki, M. Asadnia and A. Razmjou. 2022. Rare Earth Elements Recovery Using Selective Membranes via Extraction and Rejection. *Membranes*. **12**(1): 80.

Bucher, K., and U. Seelig. 2018. Bristen granite: a highly differentiated, fluorite-bearing A-type granite from the Aar massif, Central Alps, Switzerland. *Swiss Journal of Geosciences*. **111**(1-2): 317-340.

Chen, L., Y. Wu, H. Dong, M. Meng, C. Li, Y. Yan and J. Chen. 2017. An overview on membrane strategies for rare earths extraction and separation. *Separation and Purification Technology*. **197**: 70-85.

Daigle, B., and S. DeCarlo. 2021. *Rare earths and the US Electronics sector: supply chain developments and trends*: Office of Industries, US International Trade Commission Washington, DC, USA.

Dent, P. C. 2012. Rare earth elements and permanent magnets (invited). *Journal of Applied Physics*. **111**(7): 07A721.

Dietz, H., and V. McLemore. Geochemistry of the Tajo granite, Socorro County, New Mexico.

Drobniak, A., and M. Mastalerz. 2022. Rare Earth Elements - A brief overview. *Indiana Journal of Earth Sciences*. **4**, 2022.

Dushyantha, N., N. Batapola, I. M. S. K. Ilankoon, S. Rohitha, R. Premasiri, B. Abeysinghe, K. Dissanayake. 2020. The story of rare earth elements (REEs): Occurrences, global distribution, genesis, geology, mineralogy and global production. *Ore Geology Reviews*. **122**: 103521.

El-Taher, A. 2007. Rare-earth elements in Egyptian granite by instrumental neutron activation analysis. *Appl Radiat Isot*. **65**(4): 458-464.

Fathollahzadeh, H., J. Eksteen, A. Kaksonen and E. Watkin. 2019. Role of microorganisms in bioleaching of rare earth elements from primary and secondary resources. *Applied Microbiology and Biotechnology*. **103**: 1043-1057.

Garcia, A., M. Latifi, A. Amini and J. Chaouki. 2020. Separation of Radioactive Elements from Rare Earth Element-Bearing Minerals. *Metals - Open Access Metallurgy Journal*. **10**: 1524.

Gupta, C. K., and N. Krishnamurthy. 1992. Extractive metallurgy of rare earths. *International Materials Reviews*. **37**(1): 197-248.

Han, K. N. 2020. Characteristics of Precipitation of Rare Earth Elements with Various Precipitants. *Minerals*. **10**(2): 178.

Hassan, E.-S. 2023. Rare Earths in Egypt: Occurrence, Characterization and Physical Separation, A Review. *International Journal of Materials Technology and Innovation*. **3**(3): 43-59.

Hazan, R., H. Noor and K. Takip. 2022. Recovery of Light Rare Earth Elements (LREE) from Monazite by Alkaline Fusion. *Key Engineering Materials*. **908**: 503-508.

Hoshino, M., K. Sanematsu and Y. Watanabe. 2016. REE Mineralogy and Resources. In B. Jean-Claude & P. Vitalij K (Eds.), *Including Actinides*. **49**: 129-291.

Hu, Z., H. Richter, G. Sparovek and E. Schnug. 2004. Physiological and Biochemical Effects of Rare Earth Elements on Plants and Their Agricultural Significance: A Review. *Journal of Plant Nutrition*. **27**(1): 183-220.

Irzon, R., I. Syafri, P. Kurnia, V. Sendjadja, Edi Setiawan, and J. Hutabarat. 2018. Rare Earth Elements on the A-type Unggan Granite and Its Comparison to the A-type Section of Sibolga Granite. *Journal of Physics: Conference Series*. **1095**(1): 012033.

Ishihara, S., R. Hua, M. Hoshino and H. Murakami. 2008. REE Abundance and REE Minerals in Granitic Rocks in the Nanling Range, Jiangxi Province, Southern China, and Generation of the REE-rich Weathered Crust Deposits. *Resource Geology*. **58**(4): 355-372.

Jarvis, K. E., and J. G. J. C. G. Williams. 1993. Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS): a rapid technique for the direct, quantitative determination of major, trace and rare-earth elements in geological samples. **106**(3-4): 251-262.

Jha, M. K., A. Kumari, R. Panda, J. Rajesh Kumar, K. Yoo, and J. Y. Lee. 2016. Review on hydrometallurgical recovery of rare earth metals. *Hydrometallurgy*. **165**: 2-26.

Ji, B., and W. Zhang. 2021a. The effect of mechanical grinding and thermal treatment on the recovery of rare earth elements (REEs) from kaolinite. *Powder Technology*. **394**: 622-631.

Ji, B., and W. Zhang. 2021b. Rare earth elements (REEs) recovery and porous silica preparation from kaolinite. *Powder Technology*. **391**: 522-531.

Jordens, A., Y. P. Cheng and K. E. Waters. 2013. A review of the beneficiation of rare earth element bearing minerals. *Minerals Engineering*. **41**: 97-114.

Judge, W. D., and G. Azimi. 2020. Recent progress in impurity removal during rare earth element processing: A review. *Hydrometallurgy*. **196**: 105435.

Kanazawa, Y., and M. Kamitani. 2006. Rare earth minerals and resources in the world. *Journal of Alloys and Compounds*. **408-412**: 1339-1343.

Khokhulya, M. S., S. A. Alekseeva, A. A. Cherezov and A. V. Fomin. 2021. Analyses of Grinding and Gravity/Magnetic Separation with a View to Optimizing Mixed-Type Processing Technology of Rare Metals. *Физико-технические проблемы разработки полезных ископаемых*. **57**(3): 168-181.

Kumar, P., and P. R. Yaashikaa. 2020. Recent trends and challenges in bioleaching technologies. *Biovalorisation of Wastes to Renewable Chemicals and Biofuels*. 373-388.

Lashen, T., M. Cheira, D. Zaki, E. Allam and S. Mohamed. 2016. Leaching And Recovery Of Rare Earth Elements From Altered Alkaline Granite Rock From Nusab El-Balgum Area, South Western Desert, Egypt. *International Journal of Advanced Research*. **4**: 787-801.

Li, Y. H. M., W. W. Zhao and M. F. Zhou. 2017. Nature of parent rocks, mineralization styles and ore genesis of regolith-hosted REE deposits in South China: An integrated genetic model. *Journal of Asian Earth Sciences*. **148**: 65-95.

Liu, T., and J. Chen. 2021. Extraction and separation of heavy rare earth elements: A review. *Separation and Purification Technology*. **276**: 119263.

Liu, W., Z. Xiao, S. Das, and W. Zhang. 2024. Mechanism and kinetic study of rare earth extraction from allanite by direct acid leaching. *Minerals Engineering*. **205**: 108489.

Liu, Y., J. Chen, and D. Li. (2011). Application and Perspective of Ionic Liquids on Rare Earths Green Separation. *Separation Science and Technology - SEPAR SCI TECHNOL*. **47**: 223-232.

Massari, S., and M. Ruberti. (2013). Rare earth elements as critical raw materials: Focus on international markets and future strategies. *Resources Policy*. **38**(1): 36-43.

McNulty, T., N. Hazen and S. Park. (2022). Processing the ores of rare-earth elements. *MRS BulletinI*. **47**(3): 258-266.

Merroune, A., J. Ait Brahim, B. Achiou, C. Kada, H. Mazouz and R. Beniazza. 2024. Closed-loop purification process of industrial phosphoric acid: Selective recovery of heavy metals and rare earth elements via solvent extraction. *Desalination*. **850**: 117515.

Mukhachev, A., D. Yelatontsev and O. Kharytonova. 2021. Purification Of Rare Earth Elements From Thorium, Uranium, And Radioactive Isotopes. *Problems of Atomic Science and Technology*. **132**: 95-99.

Navarro, M. S., S. Andrade, H. Ulbrich, C. B. Gomes and V. A. V. Girardi. 2008. The Direct Determination of Rare Earth Elements in Basaltic and Related Rocks using ICP-MS: Testing the Efficiency of Microwave Oven Sample Decomposition Procedures. *Geostandards and Geoanalytical Research*. **32**(2): 167-180.

Nieto, A., K. Guelly and A. Kleit. 2013. Addressing criticality for rare earth elements in petroleum refining: The key supply factors approach. *Resources Policy*. **38**(4): 496-503.

Patel, D. K., V. K. Sharma and H. O. Sharma. 2024. Current Global Status of Rare Earth Elements (REEs) and Their Role as Catalysts in Reducing Air Pollution for Maintaining Environmental Sustainability. *Transactions of the Indian Institute of Metals*. **78**(1): 1-11.

Per Kalvig and E. Machacek. 2018. Examining the rare-earth elements (REE) supply– demand balance for future global wind power scenarios. *GEUS Bulletin*. **41**: 87-90.

Pinto, F. G., R. E. Junior and T. D. Saint'Pierre. 2012. Sample Preparation for Determination of Rare Earth Elements in Geological Samples by ICP-MS: A Critical Review. *Analytical Letters*. **45**(12): 1537-1556.

Prasastia, E., L. Setijadji and I. Warmada. 2015. Mineralogy, Geochemistry, and Sequential Extraction Experiment of Rice in Weathered Anggi Granite, Manokwari Regency, West Papua, Indonesia. *Journal of Applied Geology*. **7**(1): 30-41.

Pressacco, M., J. Kangas and T. Saksala. 2023. Comparative Numerical Study on the Weakening Effects of Microwave Irradiation and Surface Flux Heating Pretreatments in Comminution of Granite. *Geosciences*. **13**(5): 132.

Quijada-Maldonado, E., and J. Romero. 2020. Solvent extraction of rare-earth elements with ionic liquids: Toward a selective and sustainable extraction of these valuable elements. *Current Opinion in Green and Sustainable Chemistry*. **27**: 100428.

Reddy, R. R., and A. Pranav. 2024. Rare Earth Element (REE) Insights for Health and Diagnostic Imaging. **164**: 230-256.

Sababa, E., L. G. Essomba Owona, J. P. Temga and P. D. Ndjigui. 2021. Petrology of weathering materials developed on granites in Biou area, North-Cameroon: implication for rare-earth elements (REE) exploration in semi-arid regions. *Heliyon*. **7**(12): 08581.

Saleh, G. M., A. M. Afify, B. M. Emad, M. I. Dawoud, H. A. Shahin and F. M. Khaleal. 2019. Mineralogical and geochemical characterization of radioactive minerals and rare earth elements in granitic pegmatites at G. El Fereyid, South Eastern Desert, Egypt. *Journal of African Earth Sciences*. **160**: 103651.

Sanematsu, K., Y. Kon and A. Imai. 2015. Influence of phosphate on mobility and adsorption of REEs during weathering of granites in Thailand. *Journal of Asian Earth Sciences*. **111**: 14-30.