Abstract

Biodiversity is a function of the number of the any taxon present, the evenness with which the taxa are distributed (species evenness or family evenness) and the interaction component of richness and evenness. The present investigation was carried out to study the arthropod biodiversity in Horticultural ecosystem at RVS Agricultural College, Thanjavur, India. The farm lies between 10.6796° N latitude and 78.9194° E longitude with an altitude of 426.7M above MSL. The insect collections were done in both Agri-Horticultural crops (Maize, Castor, Thenai, Cotton, Mango, Sapota, Coconut, Guava and some weeds). In the study, a total of 39 fauna species (butterflies) were recorded in horticultural ecosystem under 39 genera, 14 families and 1 order were observed in the horticultural ecosystem. Among the insect families, the family Nymphalidae consists of many species followed by Noctuidae. In the study, a total of 11 species under the family Nymphalidae followed by Noctuidae (10 species). Among the different functional groups, a diversity of a herbivores and tourist was maximum and comprised of 27 species under herbivores and 13 species under tourists. Species richness and diversity index were calculated for comparison within weekly collection and to know the variance between lepidopteran species. It was concluded that the species richness of herbivores and tourist were found to be abundant during winter 2018 and summer 2019.

Keywords: Lepidoptera, relative abundance, diversity index and species richness

Introduction

Insects have important role in the ecosystems as herbivores, pollinators, nutrient cyclers, regulating populations of other organisms and feeding on or serving as food for other species (Losey et al., 2006) [1]. The tropical regions are known for their richness of species diversity (Mathew et al., 1993) [2].

Lepidoptera (butterflies and moths) is one of the most prevalent terrestrial orders, and perform essential ecosystem services such as decomposition, nutrient cycling, pollination and providing prey for passerine birds (Jaroensutasinee et al., 2011) [3]. Butterflies are monophyletic groups but moths are paraphyletic groups within the Lepidoptera. The diversity of Lepidoptera depends on the adaptability of a species to a particular habitat as the most significant biological elements of an ecosystem are through the dimension, diversity of species and population size (Kumar, 2013) [4].

The role of insects in the maintenance of essential life support systems in natural habitats is well recognized. The role of insect in the maintenance of essential life support systems in natural habitats is well recognized (Wells et al., 1983). At present about 80 percent of the world’s known animals are insects, and lepidopterans account s for 1,12,000 species, which include both butterflies and moths (Gunathilagaraj et al., 1998) [5]. Lepidopteran insects are of diversified nature and they occur both as crop pests and pollinators.

Review of Literature

Diversity indices provide important information about rarity and commonness of species in a community. The ability to quantify diversity in this way is an important tool for biologists trying to understand community structure (Beals, 1999) [7].
Varshney (1983) \[8\] reported that a list of 1,150 butterfly species with their common and scientific names. He assembled all known common names of butterflies as well as shown their present valid scientific names along with family names.

Kumar (2011) | worked on butterfly’s abundances Bundelkhand. Nine hundred and forty eight individuals of butterflies collected from various study sites, which include 29 genera and 38 identified species belonging in six families Nymphalidae-Brush-footed Butterfly family was the most dominant with 11 species followed by Pieridae-White and yellows (10), Lycaenidae-Blues (6), Danaidae-The tigers (4), Hesperiidae-Skippers (4), Papilionidae-Swallowtails (3).

Reddy et al. (1990) \[10\] Studied pollination of Celerodendrum infortunatum (Verbenaceae) by butterflies. This plant flowers from February to April and during 06.00 to 07.00 hr they offer nectar and pollen to insects. A total 17 species of insects are found foraging at the flowers diurnally. Of these three were bees, 13 butterflies and one hawk moth. Authors studied the nectar volume of flowers and proboscis length of butterflies.

Materials and Methods

Biodiversity of lepidoptera fauna in Horticultural ecosystem

The present investigation was carried out to study the Lepidoptera biodiversity in horticultural ecosystem at RVS Agricultural college-Thanjavur, India. The various methodologies followed for collection, preservation, identification of lepidoptera, diversity analysis are presented in this chapter.

Experimental details

The farm lies between 10.6796° N latitude and 78.9194° E longitude with an altitude of 426.7M above MSL. The insect collections were done in Horticultural crops (Maize, Castor, Thenai, Cotton, Mango, Sapota, Coconut, Guava and some major weeds).

Mode of assessment

Method of sampling of lepidoptera species

The Arthropod fauna species were collected in the early hours of the day in the main field (8 -10 hrs) at weekly intervals by using different methods of collection viz., insitu and net sweeping (Hassan et al., 1995) \[11\] and the details are presented as below.

Net sweeping method

Above ground lepidoptera pests and predator species were trapped in sweep net (32 cm diameter and 70 cm height) and were monitored. Sampling was done by net sweeping method in zig zag manner at the rate of five sweepings. The data was used to calculate the inventory of fauna Lepidoptera community.

Preservation of lepidoptera fauna

The collected insects were killed by chilling injury and these specimens were sorted, pinned, labelled and mounted in wooden boxes (Uniyal and Mathur, 1998) \[12\]. The method described by Tikader and Bal (1981) \[13\] was followed for the preservation of the field collected soft bodied insects. The lepidoptera collected by various methods were brought to the laboratory and killed by chilling injury.

Diversity analysis

1. Shannon-Wiener function (H) A function devised to determine the amount of information in a code or signal, and defined:

\[ H = -\sum_{i=1}^{S_{obs}} p_i \log_e p \]

where \( p_i \) = the proportion of individuals in the ith species; or in terms of species abundance:

\[ H = \log_e N - \frac{1}{N} \sum_{i=1}^{\infty} (p_i \log_e p_i)n_i \]

where \( n_i \) = the number of species with \( i \) individuals. The information measure is nits for base e and bits per individual for base 2 logarithms.

2. Simpson index (D) A diversity index proposed by Simpson (1949) \[15\] to describe the probability that a second individual drawn from a population should be of the same species as the first. A similar type of index had a few years earlier been proposed by G. Yule to compare an author's characteristic vocabulary (frequency of different words in his writings). The statistic, C (or Y) is given by:

\[ C = \frac{\sum_{i}^{S_{obs}} p_i^2 - p_i^2}{N_T(N_T - 1)} \]

where \( N_i \) is the number of individuals in the ith species and \( N_T \) the total individuals in the sample.

3. Margalef D

\[ D = \frac{(S - 1)}{\ln N}, \]

where \( S \) is species number and \( N \) the total number of individuals in the sample.

4. Fisher’s This is a parametric index of diversity that assumes that the abundance of species follows the log series distribution:

\[ \alpha x^2, \frac{\alpha x^3}{3} \ldots \ldots \frac{\alpha x^n}{n} \]

where each term gives the number of species predicted to have 1,2,3,…..n individuals in the sample. This is a useful index, which has been widely used. To test if a log series distribution is appropriate see 'Fitting distributions' below.\( \alpha \) is estimated by an iterative procedure that may take an appreciable amount of time with large data sets.
5. Whittaker’s

\[ \beta_w = \frac{S}{\alpha} - 1, \]

where S = the total number of species and \( \alpha \) = the average species richness of the samples. All samples must have the same size (or sampling effort).

6. Cody’s

\[ \beta_c = \frac{g(H) + l(H)}{2}, \]

where \( g(H) \) is the number of species gained and \( l(H) \) the number lost moving along the transect.

7. Routledge’s br

\[ \beta_R = \frac{S^2}{2r + S} - 1, \]

where S is the total species number for the transect and \( r \) the number of species pairs with overlapping distributions.

8. Routledge’s bi

\[ \beta_I = \log(T) - \left[ \left( \frac{1}{T} \right) \sum e_i \log(e_i) \right] - \left[ \left( \frac{1}{T} \right) \sum \alpha_i \log(\alpha_i) \right], \]

where \( e_i \) is the number of samples along the transect in which species \( i \) is present and \( \alpha \) the species richness of sample \( i \) and \( T \) is \( e_i \).

9. Routledge’s be

\[ \beta_E = \exp(\beta_I) - 1. \]

10. Wilson and Schimida’s

\[ \beta_T = \frac{[g(H) + l(H)]}{2\alpha}, \]

5. Relative abundance

It measures the percentage of individuals over all the species. It was measured by the formula,

\[ R = \frac{a}{N} \times 100 \]

Singh and Rai, 2000) [23]

Where,
R = Relative abundance
\( a \) = Total population of a particular species/taxon
\( N \) = Total population of all the species/taxon

Statistical analysis

The number of butterfly species (S), the number of individuals for each species (N), \( \alpha \) and \( \beta \)-diversity indexes were calculated. The \( \alpha \)-diversity was calculated from various indices including the Shannon-Wiener diversity index (H) (Shannon, 1948) [14] that measures the species diversity within the community of an ecosystem (Sagar and Sharma, 2012) [24]. Margalef index (d) that provides a measure of species richness, and Simpson index (D) that gives the species dominance. As the D index increases, the diversity decreases and for this reason we also calculated the form 1-D. In addition, as a measure of Fisher alpha index and species richness was calculated and all these indexes were calculated using “Species diversity & Richness” software developed by Dr. R. M. H. Seaby and Dr. P.A. Henderson (2006) [26]. Pisces Conservation Ltd-2001 Version 2.65 available at web link http://www.ichouse.demon.co.uk/

Results and Discussion

Inventory of lepidoptera fauna in Horticultural ecosystem

Lepidopteran insects were collected (Butterflies and moths) at weekly intervals during winter 2018 and summer 2019 from Horticultural ecosystem were identified to the extent of possible taxons and are presented in table 1 and Plate 1. Total of 39 fauna species (butterflies) were recorded in horticultural ecosystem under 29 genera, 14 families and 1 order were observed in the horticultural ecosystem. Among the insect families, the family Nymphalidae consists of many species followed by Noctuidae. It was also recorded a total of 11 species under the family Nymphalidae followed by Noctuidae (10 species). Among the different functional groups, a diversity of an herbivores and tourist was maximum and comprised of 27 species under herbivores and 13 species under tourists.

Relative abundance

The weekly collection and inventory of lepidoptera fauna in agricultural land horticultural ecosystem was given in table 3. Survey was conducted from 1st week and continued up to 8th week. A total number of 39 individual species were recorded in horticultural ecosystem respectively comprising 13 species as tourist and 27 species as herbivores. It was found that the relative abundance of Achraea violae was more (27.9%) followed by Delias eucharis (12.29%) while a lower relative abundance was recorded in Danaus sp., Junonia almana, J. leonias, Papilio polytes, Delias eucharis, Heboinia sp., Hippotion celerio, Achaea janata, Achaea sp., Rajendra irregularis, Eudiotpes indica, Amata cysea, Semiothisa pervolgata (0.72% each). Biodiversity of lepidoptera fauna in horticultural ecosystem In the horticultural ecosystem, the biodiversity of lepidoptera fauna is in similar trend as in agricultural ecosystem. Many other species were also recorded in agricultural and horticultural ecosystem which aid in pollination and contributes towards an increased yield in different ecosystem. The results are in accordance with Nair et al., (2014) [27], Arya et al., (2014) [28], Rajagopal et al., (2011) [29]. It was concluded that in RVSAC, the butterfly fauna especially Achraea violae, Delias eucharis, Eurma hecabe, Pachliopta aristolochia, Pachliopta hectar and were found to be dominant in agricultural and horticultural ecosystem. Considering all the lepidoptera species in each category, relative abundance of herbivores were found to be predominant over tourists.
### Table 1: Weekly collection of lepidoptera fauna in Horticulture ecosystem

| Sl. No | Family / Scientific Name | Population in Numbers 1 week | Population in Numbers 2 week | Population in Numbers 3 week | Population in Numbers 4 week | Population in Numbers 5 week | Population in Numbers 6 week | Population in Numbers 7 week | Population in Numbers 8 week | Total |
|--------|-------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-------|
|        |                         | 1 week                      | 2 week                      | 3 week                      | 4 week                      | 5 week                      | 6 week                      | 7 week                      | 8 week                      |       |
| 1      | Danaus chrysippus       | 0                           | 0                           | 0                           | 0                           | 0                           | 0                           | 0                           | 0                           | 1     |
| 2      | Danaus junata           | 0                           | 0                           | 0                           | 1                           | 0                           | 1                           | 0                           | 0                           | 2     |
| 3      | Teliero limbiate        | 4                           | 0                           | 2                           | 1                           | 0                           | 1                           | 1                           | 2                           | 11    |
| 4      | Achraea violae          | 7                           | 14                          | 6                           | 9                           | 16                          | 16                          | 2                           | 8                           | 48    |
| 5      | Janonia lemonias        | 1                           | 0                           | 3                           | 0                           | 1                           | 5                           | 0                           | 2                           | 12    |
| 6      | Janonia almona          | 0                           | 1                           | 0                           | 0                           | 0                           | 0                           | 0                           | 1                           | 2     |
| 7      | Janonia orithya         | 2                           | 0                           | 1                           | 0                           | 2                           | 1                           | 0                           | 1                           | 7     |
| 8      | Janonia hieria          | 0                           | 1                           | 0                           | 0                           | 0                           | 1                           | 0                           | 0                           | 2     |
| 9      | Ergolis merione         | 0                           | 2                           | 0                           | 0                           | 0                           | 0                           | 0                           | 0                           | 2     |
| 10     | Euploea core            | 2                           | 0                           | 2                           | 0                           | 1                           | 1                           | 0                           | 2                           | 8     |
| 11     | Hypolimnas micipses     | 1                           | 0                           | 1                           | 0                           | 0                           | 2                           | 0                           | 0                           | 4     |
| 12     | Pachliopita hectar      | 0                           | 6                           | 0                           | 4                           | 0                           | 2                           | 0                           | 0                           | 12    |
| 13     | Pachliopita aristolechia| 3                           | 3                           | 5                           | 4                           | 0                           | 2                           | 0                           | 1                           | 18    |
| 14     | Papilio demoleus        | 1                           | 0                           | 0                           | 1                           | 1                           | 0                           | 0                           | 1                           | 4     |
| 15     | Papilio polytes         | 1                           | 0                           | 0                           | 0                           | 0                           | 0                           | 0                           | 0                           | 1     |
| 16     | Catopsilia pyrante      | 0                           | 0                           | 1                           | 2                           | 0                           | 0                           | 3                           | 0                           | 8     |
| 17     | Eurema hecabe           | 2                           | 6                           | 2                           | 1                           | 6                           | 2                           | 3                           | 5                           | 27    |
| 18     | Delias eucharis         | 10                          | 9                            | 13                           | 0                           | 0                           | 5                           | 0                           | 37                           |       |
| 19     | Hebornia sp.            | 1                           | 0                            | 3                           | 1                           | 0                           | 1                           | 0                           | 2                           | 8     |
| 20     | Pelopidas mathias       | 1                           | 0                            | 4                           | 2                           | 0                           | 0                           | 1                           | 2                           | 10    |
| 21     | Hippotion Celerio       | 1                           | 0                            | 0                           | 3                           | 0                           | 1                           | 0                           | 6                             |       |
| 22     | Melanitis leda ismene   | 0                           | 1                            | 0                           | 0                           | 0                           | 0                           | 1                           | 0                           | 2     |
| 23     | Semiothisa pervolgata   | 1                           | 0                            | 0                           | 0                           | 0                           | 0                           | 0                           | 0                           | 1     |
| 24     | Orthes ancilla          | 0                           | 0                            | 1                           | 1                           | 0                           | 0                           | 1                           | 0                           | 3     |
| 25     | Achaea Janata           | 0                           | 0                            | 0                           | 0                           | 1                           | 0                           | 0                           | 0                           | 1     |
| 26     | Spiroma spp             | 1                           | 1                            | 1                           | 0                           | 0                           | 0                           | 2                           | 0                           | 5     |
| 27     | Dyspsia algira          | 1                           | 0                            | 0                           | 0                           | 1                           | 1                           | 2                           | 0                           | 5     |
| 28     | Mythimna sp             | 1                           | 0                            | 0                           | 0                           | 0                           | 0                           | 0                           | 0                           | 1     |
| 29     | Spodoptera litura       | 0                           | 0                            | 0                           | 0                           | 0                           | 0                           | 0                           | 1                           | 1     |
| 30     | Chrysodeixi seriisoma   | 0                           | 0                            | 1                           | 0                           | 0                           | 0                           | 0                           | 1                           | 2     |
| 31     | Earias vitrella         | 0                           | 0                            | 0                           | 1                           | 0                           | 0                           | 1                           | 0                           | 2     |
| 32     | Rajendra irregularis    | 0                           | 0                            | 0                           | 0                           | 0                           | 0                           | 1                           | 1                           | 2     |
| 33     | Pyrrharctica isabella   | 0                           | 1                            | 0                           | 0                           | 0                           | 1                           | 0                           | 0                           | 2     |
| 34     | Amata cyssea            | 1                           | 0                            | 0                           | 0                           | 0                           | 0                           | 0                           | 0                           | 1     |
| 35     | Lampides boeticus       | 0                           | 2                            | 0                            | 2                           | 0                           | 0                           | 0                           | 0                           | 4     |
| 36     | Euchrysops cnejes       | 0                           | 0                            | 0                           | 0                           | 1                           | 0                           | 0                           | 0                           | 1     |
| 37     | Sylepta derogata        | 0                           | 0                            | 1                           | 0                            | 0                           | 1                           | 0                           | 0                           | 2     |
| 38     | Symatomis thoraciga     | 1                           | 0                            | 2                            | 0                            | 0                           | 0                           | 1                           | 0                           | 4     |
| 39     | Hypsa ficus             | 0                           | 0                            | 0                            | 0                            | 0                           | 0                           | 1                           | 0                           | 1     |
| 40     | Unknown                 | 1                           | 0                            | 1                            | 1                            | 1                           | 1                           | 1                           | 1                           | 7     |
| **Total** |                       | 44                          | 48                          | 50                           | 29                           | 36                           | 30                           | 29                           | 35                           | 301   |

### Table 2: Alpha diversity indices

| Species collections in Weeks | Shannon wiener index | Simpsons D | Margalef J | Fishers alpha | Species Richness |
|-----------------------------|----------------------|------------|------------|---------------|------------------|
| **Week 1**                  | 2.5556               | 0.02496    | 11.038     | 4.8158        | 13.371           |
| **Week 2**                  | 2.1151               | 0.018664   | 6.963      | 3.0998        | 5.8616           |
| **Week 3**                  | 2.5155               | 0.019002   | 10.294     | 4.3456        | 10.086           |
| **Week 4**                  | 2.3116               | 0.027757   | 9.3585     | 3.751         | 9.4903           |
| **Week 5**                  | 1.8841               | 0.038061   | 4.5        | 3.0696        | 6.3026           |
Saurav et al., (2017) [30] concluded that out of 75 genera and 6 families, Nymphalidae was to found to be the most dominant in nature at Howrah district, west Bengal, India. The present findings are in conformity with the above observations. Ashish Tripal (2018) [31] stated that 35 species in Nymphalidae, 34 Lycaenidae species, 18 Hesperiidae and 18 Pieridae species were recorded in Wasdha district area (Central India), Maharashtra. The present findings are found to support the earlier findings.

Research periods are classified as winter and summer, So, first 4 week of collections were under Winter period and 5 to 8 week of collections were under summer days of 2019. Shannon wiener (H) index (Table 2) shows higher index in 6th week of collection, followed by 1st week of collection and lowest index was calculated in 5th week of collection. The variance H of Shannon wiener index was calculated, which has higher variance in 5th week of collection followed by 8th week of collection whereas in Simpson (D) index (Table 2), higher index was calculated in 7th week of collection followed by 1st week of collection and lowest index was calculated in 5th week of collection.

Margalef (J) index (Table 2) shows higher index in 1st week of collection followed by 6th week of collection and lowest index was calculated in 5th week of collection whereas Shannon wiener index, higher index was calculated in 6th week of collection followed by 1st week of collection and lowest index was calculated in 5th week of collection and in Fisher alpha index (Table 2), higher index was calculated in 6th week of collection followed by 1st week of collection and lowest index was calculated in 2nd week of collection. Finally higher species diversity was calculated in 1st week of collection followed by 3rd week of collection and lowest species diversity was calculated in 5th week of collection which proves low numbers of species were collected in fifth week of summer 2019.

Kumar et al. (2008) [32] also observed the highest diversity and evenness of lepidoptera in spring and least in winter. In Fisher alpha index, higher index was calculated in 6th week (Summer-2019) of collection and lowest index was calculated in 2nd week (Winter-2019) of collection. The present findings are found to support the earlier findings.

In 39 species were collected in both winter and summer of 2018 and 2019 around 8 weeks and The highest Beta index (Table 3) was calculated in Cody Bc index, followed by Routledge Be and lowest index was calculated in Routledge Br and their values are 18.5, 1.96 and 0.35 respectively.

### Table 3: Beta diversity indices

| No. | Index                  | Beta Diversity |
|-----|------------------------|----------------|
| i)  | Whitaker Bw            | 1.304          |
| ii) | Cody Bc                | 18.5           |
| iii) | Routledge Br           | 0.35282        |
| iv) | Routledge Bi           | 0.67263        |
| v)  | Routledge Be           | 1.9594         |
| vi) | Wilson & Shimda Bt     | 1.184          |

Fig 1: Biodiversity of lepidoptera fauna in RVSAC-Thanjavur
Fig 2: Alpha diversity index – Shannon wiener index (H)

Fig 3: Alpha diversity index – Simpson index (D)

Fig 4: Alpha diversity index – Margalef index (J)
Fig 5: Alpha diversity index – Fishers alpha index

Fig 6: Alpha diversity index – Species Richness

Fig 7: Beta diversity index – Whitaker BW index, Cody Bc index, Routledge Br, Bi & Be index and Wilson & Shimda Bt index
Summary
A total of 39 fauna species (butterflies) were recorded in agricultural and horticultural ecosystem under 33 genera, 14 families and 1 order was observed in the agricultural and horticultural ecosystem. Among the insect families, the family Nymphalidae was the most diversified with 11 species followed by Noctuidae (10 species). A total of 39 species were recorded under the order Lepidoptera which include the family Nymphalidae (11 species), Noctuidae (10 species) and Papilionidae and Pieridae each 4 species. Among the different functional groups, a diversity of a herbivores comprised of 27 species followed by tourists consisting of 13 species. A total number of 138 and 119 individuals were recorded in agricultural and horticultural ecosystem respectively comprising of 27 species of herbivores and 13 species of tourists (Fig. 1).

In horticultural ecosystem, the Species richness of the following species Achraea violae (84 Numbers) is higher followed by Delias eucharis (37 Numbers), Eurema hecabe (27 Numbers) and lowest was in Papilio polytes, Semiothisa pervolgata, Achaea Janata, Mythimna sp, Spodoptera litura, Amata cyssea, Euchrysops cnejus, Hypsa ficus (1 numbers each)

In Alpha diversity indices, Shannon wiener (H) index (Fig. 2) shows higher index in 6th week of collection, followed by 1st week of collection and lowest index was calculated in 5th week of collection. In Simpson (D) index (Fig. 3), higher index was calculated in 7th week of collection followed by 1st week of collection and lowest index was calculated in 5th week of collection. In Margalef (J) index (Fig. 4), higher index was calculated in 1st week of collection followed by 6th week of collection and lowest index was calculated in 5th week of collection. In Shannon index, higher index was calculated in 6th week of collection followed by 1st week of collection and lowest index was calculated in 5th week of collection. In Fisher alpha index (Fig. 5), higher index was calculated in 6th week of collection followed by 1st week of collection and lowest index was calculated in 2nd week of collection. In species richness (Fig. 6), higher species diversity was calculated in 1st week of collection followed by 3rd week of collection and lowest species diversity was calculated in 5th week of collection.

The highest Beta index (Fig. 7) was calculated in Cody Bc index, followed by Routledge Bc and lowest was calculated in Routledge Br and their values are 18.5, 1.96 and 0.35 respectively. Present findings concludes that Achraea violae is the dominant species in this research area which should be control before it reaches the pest level in the cropping area of RVSAC and Thanjavur district in future.

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