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Chapter

Seasonal Dynamics on Spider Population in Pathiramanal Island, Kerala, India: A Case Study

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Abstract

Impact of temperature, rainfall, and humidity varied across different seasons, and the spiders responded differently in each season. Spider community reaches its peak in growing season (October to January). The growing season is recorded as the period with average temperature, rainfall, and relative humidity and which is found to be more suitable for spider population to increase, because highest proportion of spiders is trapped during this season. Ecological factors diminished the spider fauna from February to May (dry season) with high temperature and then gradually decreased through June to September (rainy season) because of heavy rainfall. Correlation analysis of variables with species richness and number of individuals is tested to check the statistical significance between them. Season-wise dendrogram is plotted to show the similarity between the seasons. For the estimation of spider diversity in three different seasons, indices such as Fisher alpha diversity index, Shannon diversity index and Simpson's diversity index are evaluated.

Keywords: abiotic factors, diversity, ecology, ectotherms, seasonality

1. Introduction

The driving factors in the variation of species diversity and composition are a major topic in community ecology. Seasonal and daily changes in environmental conditions have a vital role to alter the performance of animals [1]. The environmental conditions have a significant effect on the distribution of animals, and a seasonal variation is clearly visible in the abundance of the invertebrates, especially on ectothermic animals [2, 3]. Ectotherms are strongly influenced by the various biotic and abiotic factors of the environment because the environmental changes affect their distribution and physiology [4]. Though spiders depend on the architectural structure of the habitat in which they live [5], environmental variables such as biotic and abiotic factors cause a resounding consequence on the population dynamics of the spiders. Spiders respond to both the biotic and abiotic factors to facilitate their maximum fitness [6]. Even though spiders are abundant almost in all habitats, they usually opt for a habitat with suitable environmental parameters in order to smooth their growth, reproduction, and survival [6]. The environmental parameters such as temperature, relative humidity and rainfall have influence on the construction of web, survival as well as on selecting the habitat for spiders [7]. All these indicate that the existence of spiders in a particular habitat is greatly mediated by different environmental variables on the ecosystem.

A healthy ecosystem and its smooth functioning is an indicator of the potentiality of the biodiversity of that particular ecosystem [8]. Pathiramanal island is a beautiful and tiny Island with an area of approximately 1 km^2 and seems to be a healthy ecosystem with a tower of biodiversity of both plants and animals located in the middle of Vembanad estuary (**Figure 1**). Though small in size, Pathiramanal Island is blessed with rich flora and fauna owing to the presence of wide forest cover and thick vegetation (**Figure 2**). The small size of the Island is the reason to consider it for this case study as small areas give accurate data compared to the larger ones.

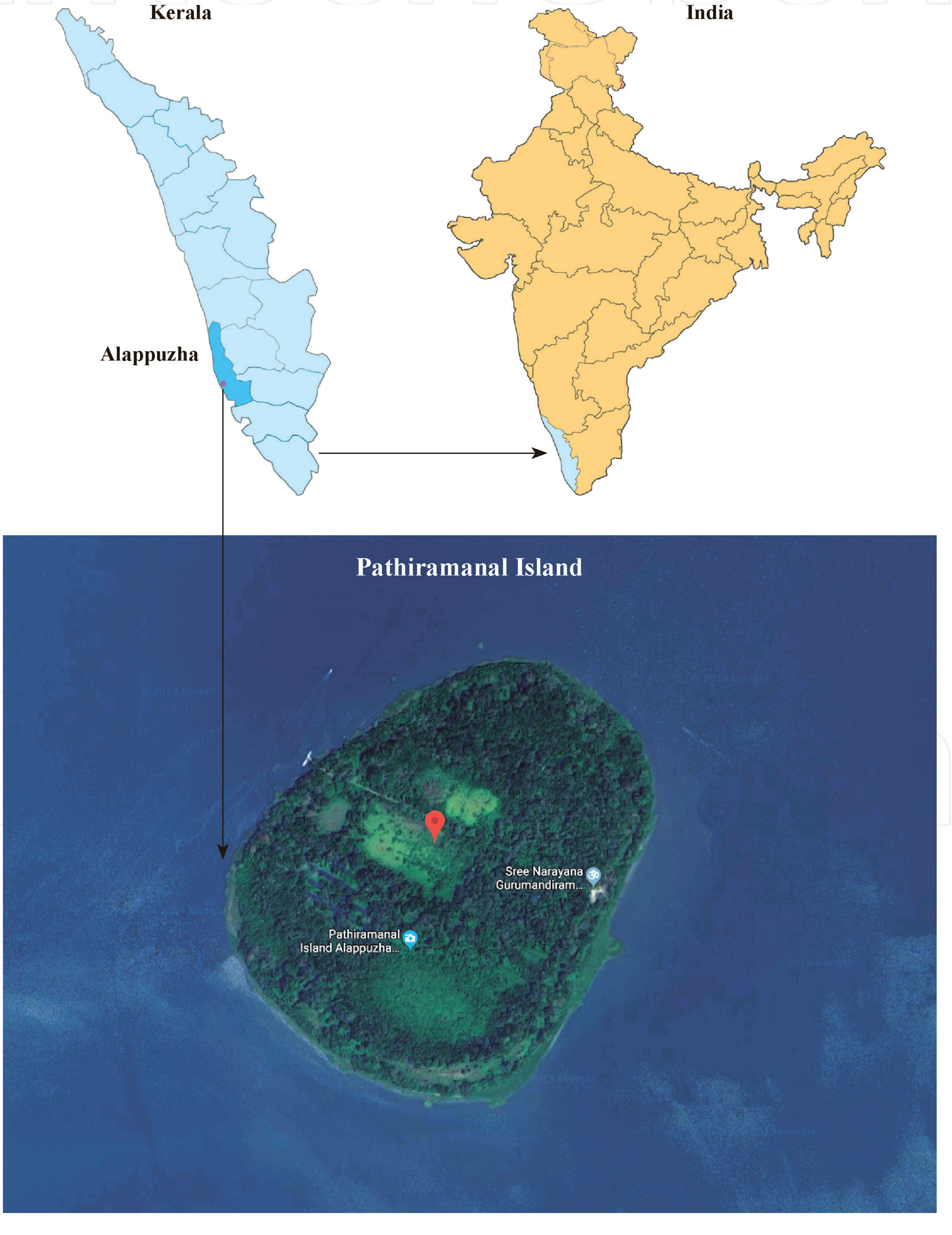

Figure 1.
Map of the study area.

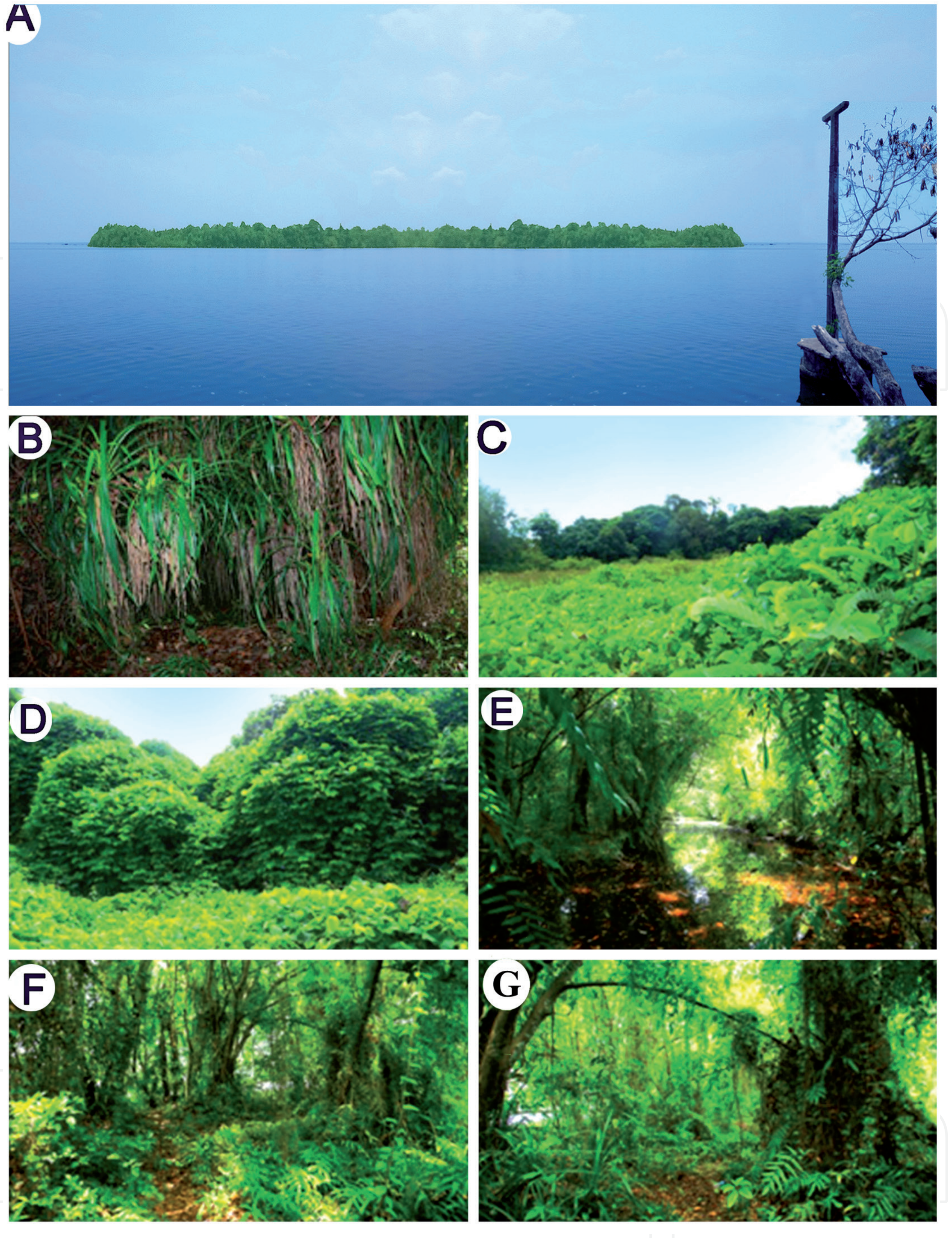

Figure 2.
(A) Pathiramanal Island; (B–G) collection localities of the study area.

Seasonality is an important factor to consider regarding the species distributions in an ecosystem for studies that discuss diversity patterns [9]. In the tropics, seasonal fluctuations have made pronounced variations among the diversity and density of different organisms [10]. In the case of arthropod populations, they are characterised either by changes in species richness and abundance with season or changes not linked with any season [9]. Spider populations have displayed both types of patterns [11], but most of the studies in tropical habitats have recorded a different tendency for each parameter regarding the season for their abundance, composition and community structure [12]. Despite its importance, the seasonal variation of spider communities in studies of tropical diversity has received little attention [13, 14].

So this study is not to deal with the precise amount and composition rather to expose how the diversity and composition of spiders in Pathiramanal Island are influenced by different abiotic factors such as temperature, rainfall and relative humidity. This chapter mainly focuses to check the variation in density and diversity of Araneae in accordance with the change in the selected environmental parameters. The study is also carried out to show the correlation of population dynamics of spiders in three different seasons in the Pathiramanal Island of Kerala, India.

2. Materials and methods

Pathiramanal Island is a small tropical Island with an area of approximately 1 km^2 lies between the latitudes 9°37′07.11″ N and longitudes 76°23′04.95″ E. It is located in the backwaters of Alappuzha District and many rare varieties of migratory birds from different parts of the country come here to nest, adding to the scenic beauty of its location on Lake Vembanad. With respect to its geographical, climatic and ecological features, the Island harbours a rich amount of arachnids of which spiders have a huge share. The temperature ranges from 28.6 to 33.5°C, with an annual mean of 31.0°C. The study was conducted from October 2014 to September 2016 and in the present study, 4 hours of sampling involved active searching for spiders employing a combination of five collection methods such as aerial hand collection, ground hand collection, litter sampling, sweep netting and vegetation beating. All the collected specimens during the survey transferred to the fixative (70% alcohol) for preservation. The sex and developmental stage of all trapped individuals are determined in the laboratory. Species-level identification is mainly recognised by looking at the genitalic features of the spiders. The palp and epigyne are dissected and cleared in 10% KOH for identifying the species. The identification and classification are done also based on the various body parts. A detailed taxonomic study is carried out using the data provided by the World Spider Catalog [15].

The investigation is done to determine how the abiotic factors influence the population dynamics of spiders in Pathiramanal Island. In order to study the variation in population density of spiders with different abiotic factors, a random collection was made in the habitat using the sampling techniques such as hand picking, beating and pitfall traps, and the number of spiders present in the Island is recorded. The collection was done once in a month from morning 8.00 am to 12.30 pm noon throughout the year. Various climatic parameters viz. temperature, relative humidity and rainfall are recorded during the period of collection.

The entire year is divided into growing season (GS), dry season (DS) and rainy season (RS). The data are subjected to statistical analysis and correlation between the spider population and abiotic factors in every three seasons are derived. Pearson's correlation coefficient (Rp) is calculated to study the correlation between different abiotic factors, viz. mean temperature (°C), relative humidity (%) and rainfall (mms) on the species richness and number of individuals using software PAST version 3.19. For the estimation of spider diversity in three different seasons, indices such as Fisher alpha diversity index, Shannon diversity index and Simpson's diversity index are evaluated.

2.1 Data analysis

Statistical relevance of the collected data was supported by calculation of the following diversity indices:

Shannon-Weiner diversity index (H) is calculated using the formula,

$$\mathbf{H = -\sum\left[(pi) \times ln(pi)\right]} \tag{1}$$

where ∑ = summation and pi = proportion of total sample represented by species i.

Simpson's diversity Index (D' = 1 – D) is calculated using the formula:

$$D=1-\sum n(n-1)/N(N-1) \tag{2}$$

$$D'=1\text{-}D=1\text{-}\frac{\sum n(n-1)}{N(N-1)} \tag{3}$$

where D = Simpson's index, n = the total number of organisms of a particular species, and N = the total number of organisms of all species.

Evenness in species distribution is calculated using Simpson's formula,

$$\mathbf{E = D / Dmax}, \tag{4}$$

where

$$D = 1/\sum Pi\,2 \tag{5}$$

Chao1: an estimate of total species richness is calculated using the formula:

$$Chao1 = S + F1(F1-1)/(2(F2+1), \tag{6}$$

where F1 = number of singleton species and F2 = number of doubleton species.

3. Results

The species composition of the spiders inhabiting Pathiramanal Island varied seasonally and each season responded to the environmental variables differently. During GS, the number of individual spiders collected from the Island was 2405, and the observed species richness, Shannon diversity and Simpson's (1-D) diversity were 129, 4.041 and 0.971, respectively. The number of individuals for DS was 1367, and the observed species richness, Shannon diversity and Simpson's (1-D) diversity were 98, 3.81 and 0.963, respectively. The number of individuals for RS was 965, and the observed species richness, Shannon diversity and Simpson's (1-D) diversity were 77, 3.64 and 0.961, respectively. It is evident from the unstandardized reference sample that GS appears to have higher observed species richness, Shannon diversity and Simpson's (1-D) diversity than others. The abundance of spiders also showed differences in the three seasons, GS showed highest abundance at 521.66 ± 311.73 (mean ± SD, n = 3), followed by DS (213.33 ± 141.50) and RS reported the lowest

(143 ± 78.63) abundance. The spider assemblages during GS showed the maximum Shannon diversity and Simpson's (1-D) diversity, RS appears to have lower Shannon diversity than GS and DS, while DS has lower diversity than GS. The overall seasonal trends in abundance of spider population in Pathiramanal Island shows a sharp decline in the rainy season and dry season, but peak in the growing season. Seasonal dynamics of the spider population in different seasons during the study revealed that the spider population attained its peak in the growing season (October to January). After the growing season, the density of spiders gradually decreased due to adverse climate condition of high temperature (**Figure 3**), while in the rainy season, the lowest numbers of spider species are observed (**Figure 4**). The study revealed that species richness varies in accordance with the relative humidity (**Figure 5**). GS is recorded as the period with average temperature, rainfall and relative humidity and which is found to be more suitable for spider population to increase because the

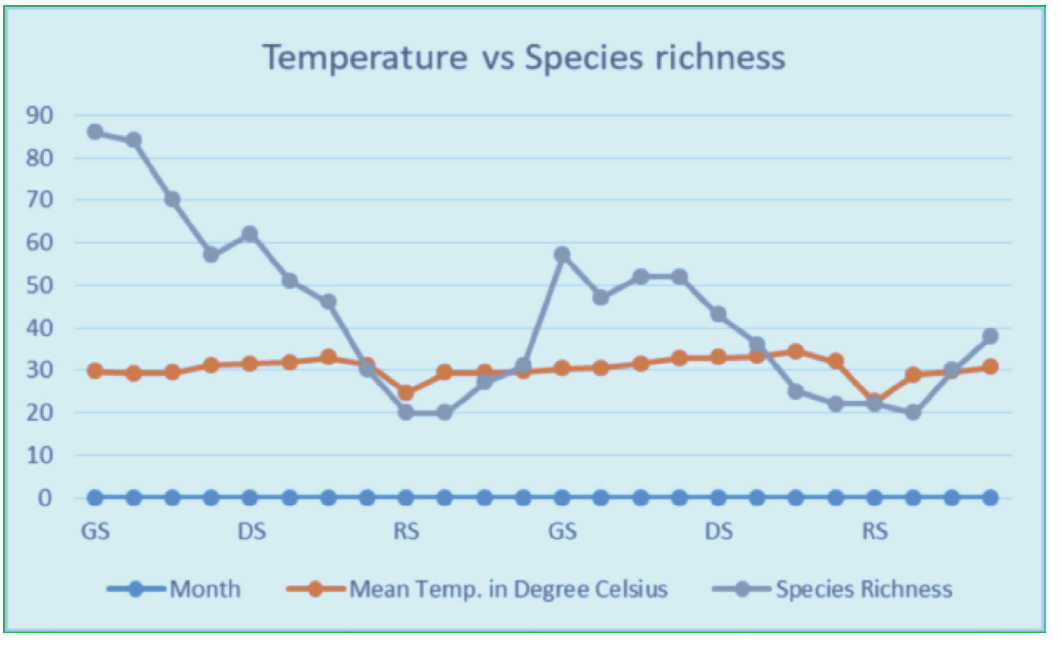

Figure 3.
Effect of temperature on species richness.

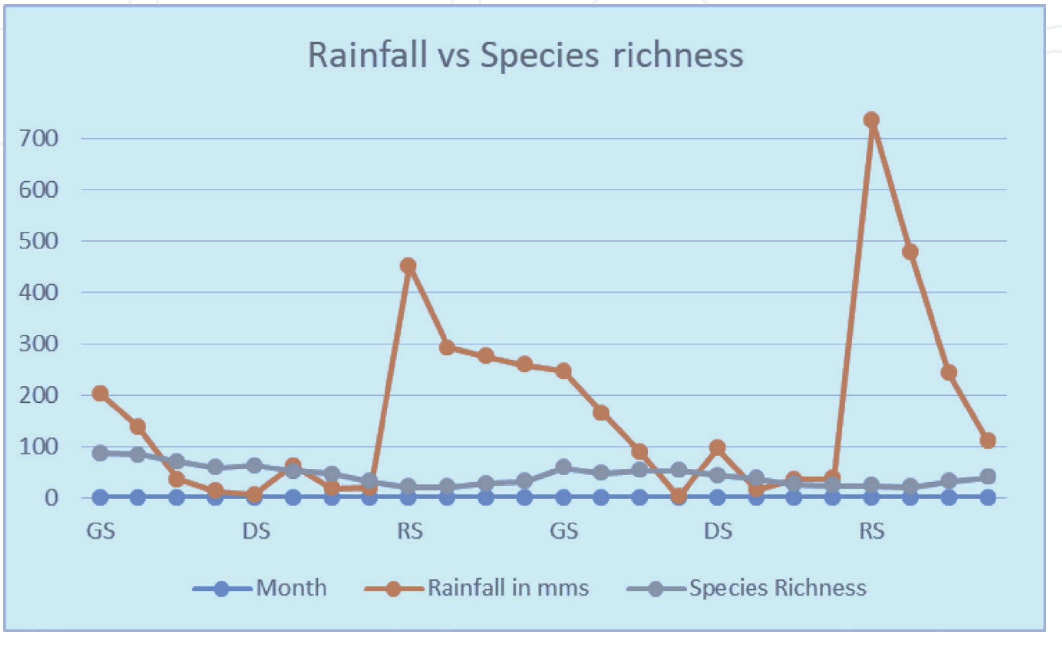

Figure 4.
Effect of rainfall on species richness.

highest proportion of spiders (50.77%) is trapped during this season. Ecological factors diminished the spider population (28.85%) from February to May (dry season) with high temperature and then gradually decreased (20.37%) through

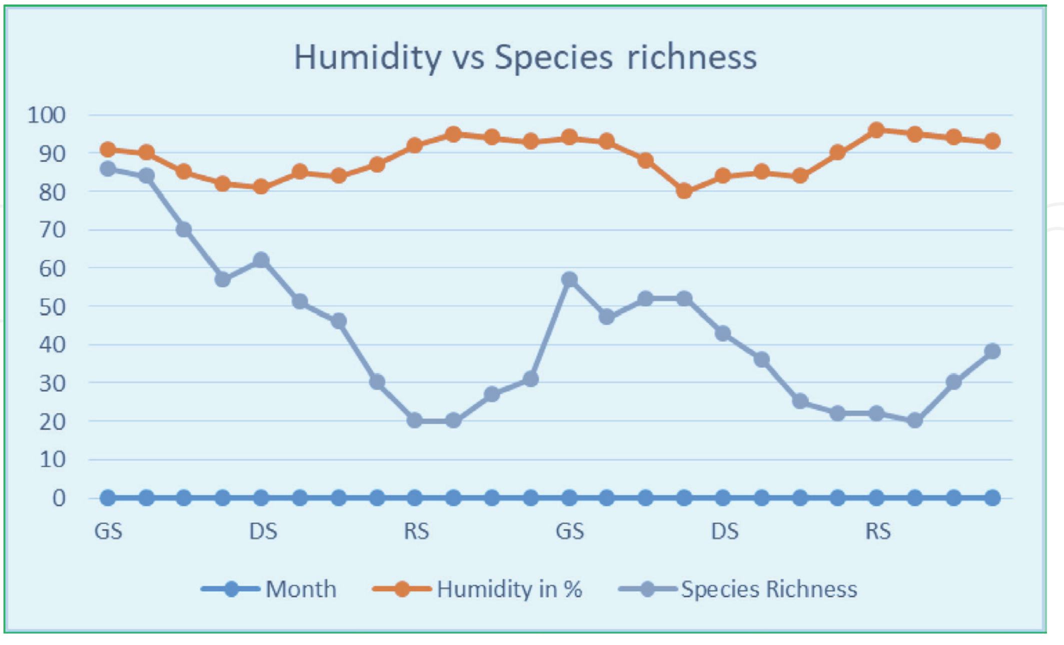

Figure 5.
Effect of relative humidity on species richness.

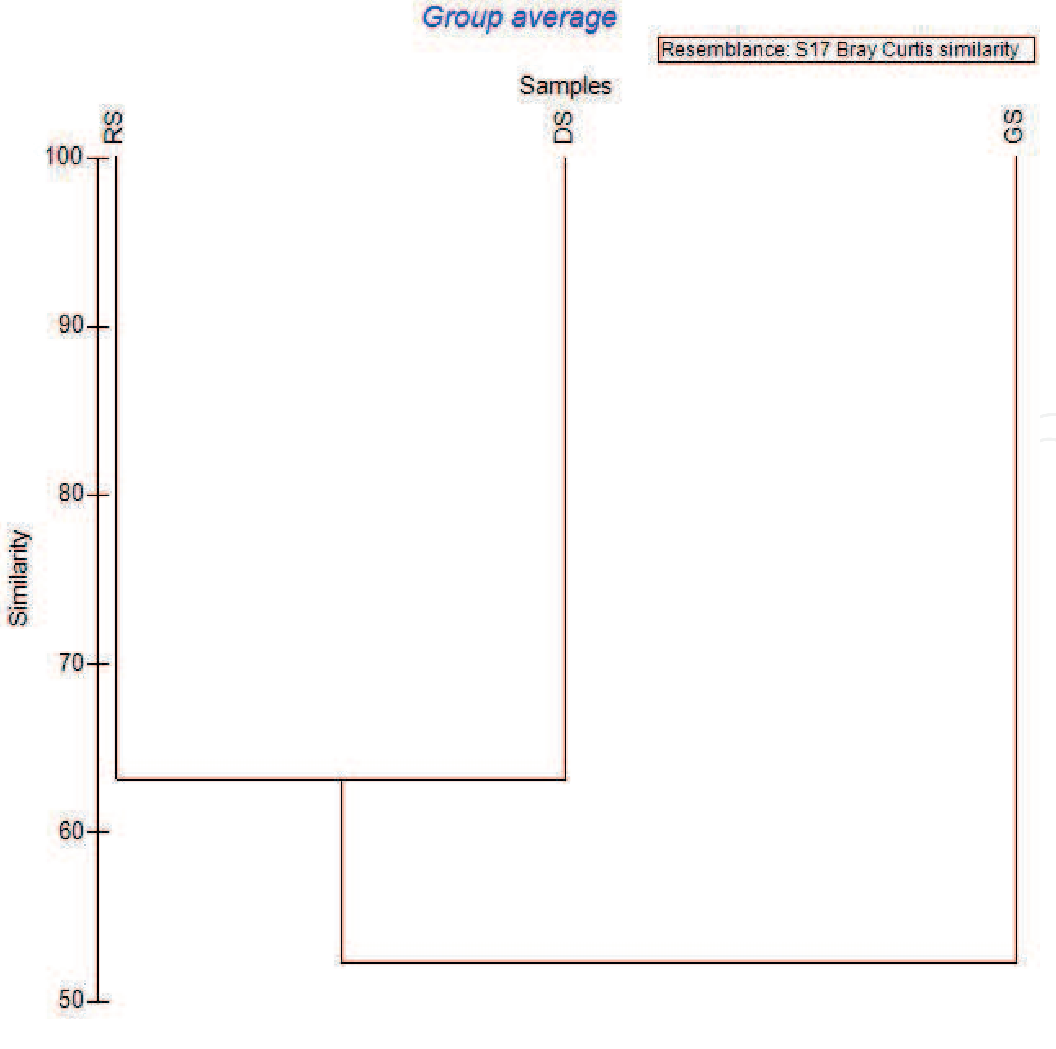

Figure 6.
Season-wise dendrogram.

June to September (rainy season) because of heavy rainfall. Although the correlation between the ecological parameters and species richness is visible from the three graphical representations, statistically no significance is shown. Season-wise dendrogram shows the spider diversity of rainy season (RS) and dry season (DS) are closely related in terms of density of the spiders, while the density of spiders in growing season was different (**Figure 6**).

Araneidae was the dominant family, and this might be due to the collecting localities of Pathiramanal Island that take care of shelter, reproductive behaviour and foraging of these orb webs. It is also observed that the occurrence of juveniles was least during the dry season. Juveniles of *Thelcticopis virescens*, *Carrhotus viduus* and *Heteropoda venatoria* occurred almost all seasons, whereas the adults had much more limited distribution. There were no species with strictly dry season and rainy season, but *Argiope pulchella*, *Anepsion maritatum*, *Gasteracantha geminata*, *Phintella vittata* and *Tylorida ventralis* occurred abundantly throughout

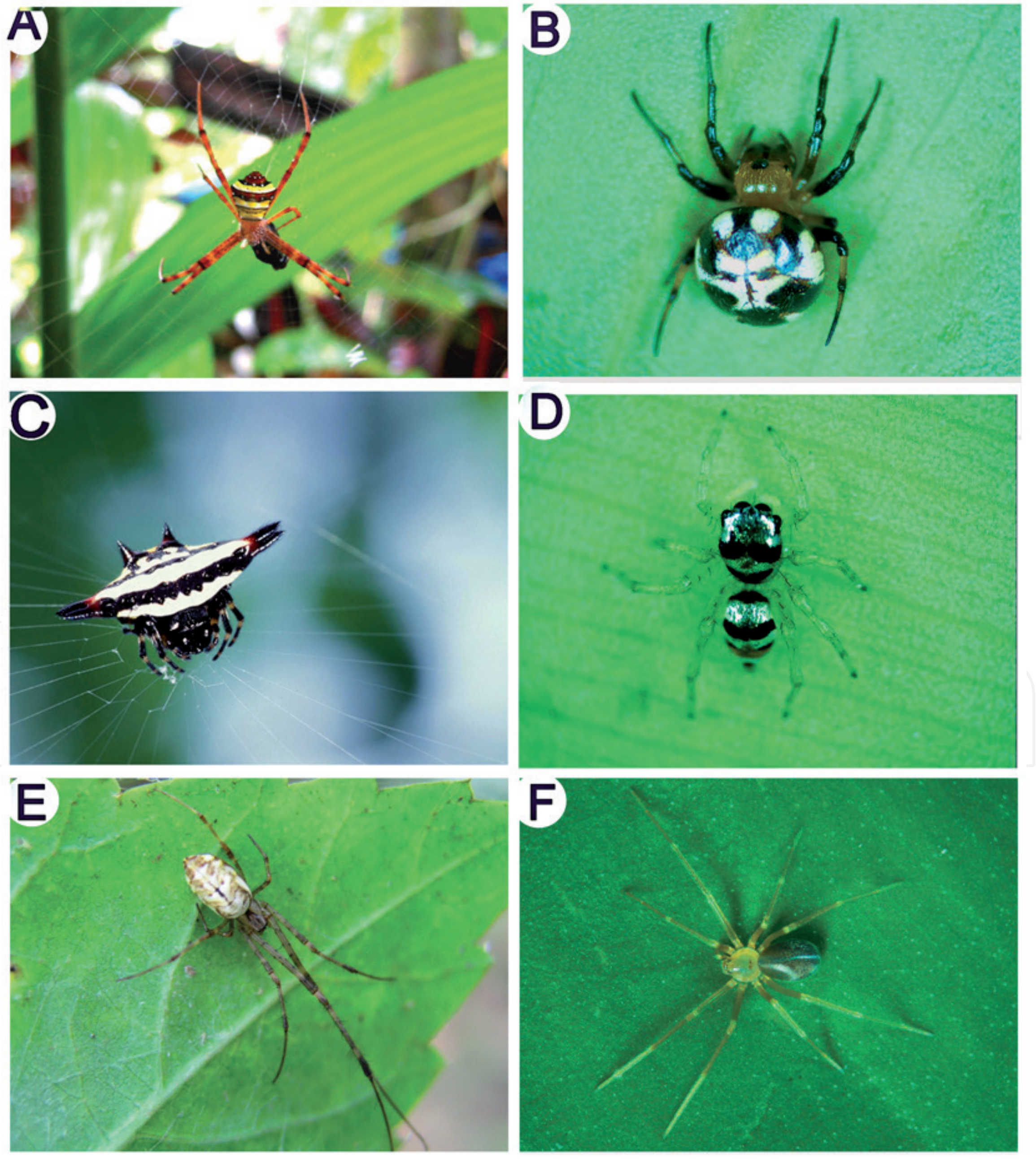

Figure 7.
(A) Argiope pulchella*; (B)* Anepsion maritatum*; (C)* Gasteracantha geminata*; (D)* Phintella vittata*; (E)* Tylorida ventralis*; and (F)* Loxosceles rufescens*.*

Environmental variables	Species richness		Number of individuals	
	Pearson's correlation coefficient (Rp)	p-value	Pearson's correlation coefficient (Rp)	p-value
Mean temperature (in °C)	0.192	0.363	0.137	0.520
Rainfall (in mm)	−0.420	0.041	−0.387	0.061
Humidity (in %)	−0.380	0.066	−0.300	0.153

Table 1.
Correlation analysis of the variables.

the year (**Figure 7A–E**). The presence of the poisonous spider *Loxosceles rufescens* (**Figure 7F**) in the Island reminds that the tourists should be aware of the spider because of their ability to cause skin necrosis or loxoscelism with their necrotizing venom. It was interesting to note that lycosid spiders made their dominance mainly during the rainy season. Kumari et al. observed that rainfall negatively affected the spider population.

Correlation analysis of the variables such as mean temperature, rainfall and humidity with species richness and a number of individuals revealed statistically no significant relationship between them except those between rainfall and species richness which has been found to have a weak negative correlation (−0.42, $p < 0.05$). However, as indicated by the Pearson's correlation coefficient (Rp) (**Table 1**), species richness and number of individuals tend to be positively correlated with mean temperature, whereas species richness and a number of individuals are negatively correlated with humidity and rainfall.

4. Discussion

The results suggest that abiotic factors and the environment play an important role in influencing the seasonality in abundance, richness and variation of spider species in Pathiramanal Island. The impact of these factors further varied among different habitats within the Island. As a general trend, the species richness was high during the growing season and decreased during the dry season, being minimum during the wet season. The abiotic factors such as temperature, humidity and rainfall influenced the ambient habitat conditions such abundance and humidity of litter, prey arthropod composition and the composition of plant species, thereby tending to reflect on the abundance, diversity and seasonality of spiders.

Habitat preference is very crucial for spiders since it plays a profound impact on the growth, reproduction and fitness of spiders [16]. Habitat utilisation of spiders is always associated with environmental factors such as temperature, wind, rain and humidity [7, 17]. Spiders are plentiful in their distribution where their habitat conditions are favourable [18, 19]. It is observed that spiders choose their habitats in view of the prey availability [20–22], and when the prey availability is less, the spiders move to other habitats with sufficient preys [23]. So, site selection is very important for spiders, and it is greatly influenced by the biotic and abiotic environmental parameters [24].

Results clearly demonstrate that an optimum temperature and relative humidity favoured spider population to increase through (October–January) on the one hand; on the other hand, increase in temperature, humidity and rainfall suppressed spider population in the other months. This study revealed the relative importance of diverse habitat types on diversity and composition of spider assemblages in the Pathiramanal

Island. The habitat heterogeneity hypothesis states that the more complex the habitat, the higher the species diversity and structure. Habitat covariates viz. humidity, temperature and rainfall were found to be important predictors for spider assemblages, and the effect of these variables varied across different seasons [25].

Being ectotherms, the temperature is found to have a key role in the habitat choice of spiders, as they are considered to be constrained by their thermal environment [26]. A recent study [27] reports that the increase in overall temperature due to global warming has resounding consequences on spider populations. The scientists also observed that spiders are unable to withstand the high temperature as well as they need a favourable temperature to cope up with the environment. Li and Jackson [28] learned that spiders adapted to warmer climates can withstand higher temperatures and reproduce at a faster pace, while spiders living in cooler climates develop sooner in response to cooler climates and more slowly at higher temperatures. They, therefore, suggested spiders have evolved to adapt to their natural environments and temperature can act as a regulator in prohibiting optimal foraging within a habitat. A wider temperature range would support greater diversity and abundance [29].

Humidity is another factor regulating the population dynamics of the spiders in an environment. Humidity crucially influences the moulting of the spiders because several moults happen in the lives of the spiders. It is studied that spiders prefer an optimum humidity prior to their moulting, because too much humidity creates fungus and too little will cause moult to go wrong [1]. Both of these conditions can result in the death of the spider.

Riechert and Tracy [16] discovered that extreme thermal stress in some areas prevent the spider from being active and resulted in a lack of prey availability. Therefore, the immature species are not fit enough to withstand the temperature in the dry season, while the adult specimens are better enough to withstand the dry season rather than small spiders.

Lycosid spiders are known as active thermoregulators since they are able to increase their body temperature in accordance with the changes in the environment [30]. Tracey [8] reported that lycosid spiders were very abundant in the high rainfall sites since they are well adapted to this type of environmental disturbance. Rainfall can alter the foraging activity of animals by precluding the visual or tactile perception of prey or predators nearby, or by hindering the mobility of small animals [31].

The season-wise dendrogram showed that species composition of spider assemblage during the DR and RS were relatively similar compared to that of the GS, both showing declining species richness, owing to non-ambient habitat conditions of the respective seasons (high temperature and heavy rainfall, respectively).

5. Conclusion

The present study found distinct compositions of spider species in the three defined seasons sampled, with seasonal distribution throughout the year. The effect of climatic variables, mainly relative humidity, temperature and rainfall, but many other factors need to be investigated, including the diversity of hunting strategies and habitat selection practiced by the animals, characteristics of the vegetation, prey availability and natural enemies. It is concluded that in Pathiramanal Island, growing season is very favourable to spider population due to its variable climatic factors and prey availability. This is the first long-term study investigating spider diversity and its relationship with seasonal variation and habitat distribution in this Island. With this work, it is intended to provide evidence of the possible usefulness of seasonal dynamics with spiders in the Island, testing it as a species richness predictor. It is to consider the effects of environmental factors to test the use of this kind of approach as a tool for conservation efforts.

This is the first intensive sampling implemented to investigate the seasonal response of spiders through different seasons in this small Island. The analysis of spider assemblages together with seasonal variation is a useful approach for understanding mechanisms shaping spider diversity in Island ecosystems. The results demonstrated that seasonal patterns of spider assemblages can differ noticeably revealing a complex spatiotemporal dynamic in this community. Undoubtedly, other habitat elements, not measured in this study, have influenced the seasonal responses of the spider community in the Island.

The results of the present study showed how the population density of spider varies with seasonal changes which, in future, can be used as a base for selecting spider as a bioindicator in a particular ecosystem. It can be used as baseline data to collect the spiders from this site in accordance with the change in the environment. It is also important to note that spider fauna is ubiquitous in nature, and their diversity cannot be explained by quantifying the seasonality of the environment. It does depend on many other factors or a combination of factors such as altitudinal variation, habitat structure, competition, predation, habitat type, environmental stability and productivity. Looking into these factors would surely bring in more interesting results, which can be relevant for stability and management of spider diversity of this region. It is recommended to have extensive surveys of spiders in this unique ecosystem which are important for a better understanding of the seasonal dynamics of such habitats, which is required to support the sustainable management of both the spiders and Island.

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