Divesity of Anurans in selected Habitats of Sattari Taluka ,Goa

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Diversity of Anurans in selected habitats of Sattari Taluka, Goa

A Dissertation for

ZOO 651 Dissertation

16 Credits

Submitted in partial fulfilment of Master's Degree in Zoology

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22P0440032

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PRN: 201900904

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April 2024

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DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, **"Diversity of Anurans in selected habitats of Sattari Taluka, Goa"** is based on the results of investigations carried out by me in the Zoology at the School of Biological Sciences and Biotechnology Goa University under the Supervision of Dr. Nitin Sawant and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will be not be responsible for the correctness of observations / experimental or other findings given the dissertation.

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This is to certify that the dissertation report **"Diversity of Anurans selected habitats of Sattari Taluka, Goa"** is a bonafide work carried out by Ms Mahi Naresh Sirsat under my supervision in partial fulfilment of the requirements for the award of the degree of Masters of Science in the Zoology discipline at the School of Biological Sciences and Biotechnology, Goa University

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PREFACE

Anurans are amongst the most vital species in an ecosystem, they play a crucial role in maintaining ecological balance and biodiversity, and have been used in ecological studies due to their sensitivity to different climatic conditions during different stages in their life. They are known to inhabit in almost all type of habitat,

Goa is rich in its biodiversity has Western Ghats as is important hotspot which has diverse variety of fauna and flora endemic to it, additionally with native forest habitats Goa has practices of growing crop plantations.

The present study is an attempt to understand diversity of anurans in such crop plantations mainly Monoculture plantation of coconut tree, where only one type of crop is grown and a mixed culture plantation of Cashew and jackfruit plantation and a forest habitat to understand how anuran community assemblages vary with habitat, along with effect of abiotic factors on them. It is important to access their habitat preferences and response to these environmental factors for developing effective conservation strategies.

The present thesis is divided into four chapters, chapter one consisting of introduction where in the role of anurans in different habitats and its use in ecological studies to understand climatic change in scientific research is explained in brief

Second chapter includes review of literature related to studies conducted on Anuran diversity in different plantations and effects of different abiotic factors on it.

Third chapter consists of Materials and methods used in study and, mainly field methods used in surveying anurans and description of selected study areas, method of identification of anurans, method of collection of abiotic factors.

Fourth chapter includes analysis and conclusion of study, analysis consists of interpreting diversity data using species diversity indices and correlation of abiotic factors with it using statistical test Discussion sections is where possible reasons for diversity richness, abundance and influence of abiotic factors in relation with related literature is discussed, followed by conclusion which gives overall outcome of the work and its findings.

ACKNOWLEDGEMENT

I wish to express my gratitude to my Dissertation guide Dr. Nitin Sawant for his constant guidance and support while completion of Project work.

I acknowledge Dr. Preeti Pereira for her guidance and support during my Dissertation work

I'm also thankful to get constant encouragement, support, and guidance from all teaching faculty members of Zoology Programme, Goa University for helping me in my dissertation work.

I would like to thank Mr. Vishnu Kurtarkar for assisting me in field study of Copardem village, Valpoi.

I would like to thank Mrs Sheetal Naik .Assitant professor in Botany for helping me in Taxonomic identification of plants

I owe my sincere gratitude to Mr Mayur Gawas (research scholar) for his guidance and timely advice and help in framing my research design and his assistance in statistical analysis of my data.

I am also thankful to Shubham Rane (research scholar) for his generous guidance in my research work

I wish to thank my friend Saheel Maulingkar and Harshvardhan Rajawath for their keen inputs and support during my research work.

I'm also thankful to my friend Anveeka Gauns for her support during my entire Dissertation work.

Lastly, I would like to thank my brother for always being supportive and motivating me throughout my dissertation work

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ABSTRACT

The study was carried out in three habitats of Sattari Taluka consisting of Monoculture Plantation, Mixed culture Plantation and Forest from July 2023 to January 2024, a total of 15 Anurans were

recorded from Monoculture Plantation, Mixed culture Plantation and forest using combination of Transect and Audio-visual method. Among the species observed only one species *Hylarana Malabarica* belonged to Vulnerable category under IUCN Red list Three species were listed under Sch IV of Wildlife protection act 1972 viz. *Haplobatrachus tigeranus, Euphlyctis cyanophilatus, Clinotarsus curtipes*. The study showed highest abundance of anurans in Forest habitat, compared to other two areas. The dicroglossidae family showed the highest abundance in all three habitats. Additionally, study revealed valuable insights on interrelation of abiotic factor and species abundance and richness.

CHAPTER 1: INTRODUCTION

Global climate change is a significant driver of biodiversity change (Barnosky et. al.,2011; Bellard et al., 2012). Conservation of biodiversity has gained a lot of attentions in recent times, as it plays a vital role to assess global and local environmental changes and sustainability of development activities (Lovejoy et al., 1995), The changing environmental conditions has direct and indirect impacts on ecological systems at great extend leading to instability in an Ecosystem.

It is a well-known fact that life on earth has been drastically changing due to human interference, in fact some species are so sensitive they are unable to survive changes eventually leading to their extinction, amongst vertebrates one such organisms are Amphibians these are tiny vertebrates that require water or moist climate for survival, The species in this group include frogs, toads, newts and salamanders They are able to respire and acquire water via their thin skin. Furthermore, amphibians have unique skin glands that produce useful proteins. (Demori et al., 2019).

Global flora and fauna face several threats and it is essential to collect data which increases our knowledge of individual species also communities of species in different locations, to make successful conservation plans (Wake & Vredenburg et al.,2008) Numerous essential roles are played by anurans and other amphibians in an ecosystem (Van der Hoek et al,2019). Currently number of Anurans species around the globe is 7,693 (*Amphibia web*,2024), According to Dinesh K.P. et al., (2023), there are around 451 species of amphibians in India and A total of 32 anuran species have been identified in Goa (Dinesh K.P et al., 2023).

Amphibians have long been used as models in ecological studies (Hopkins, 2023). They shape community organization since they were the first tetrapod to enter terrestrial areas from aquatic habitats, acclimate to new surroundings, and have a dual life adjusting to the extreme transition.

India with its varied habitats and long history of Agroecosystems offers a great place to do research on plantation crop landscapes. In India, a wide range of crops are farmed, including rice, cashews, bananas, and coconuts. These types of landscapes depict a distinct setting where natural habitats and agricultural methods interact. Goa, which is a biodiversity hotspot in the Western Ghats, stands out as a particularly important location. Numerous indigenous plant and animal species, many of which are threatened by habitat loss and fragmentation, can be found in the Western Ghats. Two plantations, one of which is a monoculture plantation of coconut and the other a mixed-culture plantation of cashew and jackfruit, are situated in the foothills of the Western Ghats and were chosen for the study area in Poriem village along with Forest habitat situated in Valpoi village of Sattari Taluka

Understanding how anurans inhabit and respond to these environments is crucial for developing effective conservation strategies. Studying amphibian diversity within them is essential for comprehensive conservation efforts. The primary focus of my present research has been on diversity patterns and how abiotic factors influence the community structure of anurans in ecosystems.

Problem statement

Amphibians are known as indicator species because they are highly sensitive to changes in their environment, making them valuable for assessing ecosystem health and biodiversity**,** Crop plantations in human-modified landscapes provide an alternate habitat for biodiversity (Komanduri et al.,2022)Cashew and coconut are one of the widely grown crops in Goa and is known to provide societal and economic benefits

,however its role as supplementary habitat for Anuran community is not well understood , The current study intends to investigate how anurans occupy specific types of habitats, in addition to the role of abiotic conditions on their ability to do so.

1.1 Objectives

1.To document the diversity of Anurans in selected habitats.

2.To examine the effect of abiotic factors on Anurans in selected sites.

1.2 Hypothesis

Different abiotic factors will have different role in shaping anuran community in selected habitats

1.3 Scope of Work

The study will fill the lacuna of knowledge about the habitat the species occupy during different months. The study will also provide details on the populations of Anuran distribution in different habitats. Adding to this, the study will also act as a baseline data on anuran diversity which will help policy makers in preparing conservation strategies.

CHAPTER 2: LITERATURE REVIEW

A study conducted in Bolvia by (Schulze et al., 2009) used transect methods to examine five study locations in typical habitats such as open grasslands, open savannas, and pond ecosystems. A total of 31 species were observed. Species partitioning was noted based on call frequency segregation, seasonal calling activity, and microhabitat preference.

(Modak et al., 2015) discovered new leaping frog *Indirana salelkari* from in Spice Plantation at Netravali South Goa, it was found that *Indirana salelkari* was genetically and phylogenetically from its sister taxa *Indirana chiravasi.*

Amphibian diversity was evaluated via surveys along transects in primary and altered forest, according to a study conducted by (Jongsma et al., (2014) on amphibian assemblages across diverse habitats in the Choco´ rainforest of northwest Ecuador. Researchers discovered that the richest and least affected by habitat modification amphibian assemblages were those located near rivers. A variety of amphibian assemblages in different habitat types were found in riparian zones, including uncommon and endangered species, indicating that the susceptibility of these assemblages to changes in their surroundings varies.

Anuran Fauna of Rajiv Gandhi National Park, Nagarahole Central Western Ghats, Karnataka, India, according to a study by (Krishna M.P. et al., 2012), Nearly 26 species of anurans from 14 genera, 7 subfamilies, and 8 families were detected in the survey. It was discovered that the type of environment can vary depending on the needs of the organism and that it is vital for the existence of species.

A study carried out by (Rathod et al., 2013) in Coffee growing practices observed in the Western Ghats of India in an effort to better understand the patterns of amphibians at the species community level within three distinct habitats. It was found that there were notable differences in the habitat variables of coffee plantations and that the use of various pest control treatments had a notable impact on the species richness and abundance of amphibians.

. In the central Kerala region of the southern Western Ghats of India, a study led by (M.S. Syamili et al., 2018) assessed the diversity of amphibians in a few chosen agroecosystems. Ten anurans from cashew, coconut, home garden, and rubber plantations were counted. Agroecosystems within and near the Western Ghats mountains it was found that it had potential to play a significant role in the conservation of generalist amphibian species and to offer a suitable habitat for endemic and threatened species. The study also demonstrated a strong correlation between the types of agroecosystems and the abundance of various amphibian species.

(Cunha et al., 2021) studied the anuran populations in ponds with varying degrees of interaction with soybean agriculture in Brazil. There were 18 species of anuran found, with an average of 421 captured tadpoles and 1230 mature males. Ponds found in soybean plantations differed from those found nearby in terms of the water characteristics, tadpole abundance and richness, was found to be makeup of both adults and tadpoles.

(Komanduri et al., 2022) conducted a study in the Tillari Conservation Reserve, Maharashtra, focusing on cashew farms, forest borders, and forest interiors. The species composition of cashew plantations was found to be significantly different from that of forests, with understorey and canopy cover having a favourable influence.s.it was found that Anuran abundance was positively impacted by understorey, whereas ambient temperature had the opposite effect. Cashew plantations undergo habitat alterations, such as reduced understorey and low canopy cover. Reduced environmental shelters for anurans could result from such structural alterations.

(Edo-Taiwo1 et al.,2023) conducted a study in Southern Nigeria Cocoa farms consisting of one type of monoculture plantation were observed for anuran diversity, The anuran diversity in these plantations compared favourably with those in non-monoculture sites, about 25 species of frogs from seven families in ten genera were noted.

CHAPTER 3: METHODOLOGY

3.1 Study area

The study is located in Sattari taluka of North Goa district of Goa state. Three areas having different vegetation cover under Forest cover habitat (FSI) are selected viz. monoculture, mixed plantation, and forest. This selection was based on the canopy cover (Area having more than 10% canopy cover), tree composition and understory vegetation.

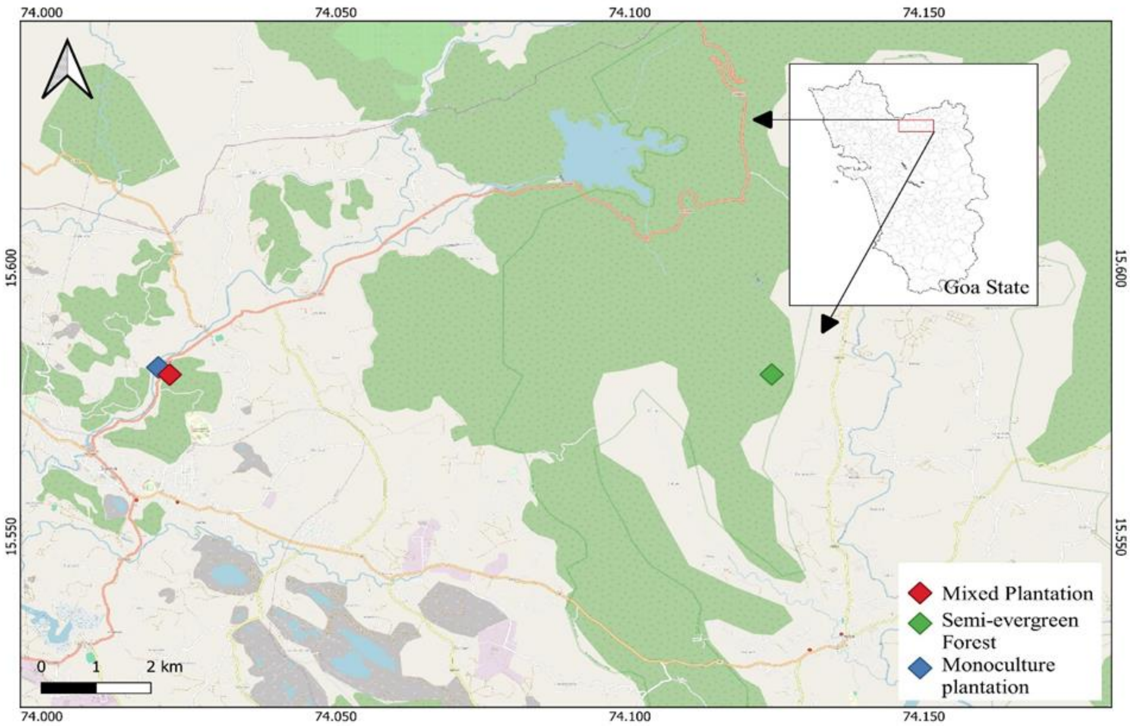

Fig:3.1.1 Map showing study area

3.2 Monoculture

The study was conducted in selected sites of Sattari Taluka, Goa. The research area, which spans 30,000 square meters in total, is located in Poriem Village, Sattari Taluka (15°34'59.77"N, 74° 1'15.10"E). Monoculture is the practice of growing only one type of crop in a particular field. The current study area is made up primarily of coconut plantations. The understory vegetation primarily consists of grasses like *Wedelia sp.* and plants like *Sindora wallichii.*

Figure 3.2.1.: Monoculture plantation

3.3 Mixed culture

The chosen study area is in the Poriem village of Sattari taluka, North Goa (15°34'57.74"N, 74° 1'17.27"E). The total area is 40,000 square meters. Mixed culture refers to the growing of multiple crop types in a given area. The selected area is made up of cashew and jackfruit plantations, creating an open type of forest habitat other understory vegetation, such as *Macaranga sp* etc.

Figure 3.3.1: Mixed culture plantation

3.4 Forest

The chosen study location is located at (15°33'36.22"N and 74° 7'26.75"E) in Valpoi village, Sattari Taluka. It is classified as a semi-evergreen forest, and among the many plant species that grow there are *Ficus Bengalensis* (Vad), *Garcinia indica* (Bhiran), *Sarava indica* (Ashoka), *Terminalia bellerica* (Ghoting), and others. This region is protected from human activity and can be used compare with other selected locations to understand the diversity patterns, as anuran variety is known to be extremely sensitive to changes in the environment, these places also offer a controlled environment for studying the effects of environmental factors on them, such areas will help in gaining insights on the health and biodiversity of an ecosystem.

Figure 3.4.1: Forest

3.5 Surveying

Surveys for data collection were carried out from the month of July 2023 to January 2024. Surveying was done at night time, The study was carried out using standard and widely accepted transect method and audio-visual survey method (Eekhout, 2010). Transact method involved laying three linear transects, each measuring 100 meters in length and 10 meters of width on each side. Three replicates of transact were laid in each area to avoid bias in sampling and to increase accuracy. To avoid the edge effect, transects were placed in the centre of the research area, sampling was done monthly three times in each habitat, they were laid such that they were not overlapping upon walking the transect during the survey, anurans were observed on both the left and right side of the path. As they are nocturnal the survey was conducted at night time between at 2000 hours and 2300 hours, in order to maximize its effectiveness. (Eekhout. 2010).

The audio-visual method approach is among the simplest and most widely applied techniques for Anuran sampling. This method involves physically locating anurans in all the possible areas in the sampling zone or sampling quadrant. It also involves locating adult anurans based on their vocalisations in the sampling zone or sampling quadrant. Around breeding season, male anurans in particular are usually noticeable as they use their mating calls to attract females and Standard calls were recorded during pilot studies and later used for identification during main studies. It is an effective method as this allows the identification of anurans that inhabit several habitats within a particular area, such as arboreal and fossorial burrowing, it is a non-invasive and cost-effective method (Eekhout, 2010; Wissen et al,.2016; Boullhesen et al., 2021).

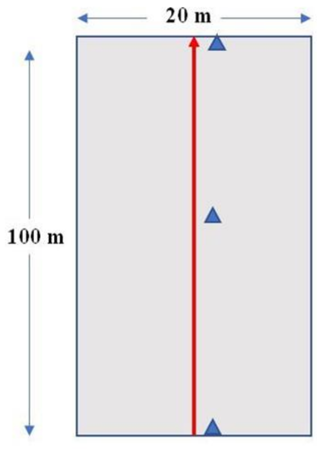

Fig 3.5.1: Transect Diagram

Precautions

Precautions were followed to avoid disturbance to the habitat. Littering, damage to plants in any way like breaking of stems, plucking leaves, or uprooting the plant was not done. Slow walking along the transect with steady pace was maintained for observing and counting of the fauna. Same route was followed every time the survey was undertaken. To prevent any bias results stoppages along the transects were avoided. Precautionary measures like wearing full sleeves and track pants to protect ourselves from ticks. Wearing camouflaging and avoiding bright coloured clothes was practiced

3.6 Data collection of abiotic factors data

Temperature, Humidity, Precipitation, are the abiotic factors which are considered to have effect on anurans. These are some of the important factors that play a role in shaping the ecological system for anurans (Ceron et al,.2020). Temperature and humidity were measured using thermometer and hygrometer, both were recorded at three different locations along each transect, of which the average was taken into account as standard temperature. Precipitation and earth skin temperature data was obtained from online repository National Aeronautics and Space Administration (NASA) which obtains its meteorological data using Modern Era Retrospective-Analysis for Research and Applications (MERRA-2)

3.7 Identification of amphibians

The identification of species was carried out with the help of identification keys available. Various anuran characteristics including both morphometric and meristic of characters such as skin texture, vocal sac, webbing in feet, fingertip dilations, type of iris, and pupil etc were utilized to identify anurans during the pilot study, and a checklist was obtained that was later used in the main study.

Idetification keys used are:

- Pictorial guide to frogs and toads of the Western Ghats, Gururaja, K. V. (2012),
- Fauna of Goa, Zoological survey of India Kolkata (2008),
- Hand Book Indian Amphibians S. K Chanda (2002),
- Photographic Field Guide Wildlife of South India, Surya R. and David R. (2020),
- An annotated Checklist of Amphibia of India with some Insights into the Patterns of species discoveries, distribution and endemism, K.P Dinesh (2009)

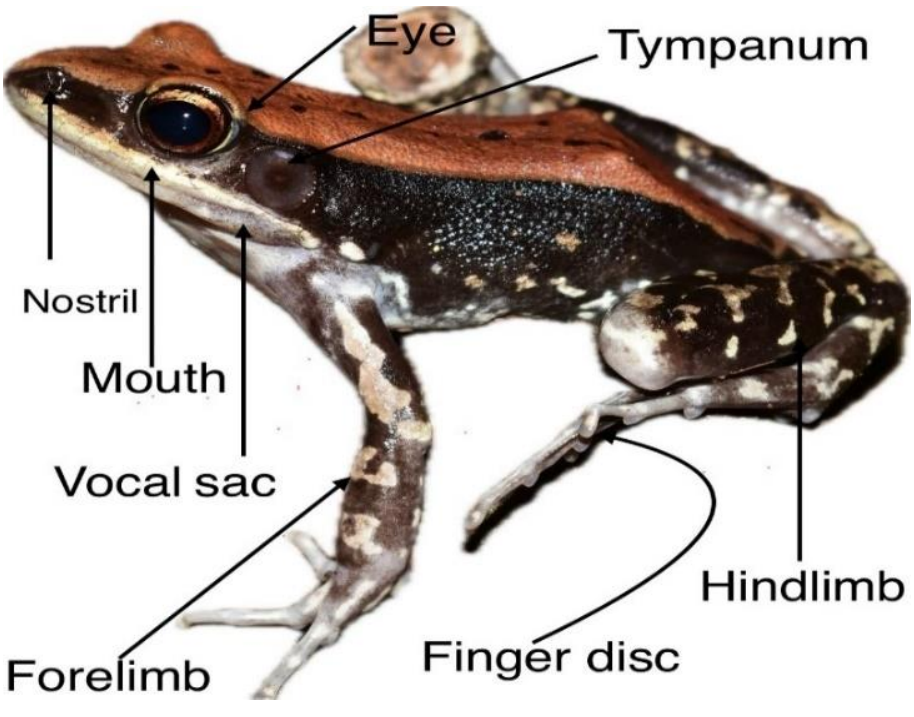

Figure 3.7.1: Different parts of Anurans

3.8 Calculations

Shannon Diversity Index: It is sometimes called the Shannon-Wiener Index, is a way to measure the diversity of species in a community. Denoted as *H*, this index is calculated as:

$$H = -\Sigma p_i * ln(p_i)$$

where:

Σ: A Greek symbol that means "sum"

ln: Natural log

p_i: The proportion of the entire community made up of species

The higher the value of *H*, the higher the diversity of species in a particular community. The lower the value of *H*, the lower the diversity. A value of $H = 0$ indicates a community that only has one species.

Simpson's Index (D): It measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species). The value of D ranges between 0 and 1. With this index, 1 represents infinite diversity and 0, no diversity. That is, the bigger the value of D, the higher the diversity. D is calculated using following formula

$$D = \Sigma (n / N)^2$$

Simpson's Index of Diversity = 1 - D

where,

Σ: A Greek symbol that means "sum"

n = the total number of organisms of a particular species

N = the total number of organisms of all species

D = Simpsons diversity index

Sorensen's Index

It measures overlap between two populations by taking the ratio of the number of species shared between the two populations, relative to the number of species in both populations

Pearson's correlation Coefficient is the most common way of measuring a linear correlation. It is a number between –1 and 1 that measures the strength and direction of the relationship between two variables. here +1 indicates the perfect positive relationship between the variables considered, -1 indicates the perfect negative relationship between the variables considered, and 0 value indicates that no relationship exists between the variables considered., Denoted as *r*, this index is calculated as:

$$r= \quad n\Sigma Y-\Sigma X\Sigma Y/\surd(n\Sigma X^2-(\Sigma X))^{2)} *(n\Sigma Y^2-(\Sigma Y)^2)$$

n = the number of data points, i.e., *(x, y)* pairs, in the data set.

ΣXY = the sum of the product of the x-value and y-value for each point in the data set.

ΣX = the sum of the x-values in the data set.

ΣY= the sum of the y-values in the data set.

ΣX^2= the sum of the squares of the x-values in the data set.

ΣY^2 = the sum of the squares of the y-values in the data set

CHAPTER 4: ANALYSIS AND CONCLUSION

4.1 Result

A Total of 15 species were observed belonging to six families, among which Dicroglossidae was the most dominant family observed, followed by Microhylidae ,Ranidae ,Rhacophoridae, Bufonidae and Ranixalidae. Among the species observed only one species *Hylarana Malabarica* belonged to Vulnerable category under IUCN Red list. Three species were listed under Sch IV of Wildlife protection act 1972 viz. *Haplobatrachus tigeranus, Euphlyctis cyanophilatus, Clinotarsus curtipes.* Two species were listed under Appx II of CITES viz. *Haplobatrachus tigeranus* and *Clinotarsus curtipes*. Four species were found to be endemic to the western ghat region of India viz. *Minerverya shyhadrensis ,Uperodon mormoratus, Clinotarsus curtipes, Raorchestes bombayensis.*(Table 4.1.2)

Amongst the surveys conducted in three habitats viz. forest, mixed culture plantation and monoculture plantation highest number of individuals were recorded in forest (79) habitat followed by monoculture plantation (77) and mixedculture plantation (71). (Table 4.1.3)

In Monoculture plantation Dicroglossidae family (51%) showed the highest number of individuals while Microhylidae family (5%) showed lowest. Highest number of species was observed from dicroglossidae family (50%) followed by Ranidae and others. (Table 4.1.4) In Mixedculture Plantation Dicroglossidae family (61%) showed the highest number of individuals while Microhylidae family (4%) showed lowest. Highest number of species was observed from dicroglossidae family (63%) followed by others (Table4.1.5). In forest habitat Dicroglossidae family (33%) showed the highest number of individuals while Bufonidae family (5%) showed lowest. Highest number of species was observed from dicroglossidae family (42%) followed by Microhylidae, Ranidae and others (Table 4.1.6).

The species evenness and diversity indices (H and D) in each of the three habitats demonstrated a strong positive relationship with one another; in contrast, temperature showed a negative correlation with the indices. The evenness and richness in the monoculture and forest habitats demonstrated a weak negative correlation with the H index, while the mixed culture Planation showed a weak positive correlation

However, in monoculture and forest, temperature, humidity, precipitation soil temperature, with diversity indices, and evenness revealed positive correlation. Conversely, the mixed culture plantation habitat displayed completely different correlation results for humidity, precipitation, and soil temperature. Humidity showed a strong positive correlation with indices and evenness, while precipitation and soil temperature showed moderate positive correlations. Rainfall pattern displayed weak negative correlations, soil temperature displayed a moderately positive association, and humidity displayed a weak positive correlation with indices and evenness. Temperature had a somewhat positive association with the D index, a very weak positive link with the H index, and richness.

When correlation between abiotic factors was observed, it revealed comparable results when humidity was connected with precipitation and soil temperature, and there was a substantial negative correlation with temperature in all three habitats. Temperature had a strong negative association with humidity and precipitation, and a moderately negative correlation with soil temperature. Precipitation had a significant negative association with temperature, moderately positive with humidity, and a moderately positive link with soil temperature. Soil temperature revealed a weak negative correlation with ambient temperature, a moderately positive connection with humidity, and a weak positive correlation with precipitation, but a moderate positive correlation in relationship in forest environment.

To conclude, the study revealed strong positive associations between species evenness and diversity indices in three ecosystems, although temperature had a negative connection. Evenness and richness in monoculture and forest habitat demonstrated weak negative associations, but mixed-culture plantation habitat had weak positive relationships. Humidity had a significant positive correlation with indices and evenness, whereas precipitation and soil temperature had moderate positive relationships. Abiotic factors showed comparable results, with humidity related to precipitation and soil temperature. Soil temperature showed only a slight negative relation with ambient temperature, humidity, and precipitation. The current study was an attempt to understand species community level of pattern of Anurans in three different habitats, the results clearly state that there was difference in distribution patterns in selected habitats.

Table 4 .1.1: Table showing Shannon diversity index and Simpsons diversity in three habitats

Habitat	Shannon Index	Simpson index	Abundance	Richness
Forest	2.43	0.90	0.11	13
Mixed culture	2.06	0.86	0.11	10
Monoculture	2.29	0.89	0.10	11

Species diversity indices were calculated based on qualitative and quantitively data collected from the study area during the study tenure. Shannon index (H index, evenness) was found to be maximum in the forest habitat, followed by monoculture plantation and mixed culture plantation. Similarly, Simpson index (D index) was found to be maximum in forest habitat, followed by monoculture plantation and mixed culture plantation. Both the H index and D index displayed similar trend of diversity amongst selected habitats. The relative abundance was found to be maximum in both forest and mixed culture plantation followed by monoculture plantation. With respect to number of species or species richness it was observed that forest (13) showed maximum species followed by monoculture (11) and mixed culture plantation (10)

Correlation results depict that in forest humidity plays the major role in shaping anuran community diversity showing positive correlation with species richness, similarly with soil temperature and precipitation as anurans require moist environment for respiration and to perform other active (Fig 4.1.3)

Similar results were observed in Monoculture plantation (Fig 4.1.1), however in both habitats temperature showed negative correlation and almost no correlation in Mixed culture plantation (Fig 4.1.2) In mixed culture plantation apart from soil temperature, none of the factors showed significant correlation with richness.

Table 4.1.2: Checklist of Anurans in three Habitats

LC-Least concern, VU-Vulnerable, EWG-Endemic to Western ghats

Sr. No	Common name	Family	Scientific name	IUCN status	WPA	CITES	Endemism
1	Maskey's burrowing frog	Dicroglossidae	*Sphaerotheca maskeyi*	LC	_	_	
2	Cepf Cricket frog	Dicroglossidae	*Minerverya cepfi*	LC	_	_	
3	Indian bull frog	Dicroglossidae	*Haplobatrachus tigeranus*	LC	Sch IV	App.II	
4	Shyhadry cricket frog	Dicroglossidae	*Minerverya shyhadrensis*	LC	-	-	EWG
5	Aloysius Skittering frog	Dicroglossidae	*Euphlyctis aloyshi*	LC	_	_	
6	Indian Skittering frog	Dicroglossidae	*Euphlyctis cyanophilatus*	LC	Sch IV	App.II	
7	Goa cricket frog	Dicroglossidae	*Minerverya gomantaki*	LC	-	-	
8	Indian dot frog	Microhylidae	*Uperodon mormoratus*	LC	_	_	EWG
9	Ornate narrow mouthed frog	Microhylidae	*Microhyla ornata*	LC	_-	_-	
10	Indian Bicoloured frog	Ranidae	*Clinotarsus curtipes*	LC	Sch IV	_	EWG
11	Malabar Fungoid frog	Ranidae	*Hylarana malabarica*	VU	-	_	
12	Indian leaping frog	Ranixalidae	*Indirana salelkari*	LC	_-	__-	
13	Bombay bush frog	Rhacophoridae	*Raorchestes bombayensis*	LC	-_	_-	EWG
14	Common Tree frog	Rhacophoridae	*Polypedates maculatus*	LC	_	_	

15	Asian common toad	Bufonidae	*Dattaphrynus melanosticus*	LC	_-	_-	

Table 4.1.3 Table showing Number of individuals in three Habitats

Common name	Number of individuals		
	Forest plantation	Mixed culture plantation	Monoculture plantation
Asian common toad	6	7	15
Maskey's burrowing frog	10	17	12
Cepf Cricket frog	5	6	18
Indian bull frog	8	13	9
Shyhadry cricket frog	7	19	8
Indian Skittering frog	9	_	5
Goa cricket frog	6	10	7
Indian dot frog	4	4	
Ornate narrow mouthed frog	11	_	3
Indian Bicoloured frog	10	_	_
Malabar Fungoid frog	18	16	11
Indian leaping frog	15	12	14
Bombay bush frog	17	_	9
Common treee frog	10	_	_
Aloysius Skittering frog	_	1	_
Total	79	71	77

Table 4.1.4 Table showing percentage contribution of Number of Individuals and Species of different Families of Anurans recorded from Monoculture Plantation

Sr no	Family	Total species	% of species	Total individuals	% of individuals
1	Bufonidae	1	8	18	16
2	Dicroglossidae	6	50	57	51
3	Microhylidae	1	8	6	5
4	Ranidae	2	16	11	10
5	Ranixalidae	1	8	10	9
6	Rhacophoridae	1	8	9	8
	Total	12		111	

Table 4.1.5 Table showing percentage contribution of Number of Individuals and Species of different Families of Anurans recorded from Mixed culture Plantation

Sr no	Family	Total species	% of species	Total individuals	% of individuals
1	Bufonidae	1	9	7	6
2	Dicroglossidae	7	63	65	61
3	Microhylidae	1	9	5	4
4	Ranidae	1	9	16	15
5	Ranixalidae	1	9	12	11
	Total	11		105	

Table 4.1.6: Table showing percentage contribution of Number of Individuals and Species of different Families of Anurans recorded from Forest Habitat

Sr no	Family	Total species	% of species	Total individuals	% of individuals
1	Bufonidae	1	8	6	5
2	Dicroglossidae	6	42	46	33
3	Microhylidae	2	14	15	11
4	Ranidae	2	14	28	20
5	Ranixalidae	1	8	14	10
6	Rhacophoridae	2	14	27	19
	Total	14		136	

Table 4.1.7 Table showing Number of Individuals and species found in each month in three forest habitats

Month	No of Individuals			No of Species		
	Monoculture	Mixedculture	Forest	Monoculture	Mixedculture	Forest
July	22	20	30	6	5	7
August	23	23	28	6	6	7
September	20	17	24	5	5	5
October	11	13	17	6	6	6
November	13	12	15	5	4	5
December	10	11	12	4	4	4
January	12	9	10	32	3	4
Total	111	105	136			

Table 4.1.8: Table showing correlation matrix between Diversity Index with Abiotic factors in Monoculture plantation

	H Index	D Index	Species richness	Temperature	Humidity	Precipitation	Soil Temp
H Index	1.00	0.99	0.99	-0.39	0.77	0.39	0.90
D Index	0.99	1.00	0.97	-0.38	0.76	0.39	0.91
Species richness	0.99	0.97	1.00	-0.37	0.77	0.38	0.88
Temperature	-0.39	-0.38	-0.37	1.00	-0.28	-0.65	-0.08
Humidity	0.77	0.76	0.77	-0.28	1.00	0.69	0.61
Precipitation	0.39	0.39	0.38	-0.65	0.69	1.00	0.20
Soil Temp	0.90	0.91	0.88	-0.08	0.61	0.20	1.00

Table 4.1.9: Table showing correlation matrix between Diversity Index with Abiotic factors in Mixed culture plantation

	H Index	D Index	Species richness	Temperature	Humidity	Precipitation	Soil Temp
H Index	1.00	0.99	0.98	0.20	0.13	-0.01	0.56
D Index	0.99	1.00	0.94	0.27	0.06	0.00	0.49
Species richness	0.98	0.94	1.00	0.08	0.23	-0.01	0.65
Temperature	0.20	0.27	0.08	1.00	-0.62	-0.73	-0.06
Humidity	0.13	0.06	0.23	-0.62	1.00	0.70	0.74
Precipitation	-0.01	0.00	-0.01	-0.73	0.70	1.00	0.17
Soil Temp	0.56	0.49	0.65	-0.06	0.74	0.17	1.00

Table 4.1.10: Table showing correlation matrix between Diversity Index with Abiotic factors in forest Habitat

	H Index	D Index	Species richness	Temperature	Humidity	Precipitation	Soil Temp
H Index	1.00	0.99	0.98	-0.29	0.96	0.63	0.54
D Index	0.99	1.00	0.95	-0.30	0.92	0.63	0.43
Species richness	0.98	0.95	1.00	-0.24	0.99	0.59	0.67
Temperature	-0.29	-0.30	-0.24	1.00	-0.29	-0.65	-0.13
Humidity	0.96	0.92	0.99	-0.29	1.00	0.68	0.72
Precipitation	0.63	0.63	0.59	-0.65	0.68	1.00	0.29
Soil Temp	0.54	0.43	0.67	-0.13	0.72	0.29	1.00

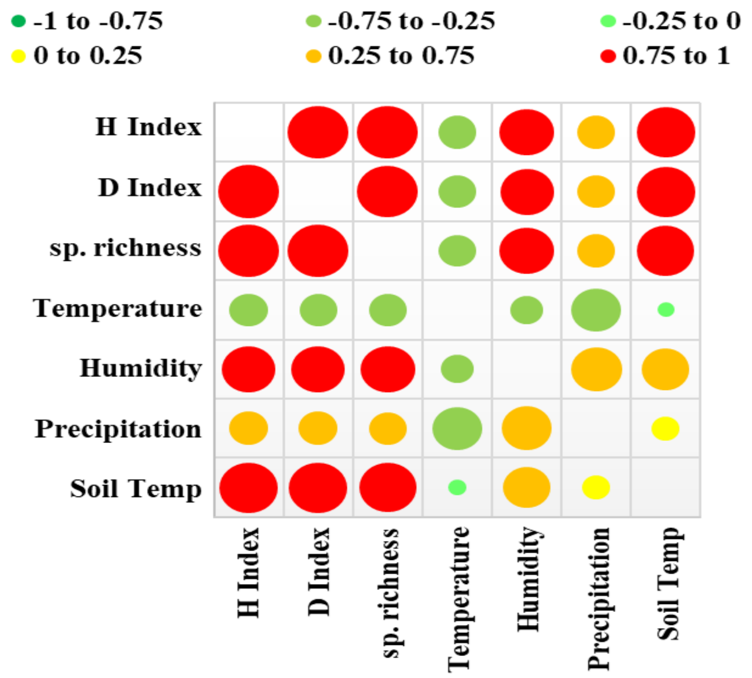

Fig 4 .1.1: Correlation matrix of Monoculture Plantation

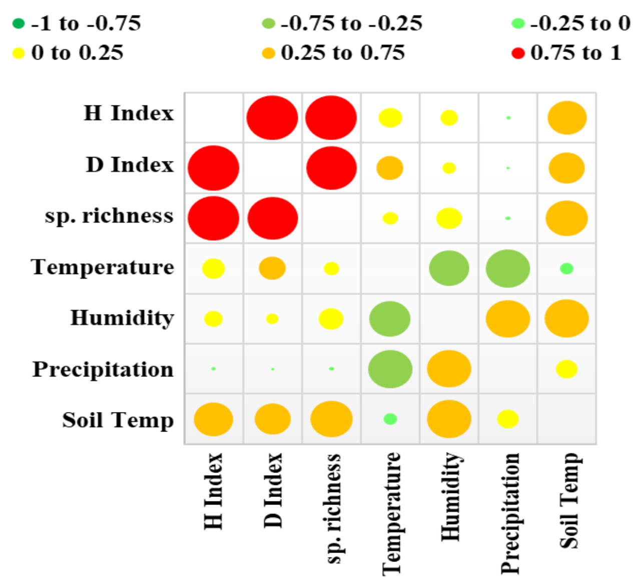

Fig 4 .1.2: Correlation matrix of Mixed culture Plantation

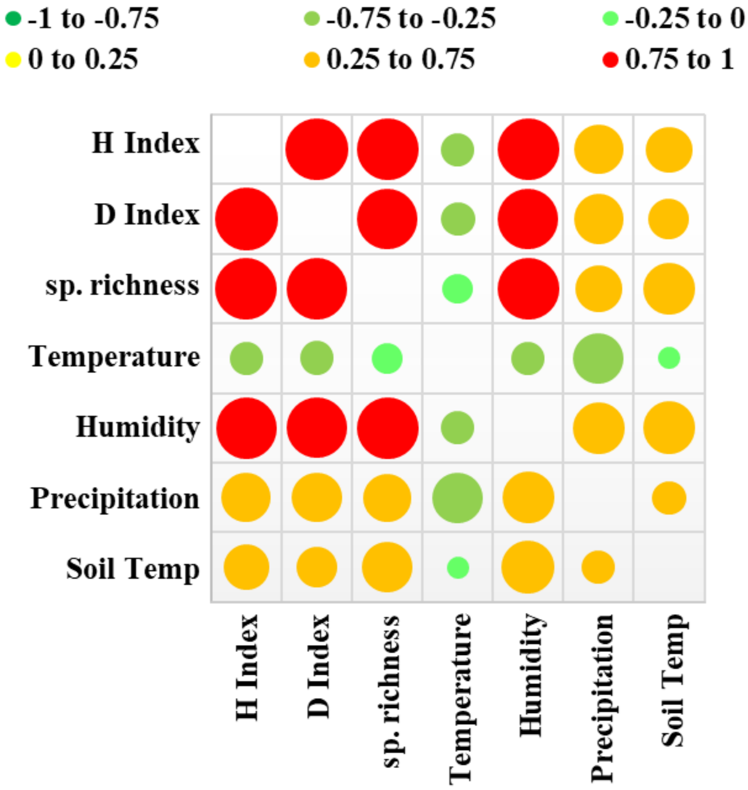

Fig 4.1.3: Correlation matrix of Forest habitat

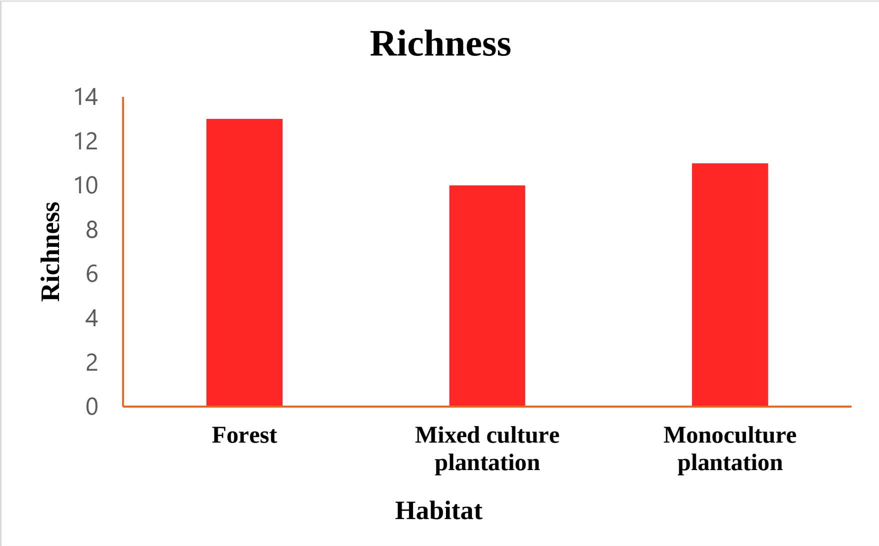

Fig 4.1.4:Graph showing total richness of anurans in all three habitats

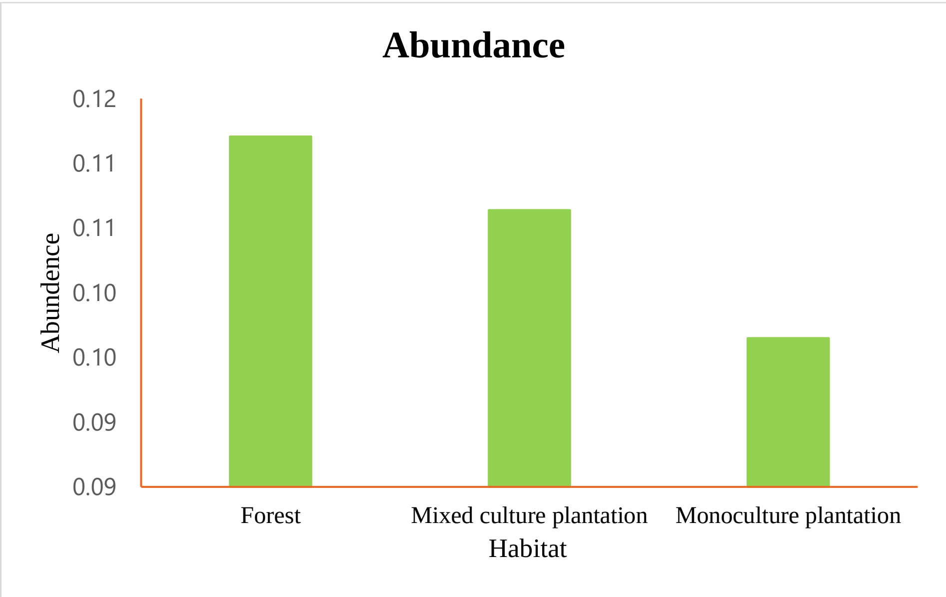

Fig 4.1.6: Graph showing total abundance of anurans in all three habitats

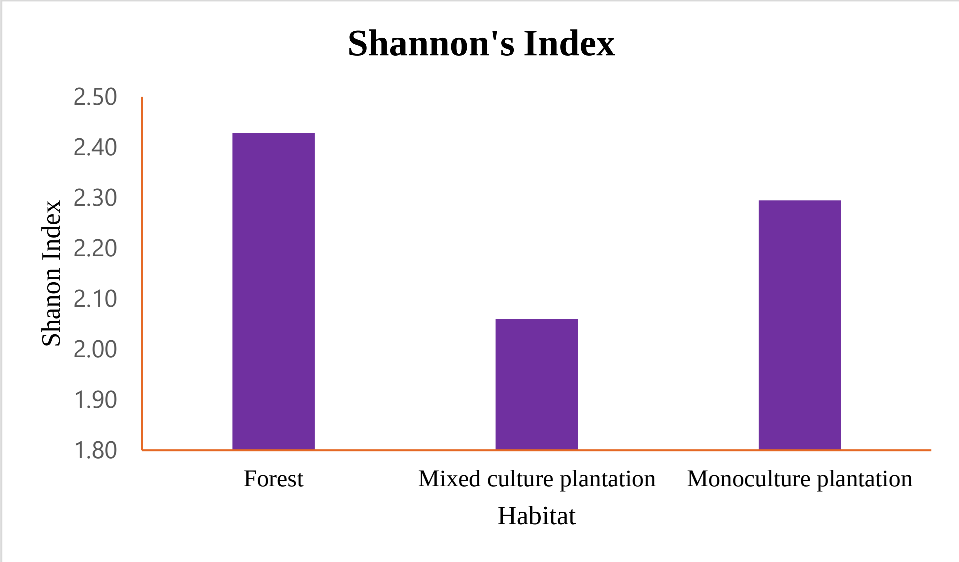

Fig 4.1.5: Graph showing Shannon index in all three habitats

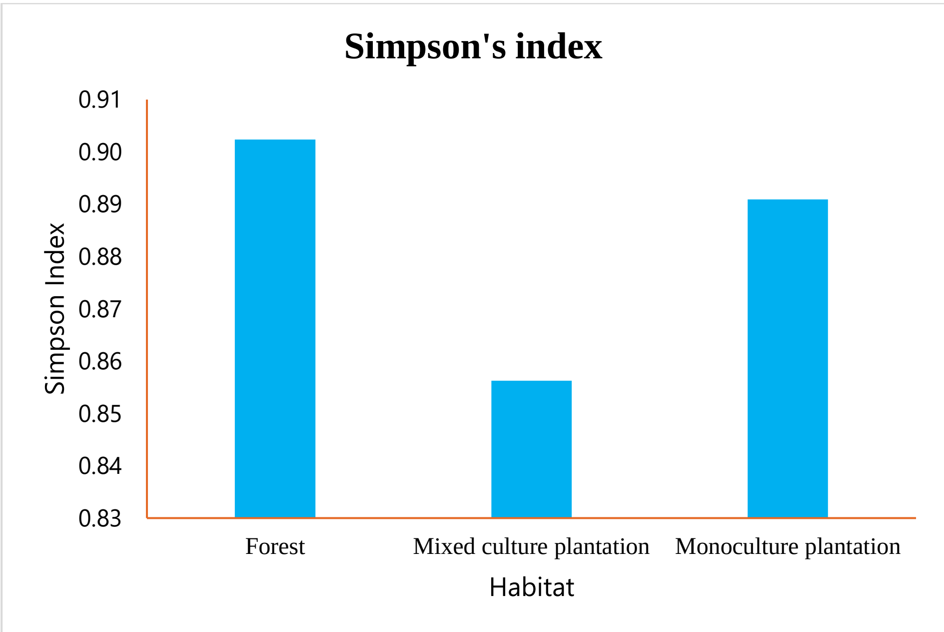

Fig 4.1.7: Graph showing Simpson's index in all three habitats

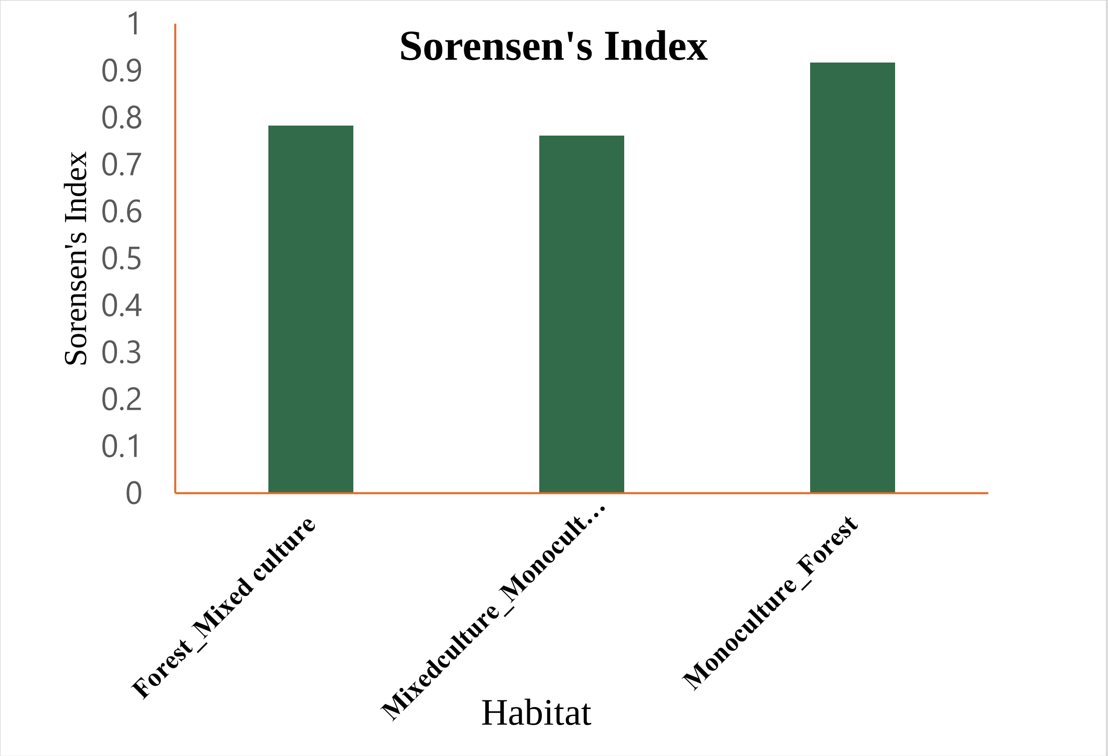

Fig 4.1.8: Graph showing Sorensen's coefficient in all three habitats

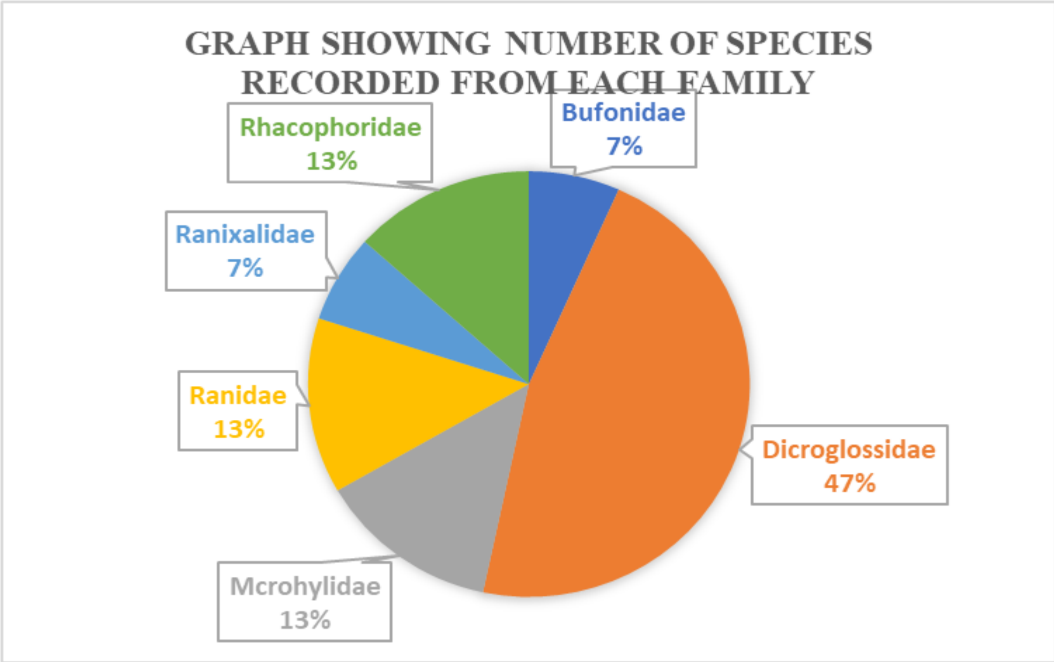

Fig4.1.9: Pie chart showing distribution of families in three habitats

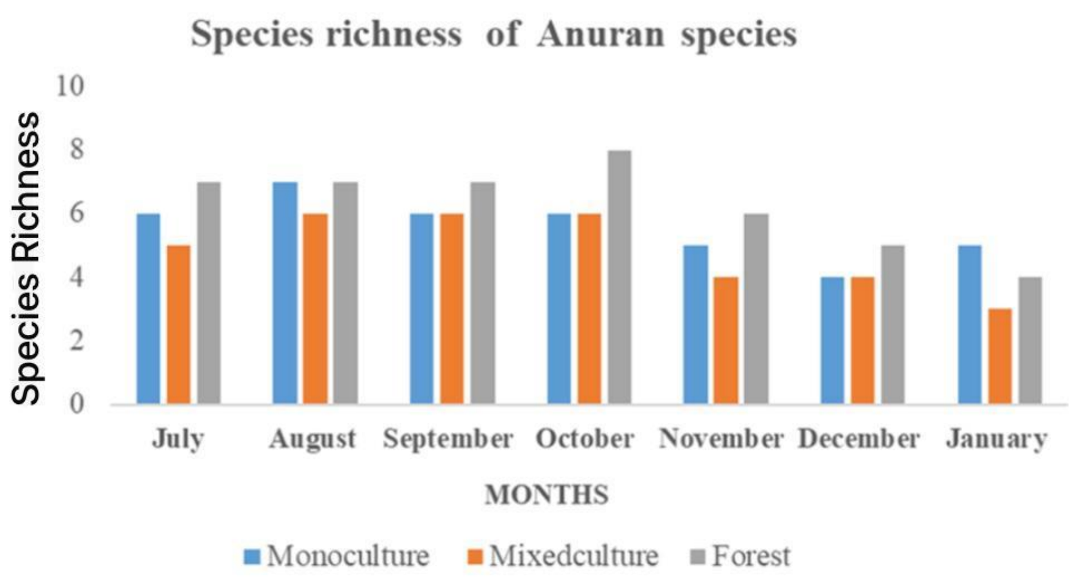

Fig4.1.10: Graph showing Species richness of Anurans in three habitats

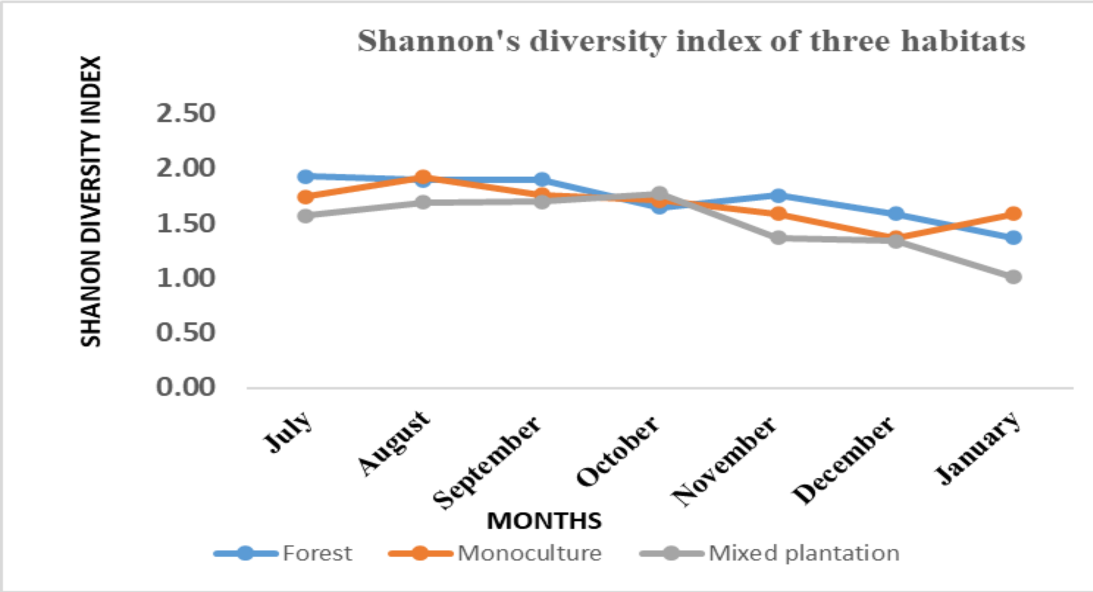

Fig4.1.11: Graph showing Shannon diversity of three habitat

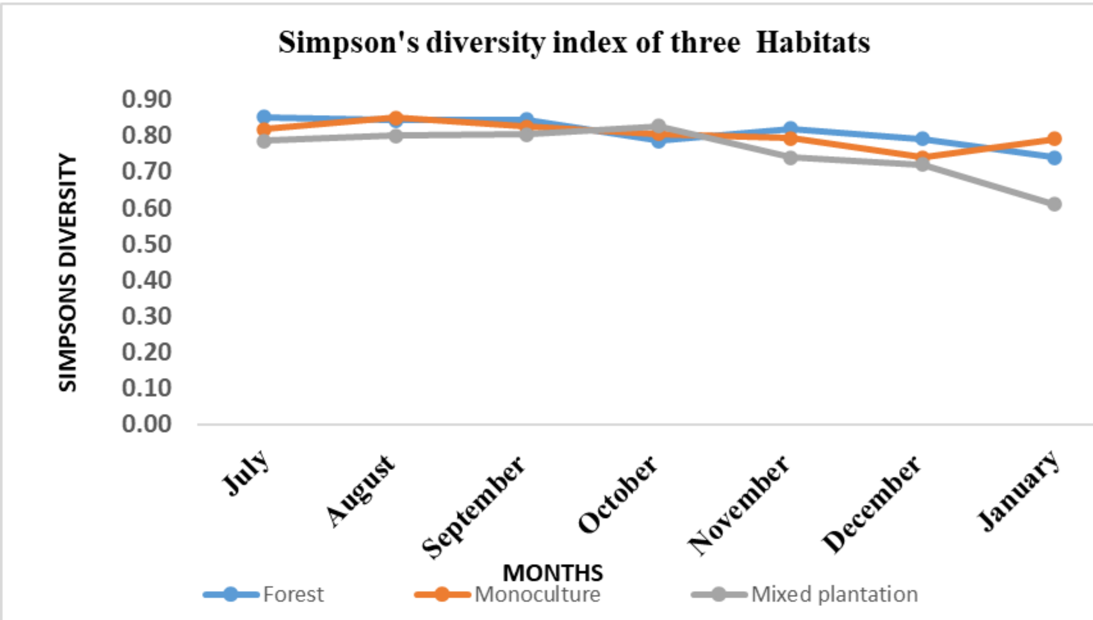

Fig 4.1.12: Graph showing Simpson's diversity index in three habitats

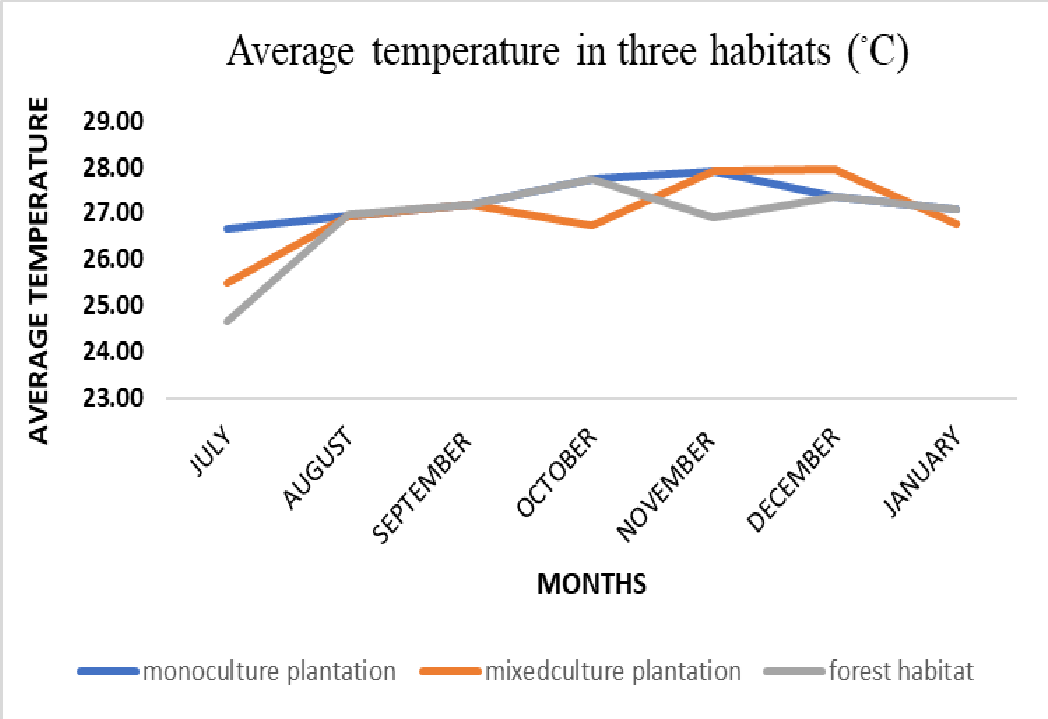

Fig 4.1.13 Graph showing average temperature in three habitats

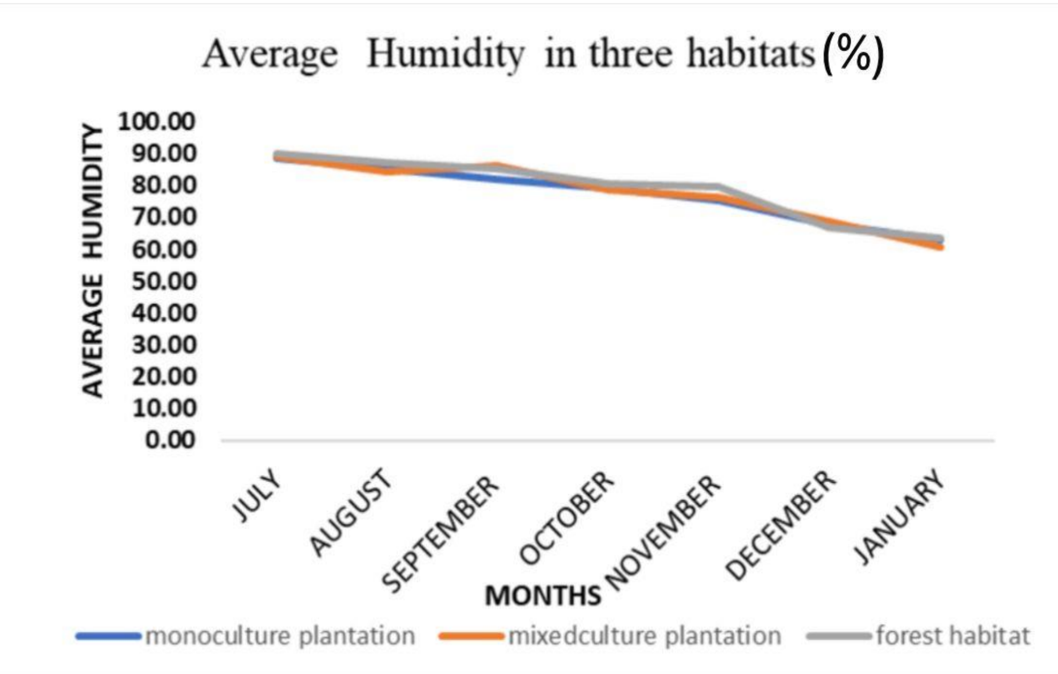

Fig 4.1.14: Graph showing average humidity in three habitats

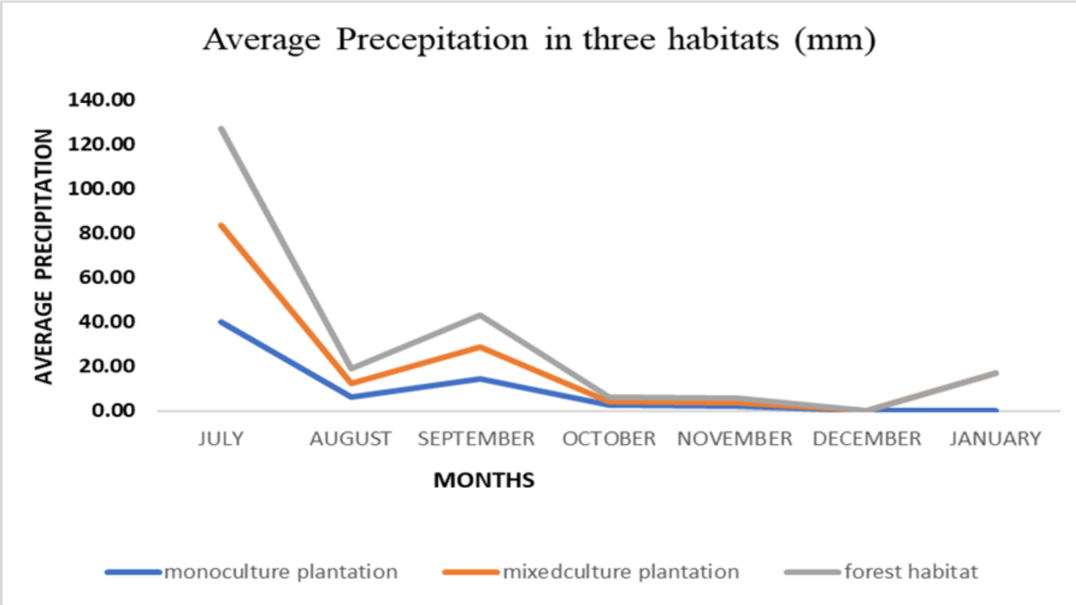

Fig 4.1.15: Graph showing average precipitation in three habitats

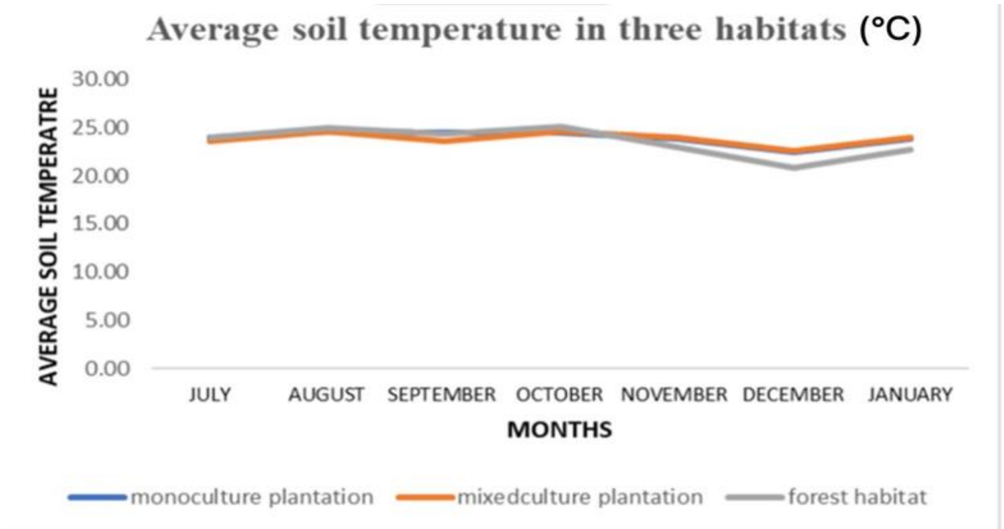

Fig 4.1.16: Graph showing Average soil temperature in three habitats

Fig 4.1.17 :Asian common toad

Fig 4.1.18:Maskey's burrowing frog

Fig 4.1.19 Cepf cricket frog

Fig 4.1.20 :Indian bull frog

Fig 4.1.21:Shyhadry cricket frog

Fig 4.1.22 Aloysius skittering frog

Fig 4.1.23 :Indian skittering frog

Fig 4.1.24:Indian dot frog

Fig 4.1.25 :Oranate narrow mouthed frog

Fig4 1.26 :Indian Bicolour frog

Fig 4.1.27 :Malabar fungoid frog

Fig 4.1.28 :Indian leaping frog

Fig 4.1.29:Bombay bush frog

Fig 4.1.30 :Common tree frog

Fig 4.1.31:Eggs of Bombay Bush frog

Observations

Table 4.1.11: Table showing observation of life stages in three habitats

Common names	Life stage		
	Eggs	Froglets	Adults
Asian common toad			+
Maskey's burrowing frog			+
Cepf Cricket frog			+
Indian bull frog		+	+
Shyhadry cricket frog			+
Aloysius Skittering frog			+
Indian Skittering frog			+
Goa cricket frog			+
Indian dot frog			+
Ornate narrow mouthed frog			+
Indian Bicoloured frog			+
Malabar Fungoid frog			+
Indian leaping frog			+
Common tree frog			+
Bombay bush frog	+		+

The study also involved investigating amphibian populations and behaviours across different habitats, observing Indian Bull Frog froglets and Bombay Bush Frog eggs in both monoculture plantations and forests, alongside vocalizations from Malabar Fungoid Frogs, Indian Bull Frogs, and Bombay Bush Frogs during monsoon peaks. Notably, Bombay Bush Frog egg clusters, each typically containing 16 eggs, were found on leaf surfaces. In mixed plantations, anurophagy—a behaviour where Aloysius Skittering Frogs prey on smaller anuran species was observed. These findings shed light on the distribution, behaviour, and ecological interactions of these amphibian species in varied environments, providing insights into their adaptations and responses to habitat diversity and seasonal change.

4.2 Discussion

The Anurans belonging to dicroglissidae family were most widely abundant in all three habitats as they are generalist species (Csurhes,2016), It has been suggested that anuran families such as the Ranixalidae are more vulnerable to habitat alteration than other families like the Bufonidae and the Dicroglossidae, which may be responsible for their low abundance in plantation habitats. (Nowakowski et al., 2017). Thus, species-habitat relationships specify the species composition of anuran communities in relation with abiotic and biotic factors.(Thompson et al., 2016).

The diversity indices—the Simpson (D) and Shannon (H) indices, in particular—offer important insights into the ecological diversity found in various ecosystems. The forest habitat had the highest value of the Shannon index in this study, which assesses both species richness and evenness, followed by the monoculture plantation and mixed culture plantation. In the same way, the forest habitat had the highest value for the Simpson index, which measures species richness; the monoculture and mixed culture plantations came next.

According to this pattern, the forest habitat appears to have the highest levels of ecological diversity in terms of both the total number of species and the homogeneity of their distribution throughout the ecosystem. This is not unusual, since forests usually support a wide variety of plant and animal species by providing a wide range of niches and microhabitats. The complex structure, wide range of vegetation species, and numerous biological relationships that define natural forest ecosystems are probably responsible for the high variety found in the forest habitat.

Contrary, compared to forests, monoculture plantations—which only grow one species—show less diversity. Despite being more varied than monoculture plantations, the overall variety of the mixed culture plantation is still not as extensive as that of the forest habitat. This shows that while although mixed-culture plantations might be more beneficial to biodiversity than monoculture systems, they might not be able to completely capture the richness and diversity of natural forest ecosystems.

Major insights into the interactions between biodiversity and environmental conditions can be gained from the correlation analysis results between species diversity indices (Shannon's index, Simpson's index) and abiotic variables (temperature, humidity, precipitation, soil temperature) across various habitats.

Understanding the process responsible for variation in species and species richness and evenness is a crucial aspect to understand habitat selection in ecology, Amphibian populations are declining due to environmental factors such as habitat loss, disease, and climate change. (Collins & Storfer 2003)

The implicit assumptions of this approach, that all diversity indices are strongly correlated (DeBenidictis ,1973) and that richness accounts for the largest proportion of variance in diversity, was supported by our analyses (Keylock, 2005)

The H index, evenness and species richness had positive relation with each other in all three habitats The abiotic factors had positive relation with diversity indices in monoculture and forest habitat however in mixed culture showed weak relation with indices

On correlation of abiotic factors with each other humidity showed strong positive correlation in all three habitats compared to other abiotic factors. Humidity and soil temperature mainly have shown high correlation in Forest habitat possibly due to the rich canopy cover and less movement of air habitat will tend to have high moisture in air and moist soil, additionally canopy cover also affects light penetration, temperature, humidity, and growth of understory vegetation. (Meijaard et al., 2005)

Additionally, humidity and temperature also play major role for anurans to maintain their metabolism and respiration process (Krishna, M. P et al.,2019), the understory vegetation was also higher in forest habitat which may have influenced the anuran assemblages

On the other hand, precipitation showed different relationships in three habitats it showed strong positive correlation with richness and evenness in forest habitat and but very negligible negative correlation in Mixed culture plantation, the mixed culture plantation has thick leaf litter and different understory vegetation along with reduced canopy cover exposing anurans alteration in abiotic which must have supported the anuran diversity in this habitat(Gomez et al.,2013) Additionally, open canopy enhances higher temperatures and increased evaporation, which may reduce aquatic body persistence in the habitat. Certain drawbacks, such as use of pesticides made in such plantation habitats, may prevent them from being an ideal place for their habitat (Rathod et al., 2013). These could be possible explanation for the lack of diversity in plantations

The study also revealed that different abiotic factors also have significant relationship with each other, which shows that all abiotic factors have a play independent role in shaping the anuran community in a particular habitat, prolonged studies are required to understand the impact of abiotic factors as changing environmental parameters has drastically impacted the Amphibians diversity (Lawler et al.,2009)

The current study attempted to highlight the intricate interplay between Anuran diversity and environmental factors across different habitats. It revealed that human-managed ecosystems, such as plantations, can also serve as potential habitats, supporting enormous amounts of biodiversity, including rare and endangered native faunal diversity. The study showed that plantation ecosystems can conserve generalist species while also providing home for vulnerable and endemic amphibians along with the ideal forest ecosystem. Understanding these relationships is crucial for effective conservation and management strategies, as they provide valuable insights into how changes in environmental conditions may impact biodiversity and ecosystem health.

Overall, the findings provide a baseline data on the diversity of Anuran diversity in Goa and imply that different habitats support distinct Anuran communities with varying species richness and composition. This study emphasizes the value of evaluating diversity in a variety of habitats in order to have a more insights on the ecological groups that are present in a particular habitat .

4.3 Conclusion

The comparative analysis of Anuaran communities in different habitats revealed significant relative abundance and association with abiotic variables in three habitats .The dicroglossidae family showed the highest abundance in all three habitats .

The highest diversity was found in forest habitat, which can be explained by the presence of rich canopy covers, sufficient rainfall, and high humidity providing them with suitable environment . Monoculture plantations, characterized by simplified ecosystems, display lower diversity compared to forests, while mixed culture plantations fall in between the two. In each habitat, a variety of environmental conditions, such as temperature, humidity, precipitation, and soil temperature, have significant effects on the diversity of species present. The distribution, abundance, and evenness of anuran populations in all three habitats showed influenced on anuran community which indicate that their habitat specificity and role of habitat and abiotic factors in shaping healthy ecosystem for their survival.

Long-term research is needed to have a greater understanding of the composition of anuran species. Conservation efforts should be taken on maintaining habitat complexity and diversity to support a wide range of Anuran species, as the study also revealed the supplementary role of human-modified habitat -plantations for Anurans. More research is required to explore the underlying mechanisms driving species-habitat relationships.

This study contributes to understanding Anuran diversity composition in different habitat composition in Goa ,it revealed major importance of native forest habit for anurans along with how the human modified landsacpe -plantations support anuran diversity

The finding can potentially be useful to conserve the diversity of Anurans in different habitats and provide better understanding of ecology of Anuran communities.

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