

*Full Length Research Paper*

# Butterfly species composition and diversity in a protected area of Karnataka, India

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Field investigations were made to record the diversity of butterflies at six forest ranges in Nagarahole National Park (NNP), Karnataka during 2014 to 2015. 138 butterfly species were recorded from 94 genera, which belong to five families such as Hesperidae, Lycaenidae, Nymphalidae, Papilionidae, and Pieridae. Species composition varied significantly ( $F = 93.85$ ;  $P < 0.05$ ) among forest ranges in NNP; 113 butterfly species were common at different forest ranges in NNP, but 25 species were confined to specific forest ranges. Nymphalidae had the highest (47) species composition compared to other families. The genus *Junonia* was represented by six species, followed by *Papilio* and *Eurema* with five species each. The Shannon diversity index ranged between 4.49 and 4.59 and the Fisher alpha value ranged between 20.88 and 22.92. The Simpson and Shannon 'J' (Equitability) indices were 0.98 and 0.94, suggesting evenness between the six forest ranges. Thus, the present investigation provided insight into the butterflies of NNP and has instigated further research for restoration of forest habitats in NNP.

**Key words:** Diversity, butterflies, protected area, Nagarahole National Park, Karnataka.

## INTRODUCTION

Systematic studies on butterflies have been made in different parts of the world since the turn of the 18th century. Heppner (1998) has documented 19,238 butterfly species throughout the world. Over the past century, many researchers have significantly contributed to the field of butterfly ecology within the various ecosystems in India (Bingham, 1905, 1907; Williams,

1930; Evans, 1932; Talbot, 1938, 1947; Wynter-Blyth, 1947; Larsen, 1987; Kunte, 2000, 2001). All these authors have contributed much to the field of butterfly fauna at various ecosystems in few regions of the world.

In India, Singh et al. (2001), Sreekumar and Balakrishna (2001), Sharma (2009), Raut and Pendharkar (2010), Kunte et al. (2012), Tewari and Rawat (2013),

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Sharma and Sharma (2013), and Quareshi et al. (2014) have reported on the butterfly fauna in a few protected areas of central, northern and north-eastern parts of India. Radhakrishna and Lakshminaryana (2001) and Radhakrishna and Sharma (2002) have studied the butterfly fauna in Nilgiri Biosphere and Eravikulam National Park in South India. However, Watson (1890) published the butterflies of Mysore, Karnataka. Later, Yates (1933) published the butterflies of Bangalore and its neighborhood in Karnataka. Further, Radhakrishna and Ralot (2006) have reported the butterfly fauna of Biligiri Rangaswamy Wildlife Sanctuary, Karnataka. These three reports clearly suggested that researches of butterfly diversity in protected areas of Karnataka are wanting. In this region, butterflies play a pivotal role in environmental quality assessment in terrestrial ecosystems (Ghazol, 2002). Their presence serves as an indicator of habitat quality as well as regional vegetation. Moreover, butterflies are helpful to natural ecosystems by pollinating different plant species (Padhya et al., 2006). Further, they show migratory behavior, which is strictly seasonal; and because some are confined to specific habitats, they reveal the enriched biodiversity of that region. Therefore, butterflies become ideal candidates for biodiversity studies (Pullin et al., 1995; Thomas, 2001). Hence, emphasis has been placed on the study of butterfly diversity under various habitat conditions at protected areas of India in general and Karnataka in particular (Basavarajappa et al., 2018). Many butterfly species have exhibited population decline due to hunting, poaching and forest fires (Grewal, 1996). As a result, many butterfly species are facing threat in natural ecosystems including protected areas (Ghazol, 2002; Solomon and Rao, 2002). Hence, information on species composition, diversity, preferred host plants, food plants and distribution pattern of butterflies requires periodic updating in protected areas.

## MATERIALS AND METHODS

### Study area

The Western Ghats, mountain range is considered a biodiversity hotspot, representing highly diversified mountain chains with three broad regions: north, south and central. The south region constitutes part of Hassan, Mysore and Kodagu districts in Karnataka (Kamath, 2001) and possesses the most diverse groups of endangered flora and fauna. The south region also contains many endemic species amidst tropical lowland, mountainous evergreen forests and grasslands (Kamath, 2001; Basavarajappa et al., 2018).

In this part of the state, the Nagarahole National Park (NNP) is located in the Southwestern region and is considered one of the biologically diverse regions of Karnataka. The NNP covers 643.39 km<sup>2</sup> and is in the Mysore and Kodagu districts (Figure 1) (Kamath, 2001). The terrain is undulating with small hills and an elevation range of 701 m above mean sea level (MSL) in the low lands and 950 m above sea level (Kamath, 2001). The NNP spreads from the

foothills of Western Ghats down to the Brahmagiri hills and extends south towards Bandipur National Park, Mudumalai and Wayanad Wildlife sanctuaries. The area is drained by perennial rivers and small to medium sized tributaries. The NNP receives 1000 to 1500 mm rainfall from southwest monsoons (June to September) and northeast monsoon (October to November).

The western part receives relatively high rainfall and eastern part receives less precipitation. The temperature varies between 12 and 32°C (Kamath, 2001). These conditions favor varied vegetation that comprises scrubland to semi-evergreen forests (Basavarajappa, 2015). There are also microhabitats such as '*Hadlus*' characterized by open grassland with moist clayey soil that supports grasses and sedges.

### Methodology

The NNP is divided into seven major forest ranges: Antarsanthe, Anechowkur, Kallahalla, Nagarahole, Mattikuppe, D.B. Kuppe and Veeranahosahalli (Figure 1). The study area included areas within all forest ranges except Anechowkur (Table 1). Five study sites were randomly selected within each of the forest ranges. A distance of 3 to 4 kms was left between the study sites, in order to cover the different vegetation and topography of each range (Amala et al., 2011; Guptha et al., 2012; Kumar et al., 2007) (Table 1). The Pollard Walk Method was also adopted sometimes (Pollard et al., 1995; Kunte, 1997; Walpole and Sheldon, 1999) by fixing a 100-m permanent line transect in forest ranges. The butterflies were observed by traversing slowly (30 min per transect) and observing within 3 m radius of the observer (Caldas and Ribbis, 2003; Ramesh et al., 2010). Observations of butterflies were made from 8.00 to 12.00 h and 14.00 to 18.00 h (Kunte, 1997; Rajagopal et al., 2011) and photographed using a Canon and Nikon Power shot camera with appropriate megapixel lenses. Each study site was visited once in a quarter in all the six forest ranges. Field photographed butterflies were identified with the help of field guides. Capturing of butterflies is strictly prohibited in NNP and hence, a visual count method (VCM) was adopted during the present investigation.

### Statistical analysis

Analysis of variance (ANOVA) was used (Saha, 2009). The butterfly diversity was calculated by using PAST version 2.10. The  $\alpha$  diversity of butterfly species was calculated by using Shannon Diversity Index ( $H^1$ ) that combines the number of species within a range with the relative abundance of each species (Maguran, 2004).

Shannon Diversity Index ( $H^1$ ):  $H^1 = -\sum (p_i \ln p_i)$ ,

where  $p_i$  is the proportion of the  $i^{\text{th}}$  species in the total sample and  $\ln p_i$  is the natural log of  $p_i$ .

The number of species (species richness) in the community and their evenness in abundance (or equitability) are the two parameters that define 'H'. The evenness of species within a range was calculated by using Pielou's Evenness Index ( $J^1$ ) to identify the variation within the community among species.

Pielou's Evenness Index:  $J^1 = H^1 / \ln S$ ,

where S is the number of species present in the site and  $H^1$  is the diversity index.

Moreover, the value of  $J^1$  ranges from 0 to 1. Lesser variation within the communities among the species results in higher value of



**Figure 1.** Map showing the study areas at Nagarahole National Park.

$J^1$ . Further,  $\beta$  (beta) diversity of butterflies was calculated by using Sorensen’s Index. It is a simple method used to identify the beta ( $\beta$ ) diversity and indicates the similarity of species distribution within the study sites. Sorensen’s Similarity Index is defined as:

$$\beta = 2c / (S1 + S2),$$

where S1= total number of species recorded in the first community, S2 = total number of species recorded in the second community and c = the number of species common to both communities.

Moreover, the value of Sorensen’s Index ranges from 0 to 1. If

the value is 0, there is no species overlap between the communities and if the value is 1, the same species are found in both communities as per Maguran (2004).

## RESULTS

### Butterfly species composition

Altogether 138 butterfly species were recorded, of which

**Table 1.** Physiographic features of six forest ranges in Nagarahole National Park.

S/N	Forest range	Longitude (E)	Latitude (N)	Topography	Vegetation
1	Antarsanthe	12.01°	76.26°	Undulating mountainous type.	Dry deciduous type
2	D.B. Kuppe	11.93°	76.20°	Many mountain chains with Masala Betta are the highest peak (950 msl).	Dry deciduous type towards east, moist deciduous towards the west and large area of open grass land.
3	Kallahalla	12.08°	76.23°	Soil is perennially moist clayey and support luxuriant growth of grasses and sedges. Food mud puddling places for various butterfly species.	Dry deciduous type dominated with teak plantation. Large number of small microhabitats ('Hadlus') with open grassy swampy places.
4	Mattikuppe	12.10°	76.23°	Undulating topography with small mountain ranges.	Dry deciduous type.
5	Nagarahole	12.02°	76.13°	The hadlus are grass lands, which are occupied with riparian forest vegetation.	Dry deciduous, moist deciduous forest type with small portion of moist evergreen forest. It is known for large number of 'Hadlus'.
6	Veeranahosahalli	12.19°	76.21°	Grass lands dominated with Lantana weed.	Dry deciduous forest, scrub forest vegetation along with eucalyptus plantation.

Source: Google earth.com; Basavarajappa (2015).

113 species were observed at six forest ranges that comprised 81.9% of the total; the remaining 25 butterfly species (18.1%) were specific in their distribution, that is, found only in a few forest ranges in NNP. The butterflies found at NNP belonged to five families, namely: Hesperidae, Lycaenidae, Nymphalidae, Papilionidae and Pieridae and their species compositions were respectively 24, 21, 39, 19 and 10 (Tables 2 to 4). Among the Hesperidae family, there were 22 genera with 24 species and in the Lycaenidae family, 19 genera with 21 species found at six forest ranges (Table 2). For the genera *Notocrypta* and *Taractrocera*, two species were recorded in the Hesperidae family. Two species were recorded in the genus *Chilades* within the Lycaenidae family (Table 2). Further, 39 butterfly species belonging to the Nymphalidae family were found in NNP (Table 3). Interestingly, the genus *Junonia* has the highest (six) recorded species and it was followed by the genera *Mycalesis* and *Ypthima* with four species each. However, the genera *Ariadne*, *Danaus*, *Euploea*, *Hypolimnas*, *Lethe*, *Melanitis* and *Tirumala* have only two species each recorded from the sampling sites (Table 3). Thus, the Nymphalidae family exhibited the highest diversity, with 21 genera and 39 species in NNP as compared to all other families. There were 11 genera with 19 species found in the Pieridae family, and only four genera with 10

species were recorded in the Papilionidae family in the NNP. Among Pieridae butterflies, the genus *Eurema* has the highest recorded (five) species and three species were observed for the genus *Colotis*. However, the genera *Catopsilia* and *Ixias* were represented by two observed species, each in the Pieridae family (Table 4). In Papilionidae, the genus *Papilio* had the highest recorded (four) species, and it was followed by *Graphium* with three species and *Atrophaneura* with two species (Table 4). Commonly occurring *Papilio* species are *Papilio demoleus*, *Papilio helenus*, *Papilio memnon*, and *Papilio polytes*, and the *Graphium* species are *Graphium sarpedon*, *Graphium doson* and *Graphium agamemnon* (Table 4). Thus, the Pieridae family was represented with 7 genera and 19 species, and Papilionidae family with only 4 genera and 10 species in the NNP (Table 4). Thus, Nymphalidae, Lycaenidae, Hesperidae, Pieridae and Papilionidae family species compositions were respectively 47, 30, 29, 20 and 10 (Table 5). Analysis of variance of butterfly species observations indicated that there was a significant variation ( $F = 96.68$ ;  $P < 0.05$ ) between the butterfly species observed in different families within the NNP. However, there was no significant variation ( $F = 0.053$ ;  $P > 0.05$ ) between the butterfly species that occurred among the forest ranges in NNP (Table 6).

**Table 2.** Scientific and common names of HesperIIDae and LycaenIDae family members found at Nagarahole National Park.

HesperIIDae			LycaenIDae		
S/N	Scientific name	Common name	S/N	Scientific name	Common name
1	<i>Aeromachus pygmaeus</i> Fabricius	Pygmy Scrub Hopper	1	<i>Abisara echerius</i> Stoll	Plum Judy
2	<i>Amitia dioscorides</i> Fabricius	Bush Hopper	2	<i>Acytolepis puspa</i> Horsefield	Common Hedge Blue
3	<i>Badamia exclamationis</i> Fabricius	Brown Awl	3	<i>Amblypodia anita</i> Hewitson	Leaf Blue
4	<i>Baoris farri</i> Moore	Paintbrush swift	4	<i>Anthene emolus</i> Godart	Common Ciliate Blue
5	<i>Borbo cinnara</i> Wallace	Rice Swift	5	<i>Caleta caleta</i> Hewison	Angled Pierrot
6	<i>Caprona ransonnetti</i> C. & R. Falder	Golden Angle	6	<i>Castalius rosimon</i> Fabricius	Common Pierrot
7	<i>Halpe homolea</i> Hewitson	Indian Ace	7	<i>Catochrysops strabo</i> Fabricius	Forget Me Not
8	<i>Hasora chromus</i> Cramer	Common Banded Awl	8	<i>Chilades lajus</i> Stoll	Lime Blue
9	<i>Iambrix salsala</i> Moore	Chestnut Bob	9	<i>C. pandava</i> Horsefield	Plain Cupid
10	<i>Notocrypta curvifascius</i> C. & R. Felder	Restricted Demon	10	<i>Discolampa ethion</i> Westwood	Banded Blue Pierrot
11	<i>N. paralysos</i> Wood-Mason & de Niceville	Common Banded Demon	11	<i>Euchrysops cnejus</i> Fabricius	Gram Blue
12	<i>Oriens goloides</i> Moore	Common Dart let	12	<i>Everes lacturnus</i> Godart	Indian Cupid
13	<i>Pelopidas mathias</i> Fabricius	Small Branded Swift	13	<i>Lampides boeticus</i> Linnaeus	Pea Blue
14	<i>Pseudoborbo bevani</i> Moore	Bevan's Swift	14	<i>Leptotes plinius</i> Fabricius	Zebra Blue
15	<i>Pseudocoladenia dan</i> Fabricius	Fulvous Pied Flat	15	<i>Megisba malaya</i> Horsefield	Malayan
16	<i>Sarangesa dasahara</i> Moore	Common Small Flat	16	<i>Prosotas nora</i> C.Felder	Common Line Blue
17	<i>Sancus fuligo</i> Mabille	Coon	17	<i>Pseudozizeeria maha</i> Kollar	Pale Grass Blue
18	<i>Spialia galba</i> Fabricius	Indian Skipper	18	<i>Rapale monea</i> Hewitson	Slate Flash
19	<i>Suastus germinus</i> Fabricius	Indian Palm Bob	19	<i>Talica da nyseus</i> Guerin-Meneville	Red Pierrot
20	<i>Tagiades litigiosa</i> Moschler	Water Snow Flat	20	<i>Zizeeria karsandra</i> Moore	Dark Grass Blue
21	<i>Tapena twaitthesi</i> Moore	Angled Flat	21	<i>Zizina otis</i> Fabricius	Lesser Grass Blue
22	<i>Taractrocera maevius</i> Fabricius	Common Grass Dart			
23	<i>T. ceramas</i> Hewitson	Tamil Grass Dart			
24	<i>Udaspes folus</i> Cramer	Grass Demon			

### Habitat specificity of a few butterfly species in NNP

Around 25 butterfly species were not evenly distributed in all the forest ranges, but they were found at specific forest ranges in the NNP (Table 7). In general, five species of HesperIIDae, nine species of LycaenIDae, eight species of NymphalIDae, two species of PapilionIDae, and

one species of PierIDae were confined to specific forest ranges in the NNP. The *Cupitha punrreea*, *Curitis acuta* and *Graphium nomius* were found only at D.B. Kuppe Forest Range (DBKFR). The *Tagiades gana*, *Lethe europa*, *Cirrochroa thias*, *Freyeria trochylus*, *Horaga onyx*, *Freyeria trochylus*, *Horaga onyx*, *Jamides celeno*, *Prosotus dubiosa*, *Athyma selenophora* and *Neptis jumbah* were found in four forest ranges: Nagarahole

(NFR), Kallahalla (KFR), Mattikuppe (MFR) and Antarsanth (AFR). The *Appias albino*, *Charaxes bernardus*, *Elymnias hypermnestra*, *Curetis thetis*, *Rathinda amora* and *Zizula hylax*, *Tanaecia lepidea*, *Cirrochroa thias*, *Papilio Buddha*, *Gerosis bhagava* and *Odontoptilum angulate* were found in NFR, KFR, MFR, AFR and Veeranahosahalli Forest Range (VFR) also.

The *Calaenorohins ambareesa* was the only

**Table 3.** Scientific and common names of Nymphalidae family members found at Nagarahole National Park.

S/N	Scientific name	Common name	S/N	Scientific name	Common name
1	<i>Acraea violae</i> Fabricius	Tawny Caster	25	<i>Mycalesis perseus</i> Fabricius	Common Bush Brown
2	<i>Ariadne ariadne</i> Linnaeus	Angled Castor	26	<i>M. mineus</i> Linnaeus	Dark Brand Bush Brown
3	<i>Ariadne merione</i> Cramer	Common Castor	27	<i>M. visala</i> Moore	Long Brand Bush Brown
4	<i>Athyma perius</i> Linnaeus	Common Sergeant	28	<i>Neptis hylas</i> Linnaeus	Common Sailer
5	<i>Culha erymanthis</i> Drury	Rustic	29	<i>Orsotrioena medus</i> Fabricius	Nigger
6	<i>Danaus chrysippus</i> Linnaeus	Plain Tiger	30	<i>Pantica aglea</i> Stoll	Glassy Tiger
7	<i>D. genutia</i> Cramer	Striped Tiger	31	<i>Pantoporia hordonia</i> Stoll	Common Lascar
8	<i>Euploea core</i> Cramer	Common Crow	32	<i>Phalanta phalantha</i> Drury	Common Leopard
9	<i>Euthalia nais</i> Forster	Baronet	33	<i>Polyura athamas</i> Drury	Common Nawab
10	<i>Euploea sylvester</i> Fabricius	Double Banded Crow	34	<i>Tirumala limniace</i> Cramer	Blue Tiger
11	<i>Hypolimnas bolina</i> Linnaeus	Great Egg fly	35	<i>T. septentrionis</i> Butler	Dark Blue Tiger
12	<i>H. misippus</i> Linnaeus	Danaid Egg fly	36	<i>Ypthima baldus</i> Fabricius	Common Fivering
13	<i>Junonia almanac</i> Linnaeus	Peacock Pansy	37	<i>Y. ceylonica</i> Hewitson	White Furring
14	<i>J. atlites</i> Linnaeus	Grey Pansy	38	<i>Y. chenui</i> Guerin-Meneville	Nilgiri Furring
15	<i>J. hierta</i> Fabricius	Yellow Pansy	39	<i>Y. huebneri</i> Kirby	Common Furring
16	<i>J. iphita</i> Cramer	Chocolate Pansy			
17	<i>J. lemonias</i> Linnaeus	Lemon Pansy			
18	<i>J. orithiya</i> Linnaeus	Blue Pansy			
19	<i>Lethe drypetis</i> Hewitson	Tamil Tree Brown			
20	<i>L. rohria</i> Fabricius	Common Tree Brown			
21	<i>Melanitis leda</i> Linnaeus	Common Evening Brown			
22	<i>M. zitenius</i> Herbst	Great Evening Brown			
23	<i>Moduza procris</i> Cramer	Commander			
24	<i>Mycalesis patina</i> Moore	Gladeye Bush Brown			

butterfly species found in VFR, but it also appeared in AFR in NNP. This has clearly indicated that the majority of butterfly species were distributed among six forest ranges, but 25 butterfly species were habitat specific, confined to particular forest ranges. Thus, *C. punrreea* (Hesperiidae), *C. acuta*, *F. trochylus* and *H. onyx* (Lycaenidae), *E. hypermnestra* (Nymphalidae) and *G. nomius* (Papilionidae) were strictly confined only to DBKFR, MFR, KFR and VFR,

respectively.

#### Butterfly diversity index

Table 8 shows the butterfly species diversity index in Nagarahole National Park. The diversity indices like Shannon Index ('H') and Sorenson's Index ( $\beta$  diversity) were calculated as diversity indices, which incorporated both species richness and

abundance into a single value. The Shannon index ('H') value ranged between 4.49 and 4.59 and Fisher alpha value ranged between 20.88 and 22.92, without much variation between the indices. Moreover, the Simpson and Shannon 'J' (Equitability) indices revealed that the distribution of a majority of butterfly species within the six forest ranges was almost the same (0.98) and (0.94), and suggested the evenness between the six forests ranges. The Sorenson's Index ( $\beta$

**Table 4.** Scientific and common names of Pieridae and Papilionidae family members found at Nagarahole National Park

Pieridae			Papilionidae		
S/N	Scientific name	Common name	S/N	Scientific name	Common name
1	<i>Appias lyncida</i> Cramer	Chocolate Albatross	1	<i>Atrophaneura aristolochiae</i> Fabricius	Common Rose
2	<i>Belenois autrota</i> Fabricius	Pioneer	2	<i>A. hector</i> Linnaeus	Crimson Rose
3	<i>Catopsilia pomona</i> Fabricius	Common Emigrant	3	<i>Graphium sarpedon</i> Linnaeus	Common Bluebottle
4	<i>Catopsilia pyranthe</i> Linnaeus	Mottled Emigrant	4	<i>G. doson</i> C.&R. Felder	Common Jay
5	<i>Cepora nerissa</i> Fabricius	Common Gull	5	<i>G. agamemnon</i> Linnaeus	Tailed Jay
6	<i>Colotis amatta</i> Fabricius	Small Salmon Arab	6	<i>Papilio demoleus</i> Linnaeus	Lime Butterfly
7	<i>C. danae</i> Fabricius	Crimson Tip	7	<i>P. helenus</i> Linnaeus	Red Helen
8	<i>C. eucharis</i> Fabricius	Plain Orange Tip	8	<i>P. memnon</i> Linnaeus	Blue Mormon
9	<i>Delias eucharis</i> Drury	Common jezebel	9	<i>P. polytes</i> Linnaeus	Common Mormon
10	<i>Eurema andersoni</i> Moore	One Spot Grass Yellow	10	<i>Troides minos</i> Cramer	Southern Bird wing
11	<i>E. blanda</i> Biosduval	Three Spot Grass Yellow			
12	<i>E. brigitta</i> Cramer	Small Grass Yellow			
13	<i>E. hecaba</i> Linnaeus	Common Grass Yellow			
14	<i>E. laeta</i> Boisduval	Spotless Grass Yellow			
15	<i>Hebomoia glaucippe</i> Linnaeus	Great Orange Tip			
16	<i>Ixias marianne</i> Cramer	White Orange Tip			
17	<i>I. pyrene</i> Linnaeus	Yellow Orange Tip			
18	<i>Leptosia nina</i> Fabricius	Psych			
19	<i>Pareronia valeria</i> Cramer	Common Wanderer			

**Table 5.** No. of butterfly species and their families observed at different Forest Ranges in Nagarahole National Park

S/N	Family	All Ranges	NFR, MFR & KFR	NFR, KFR & DBKFR	DBKFR	NFR, KFR, AFR & DBKFR	AFR & MFR	NFR, KFR, MFR & DBKFR	KFR	MFR	NFR & MFR	KFR, MFR & VFR	NFR & KFR	NFR, AFR & DBKFR	Total
1	Hesperiidae	24	-	01	01	-	-	01	-	-	-	-	02	-	29
2	Lycanidae	21	01	01	01	01	02	01	01	01	-	-	-	-	30
3	Nymphalidae	39	-	01	-	-	-	01	-	-	01	01	02	02	47
4	Papilionidae	10	-	-	01	-	-	-	-	-	-	-	01	-	12
5	Pieridae	19	01	-	-	-	-	-	-	-	-	-	-	-	20
Total		113 (81.9%)	02	03	03	01	02	03	01	01	01	01	05	02	138 (100.0%)

Data is based on Tables 2 to 5. AFR: Antharasanthe Forest Range; DBKFR: D. B. Kuppe Forest Range; KFR: Kallahalla Forest Range; MFR: Mattikuppe Forest Range; NFR: Nagarahole Forest Range; VRF: Veeranahosahalli Forest Range.

**Table 6.** ANOVA for butterfly species found between and within Forest Ranges in Nagarahole National Park.

S/N	Forest range	Butterfly species recorded in					Mean	'F' Value
		Hesperiidae	Lycaenidae	Nymphalidae	Papilionidae	Pieridae		
1	Antarsanthe	24	24	41	10	19	23.6 ± 11.3	0.053**
2	D.B. Kuppe	27	24	43	11	19	24.8 ± 11.8	
3	Kallahalla	27	26	44	11	20	25.6 ± 12.1	
4	Mattikuppe	24	26	42	10	20	24.4 ± 11.6	
5	Nagarahole	27	25	46	11	20	25.8 ± 12.9	
6	Veeranahosahalli	23	21	40	10	19	22.6 ± 12.9	
Mean		25.3 ± 1.7	24.3 ± 1.9	42.7 ± 2.2	10.5 ± 0.5	19.5 ± 0.5	24.5	
'F' Value		96.68*						

Each value is a mean of 120 observations; \*Value is significant at 5% level; \*\* Value is not significant. Data is based on Tables 1, 2, 3, 4 and 5.

diversity) is a useful index to measure the difference or similarities of variety and abundance of species between the habitats. During the present study, Sorenson's Index was used to compare the species recorded in each and every forest range, but the values did not indicate much variation between the forest ranges with values ranging between 0.9444 and 0.9881 (Table 9). The diversity curve showed a typical decreasing trend for all the six forest ranges, and thus displayed the properties typically with respect to diversity profile of different forest ranges in the NNP (Figure 2). All the curves showed a unique type of variation and similarity in butterfly species distribution at six forest ranges. Moreover, curves showed more values towards the alpha ( $\alpha$ ) indicating all the ranges revealed dominance in their butterfly species diversity.

## DISCUSSION

During the present investigation, 138 butterfly species were recorded from five lepidopteron families in the NNP. The 'H' indexes (4.49 and

4.59) and Fisher alpha values (20.88 and 22.92) indicated the presence of good butterfly diversity, with evenness between the six forests ranges in the NNP. Further, Sorenson's Index ( $\beta$  diversity) did not indicate much variation between the forest ranges, and displayed the properties typically with respect to diversity profiles of the different forest ranges in the NNP. However, five lepidopteron families such as Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae and Pieridae were represented by 24, 21, 39, 19 and 10 species; and there was a significant variation between forest ranges in the NNP. Butterflies prefer specific habitats (Sreekumar and Balakrishna, 2001), to avail themselves of available resources for survival in the forest ecosystem. They show diverse feeding habits, and the varied forest habitats offer suitable sites for breeding, foraging and resting during different stages in their life cycle (Santhosh and Basavarajappa, 2017). Interestingly, the NNP has a good annual precipitation, and favorable, congenial temperature and relative humidity during various seasons in most of the forest ranges in the NNP. Moreover, the mountainous terrains (undulating with small to

medium sized hills) are covered with evergreen and deciduous tree species at different forest ranges. The foothills and lowland areas are enriched with herbaceous plant species, shrubby vegetation at open grassy areas, and all along the banks of perennial rivers and small to medium sized tributaries amidst the NNP (Kamath, 2001). Perhaps, all these life-supporting conditions might have contributed to the good values of the butterfly diversity index, with evenness among the forest ranges in the NNP. Moreover, certain nectar producing tree species might have provided nectar for adult butterflies; and foliage from trees, shrubs and herbaceous vegetation could have provided the food for larval forms. Further, the wild grasses and sedges growing in open areas and all along the banks of perennial rivers and small to medium sized tributaries amidst the NNP might have provided congenial life supporting stopover sites during different stages in the life cycle of butterflies.

Furthermore, a few microhabitats namely '*Hadlus*,' characterized by open grassland with moist clayey soil, could have supplemented the butterfly's mineral nutritional requirements for



**Table 7.** Butterfly species found at specific Forest Ranges in Nagarhole National Park.

Family	S/N	Scientific name	Common name	Forest range					
				NFR	KFR	AFR	DBKFR	MFR	VFR
Hesperiidae	1	<i>Calaenorrhins ambareesa</i> Moore	Malabar Spotted Flat	+	+	-	+	+	-
	2	<i>Cupitha punrreea</i> Moore	Wax Dart	-	-	-	+	-	-
	3	<i>Gerosis bhagava</i> Moore	Common Yellow Breasted Flat	+	+	-	-	-	-
	4	<i>Odontoptilum angulate</i> C. & R. Felder	Chestnut Angle	+	+	-	-	-	-
	5	<i>Tagiades gana</i> Moore	Suffused Snow Flat	+	+	-	+	-	-
Lycaenidae	6	<i>Curitis acuta</i> Moore	Angled Sunbeam	-	-	-	+	-	-
	7	<i>C. thetis</i> Drury	Indian Sunbeam	+	+	-	-	+	-
	8	<i>Freyeria trochylus</i> Freyer	Grass Jewel	-	-	-	-	+	-
	9	<i>Horaga onyx</i> Moore	Common Onyx	-	+	-	-	-	-
	10	<i>Jamides celeno</i> Cramer	Common Cerulean	+	+	+	+	-	-
	11	<i>Neopithecops zalmora</i> Butler	Quaker	+	+	-	+	-	-
	12	<i>Prosotas dubiosa indica</i> Evans	Tailless Line Blue	+	+	-	+	+	-
	13	<i>Rathinda amor</i> Fabricius	Monkey Puzzle	-	-	+	-	+	-
	14	<i>Zizula hylax</i> Fabricius	Tiny Grass Blue	-	-	+	-	+	-
Nymphalidae	15	<i>Athyma selenophora</i> Kollar	Staff Sergeant	+	-	+	+	-	-
	16	<i>Cyrestis thyodamas</i> Boisduval	Common Map	+	+	-	-	-	-
	17	<i>Cirrochroa thais</i> Fabricius	Tamil Yeoman	+	+	-	+	+	-
	18	<i>Charaxes bernardus</i> Fabricius	Tawny Rajah	+	-	-	-	+	-
	19	<i>Elymnias hypermnestra</i> Linnaeus	Common Palm fly	-	+	-	-	+	+
	20	<i>Lethe europa</i> Fabricius	Bamboo Tree Brown	+	+	-	+	-	-
	21	<i>Neptis jumbah</i> Moore	Chestnut-Streaked Sailer	+	-	+	+	-	-
	22	<i>Tanaecia lepidea</i> Butler	Grey Count	+	+	-	-	-	-
Papilionidae	23	<i>Graphium nomius</i> Esper	Spot swordtail	-	-	-	+	-	-
	24	<i>Papilio buddha</i> Westwood	Malabar Banded Peacock	+	+	-	-	-	-
Pieridae	25	<i>Appias albina</i> Fabricius	Common Albatross	+	+	-	-	+	-

VFR: Veeranaahasahalli Forest Range; MFR: Mattikuppe Forest Range; KFR: Kallahalla Forest Range; NFR: Nagarhole Forest Range; AFR: Antarsanthe Forest Range; DBKFR: D. B. Kuppe Forest Range; +: Present, -: Absent.

certain species. Perhaps, all these prevailing, biologically rich life supporting conditions at

different forest ranges in the NNP might have supported as much as 113 butterfly species.

However 25 butterfly species, constituting 18.1%, were more specific in their distribution in the NNP.

**Table 8.** Butterfly species diversity Index in Nagarahole National Park.

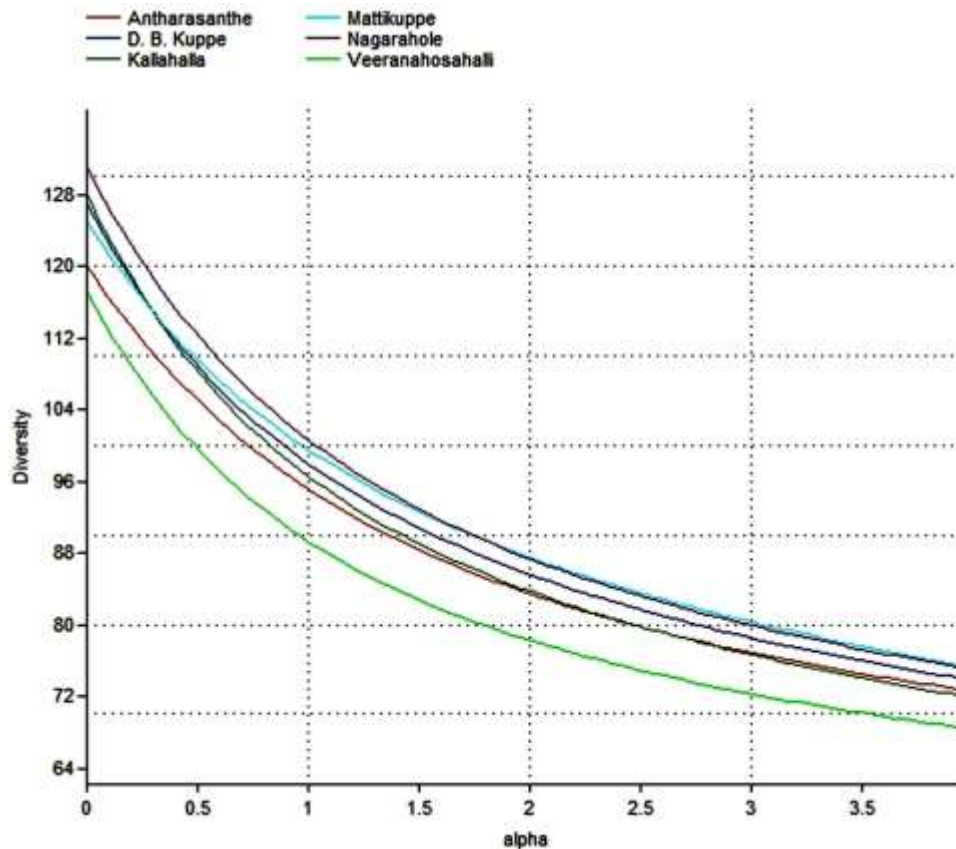
S/N	Diversity index	Forest range					
		Antherasanthe	D. B. Kuppe	Kallahalla	Mattikuppe	Nagarahole	Veeranahosahalli
1	Shannon 'H'	4.517	4.583	4.568	4.599	4.611	4.49
2	Simpson 1_D	0.9872	0.988	0.9885	0.9833	0.9866	0.9885
3	Equitability_ J	0.9429	0.9415	0.9456	0.9461	0.9435	0.9524
4	Fisher alpha	20.82	22.92	23.26	22.53	20.88	22.11

Data is based on Tables 2, 3, 4 and 5.

**Table 9.** Beta diversity (Sorenson's Index) of butterfly species in Nagarahole National Park.

S/N	Forest range	Forest Range					
		Antherasanthe	D. B. Kuppe	Kallahalla	Mattikuppe	Nagarahole	Veeranahosahalli
1	Antherasanthe	-	0.9626	0.9382	0.9538	0.9626	0.9696
2	D. B. Kuppe	-	-	0.9596	0.9387	0.9641	0.9491
3	Kallahalla	-	-	-	0.9554	0.9881	0.9495
4	Mattikuppe	-	-	-	-	0.9440	0.9617
5	Nagarahole	-	-	-	-	-	0.9294
6	Veeranahosahalli	-	-	-	-	-	-

Data is based on Tables 2, 3, 4 and 5.



**Figure 2.** Butterfly species diversity profile at Nagarahole National Park.

The requirement of foliage as food for the growing larvae, and nectar and minerals as a nutritional source for the few adult butterfly species, are not alike for these two different stages of reproductive development. Moreover, it is obvious that nutritional requirements including need for water, food plants and their chemical constituents in relation to the larval feeding, growth rate and habitat preferences are not uniform among the butterfly species. Perhaps, all these variations might have influenced the distribution of butterfly species, which belong to Hesperidae, Lycaenidae, Nymphalidae, Papilionidae and Pieridae families, differently at NFR, KFR, MFR, AFR and VFR and DBKFR in the NNP.

This clearly indicated that certain butterfly species prefer specific habitats amidst the forest ecosystems; the temporal and spatial distribution of the butterfly species is directly correlated with the floral diversity and ecological conditions of the region (Sreekumar and Balakrishna, 2001). Thus, butterflies are ubiquitous creatures, and exhibit unique evolutionary adaptations that enable them to associate with diversified ecosystems (Pierce et al., 2002).

Similar observations were made by Nimbalkar et al. (2011) and Atluri et al. (2012). However, butterfly species habitat specificity requires thorough in-depth studies to better understand the butterfly biology, host plant ecology, and the food plants distribution and abundance in the NNP. Such information is essential to establish sound policy measures aimed at restoring existing flora among forest ecosystems in general, and protected areas in particular (Kunte, 1997; Padhya et al., 2006). Further, seasonal migration of butterfly species and occurrence of few butterflies within a particular forest range help to reveal their unique life supporting requirements to complete their life cycle during their visit to such ecosystems.

All these features indicate the importance of more additional studies to record periodically, and more systematically, the butterfly species' composition, species diversity, habitat quality and distribution pattern in fragile habitats such as the NNP. Such studies could provide insight about the status of butterfly species, and in turn to initiate further research for their conservation (Pullin et al., 1995; Kunte et al., 2012). Our observations are in agreement with the observations of Ghazol (2002), Kunte (1997 and 2001), Kumar et al. (2007), Amala et al. (2011), Guptha et al. (2012), Kunte et al. (2012), Tewari and Rawat (2013) and Quareshi et al. (2014). Thus, all these authors have emphasized the need for additional butterfly studies in protected areas of India.

## Conclusion

A total of 138 butterfly species from five lepidopteron families were recorded in the NNP. Among them, 113

species were common in their appearance at all forest ranges in the NNP. This was evidenced in the Simpson 'J' (Equitability) and Shannon 'H' indices of evenness for all butterfly species encountered, except 25 butterfly species, which exhibited habitat specificity. Further, the Shannon diversity index was 4.49 to 4.59 with good Fisher alpha value and Sorenson's Index. Thus, the biodiversity profile showed a typical decreasing trend and displayed the good diversity profile of butterflies amidst the NNP. The presence of butterflies is very essential for pollinating different plant species within protected natural ecosystems. Moreover, seasonal migratory patterns of these winged creatures with preferences for given habitats indicates their need to avail themselves of particular prevailing conditions for their survival. Therefore, assays of butterfly populations should be updated periodically so as to reveal species diversity and distribution patterns that could help provide an insight about the population statuses of these varied species, and in turn to initiate further research for their conservation.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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