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Impact of Geographical elevations on the eco-distributional pattern of *Drosophila* (Diptera) species in four different ecosystems of Karnataka, India

Alwyn D'Souza[1], Manjunath Mahalingappa[2], Shakunthala Venkat[3]
[1, 2] Ph.D. Research Scholar, Chronobiology Lab, Department of Studies in Zoology, Manasagangotri University of Mysore, Mysuru, Karnataka, India
[3] Assistant Professor, Department of Studies in Zoology, Manasagangotri University of Mysore, Mysore, Karnataka, India

Abstract
Analyzing the changes in eco system co-related with species diversity across different altitudinal and latitudinal gradients are essential in understanding the complex nature of biodiversity. Four different eco systems was selected and analyzed to examine the altitudinal and latitudinal variations in the distributional pattern of *Drosophila* (Diptera: Drosophiladae) Population in Kodachadri Hills, Kath lekhan, Gopal Swamy Hills and Nandi Hill regions of Karnataka state, India. Cluster analysis, constancy methods, Simpson's, Berger-Parker's, and Shannon-Weiner indices were used to analyze the species occurrence qualitatively. We hypothesized that the Gause's competitive exclusion principle still remains to be questionable and have used 4 sets of environmental data to build a model using Venn's 4 set diagram illustrating the common species accommodated at differing eco systems and have characterized species- environment relationship. We recorded 13 species from 8 different altitudes varying between 530m and 1478m and evaluated clinal trends in species distributional pattern among different ecological niche. The result indicates that *Drosophila* community was significantly affected by elevation as the density of *Drosophila* decreased with increasing altitudes. *Drosophila ananssae, Drosophila bipectinata, Drosophila malerkotliana, Drosophila nasuta* and *Phorticella striata* were the 5 common dominant species, further, *Drosophila bipectinata* and *Drosophila malerkotliana* being the two competing sympatric species was co-existed in all the four different eco systems. These data indicate there is a positive correlation between species diversity and elevation and also there is an emphatical interaction between competing species to co-exist in the same niche.

Keywords: altitude, sympatric, abundance, richness, niche, co-existence

1. Introduction
Adaptation is a genetically determined characteristic that improve an organism's ability to survive and reproduce in a particular environment, it involves the acquisition of genetic traits that improve performance or survival over multiple generations [1], and Species adaptations to environmental heterogeneity are a basic interest in understanding population dynamics and evolutionary biology. Populations are continually changing entities relaying upon natural factors such as temperature, humidity, rainfall, photo period, population density, age distribution, intra and interspecific competition and also the accessibility of food resources which correlates with the altitude and latitudinal variations of the topographical zones. Altitudinal transect study is especially suitable to know the relationship between species distribution, coexistence, biotic and abiotic factors since these variables change at a more prominent degree contrasted with latitudinal inclination. Insects (Arthropoda: Insecta) provide a moderately simple approach to think about crucial environmental questions, since they are present in every habitat, niche and guild of this planet. In spite of their enormous diversity, insects are regularly under spoken in ecological studies, their contribution to ecosystem functioning has been relatively less researched than other species [2]. Insects play an imperative part within the differences of characteristic environments and are fundamental for environment support [3, 4]. Genus *Drosophila* with its cosmopolitan nature and complexities in species composition, exhibiting worldwide distribution is an exemplary model to examine the eco distributional pattern of various species [5]. The family *Drosophilidae* consists of more than 3500 species all over the world [6], where more than 500 species are found in Hawaiian Islands itself and 200 species belonging to 20 genera have been found in India [7].

Drosophila genus are pertinent to understand the effects of elevation trends on species distribution since these insects are highly susceptible to varying environmental conditions which are emulated in the size of species population, with amazing potential as bioindicators [8]. The existence, abundance and distribution of a species in an ecosystem are determined by whether the levels of one or more physical or chemical factors fall within the range tolerated by that species. The growth period and metabolic rates of insects significantly reduces as strident environmental conditions influence their survival including their altitudinal distribution range [9, 10].

To gain a comprehensive understanding of species distributional patterns it is necessary to know the extent to which, species altitudinal distributions change among different taxa and across geographically separated areas [11, 12]. Several studies have found a decreasing trend in species richness with altitude [13, 14, 15]. Indeed, even fundamental, however regardless basic data on species circulations along altitudinal inclinations is scarce [16]. Therefore there is a need to analyze the species distributional pattern along

altitudinal gradients [17], in different geographical areas with different ecological contexts [18] and apply the results to make reliable predictions on the process affecting species altitudinal distributions while studying other areas.

Furthermore as classical competitive exclusion principle suggests two species competing for the same resource cannot coexist at constant population values and the one with slightest advantage will out compete the other, which leads to the extinction of the weaker competitor or to an evolutionary shift to a different ecological niche [19]. However a large number of different species possibly coexist relaying on few resources in several ecological communities. Contradictory to Gause's principle, contemporary coexistence theory suggests similar species may coexist in ecologically similar environments and stave off competitive exclusion [20, 21].

Considering all these, population ecology lacks a unifying theory that could explain how selection forces interact with natural factors and allow taxonomically or phylogenetically related species depending on same ecological niche can coexist. The purpose of this study also has been attempted to comprehend the effects of altitudinal and latitudinal variations on species distribution and population fluctuations of *Drosophila* species.

India with its huge range of vegetation and atmospheres likewise harbors assortment of *Drosophila*, [22], so in our examination we have chosen four diverse geological territories of Karnataka, India

The evergreen, semi evergreen, moist deciduous and scrub forest along with patches of rubber plantations of Kodachadri hills, houses for diverse species of plants and animals. The Kodachadri hill ranges which forms a part of Mookambika wild life sanctuary, altitudinal zonations shows that Kodachadri peak lies at an altitude of 1,334 meters above sea level.

Katha lekan is a relic forest ranging from 500 to 700m above sea level, which is located in central western Ghats of Uttara kannada and Shimoga, it is surrounded on all sides by slope ranges with high level of plant endemism and myristica swamps and have the absolute most old vegetation interwined with the socio cultural and religious rehearses,

Open dry deciduous forest, tropical mixed deciduous forests of Gopal Swamy hills houses enormous species of plants and animals, it lies in the core area of Bandipur national park with the altitude of 1450 meters above sea level,

Nandi hills has general pattern of scrub and deciduous type of vegetation which lies within the Nandi state forest with the elevation of 1478meters above sea level.

2. Materials and Methods

Altitudinal variations in *Drosophila* fauna was studied in four different geographical locations of Karnataka, to accomplish this *Drosophila* flies were collected during the months between April and May 2018, in four different geographical locations of Karnataka, India- Kodachadri hills (KO) 1343 m, 569m; Kath lekhana (KA) 700m,530m; Gopal swamy hills (GS) 1450m,816m; Nandi hills (NH) 1478m,920m. Net sweeping and bottle trapping methods were used to collect *Drosophila* flies, net sweeping was done on the naturally rotting fruits accessible in the collection sites, and also the blend of fruits were used, the fruits used were *Musa acuminate* (Banana), *Citrus sinesis* (Orange), *Magniferaindica* (Mango), *Carica papaya* (Papaya) and *Artocarpus heterophyllus* (Jack fruit) all the fruits were smashed and the blend was placed underneath the tree shades one day before collections, the flies on the blend of fruits was swept using net, after each sweep flies were transferred to the bottles containing fresh food medium, to maintain uniformity 12 sweeps were made in each site, for bottle trapping method, milk bottles of 250ml capacity containing smashed banana sprinkled with dry yeast were tied to the twigs below small bushes at the height of 3 to 5 feet above the ground, 12 traps were kept at each altitude after 24 hours the mouth of each bottle was plugged with cotton, the collected flies were transferred to fresh bottles containing wheat cream agar medium (contains, 100g wheat powder, 120g raw sugar, 10g agar agar, 7ml propionic acid boiled in 1000ml of water and cooled) [23] as food. The flies were then brought to the laboratory, isolated, identified and sexed. Categorization of the collected *Drosophila* flies was made to respective taxonomic groups by using the keys suggested by [24, 25, 26].

3. Data Analysis

The Simpson's diversity, Simpson's dominance, Shannon-Weiner and Berger-Parker indices are used to analyze the abundance, richness and diversity of the collected *Drosophila* flies in varying geographical locations,

Simpson's diversity index measures the likelihood that two individuals haphazardly chose from a sample will belong to the same species [27], were determined using the formula, Formula to determine Simpson's diversity index:

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

Where;

n= the total number of organisms of a particular species

N=the total number of organisms of all population

Shannon-Weiner index measures the value of species as a function of their frequency in the community, and was determined using the formula, Formula to determine Shannon-Weiner index

$$H = -\sum p_i \ln p_i.$$

Where;

p_i= the proportion of individuals belonging to the ith species in the dataset of interest.

Berger-Parker index measures the relative abundance, and was measured using the formula,

$$1/d = \frac{N}{N_{Max}}$$

Where;

N = number of individuals of all species

N_{max} = number of individuals in the most common species.

Cluster analysis was performed using SPSS software, in cluster study Euclidean distance was used to measure the similarity between different *Drosophila* species, Ward, s method was used to join two clusters.

4. Flora of *Drosophila* collected geographical regions

Common Flora: *Tamarindus indica, Ficus benghalensis, Ficus religiosa, Azadirachta indica, Syzygium cumini, Millettia pinnata, Cocos nucifera, Mangifera indica, Ficus racemosa, Artocarpus hirsutus, Annona reticulate, Psidium guajava.*

Kodachadri Hills: *Flacourtia montana, Glycosmis pentaphylla, Grewia heterotrichia, Helicteres isora, Hopea ponga, Lagerstroemia microcarpa, Macranga pellata, Maesa indica, Nothopodytes nimmoniana, Rubia cordifolia, Symplocos racemosa, Thottea siliquosa, Caryota urens, Ensete superbum, Cinnamomum verum, Anacardium occidentale,*

Kath lekhan: *Calophyllum tomentosum, Tectona grandis, Dipterocarpus indicus, Palaquium ellipticum, Mesuaferra, Myristicafatua, Gymnacranthera canarica, Pinanga dicksonii. Cinnamomum verum,*

Nandi hills: *Shorea talura, Eucalyptus globulus, Lantana camara, Spagnaum moss, Caesalpinia, Peltophorum pterocarpum, Bougainvillea, Coffea Arabica,*

Gopalswamy hills: *Phyllanthus emblica, Santalum album, Tectona grandis, Dalbergia sissoo, Acacieae, Delonix regia, Cassia, Delonix, Plumeria rubra, Pterocarpus marsupium,*

5. Results

The *Drosophila* species were collected in different geographical conditions of Karnataka at different altitudes in the month of April to May 2018, (Fig.1) shows the map of Karnataka, which depicts the collection sites. The list of *Drosophila* species collected at different geographical areas, the number of *Drosophila* flies collected at different altitudes and the value of Shannon index, Simpsons diversity index, Simpsons dominance index, Berger-Parker dominance index for the collected *Drosophila* flies along with the mean temperature of the collected sites is represented in Table 1, A total of 13 species were collected, *Drosophila agumbensis* (Prakash & Reddy, 1978), *Drosophila ananassae* (Doleschall, 1858), *Drosophila anomalani* (Reddy & Krishnamurthy, 1973), *Drosophila bipectinata* (Duda, 1923), *Drosophila jambuliana* (Parshad & Paika, 1965), *Drosophila* kikkawai (Burla, 1954), *Drosophila malerkotliana* (Parshad & Paika, 1964), *Drosophila rajasekari* (Reddy & Krishnamurthy, 1968), *Drosophila variens* (Bock & Wheeler, 1972), *Drosophila nasuta* (Lamb,1914), *Drosophila neonasuta* (Sajjan & Krishnamurthy, 1972), *Drosophila nigara* (Grimshaw, 1901) and *Phorticella striata* (Sajjan & Krishnamurthy, 1975), which belongs to 4 sub genera (*Sophophora, Drosophila, Scaptodrosophila, Phorticellastraiata*) among which, 4465 individuals belongs to 9 species of sub genus *Sophophora,* 599 individuals belongs to 2 species of the sub genus *Drosophila,* 326 individuals belongs to 1 species of the sub genus *Scaptodrosophila* and 338 individuals belongs to 1 species of subgenus *Phorticellastraiata*. The value of Shannon index, Simpsons diversity index, Simpsons dominance index, Berger-Parker dominance index indicates the abundance, richness and diversity of *Drosophila* flies at varying geographical conditions. The altitudinal variation of the *Drosophila* population is portrayed (Fig. 2). The number of drosophila flies decreased with increasing altitude.

Venn's four set diagram using ellipses (Fig. 3) represents the distribution of 13 different *Drosophila* species at four different regions and also it unfolds the shared *Drosophila* species at all the four regions (*D. ananassae*:10.1%, *D. bipectinata*: 27.2%, *D. malerkotliana*:26.4%, *D. nasuta*: 9.4%, *Phorticella straiata*: 5.9%), three regions (*D.anomelani*: 1%, *D.kikkawai*:6.2%, *D.nigra*: 5.6%), two regions (*D.rajasekari*:0.94%, *D.jambulina*:3.7%, *D. neonasuta*: 1.03%, *D.variens*:1.33%) and *D. agumbensis*is the only non-shared species among the collected *Drosophila* flies. The constancy value (C) of all the species collected along with absolute (A) numbers and Relative abundance (R) is depicted in Table 2 and Table 3. Constant species($C \geq 50$) represented, 53.84% of the total collected species (7 out of 13), 30.76% were considered as accessory species (4 out of 13) and 15.38% were considered as accidental species (2 out of 13).Among which constant species were *D. ananassae, D. bipectinata, D. malerkotliana, D. nasuta, D. nigra* and *Phorticella striata*. : Accessory species were *D. jambuliana, D. rajasekari, D. neonasuta, D. variens*: Accidental species were *D. agumbensis* and *D. anomelani*. The cluster analysis constructed on the basis of densities of different species showed two clusters (Fig.4). Of these two clusters, all the accessory and accidental species along with certain constant species belongs to the first cluster, were as second cluster consists of two constant species. *D. kikkawai,D. nigra, Phorticella striata, D. jambulina, D. ananassae* and *D. nasuta* which is linked with the *D. agumbensis, D. anomelani, D. neonasuta, D. rajasekari* and *D. variens* belongs to the first cluster. *D. bipectinata* and *D. malerkotliana* belongs to the second cluster.

6. Discussion

In the present investigation the density of *Drosophila* at varying altitudes of four geographical areas, decreases with increasing altitude (Table 1). At all the lower altitudes of the four collection regions (569m: 530m: 816m: 920m) the density of collected *Drosophila* was high compared to the density of *Drosophila* collected at higher altitudes (1343m: 700m: 1450m: 1478m) (Fig. 2). The results indicated that *Drosophila* community is significantly affected by elevation. Higher altitudinal regions are threatened by land abandonment [28], with the considerable loss of open habitats caused by forest re-growth and tree land upward shift [29, 30]. The pure or combined action of these factors might have negative direct effects on the distribution of *Drosophila* fauna. Territory modifications and climate warming may produce other unfriendly procedures, as higher predation rate [31], higher competitive pressure [32], increase of physiological stress [33] and reduction in food supply [34] intensifying the already known negative scenario [35]. As a response, species changed and are still changing their distributional ranges in elevation [36].

In our study areas, in lower altitudes i.e. Kodachadri region population density of collected drosophila species were higher compared to the density in higher altitude, this may be due to the reasons that at lower altitudinal regions is endowed with rich flora and the availability of adequate food in the form of rotting fruits and the delightful climatic condition for the multiplication of flies. The fact that the collection of *Drosophila* from April–May coincides with fruiting season also supports for this conclusion but at higher altitudes most of the region is covered with grass lands and it lacks in fruit bearing trees,

The Kathalekan as a relic forest with high level of plant endemism and myristica swamps being the pinnacle articulation of the high water content likewise wellsprings of perennial streams and have probably the most old land biodiversity of the earth going back to the Gondwanaland, consequently we found highest species richness in contrast with other three geographical regions (Table 1). According to Slobodkin & Sanders, species richness of a community depends on severity, fluctuation and consistency of the

environment [37], consequently. As the environment becomes more favorable, diversity increases observed by the Putman [38]. Upadhyaaya have stated that, in the sacrosanct forest the favorable climatic conditions and due to the protection of area for the long period of time have played a major part in making these forest patches exceedingly complex and species rich [39]. The present investigation agrees previous study that the clear ideal conditions such as great precipitation, undisturbed soil with much dampness cover, have moreover benefitted Katha lekan's ecosystem. The climatic conditions of Gopal swamy hills is basically overwhelmed by thick haze, lashing cold rain and nonstop wind, In our study the density of *Drosophila* species at higher altitude is affected by colder environment but the richness of species is higher due to continuous precipitation, Dobzhansky & Pavan opines that rainfall appears to have a greater influence on the abundance of *Drosophila* [40], in temperate regions population densities decline to an extremely low level during cold winter months indicating the influence of temperature on the regulation of population size as is true in several *Drosophila* species inhabiting temperate regions [41, 42, 43].

The Nandi hill slopes and valleys are covered with open scrub, and at places there are introduced *Eucalyptus* and *Shoreatalura*. Most of the original forest cover has disappeared, replaced by secondary growth, primarily thorny scrub. However, some natural forest is still surviving, especially near the summit [44], *Lantana* grows like a weed and has invaded the undergrowth, replacing native flora. Hillsides are clothed with scrub forest, mixed with *Eucalyptus*, since this region is located at the highest altitude compared to other three regions, the abundance of collected *Drosophila* flies were lower at both the altitude where one can significantly observe the correlation between abundance of species and elevation (Table 1). 13 species were identified amongst a total of 5,728 flies collected, being 2,855 captured in the Kodachadri hills, 950 captured in Kathalekhan, 1,113 captured in Gopalswamy hill and 810 flies was collected in Nandi hill. In the collected data Kodachadri region shows higher abundance (Fig. 2) and Kathalekhan region represents higher species richness (Table 1) comparatively among all the four zones. The species diversity of a community depends on both its richness and its evenness: higher species numbers, with the individuals more evenly distributed among them, contribute to higher community diversity. *D.ananassae, D.bipectinata* and *D.malerkotliana* shows significantly higher abundance in contrast to other species collected in Kodachadri and *D.bipectinata* also enumerate a higher abundance comparatively with other species found in Gopalswamy hills which depicts a high dominance and low evenness among species diversity of these communities, while Kathalekhan and Nandi hills shows low dominance and high evenness.

Even though ecosystem varies in the respective four different geographical regions and also considering altitudinal ecological changes, these regions share common *Drosophila* species which can be examined in Venn diagram (Fig. 3)**.** *D. ananassae, D.bipectinata, D. malerkotliana, D. nasuta* and *Phorticella straiata* are the five common species making an account of 79% of total collected drosophila flies which was present in all the four different geographical regions. *D. agumbensis* (0.66%) was the only species which was endemic to Kodachadri region. Although Kodachadri, Kath lekhan, Gopal swamy and Nandi hills accommodates different ecosystem and a variety of niche at differing altitudes, one can observe that these regions are hosting few common species which illustrates the competence of these species. But, *D. bipectinata,* and *D. Malerkotliana* being the two sympatric species which are coexisting in all the regions is a good example to question the competitive exclusion principle, thus these two morphologically and phylogenetically related species exemplifies that niche differentiation is by no means universal. Niche differentiation is also not the only means by which coexistence is possible between two competing species [45]. The Lotka-Volterra equation states that two competing species can coexist when intra-specific (within species) competition is greater than inter-specific (between species) competition [46], Further according to constant, accessory and accidental species our study implies several species that coexisted had similar ecological preferences (Table 2 and 3).

In the Simpson's index (D), the value of D ranges between 0 and 1, 0 represents an infinite diversity and 1 represents no diversity i.e., the bigger the value of D, the lower the diversity. Simpson's index of diversity (1-D) also ranges between 0 and 1, here greater the value, greater the sample diversity, whereas Berger-Parker index shows the relative abundance and Shannon-Weiner index accounts for both abundance and evenness of the species present [47, 48]. Applying these indices to understand the species diversity in a community at different altitudes of four different ecosystems implies that lowest altitudes studied had the lower D value and higher 1-D Value, indicating more biodiversity compared to highest altitudes, while Berger-Parker index and Shannon-Weiner index also shows a greater species abundance at lowest altitudes, it is also observed that species richness is maximum at lowest altitudes. Thus from the eco-distributional analysis at four different ecosystems, we observed that *Drosophila* species richness and abundance is lower at all the higher altitudes which can be ascribed to changes as the altitude increases, involving the changes in temperature, humidity, precipitation, atmospheric turbulence, partial pressure of atmospheric gases and radiation input including short wave ultra violet radiation at various wave lengths [49], according to Hodkinsons the previously mentioned factors are regularly emphatically interactive and together make a natural envelope within which insect species survive and reproduce [50], further this investigation is also contradictory to Competitive exclusion principle as certain phylogenetically related competing species is co-existing in an homogeneous environment which can only be answered through detailed ecological studies, and most importantly this investigation also depicts the competence of similar *Drosophila* species which has been acclimatized to different ecosystems.

7. Tables & Figures

Table 1: Showing the list, number of *Drosophila* species collected at different geographical areas of Karnataka in the month of April–May 2018 and the value of Shannon index, Simpsons index, Simpsons diversity index, Berger-Parker dominance index for the collected *Drosophila* flies along with the mean temperature of the collected sites.

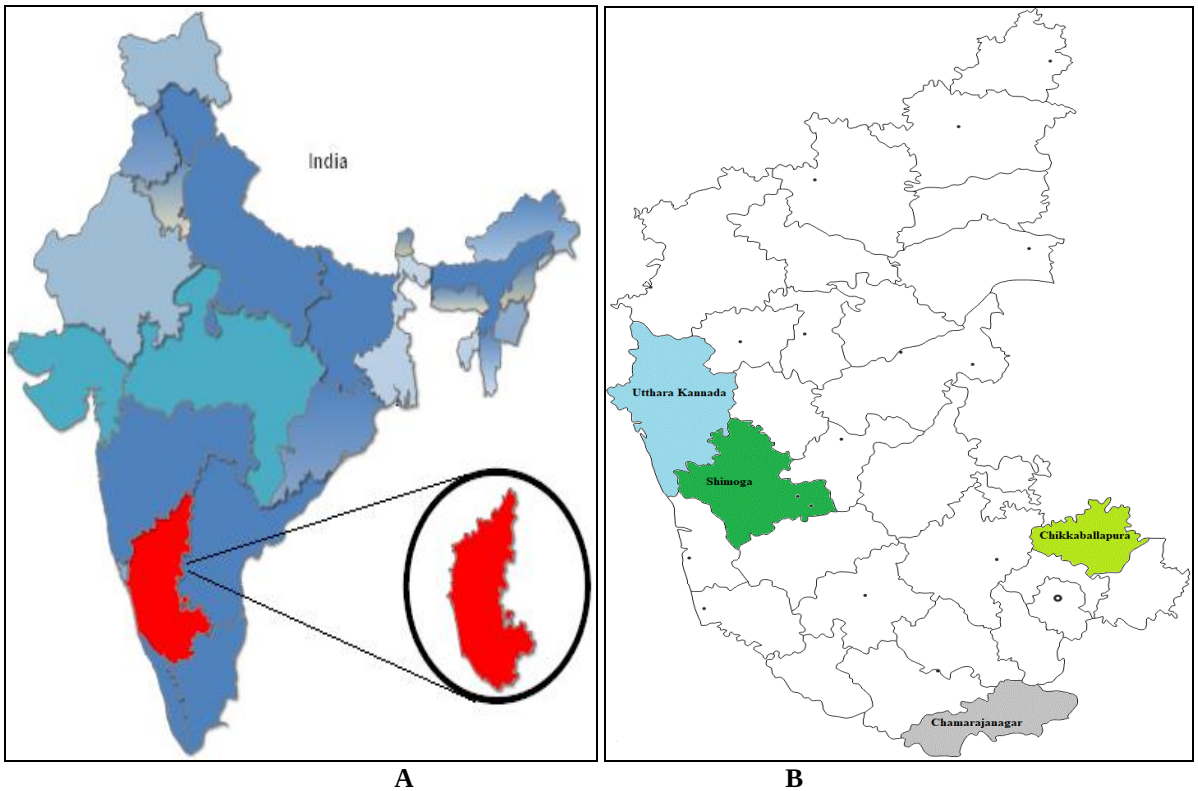
Species	**Kodachadri**		**Kathlekhana**		**Gopal swamy**		**Nandi hills**		**Total**
Genus: *Drosophila*	1343m	569m	700m	530m	1450m	816m	1478m	920m	
Subgenus: *Sophophora*									
D.agumbensis	0	38	0	0	0	0	0	0	38
D.ananassae	113	144	18	48	48	69	61	83	584
D.anomalani	0	0	6	26	0	16	0	14	62
D.bipectinata	453	568	58	86	87	130	74	106	1562
D.jambuliana	0	0	49	61	36	68	0	0	214
D.kikkawai	56	41	68	81	43	71	0	0	360
D.malerkotliana	521	511	54	112	63	96	62	97	1516
D.rajasekari	0	13	12	29	0	0	0	0	54
D.variens	0	0	21	28	0	0	9	17	75
Total	1143	1315	286	471	277	450	206	317	4465
Subgenus: *Drosophila*									
D.nasuta	98	112	61	52	71	86	22	38	540
D.neonasuta	0	0	0	0	0	21	17	21	59
Total	98	112	61	52	71	107	39	59	599
Subgenus: *Scaptodrosophila*									
D.nigara	32	81	0	0	38	71	40	64	326
Total	32	81	0	0	38	71	40	64	326
Subgenus: *Phorticellastriata*									
Phorticella striata	46	28	43	37	46	53	29	56	338
Total	46	28	43	37	46	53	29	56	338
Grand Total	1319	1536	390	560	432	681	314	496	5728
Richness	7	9	10	10	8	10	8	9	
Shannon index	1.479	1.604	2.126	2.187	2.03	2.181	1.90	2.006	
Simpsons index	0.289	0.265	0.128	0.122	0.135	0.120	0.163	0.149	
Simpsons diversity	0.710	0.734	0.871	0.877	0.864	0.879	0.837	0.850	
Berger-Parker dominance	0.395	0.369	0.174	0.20	0.20	0.190	0.235	0.213	
Mean Temperature	28˚c	28˚c	27℃	29˚c	29℃	29˚c	28˚c	28˚c	

Table 2: Absolute (A) and relative abundance(R) and constancy value (C) for each species collected at different altitudes of Kodachadri hills and Kathlekhana in April and May 2018.

Species	**Kodachadri Hills**						**Kathlekhana**					
Genus: *Drosophila*	1343m			569m			700m			530m		
Subgenus: *Sophophora*	A	R	C	A	R	C	A	R	C	A	R	C
D.agumbensis	0	0	0	38	0.02	25	0	0	0	0	0	0
D.ananassae	113	0.09	66.7	144	0.09	75	18	0.05	25	48	0.09	50
D.anomalani	0	0	0	0	0	0	6	0.02	8.33	26	0.05	16.7
D.bipectinata	453	0.34	83.3	568	0.37	100	58	0.15	66.6	86	0.15	75
D.jambuliana	0	0	0	0	0	0	49	0.13	33.3	61	0.11	41.7
D.kikkawai	56	0.04	83.3	41	0.03	25	68	0.17	75	81	0.14	83.3
D.malerkotliana	521	0.39	91.6	511	0.33	83.3	54	0.14	41.7	112	0.20	91.6
D.rajasekari	0	0	0	13	0.01	8.33	12	0.03	16.7	29	0.05	41.7
D.variens	0	0	0	0	0	0	21	0.05	25	28	0.05	33.3
Total	1143			1315			286			471		
Subgenus: *Drosophila*												
D.nasuta	98	0.07	58.3	112	0.07	66.7	61	0.16	66.6	52	0.09	58.3
D.neonasuta	0	0	0			0	0	0	0	0		0
Total	98			112			61			52		
Subgenus:*Scaptodrosophila*												
D.nigara	32	0.02	75	81	0.05	83.3	0	0	0	0	0	0
Total	32			81			0			0		
Subgenus:*Phorticellastraiata*												
Phorticella straiata	46	0.03	66.6	28	0.02	50	43	0.11	41.7	37	0.07	33.3
Total	46			28			43			37		
Grand Total	1319			1536			390			560		

Table 3: Absolute (A) and relative abundance(R) and constancy value (C) for each species collected at different altitudes of Gopalswamy hills and Nandi Hills in April and May 2018.

Species	**Gopal Swamy Hills**						**Nandi Hills**					
Genus: *Drosophila*	1450m			816m			1478m			920m		
Subgenus: *Sophophora*	A	R	C	A	R	C	A	R	C	A	R	C
D.agumbensis	0	0	0	0	0	0	0	0	0	0	0	0
D.ananassae	48	0.11	8.33	69	0.11	25	61	0.19	66.6	83	0.17	75
D.anomalani	0	0	0	16	0.02	8.33	0	0	0	14	0.03	8.33
D.bipectinata	87	0.20	41.7	130	0.19	66.6	74	0.24	41.7	106	0.21	58.3
D.jambuliana	36	0.08	33.3	68	0.10	41.7	0	0	0	0	0	0
D.kikkawai	43	0.10	66.6	71	0.10	8.33	0	0	0	0	0	0
D.malerkotliana	63	0.15	41.7	96	0.14	50	62	0.20	50	97	0.20	66.6
D.rajasekari	0	0	0	0	0	0	0	0	0	0	0	0
D.variens	0	0	0	0	0	0	9	0.03	8.33	17	0.03	8.33
Total	277			450			206			317		
Subgenus: *Drosophila*												
D.nasuta	71	0.16	75	86	0.13	50	22	0.07	8.33	38	0.08	25
D.neonasuta	0	0	0	21	0.03	16.7	17	0.05	25	21	0.04	8.33
Total	71			107			39			59		
Subgenus: *Scaptodrosophila*												
D.nigara	38	0.09	41.7	71	0.10	66.6	40	0.13	33.3	64	0.13	75
Total	38			71			40			64		
Subgenus: *Phorticellastraiata*												
Phorticella straiata	46	0.11	50	53	0.08	25	29	0.09	66.6	56	0.11	33.3
Total	46			53			29			56		
Grand Total	432			681			314			496		



A **B**

Fig 1(A): Map of India representing the Karnataka state.
1(B): Karnataka Map showing the four localities sampled for *Drosophila* species reported in the present study.

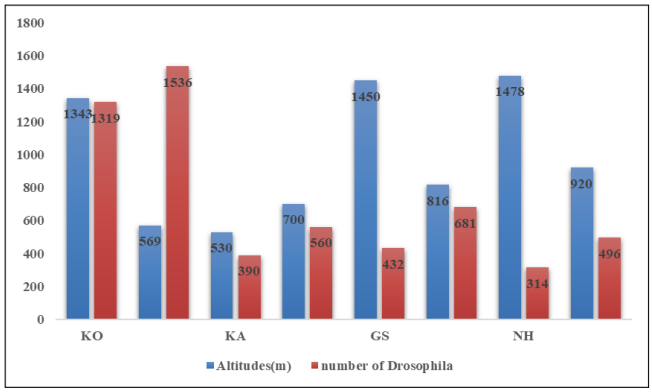


Fig 2: Altitudinal variation of *Drosophila* Population at different altitudes of four different geographical regions in Karnataka state, India

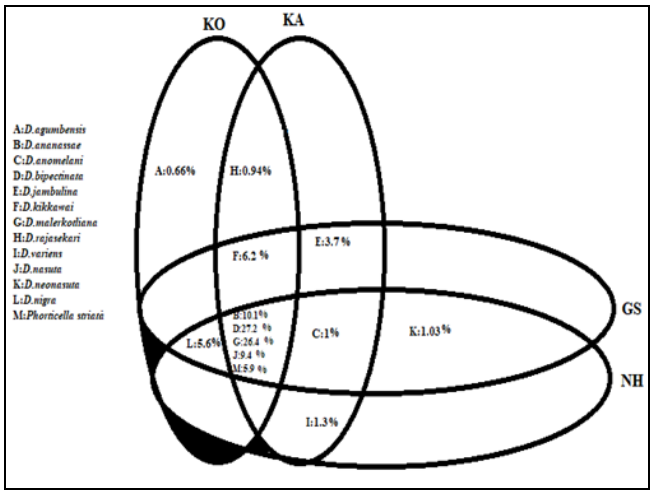


Fig 3: Venn diagram representing the frequency of *Drosophila* species that are shared among the four different regions of the Karnataka state. (KO: Kodachadri hills,KA: Kathlekhan,GS: Gopal Swamy hills, Nandi hills)

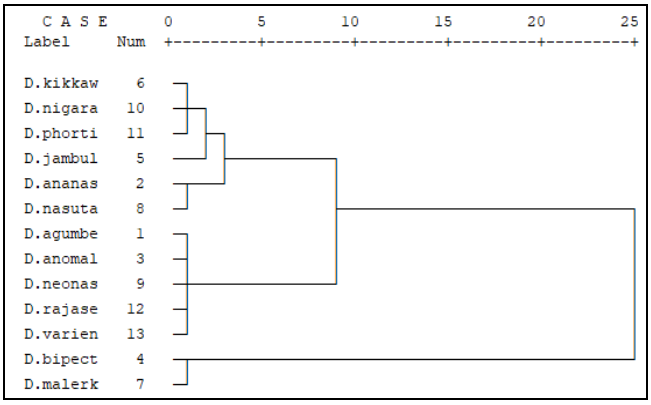


Fig 4: Dendrogram of *Drosophila* species performed through cluster analysis using Wards method.

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