TAXONOMIC ACCOUNTS WITH NOTES ON SPATIAL DIVERSITY AND RELATIVE ABUNDANCE PATTERN OF HORSEFLIES (DIPTERA: TABANIDAE) FROM SONAMUKHI PROTECTED FOREST AREA OF WEST BENGAL, INDIA

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ABSTRACT: Haematophagy is perhaps one of the common and of advantageous mode of feeding as far as horse fly fauna are concerned. Taxonomic studies of this haematophagous and veterinary important fly revealed a total of nine tabanid species namely *Chrysops dispar* (Fabricius, 1798); *Atylotus virgo* (Wiedemann, 1824); *Tabanus dorsiger* Wiedemann, 1821; *Tabanus (Tabanus) rubidus* Wiedemann, 1821; *Tabanus (Tabanus) striatus* Fabricius, 1787; *Tabanus (Tabanus) tenens* Walker, 1850; *Haematopota javana* Wiedemann, 1821; *Haematopota marginata* Ricardo, 1911; *Hippocentrodes desmotes* Philip, 1961 under four genera viz. *Atylotus* Osten Sacken, 1876; *Tabanus* Linnaeus, 1758; *Haematopota* Meigen, 1803; *Hippocentrodes* Philip, 1961 and two subfamilies i.e. Chrysopsinae and Tabaninae from study sites of Sonamukhi dry deciduous protected forest habitat across arid zone of West Bengal. Among these nine tabanid species, one species namely *Tabanus dorsiger* Wiedemann, 1821 are recorded for the first time from this zone of the state. Diversity analyses of tabanid species comparatively throughout the three season revealed that most of the diversity and evenness indices of tabanid species yielded maximum value during post monsoon, whereas dominance indices recorded maximum value during pre-monsoon and post monsoon respectively. Margalef's species richness index and Chao-1 index of tabanid species yielded maximum value during monsoon. Rank abundance model of tabanid species revealed best suited with log series model (bootstrap value: 9999; $p<0.05$). Mau-Tau's sample rarefaction analyses revealed that present sampling of tabanids almost approached towards the asymptote and sampling of tabanid species throughout the three season is well within the acceptable range significantly (95% confidence level; $p<0.05$). Moreover abundance based indices yielded maximum value during monsoon, and diversity based indices yielded maximum value during post monsoon. This results might indicate a clear correlationship of abundance with relative humidity and and diversity with temperature parameters. This will need to be confirmed through more rigorous and long term monitoring of environmental parameters in future.

KEY WORDS: Taxonomy, spatial diversity, relative abundance, Tabanidae, Sonamukhi protected forest

Blood-sucking insects are the vectors of many of the most debilitating parasites of humans and their domesticated animals. In addition they are of considerable direct cost to the agricultural industry through losses in milk and meat yields, and through damage to hides, wool and other products (Lehane, 2005). It is believed that haematophagy arose independently at least six times among the arthropods of the Jurassic and Cretaceous periods (145–65 million years ago) (Balashov, 1984; Ribeiro, 1995). Once blood was regularly encountered by insects, it is likely that its high nutritional value favoured the development of a group of insects that regularly exploited blood as a resource. This would have developed progressively, through physiological, behavioural and morphological

adaptations, first to facultative haematophagy and eventually, in some insects, to obligate haematophagy. Overall prolonged close association with vertebrates along with morphological pre-adaptation for piercing habit in tabanids might favour their adaptive fitness in course of evolution. Tabanids are one of those well-known dipteran fauna with reputation of fierce biting and sucking blood meal from different domesticated, wild animals and even human.

The family Tabanidae (Insecta: Diptera), also known as daans-makkhi elsewhere in the India and dansmachi in Bengal, are widely known for their disease causing capabilities in different wild animals, like horses, deer, cattle and livestock. They are a widespread dipteran family with considerable vector potentiality and ability to transmit around 100 different types of bacterial, protozoan and viral diseases. They are ordinarily known as deerfly, horsefly and clegs. They are large bodied, sturdy fliers ranging from 7-33 mm, known for their furious bite to vertebrate animals including humans. The flies are easily identified by their sickle shaped antennae (3rd segment annulated), pulvilliform empodium, and 4th & 5th radial veins which always terminate on either side of the wing (Thomas, 2011). They are generally with broad bodies and bulging eyes. Sexes are easily distinguishable on the basis of eyes, i.e. they are contiguous in males and widely separated by fore head in females (Mitra & Sharma, 2009). Males and females of this family are mainly differentiated in terms of eyes that are separated in females and are contiguous in males. The adults of both sexes feed on nectar and pollen of flowers. Females of most species have piercing mandibles and also known to sustain on blood meals from vertebrate animals during their reproductive period (Chainey, 2014).

"Surra disease" or trypanosomiasis, caused by *Trypanosoma evansi* (Steel) is one of the most important diseases of animals affecting health and survival of a number of domestic and wild animals (Veer et al., 2002) in India and abroad . The disease has been reported from a wide variety of domestic and wild animals in Asia, Africa, South America, and Europe (Desquesnes et al., 2013; Truc et al., 2013), and is categorized under list B diseases by the Office International Epizooties (OIE, 2014). Surra disease can seriously impact the health of infected wild animals leading to mass mortality. Thirteen tigers (*Panthera tigris* Linn.) died at Nandankanan Biological Park in Orissa state of India (Veer et al., 2002) in an epidemic. Human cases of trypanosomiasis are not unusual, and a few cases have been reported from India and other parts of the world in the last decade, sometimes leading to death of the patient (Truc et al., 2013). Surra is mechanically transmitted by haematophagous Diptera of the families Tabanidae and Muscidae mainly (Veer et al., 2002), and several tabanid species have been indicted as major vectors (Veer and Parashar, 2008). The tabanid flies are also deadly vectors of several other diseases of livestock with over 35 pathogenic agents. They are the main causative vectors of equine infectious anaemia virus, *Anaplasma marginale,* and *T. vivax,* as well as the agents of cutaneous anthrax, tularaemia, bovine viral leucosis, vesicular stomatitis and hog cholera including *Trypanosoma evansi* (responsible for causing Trypanosomiasis), that affect cattle, horses and wild animals and also spill over to adjoining humans (Veer, 1999).

Although Diptera specially vector groups have several economic implications in our society, is less studied and much attention is needed to work on medico-veterinary important groups of flies. Tabanidae is one of such important dipteran family considering their vector potentiality and abilities of transmitting around 100 different types of bacterial, protozoan and viral diseases. Blood-sucking females of tabanid flies not only cause serious discomfort for humans and animals

(Wilson 1968; Foil et al., 1983; Baldacchino et al. 2014) but also transmit the pathogens of numerous diseases (Foil 1989; Hall and Wall 2004; Lehane 2005). Tabanids disturb the grazing of large herbivores, like cattle, resulting in reduced meat and milk production in cattle farms (Hunter and Moorhouse 1976; Harris et al. 1987). An intense tabanid annoyance makes horse riding impossible outside or even may cause traumatic injuries by running the horses riot (Lin et al. 2011).

For the control of tabanids, the knowledge about their seasonal activities is of great importance. The diversity and distribution of insect population is directly affected by the available food resource and the climatic condition. The influence of the climate, vegetation and their interaction plays a crucial role in diversity, abundance and richness of insect species can be influenced by the climate, vegetation and their interactions (Wolda 1978; Marinoni & Ganho 2003; Kittelson 2004; Torres & Madi-Ravazzi 2006). Food resources and climatic conditions vary in space and time, directly affecting the diversity and distribution of insect populations (Morais et al. 1999; Kittelson 2004; Bispo et al. 2006; Bispo & Oliveira 2007; Goldsmith 2007). Climate is one of the determining factors in insect population fluctuations throughout the year (Wolda 1978; Torres & Madi-Ravazzi 2006).

Kozlov et al. studied diversity and abundance of human bitting flies and found Simuliidae and Tabanidae as most abundant flies specially in pre-monsoon and recorded their highest activities in pre-monsoon and also reported that their abundance pattern remained unchanged irrespective of pollution and other anthropogenic disturbances (Kozlov *et al.*, 2005). But there is no such data available on their distribution in India. Few scattered works reported that abundance of tabanid fauna increased by many folds during monsoon (Datta et al., 1998; Veer et al., 2002). So, there is a constant dilemma present over the diversity and seasonal abundance of tabanid flies. Besides this the study also emphasises on change in land use pattern as one of the non-climatic influential factor affecting assemblage of tabanid fauna specially in connection with their disease transmitting capabilities (Baldacchino et al., 2017).

Moreover worldwide information about Tabanidae is biased towards taxonomical research, which has been the main source of diversity data for this group of flies (Cardenas et al., 2009). Main focus is levied on the taxonomic studies of tabanids specially in India. Though few diversity studies were conducted but that were mainly on the basis of availability of species from different study sites and their faunal composition from different distribution sites (Datta, 1997; Veer et al., 2002; Vasudeva et al., 2007).

The Indian Tabanidae was studied which included a species and described from India herself earlier in 1798 by Fabricius (1798), who has later added three more species (Fabricius, 1805). Subsequently, in the nineteenth century, Wiedemann (1821; 1824), Macquart (1838; 1846; 1850; 1855), Saunders (1841), Walker (1848; 1850; 1854), Schiner (1868) and Bigot (1891; 1892) have described several species from different parts of India. With the beginning of the twentieth century, Ricardo (1902; 1906; 1909; 1911a; 1911b; 1913; 1914; 1917) has contributed much to the Indian fauna and her outstanding contribution of 1911 is the most important source of reference till today. Besides, Brunetti (1912), Surcouf (1921), Austen (1922), Senior-White (1922a; 1922b; 1924; 1927), Enderlein (1922), Szilady (1926), Schuurmans Stekhoven (1926; 1928; 1932), Krober (1930), Basu & Menon (1952), Philip (1959; 1960a; 1960b; 1962; 1970; 1972), Philip &. Mackerras (1960), Mackerras (1962), Sen & Fletcher (1962), Chvala (1969), Stone &. Philip (1974), Stone (1975), Datta & Biswas (1977), Datta & Das (1978), Datta (1980; 1981) and Veer (1999) have also made commendable

works by describing and recording species occurring in India. A check-list of Tabanidae hitherto known, is provided synoptically in order to have a general idea of the faunal composition in India after Datta (1985); Vasudeva *et al.* (2007); Mitra & Sharma (2009). But the overall taxonomic analysis of different tabanid fauna in arid zone with special reference to Sonamukhi dry deciduous protected forest habitat of the state of West Bengal is largely coveted. The comprehensive ecological studies also largely wanted from this important dry deciduous protected forest landscape. By studying abundance pattern, one can infer about their frequency of occurrence in different season in their availability.

MATERIALS AND METHODS

(i) ***Collection and preservation techniques***

Tabanid flies specially females can be more convenient to be collected from cattle animals as they usually exhibit the characteristic haematophagy and males can be collected from tree trunks or on vegetation by sweeping with insect net in warm sunny weather or from lights at night. Traps specially malaise trap, canopy trap etc. can also be known as most effective method to catch large amount of Tabanids in a short time with minimum effort. For night collection light trap is an essential method. After collecting samples are usually killed by exposing them to the killing jar filled with benzene or high dose chloroform, this procedure takes just fraction of time, immediately after that the entomo-fauna has been transferred to the special drying envelope for the dehydration purpose, this specimens had been kept there until they would be bring back to the lab (ZSI, HQ) for further identification purpose. After catching, adults are killed in killing jars as it contains benzene and it should be pinned as early as possible for studying most of the characters that might be present at live condition. Then specimens are kept in special envelopes composed of blotting papers.

(ii) ***Identification and taxonomic studies***

Diptera structurally comprises the most highly specialised members of the class Insecta. All the subfamilies, tribe, genera and species of family Tabanidae are presented following the classification scheme of Burger and Thompson, 1981 for convenience. Proper identification was performed using Leica EZ4 stereo microscope and Leica stereo-iso microscope M205A fitted with Leica software 3.0 were used for taking their snapshot. All the terminologies used in the present study are from McAlpine (1989).

(iii) ***Diversity indices and relative abundance***

α-diversity analysis:

Structural associations i.e. percentage abundance were also calculated and analysed from the pooled data and finally enumerating Tabanidae diversity with the help of several biodiversity indices. These include Shannon-weaver index, Species richness index, Evenness index and dominance diversity index.

Shannon-weaver index (Shannon & Weaver, 1948):

$$\text{Shannon-weaver index } (H') = -\Sigma (ni/N) \ln (ni/N)$$

Where (ni/N) is proportion of individuals found in calculated sample and ln (ni/N) is natural logarithm of proportion of individuals of each species.

Simpson's Index of Diversity 1 – D (Simpson, 1949):

Simpson's Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species). There are two versions of the formula for calculating D. Either is acceptable, but be consistent. n = Total number of organisms of a particular species, N = The total number of organisms of all species.

$$D = \Sigma (n/N)^2 \qquad D = \Sigma \frac{n (n-1)}{N (N-1)}$$

The value of this index also ranges between 0 and 1, but now, the greater the value, the greater the sample diversity. This makes more sense. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species.

Evenness index (Pielou, 1969):

It is the mean distribution of individuals among the species. Evenness is expressed by considering how close a set of observed species abundances are to those from aggregation of species having maximum possible diversity for a given N and S.

Evenness index (e) = H′ / ln S

Where H′ is Shannon-weaver index and ln S is natural logarithm value of no. of species present.

Brillouin index (Brillouin, 1956):

When the randomness of a sample cannot be guaranteed, for example during trapping where different species of flies are differentially attracted to the stimulus, or if the community is completely censused and every individual accounted for, the Brillouin index (HB) is the appropriate form of the information index (Pielou 1969, 1975). It is calculated as follows:

HB = 1nN! – Y ln ni! N

Evenness (E) for the Brillouin diversity index is obtained from:

E = HB/Hbmax

Menhinick's index (Menhinick, 1964):

Menhinick's index, D_{mn} (Whittaker, 1977), is calculated using:

$$D_{mn} = S / \sqrt{N}$$

Where N is the total number of individuals in the sample and S the species number.

Species richness index (Margalef, 1958):

This index can simply be presented as no. of species present in a community.

Richness = (S-1) / ln N

Where S= total no. of species found and ln N is sum of all individuals of all the species present there.

Equitability index (Lloyd & Ghelardi, 1964):

Lloyd & Ghelardi defined their index as follows:

$$\varepsilon = S' / S$$

Where S is the observed number of species and S′ is the theoretical number of species which would yield the observed diversity H, if their relative abundances followed the broken stick model of McAurther (1957).

Fisher's alpha index (Fisher et al., 1943):

This is a parametric index of diversity that assumes that the abundance of species follows the log series distribution:

$$\alpha x, \alpha x^2 / 2, \alpha x^3 / 3, \ldots \alpha x^n / n$$

Where each term gives the number of species predicted to have 1,2,3,....n individuals in the sample. The index is the alpha parameter.

This is a useful index, which has been widely used. To test if a log series distribution is appropriate. It is estimated by an iterative procedure that may take an appreciable amount of time with large data sets.

Where αx is the number of species predicted to have one individual, αx2 to have two individuals etc.

Estimate x from the iterative solution of:

S/N = (1-x)/x (-ln (1-x)) where S=number of spp., N = total individuals

Once you know x, calculate α, the diversity index

$\alpha = N(1-x)/x$

Chao-1 species richness index (Chao, 1984):

The Chao1 estimator uses only the numbers of singletons and doubletons (and the observed richness) to obtain the following lower bound for the expected asymptotic species richness (Chao, 1984):

$\hat{S}_{Chao1} = \{S_{obs} + f_1^2/2f_2\}$ if, $f_2>0$

$\hat{S}_{Chao1} = \{S_{obs} + f_1(f_1-1)/2\}$ if, $f_2=0$

ln SHE index:

It is a combined index of log transformed value of species richness(S), species evenness (E) and original value of Shannon Weaver's index (H).

Dominance-diversity index (Berger and Parker, 1970)*:*

Dominance indices are weighted toward abundance of commonest species. It is result of division of total no. of individuals of most common species (N_{max}) and sum of all the individuals of all the species present in that site.

$$\text{Dominance index (D)} = N_{max}/N$$

And finally dominance was determined by dividing the obtained value by 1.

$$DBP = 1/D$$

Relative abundance & sample rarefaction*:*

Relative abundance is a component of biodiversity and refers to how frequent or rare a species is in relation to other species in a defined location. Relative species abundance describes key factor of biodiversity. During the present study, the relative abundance of different species of tabanid fauna across the Sonamukhi protected forest area of West Bengal were analysed. Besides that graphs of log series model of rank abundance for tabanid species and species accumulation curves (Sanders, 1968) for tabanid sample rarefaction were generated on 5 times replication of the collected field data after method (Simberloff, 1972) using Past 3.0.

(iv) ***Preparation of GIS based maps and graphs***

Maps were produced using software DIVA GIS version 7.5.0.0. Photographs in the field were captured using Nikon D7000 camera and Nikkor lens. Graphs were produced using MS Excel 2013, Past 3.0.

(v) ***Study areas***

Sonamukhi Protected Forest area, located in the Sonamukhi block of Bankura district, West Bengal is our proposed study area, which was surveyed extensively in the period of three years (2013-16). Sonamukhi protected forest, Bankura holds one of the best quality Sal forests in West Bengal. A typical red-lateritic soil covered with medium density Sal forests is the typical feature of that area. Sonamukhi protected forest area was surveyed because it's floral bio diversity and unique soil quality. The qualitative change in the species mix really made facelift in the Sonamukhi forest. There is no consolidated report on the Dipteran fauna and this is the first time attempt to inventories the Dipteran fauna of Sonamukhi Protected Forest. 61 specimens of Tabanidae were collected and these are pinned, labelled and sorted according to their family and made ready for identification. Survey was done thoroughly in Sonamukhi protected forest and its adjacent villages to get a complete scenario of horsefly diversity in this protected forest area. The places that have been surveyed mostly are namely: Sonamukhi forest area, Churamanipur, Muslo, Patharmura, Kalyanpur, Lokesol, Palsora,

Hamirhati, Kasdihi beat area. The landscape and vegetation pattern of this area where collection has been done extensively has been discussed. It includes 3 study sites from each of these stations mentioned above.

RESULTS

Present study is part of the study of Tabanid fauna of arid region of West Bengal enumerated a total of nine tabanid species under five genera and two subfamilies namely Chrysopsinae and Tabaninae. Among them single species i.e. *Tabanus dorsiger* Wiedemann, 1821 reported for the first time from the state (Maity et al., 2017). Systematic account with key is given wherever deemed necessary along with first reference, current reference, type locality, material examined, and distribution are given for each tabanid species. Wherever diagnosis of only single species which is reported for the first time from the state, is provided.

(i) Systematic list (newly recorded species is indicated with double asterisks sign)

Family TABANIDAE (Latreille, 1802)
Subfamily CHRYSOPSINAE (Lutz, 1905)
Tribe Chrysopsini (Lutz, 1905)

I. Genus ***Chrysops*** Meigen, 1803

1. ***Chrysops dispar*** (Fabricius, 1798)

Subfamily TABANINAE (Latreille, 1802)
Tribe Tabanini (Chainey & Oldroyd, 1980)

II. Genus ***Atylotus*** Osten Sacken, 1876

2. ***Atylotus virgo*** (Wiedemann, 1824)

III. Genus ***Tabanus*** Linnaeus, 1758

3. ***Tabanus dorsiger*** Wiedemann, 1821**

Subgenus ***Tabanus*** Linnaeus, 1758

4. ***Tabanus (Tabanus) rubidus*** Wiedemann, 1821
5. ***Tabanus (Tabanus) striatus*** Fabricius, 1787
6. ***Tabanus (Tabanus) tenens*** Walker, 1850

Tribe Haematopotini (Chainey & Oldroyd, 1980)

IV. Genus ***Haematopota*** Meigen, 1803

7. ***Haematopota javana*** Wiedemann, 1821
8. ***Haematopota marginata*** Ricardo, 1911

V. Genus ***Hippocentrodes*** Philip, 1961

9. ***Hippocentrodes desmotes*** Philip, 1961

(ii) Detailed systematic accounts

Family TABANIDAE
Subfamily CHRYSOPSINAE
Tribe Chrysopsini

I. Genus ***Chrysops*** Meigen, 1803

1. ***Chrysops dispar*** (Fabricius, 1798)
   1798, *Chrysops dispar* Fabricius, Ent. Syst. Suppl., 567 (♂, ♀; *Tabanus*).
   Type-locality: India
   Distribution: India,
   Elsewhere: Borneo, Burma, Ceylon, China, Formosa, Hainan, Laos, Malaya, Nepal, Philippines, [Luzon] Sumatra, Thailand, Viet Nam.

Subfamily TABANINAE

Tribe Tabanini

II. Genus ***Atylotus*** Osten Sacken, 1876

2. ***Atylotus virgo*** (Wiedemann, 1824)
   1824, *Atylotus virgo* Wiedemann, Analecta Ent., 22 (♂, ♀; *Tabanus*)
   Type-locality: "Ind. Orient"
   albulus Walker, 1850 Insecta Saundersiana, 1:46 (♂, ♀; *Tabanus*), Type-locality: East India
   puella Walker, 1850, Insecta Saundersiana, 1: 53 (♂; *Tabanus*), Type-locality: East India
   Distribution: India "Orient"
   Elsewhere: Nil

III. Genus ***Tabanus*** Linnaeus, 1758

3. ***Tabanus dorsiger*** Wiedemann, 1821**
   1821. *Tabanus dorsiger* Wiedemann, Diptera Exotica, Kiliae, pp. 43-50, 101.
   Type locality: Brazil
   Distribution: India (Orissa, West Bengal)
   Elsewhere: Mexico to Argentina; Trinidad

   Subgenus ***Tabanus*** Linnaeus, 1758

4. ***Tabanus (Tabanus) rubidus*** Wiedemann, 1821
   1821, *Tabanus (Pseudobolbodimyia) rubidus* Wiedemann, Dipt. exot., 1: 69 (♀).
   Type-locality: "Bengalia"
   Distribution: India,
   Elsewhere: Burma, Ceylon, China [Kwangtung] Java, Malaya, Nepal, Nias Island, Sumatra, Thailand , Viet Nam

5. ***Tabanus (Tabanus) striatus*** Fabricius, 1787
   1787, *Tabanus (Pseudobolbodimyia) striatus* Fabricius, Mantissa Insect, 2: 356 (sex-?).
   Type-locality: China
   Distribution: India, [Bengal, Bihar, Punjab]
   Elsewhere: Ceylon, China, [Kwangtung], N.Thailand, N. Viet Nam W. Pakistan, Africa.
   ? dorsilinea Wiedemann, 1824, Analecta Ent.: 22 (♂) Type-locality , Ind. Orient
   ? chinensis Thunberg 1827, Nova. Acta, Soc. Sci. upsal., 9: 61 (? sex) Type-loc. China, Cape of God Hope.
   hilaris Walker, 1850, Insecta Saundersiana, 1: 49 (♂).Type-locality: East India

6. ***Tabanus (Tabanus) tenens*** Walker, 1850
   1850, *Tabanus (Pseudobolbodimyia) tenens* Walker, Insecta Saundeersiana, 1: 49 (♀).
   Type-locality: East India

Distribution: India. [Chenai, Maharashtra, Punjab]
Elsewhere: Bali, Burma, Ceylon, Java, Madura Islands, Malaya, Philippines, [Luzon, Mindoro, Sumar, Leyte, Negros, Mindanao] Soembawa, Sumatra, Thailand, Timor, Guam

Tribe Haematopotini

IV. Genus ***Haematopota*** Meigen, 1803

7. ***Haematopota javana*** Wiedemann, 1821

1821, *Haematopota javana* Wiedemann, Dipt. exot., 1: 100 (♀).
Type-locality: Java
Distribution: India
Elsewhere: Burma, Java, Laos, Malaya, Sumatra, Thailand, Viet Nam.
Pasiatica Rondani (Wiedemann MS), 1875, Annali, Mus. civ. Stor. nat. Giacomo Doria 7: 461 (♀), Type-locality: unknown

8. ***Haematopota marginata*** Ricardo, 1911

1911, *Haematopota marginata* Ricardo, Rec. Indian Mus., 4: 347 (♂ ♀)
Type-locality: Pusa and Goalbathan Bengal, Tezpore, Assam, India
Distribution: India, W. Bengal, Bihar [Pusa and Goalbathan] Assam, [Tezpore]
Elsewhere: Nil

V. Genus ***Hippocentrodes*** Philip, 1961

9. ***Hippocentrodes desmotes*** Philip, 1961

1961. *Hippocentro desdesmotes* Philip, Indian J. Entomol., 21 (2): 83.
Type location: Kanchrapara, West Bengal
Distribution: India [Rajasthan, West Bengal; Nepal]
Elsewhere: Nil

(iii) Identification keys of family Tabanidae up to species level (representative family of haematophagous vector flies)

Family TABANIDAE

Key to the subfamilies

1. Hind tibiae with paired apical spurs mostly, vertex with well-developed functional ocelli; caudal ends of spermathecal ducts of female without cup-like expansion.....CHRYSOPSINAE (one genus, one species)

- Caudal ends of spermathecal ducts of female with cup-like expansion; vertex with rudimentary or no ocelli, hind tibiae without apical spurs.....
.....TABANINAE (four genera, eight species)

Subfamily TABANINAE

Key to tribes

1. Frons in females much longer than wide, frontal callus usually longitudinal when present, flagellum with large basal plate and 4 annuli; wing hyaline or dusty; basicosta in wing with strong setae.....Tabanini (two genera)

-. Frons in females wider than long, frontal callus transverse, antennae long and slender, flagellum with narrow base and 3 annuli; pictured wing pattern with pale markings, basicosta with thin setae.....Haematopotini (two genera)

Tribe Tabanini

Key to genera

1. Antennal style with 4 annulations, frons with prominent callus..... .....***Tabanus*** Linnaeus (four species)

-. Frons with reduced or spotted calli.....***Atylotus*** Osten-Sacken (one species)

Genus ***Tabanus*** Linnaeus

Key to species

1. Frontal callus with a spindle shaped linear extension.....2

– Frontal callus with the linear extension not spindle shaped..... .....***rubidus*** Wiedemann, 1821

2. Abdomen with median stripe continuous up to 6th segment, except on 2nd tergite absent; costal cell clear.....***striatus*** Fabricius, 1787

– Abdomen with median stripe complete, present on 2nd tergite; costal cell not clear.....3

3. Abdomen with median stripe light and complete, present on 2nd tergite, lateral stripes much straight, costal cell tinge yellowish.....***tenens*** Walker, 1850

– Abdomen with median stripe complete, broad on 2nd tergite, lateral stripes in form of irregular spots appearing as steps, costal cell light yellowish..... .....***dorsiger*** Wiedemann, 1821

Tribe Haematopotini

Key to genera

1. Wings with pale spots, wavy lines or punctulate forming circles and/or rosettes.....***Haematopota*** Meigen (two species)

– Wings infuscated with 6 or more pale transverse bands, no rosettes..... .....***Hippocentrodes*** Philip (one species)

Genus ***Haematopota*** Meigen, 1803

Key to species

1. Wings dark brown with fairly distinct rosettes; 3rd rosette very irregular, no such transverse bars on posterior border, anal cell has curved white streak..... .....***javana*** Wiedemann, 1821

-. Wings brown, numerous light markings, three rosettes distinct, small transverse bars on posterior border zigzag, anal cell has no such streak..... .....***marginata*** Ricardo, 1911

(iv) Diagnostic accounts

Subfamily CHRYSOPSINAE (Lutz, 1905)

Diagnosis: Abdominal tergite IX divided. Style of male gonocoxite bluntly ended. Antennae with 3–4 flagellomeres. Caudal ends of spermathecal ducts with simple tubes. Hind tibiae mostly with pair of apical spurs.

Tribe Chrysopsini (Lutz, 1905)

Diagnosis: Scape much elongated than broad, flagellomere narrow without dorsal angle. Eyes bare with spots or variegated dark markings, rarely with bands. Posterior margin of cells open.

I. Genus ***Chrysops*** Meigen, 1803

1803. *Chrysops* Meigen, Mag. Insekten Kude, 2: 267.

Type species: Tabanus caecutiens Linnaeus, 1761

Diagnosis: Varies from small to moderately long in size (5.5-12.5 mm in length), usually bright yellow to black coloured species. Callus usually transverse with three functional ocelli. Scape and pedicel much longer and scape in most often swollen. Proboscis long. Wings infuscated in irregular fashion or with dark cross band, Sc vein bare, r5 and m2 cells open widely. Abdomen with specific yellow and black patterns or yellowish or dark stripes, spots or triangles.

1. ***Chrysops dispar*** (Fabricius, 1798)

1798. *Tabanus dispar* Fabricius, Ent. Syst. Suppl., 1: 567.

Type locality: India orientalis

Material examined: 2♀♀, collected from cow, 23°17′25.29″ N, 87°15′2.58″ E, 92.9 m, Station 1, Bankura, 23.ix.2013, Coll. A. Naskar; 1♀, collected from cow, 23°19'15.15"N, 87°12'28.52"E, 96.8 m, Station 2, Bankura, 23.ix.2014, Coll. A. Naskar.

Distribution: India (West Bengal: Nadia; S 24 Paraganas; Andaman island, Arunachal Pradesh, Assam, Bihar, Karnataka, Kerala, Manipur, Meghalaya, Nagaland, Orissa, Sikkim, Tripura).

Elsewhere: Bangladesh, China, Java, Laos, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sumatra, Sri Lanka, Taiwan, Thailand and Vietnam.

Remarks: They become active in low light or towards evening. Their abundance is notably high in rainy season.

Subfamily TABANINAE (Latreille, 1802)

Diagnosis: Hind tibia without apical spurs. Style of gonocoxite truncate by a shallow incision. Caudal ends of spermathecal ducts of female with cup like expansion. Antennae with 3-4 flagellomeres. Cell r5 mostly closed, m3 always open.

Tribe Tabanini (Chainey & Oldroyd, 1980)

Diagnosis: Basicosta densely setulose except in some palearctic species. Antennae usually short and stout. Basal flagellomere with well-developed dorsal angle. Flagellum with 4 flagellomeres.

II. Genus ***Atylotus*** Osten-Sacken, 1876

1876. *Atylotus* Osten-Sacken, Mem. Boston Soc. Nat. Hist., 2: 425-426.

Type species: Tabanus bicolour Wiedemann, 1821.

Diagnosis: Usually small sized fly, frons with spotted calli or without calli. Colour of eyes in living specimen green or yellow. Basal plate of flagellum broad and obtuse dorsal angle. Basicosta pale to brown setulose.

2. ***Atylotus virgo*** (Wiedemann, 1824)

1824. *Tabanus virgo* Wiedemann, Analecta. Entomol., p. 22.

1973. *Atylotus virgo* Philip, Entomol. Scand. Suppl., 4: 57.

Type locality: "Indies orientalis"

Material examined: 1♀, collected from cow, 23°17′25.29″ N, 87°15′2.58″ E, 92.9 m, Station 1, Bankura, 23.ix.2013, Coll. A. Naskar; 1♀, collected from cow, 23°16'13.29"N, 87°11'51.51"E, 108.7 m, Station 3, Bankura, 12.iii.2015, Coll. A. Maity.

Distribution: India (West Bengal: Bankura, Puruliya, S 24 Paraganas; Andaman Island, Himachal Pradesh, Madhya Pradesh, Punjab, Uttarakhand).

Elsewhere: Sri Lanka, Pakistan.

Remarks: Burger (1981) put forwarded the conflict regarding placement of this species under genus *Atylotus* as it differs in many features from it. It can transmit Surra disease pathogens.

III. Genus ***Tabanus*** Linnaeus, 1758

1758. *Tabanus* Linnaeus, Syst. Nat. Ed., 10: 601.

Type species: *Tabanus bovinus* Linnaeus, 1758

Diagnosis: Robust flies with colourful eyes in live condition; vertex without prominent ocellar tubercle; in males entirely pollinose when present; eyes bare.

3. ***Tabanus dorsiger*** Wiedemann, 1821

1821. *Tabanus dorsiger*. Wiedemann, Diptera Exotica, Kiliae, pp. 43-50, 101.

Type locality: Indian subcontinent.

Material examined: 2♀♀, collected from cow, 23°13'25.65"N, 87°13'46.55"E, 93.7 m, Station 4, Bankura, 27.ix.2013, Coll. A. Maity; 1♀, collected from cow, 23°18'31.42"N, 87°18'14.02"E, 85.9 m, Station 5, Bankura, 17.ix.2014, Coll. A. Maity; 1♀, collected from cow, 23°14'33.50"N, 87°21'20.85"E, 91 m, Station 6, Bankura, 21.iii.2015, Coll. A. Maity.

Diagnosis: Adult fly is usually larger (14–16 mm in length) than the other two trivittate flies, *T. striatus* and *T. tenens*. Fore head slightly divergent above, frontal callus narrowly separated from eye margins and median callus spindle shaped and narrowly joined to dorsal extension of frontal callus. Abdomen trivittate, mid dorsal stripe complete and broad on tergum II, sub lateral pale stripes noticeably step-like; venter uniform with grey tomentum and light pilose. Fore femur and fore tibia are uniformly orange to orangy brown in colour but are darkened apically. Thoracic stripes are distinct. The male has a yellow tinted costal cell on the wing.

Distribution: India (West Bengal: Bankura, East Midnapre, Hooghly, S 24 Paragana; Orissa).

Elsewhere: Mexico to Argentina, Trinidad.

Remarks: This species is previously known to us as *Tabanus triceps* Thunberg, 1827, later the species was synonymised under *Tabanus dorsiger* Wiedemann, 1821 due to basically same character of callus in fore head and abdominal pattern with sub lateral stripes step like in both species. This species is recorded for the first time from the state of West Bengal.

Subgenus ***Tabanus*** Linnaeus, 1758

4. ***Tabanus (Tabanus) rubidus*** Wiedemann, 1821

1821. *Tabanus rubidus* Wiedemann, Dipt. Exot., 1: 69.

Type locality: Bengalia.

Material examined: 2♀♀, collected from cow, 23°17'24.55"N, 87°24'52.28"E, 76.4 m, Station 8, Bankura, 20.iv.2014, Coll. A. Maity; 5♀♀, collected from cow, 23°16'23.26"N, 87°22'32.06"E, 83.2 m, Station 7, Bankura, 27.ix.2013, Coll. A. Naskar.

Distribution: India (West Bengal: Bankura, Birbhum, Hooghly, Maldah; Arunachal Pradesh, Meghalaya, Orissa, Sikkim).

Elsewhere: Pakistan, Philippines, China, Indonesia.

Remarks: This species is very common across different study area of West Bengal. This species shows wide distribution pattern across different districts of the state.

5. ***Tabanus (Tabanus) striatus*** Fabricius, 1787

1787. *Tabanus striatus*. Fabricius, Mantissa insect, 2: 356.

Type locality: China.

Material examined: 7♀♀, collected from cow, 23°16'23.26"N, 87°22'32.06"E, 83.2 m, Station 7, Bankura, 27.ix.2013, Coll. R.S. Mridha; 1♀, collected from cow, 6♀♀, collected from buffalo, 23°17'24.55"N, 87°24'52.28"E, 76.4 m, Station 8, Bankura, 29.ix.2013, Coll. R.S. Mridha; 2♀♀, collected from cow, 23°17'24.55"N, 87°24'52.28"E, 76.4 m, Station 8, Bankura, 29.ix.2013, Coll. S.K. Sinha; 10♀♀, collected from cow, 23°16'23.26"N, 87°22'32.06"E, 83.2 m, Station 7, Bankura, 27.vii.2014, Coll. A. Maity; 7♀♀, collected from buffalo, 23°16'23.26"N, 87°22'32.06"E, 83.2 m, Station 7, Bankura, 26.vii.2014, Coll. A. Maity; 1♀, collected from cow, 23°13'31.79"N, 87°23'50.42"E, 84.9 m, Station 9, Bankura, 20.iv.2014, Coll. A. Maity; 1♀, collected from cow, 23°15'18.73"N, 87°25'49.44"E, 83.5 m, Station 10, Bankura, 20.iv.2014, Coll. A. Maity.

Distribution: India (West Bengal: Alipurduar, Bankura, Birbhum, Bardhaman, Darjeeling, East Midnapore, Hooghly, Howrah, Jalpaiguri, Kolkata, Maldah, Murshidabad, N 24 Paragana, Nadiya, Puruliya, S 24 Paragana, S Dinazpur, West Midnapore; Arunachal Pradesh, Assam, Bihar, Delhi, Gujrat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharastra, Manipur, Meghalaya, Nagaland, Orissa, Punjab, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh).

Elsewhere: Bangladesh, Bhutan, Combodia, China, Laos, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand and Vietnam.

Remarks: There was taxonomic misinterpretation through ages and hence the distributional records associated with the species were in a mess everywhere before Burton (1978) who took pains to sort out the perplexed identity of the species from its allies. Later, Burger and Thompson (1981) aptly illustrated, keyed and discussed these species with a view to making away with the recurrent confusion. This is a very common and widespread species in India, and is often found to enter the house, being attracted by light in hot summer night.

6. ***Tabanus (Tabanus) tenens*** Walker, 1850

1850. *Tabanus tenens* Walker, Insecta Saunders., Dipt., 1: 49.

Type locality: East India.

Material examined: 1♀, collected from cow, 23°17'24.55"N, 87°24'52.28"E, 76.4 m, Station 8, Bankura, 29.ix.2013, Coll. S.K. Sinha; 2♀♀, collected from cow, 23°18'31.42"N, 87°18'14.02"E, 85.9 m, Station 5, Bankura, 20.iv.2014, Coll. A. Maity.

Distribution: India (West Bengal: E Midnapore, Bankura, Maldah, Birbhum, Hooghly, S 24 Paragana; Assam, Orissa, Sikkim); SE Asia.

Remarks: The adult fly is an important mechanical vector of Surra disease and is also implicated in the transmission of anthrax.

Tribe Haematopotini (Chainey & Oldroyd, 1980)

Diagnosis: Fore head broad usually with paired dark velvety spots above the wide and glossy callus. Antennae usually long and narrow. Scape cylindrical, longer than wide. Basal flagellomere cylindrical with under developed or rounded dorsal

angle and with 3 flagellomeres. Characteristic dappled wing. Vein R4 usually with strong appendix.

IV. Genus ***Haematopota*** Meigen, 1803

1803. *Haematopota* Meigen, Magazin Insekt Kude, 2: 67.

Type species: Tabanus pluvialis Linnaeus, 1758.

Diagnosis: Generally small and slender flies of brownish to blackish grey in colour; eyes with several wavy bands in live condition; frons with velvety black spot on each side above the frontal callus and often a mid-frontal spot above these; picture wing pattern i.e. dark wing with pattern of pale spots; mid tibiae and hind tibiae often with pale rings.

7. ***Haematopota javana*** Wiedemann, 1821

1821. *Haematopota javana* Wiedemann, Dipt. Exot., 1: 100.

Type locality: Java.

Material examined: 2♀♀, collected from cow, 23°18'31.42"N, 87°18'14.02"E, 85.9 m, Station 5, Bankura, 20.ii.2014, Coll. A. Maity; 2♀♀, collected from cow, 23°16'23.26"N, 87°22'32.06"E, 83.2 m, Station 7, Bankura, 20.ii.2014, Coll. A. Maity.

Distribution: India (West Bengal: Birbhum, Nadia; Bihar, Himachal Pradesh, Kerala, Meghalaya, Mizoram, Tamil Nadu).

Elsewhere: Andalas, Bangladesh, China, Java, Laos, Malaya, Myanmar, Thailand and Vietnam.

Remarks: This is a common and widespread species, and hence it shows certain amount of variable characters (vide Stone & Philip, 1974).

8. ***Haematopota marginata*** Ricardo, 1911

1911. *Haematopota marginata* Ricardo, Rec. Indian Mus., 4: 347.

Type locality: Pusa, Bihar.

Material examined: 1♀, collected from cow, 23°17′25.29″ N, 87°15′2.58″ E, 92.9 m, Station 1, Bankura, 20.ii.2014, Coll. A. Maity; 1♀, collected from cow, 23°15'18.73"N, 87°25'49.44"E, 83.5 m, Station 10, Bankura, 20.ii.2014, Coll. A. Maity.

Distribution: India (West Bengal: Birbhum; Assam, Bihar, Meghalaya).

Elsewhere: Bangladesh.

Remarks: This species is commonly found in hilly region of North Bengal.

V. Genus ***Hippocentrodes*** Philip, 1961

1961. *Hippocentrodes* Philip, Magazin Insekt Kude, p. 82.

Type species: Hippocntrodes desmotes Philip, 1961 by monotypy.

Diagnosis: Transversely banded wings; straight bands of eyes; short appendix in relation to base of vein R_4; mostly yellowish mid tibia, hind tibia and tarsi.

9. ***Hippocentrodes desmotes*** Philip, 1961

1961. *Hippocentrodes desmotes* Philip, Indian J. Entomol., 21 (2): 83.

Type locality: Kanchrapara, West Bengal.

Material examined: 1♀, collected from cow, 23°17'24.55"N, 87°24'52.28"E, 76.4 m, Station 8, Bankura, 27.ix.2013, Coll. R.S. Mridha.

Distribution: India (West Bengal: Bankura, N 24 Paraganas; Rajasthan).

Elsewhere: Nepal.

Remarks: This species is rare in occurrence across study area of West Bengal.

(v) Detailed diversity accounts

A. Comparative analyses of several diversity indices in three different season:

Figure 1A depicted that maximum diversity (Shannon) of tabanid species recorded during post monsoon (1.673), in comparison to pre-monsoon (0.976) and monsoon (1.097). Figure 1B depicted that maximum dominance of tabanid species recorded during pre-monsoon (0.528), in comparison to monsoon (0.361) and post monsoon (0.207). Figure 1C depicted that maximum Simpson's dominance of tabanid species recorded during post monsoon (0.793), in comparison to pre-monsoon (0.472) and monsoon (0.639). Figure 1D depicted that maximum evenness of tabanid species recorded during post monsoon (0.888), in comparison to pre-monsoon (0.531) and monsoon (0.506). Figure 1E depicted that maximum Brillouin's index of tabanid species recorded during post monsoon (1.202), in comparison to pre-monsoon (0.783) and monsoon (1.188). Figure 1F depicted that maximum Menhinick's index of tabanid species recorded during post monsoon (1.809), in comparison to pre-monsoon (1.021) and monsoon (1.765). Figure 1G depicted Margalef's species richness index of tabanid species recorded maximum during monsoon (2.455), in comparison to pre-monsoon (1.259) and post monsoon (2.085). Figure 1H depicted maximum equitability index of tabanid species recorded during post monsoon (0.934), in comparison to pre-monsoon (0.607) and monsoon (0.690). Figure 1I depicted that maximum Fisher's alpha index of tabanid species recorded during post monsoon (5.403), in comparison to pre-monsoon (1.922) and monsoon (4.877). Figure 1J depicted that maximum Berger-Parker's dominance index of tabanid species recorded during pre-monsoon (0.708), in comparison to monsoon (0.577) and post monsoon (0.273). Figure 1K depicted that maximum Chao-1 index of tabanid species recorded during monsoon (16.5), in comparison to pre-monsoon (5.5) and post monsoon (7.5). Figure 1L (log of SHE index) depicted that maximum ln S of tabanid species recorded during monsoon and post monsoon (2.197), in comparison to pre-monsoon (1.609); maximum H of tabanid species recorded during post monsoon (1.512), in comparison to pre-monsoon (0.976) and monsoon (1.346); maximum ln E of tabanid species recorded during pre-monsoon (-0.633), in comparison to monsoon (-0.852) and post monsoon (-0.685).

B. Log series model of rank abundance of Tabanidae throughout three seasons:

Figures 2.A-C. showing present samples of tabanid species best suited in log series model of rank abundance, depicting maximum abundance during pre-monsoon and monsoon of species *T. straitus* (17, 12.545; 15, 8.298) and of species *T. striatus* (3, 3.857) and *H. javana* (3, 2.429) respectively during post monsoon, as evident and significantly supported by bootstrap value of *9999 ($p<0.05$).

C. Mau-Tau's sample rarefaction analyses of tabanid species collected throughout the three seasons:

Mau-Tau's sample rarefaction analyses of tabanid species sampled throughout the three seasons revealed that present sampling of tabanids almost approached towards the asymptote and though more sampling needed to reduce the sampling error, but overall sampling of tabanids species throughout the three season is well

within the acceptable range significantly, as evident from the species accumulation curves (95% confidence level; $p<0.05$).

DISCUSSION

A total of nine tabanid species namely *Chrysops dispar* (Fabricius, 1798); *Atylotus virgo* (Wiedemann, 1824); *Tabanus dorsiger* Wiedemann, 1821; *Tabanus (Tabanus) rubidus* Wiedemann, 1821; *Tabanus (Tabanus) striatus* Fabricius, 1787; *Tabanus (Tabanus) tenens* Walker, 1850; *Haematopota javana* Wiedemann, 1821; *Haematopota marginata* Ricardo, 1911; *Hippocentrodes desmotes* Philip, 1961 under four genera viz. *Atylotus* Osten Sacken, 1876; *Tabanus* Linnaeus, 1758; *Haematopota* Meigen, 1803; *Hippocentrodes* Philip, 1961 and single subfamily i.e. Tabaninae are recorded during study period in study sites of Sonamukhi dry deciduous protected forest habitat across arid zone of West Bengal. Among these nine tabanid species, one species namely *Tabanus dorsiger* Wiedemann, 1821 are recorded for the first time from this zone of the state. Notably the species *Hippocentrodes desmotes* Philip, 1961 of genus *Hippocentrodes* Philip, 1961 are recorded only for the second time from the state.

Diversity analyses of tabanid species comparatively throughout the three season revealed that most of the diversity and evenness indices of tabanid species yielded maximum value during post monsoon (Shannon index- 1.673; Pielou's evenness- 0.888; Brillouin's index- 1.202; Menhinick's index- 1.809; Equitability index- 0.934; Fisher's alpha index- 5.403), whereas dominance indices recorded maximum value during pre-monsoon (dominance index- 0.528; Berger-Parker's dominance- 0.708) and post monsoon (Simpson's dominance index- 0.793) respectively. Margalef's species richness index and Chao-1 index of tabanid species yielded maximum value during monsoon (Margalef's richness- 2.455; Chao-1: 16.5).

Rank abundance model of tabanid species revealed best suited with log series model, as evident from maximum abundance during pre-monsoon and monsoon of species *T. straitus* (17, 12.545; 15, 8.298) and of species *T. striatus* (3, 3.857) and *H. javana* (3, 2.429) respectively during post monsoon, significantly supported by bootstrap value of *9999 ($p<0.05$).

Mau-Tau's sample rarefaction analyses revealed that present sampling of tabanids almost approached towards the asymptote and sampling of tabanid species throughout the three season is well within the acceptable range significantly (95% confidence level; $p<0.05$).

Among all these tabanid fauna recorded from Sonamukhi protected forest and adjacent area representing arid zone of the state, only one species i.e. *Haematopota marginata* Ricardo, 1911 exhibit endemism to this zone within the state. Other 8 tabanids are more or less distributed widely with one species namely *Tabanus (Tabanus) striatus* Fabricius, 1787 is most widespread and almost found to be cosmopolitan in distribution. Distribution map of Tabanidae in arid region of West Bengal (Map 1) exhibited their collection sites and species richness of the family on the basis of number of species collected from study sites. It revealed that station 8 in Sonamukhi protected forest area under Chotanagpur dry deciduous eco region is most species rich as far as tabanid fauna are concerned. Besides, it can be said that certain tabanid species occurring in Sonamukhi protected forest and adjacent area under eco-region of Chotanagpur dry deciduous forest and associated arid region of West Bengal may immigrate at

least to the neighbouring states i.e. Bihar, Jharkhand, Chhattisgarh and countries, such as Bangladesh, Myanmar, Thailand, etc. or emigrate from those states and countries. Though family Tabanidae are presumed to exhibit discontinuous distribution in arid region of the state and this appears to be due to the need of thorough exploration of several area, unfavourable natural conditions in the area for survival and colonization, inaccessible area specially large part of Jungle mahal. But in far future, the distribution is expected to be continuous due to influence of similar topographic conditions prevailing in surrounding states encompassing same eco-region of Chotanagpur dry deciduous forest of arid zone.

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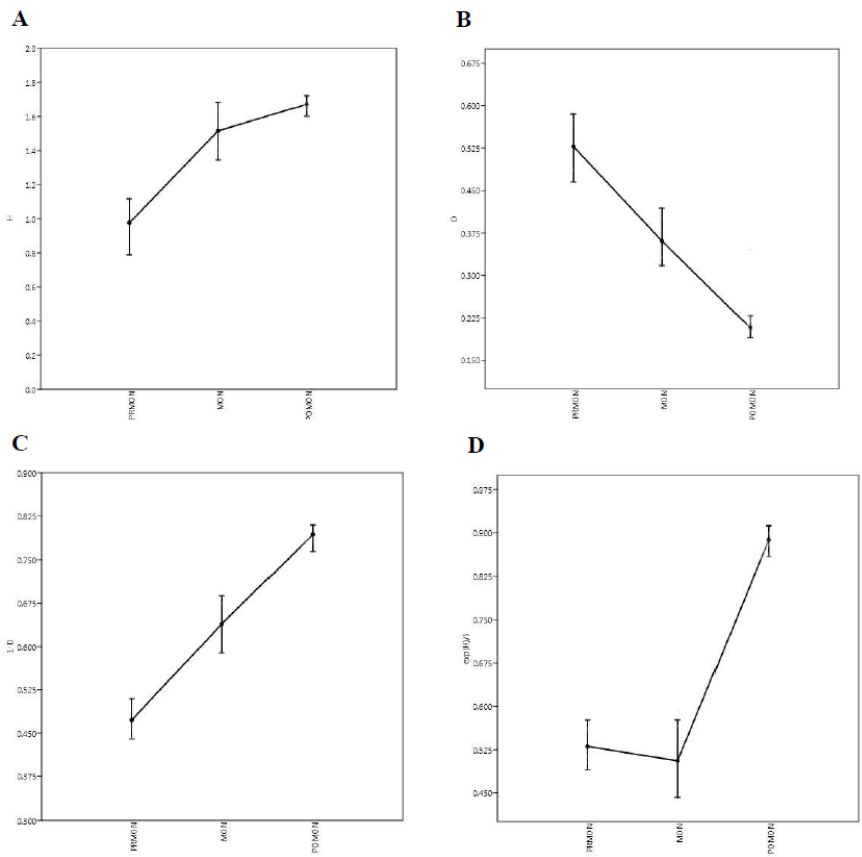

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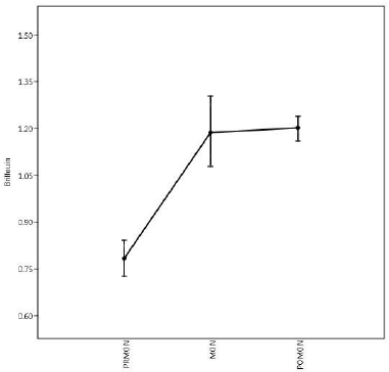
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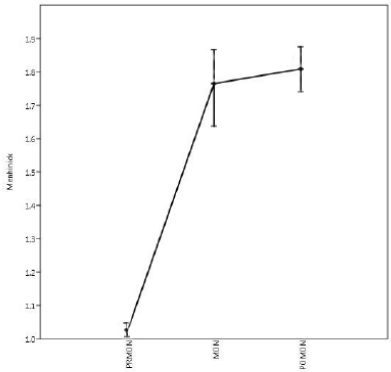
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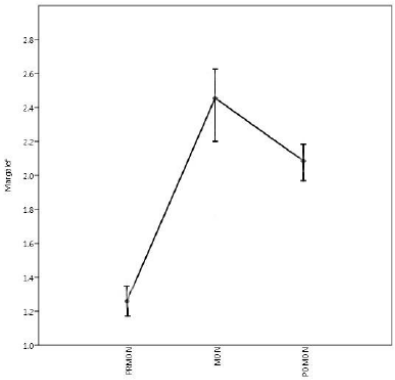
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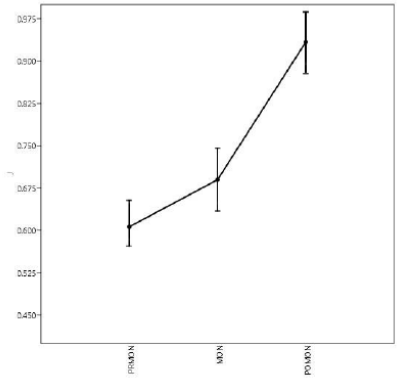
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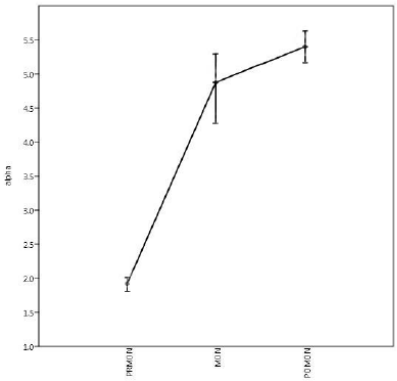
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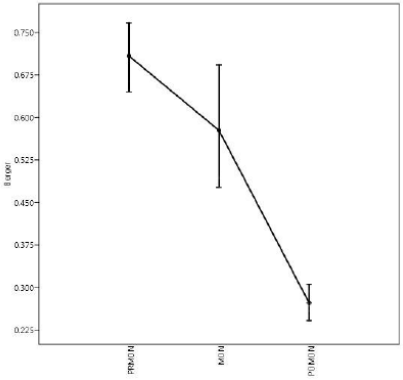
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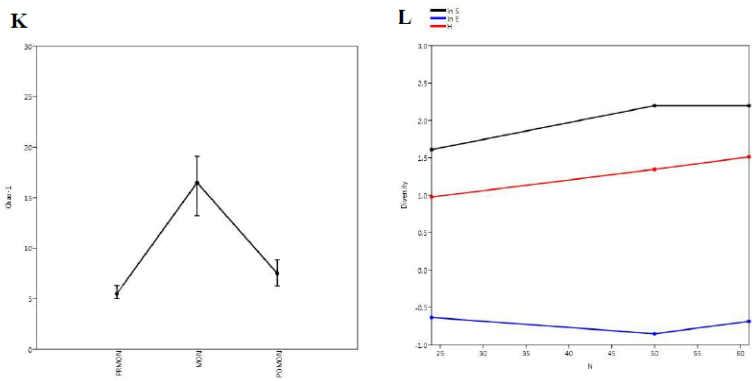


Figure 1. A-L. Comparative analyses of different alpha diversity indices of tabanids seasonally through pre-monsoon, monsoon and post monsoon i.e. A: Shanon diversity index; B: Dominance index; C: Simpson's dominance index; D: Evenness index; E: Brillouin's index; F: Menhinick index; G: Margalef's index; H: Equitability index; I: Fisher's alpha index; J: Berger-Parker index; K: Chao-1 index; L: ln SHE index.

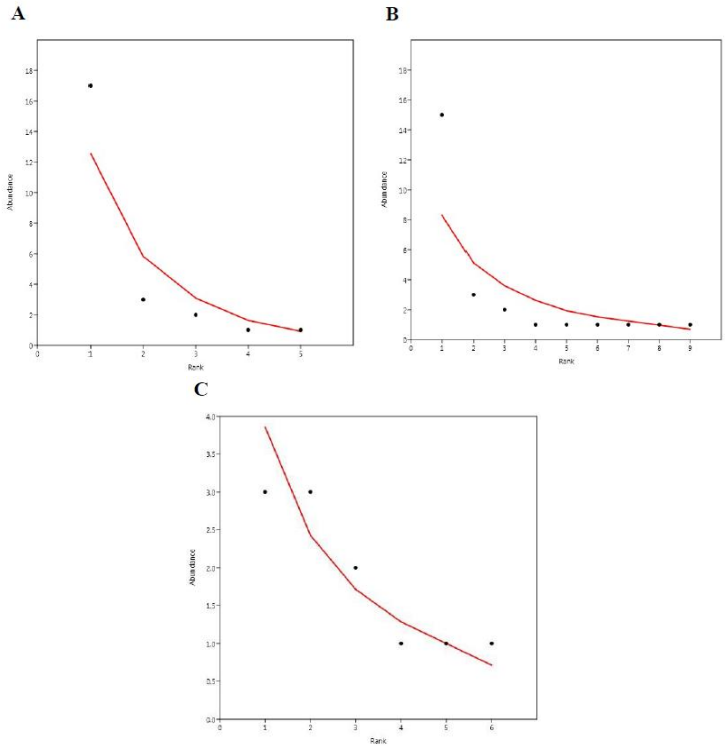


Figure 2. A-C. Graphs showing log series model of rank abundance of tabanids depicting maximum abundance during pre-monsoon and monsoon of species *T. straitus* (17, 15) and of species *T. striatus* (3) and *H. javana* (3) respectively during post monsoon.

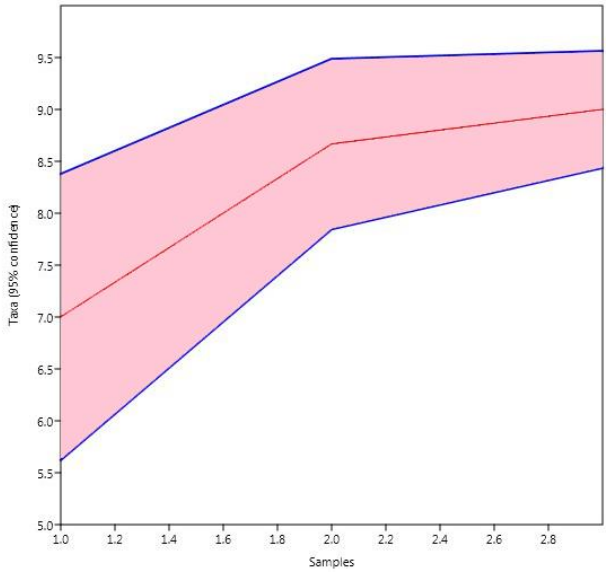


Figure 3. Species accumulation curves showing sample rarefaction (Mau Tau's) of the tabanids sampled throughout the season.

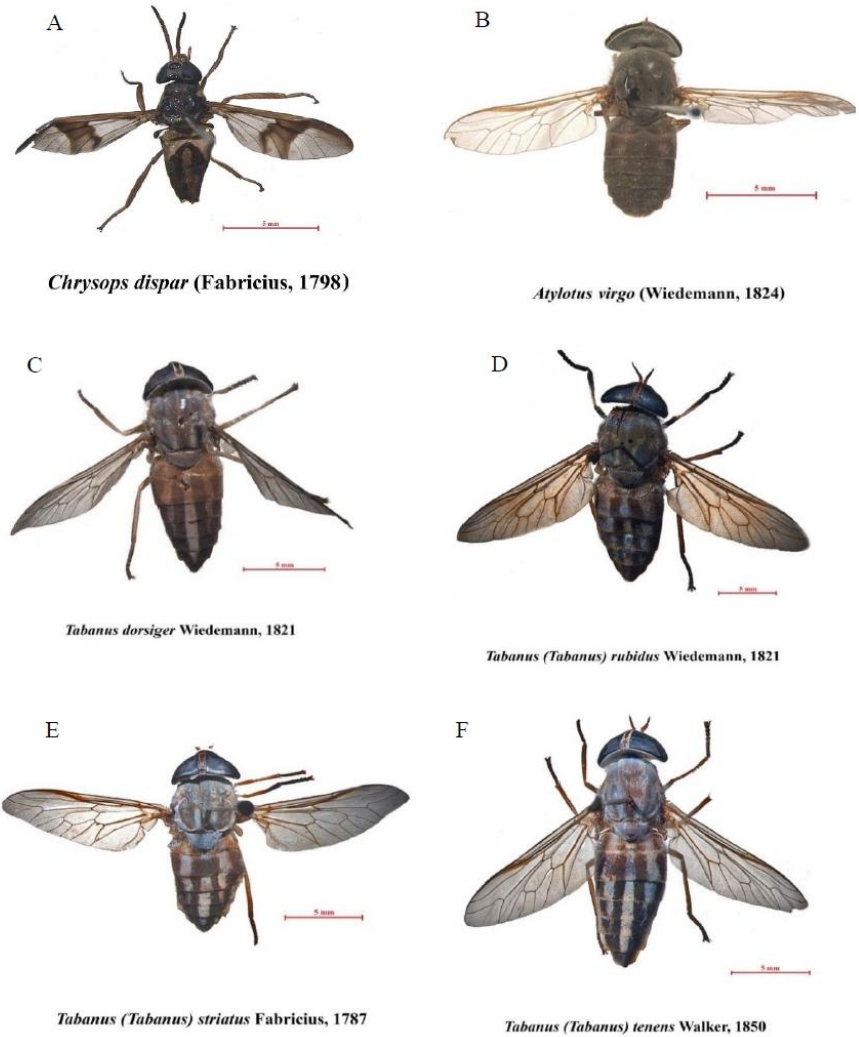


Plate 1. Habitus of six species of Tabanidae, i.e. A: *Chrysops dispar* (Fabricius, 1798); B: *Atylotus virgo* (Wiedemann, 1824); C: *Tabanus dorsiger* Wiedemann, 1821 (new record from Sonamukhi protected forest area under arid zone of West Bengal); D: *Tabanus (Tabanus) rubidus* Wiedemann, 1821; E: *Tabanus (Tabanus) striatus* Fabricius, 1787 and F: *Tabanus (Tabanus) tenens* Walker, 1850.

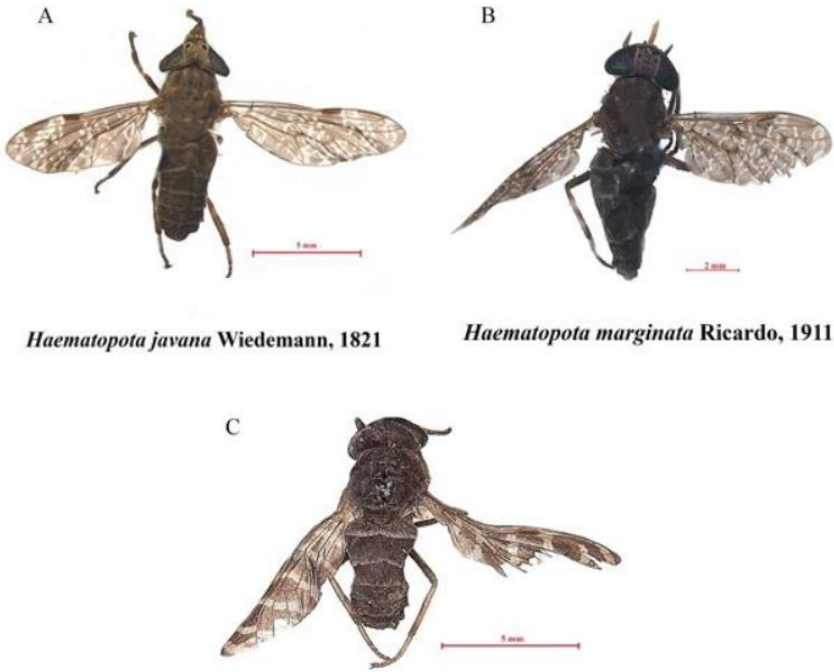
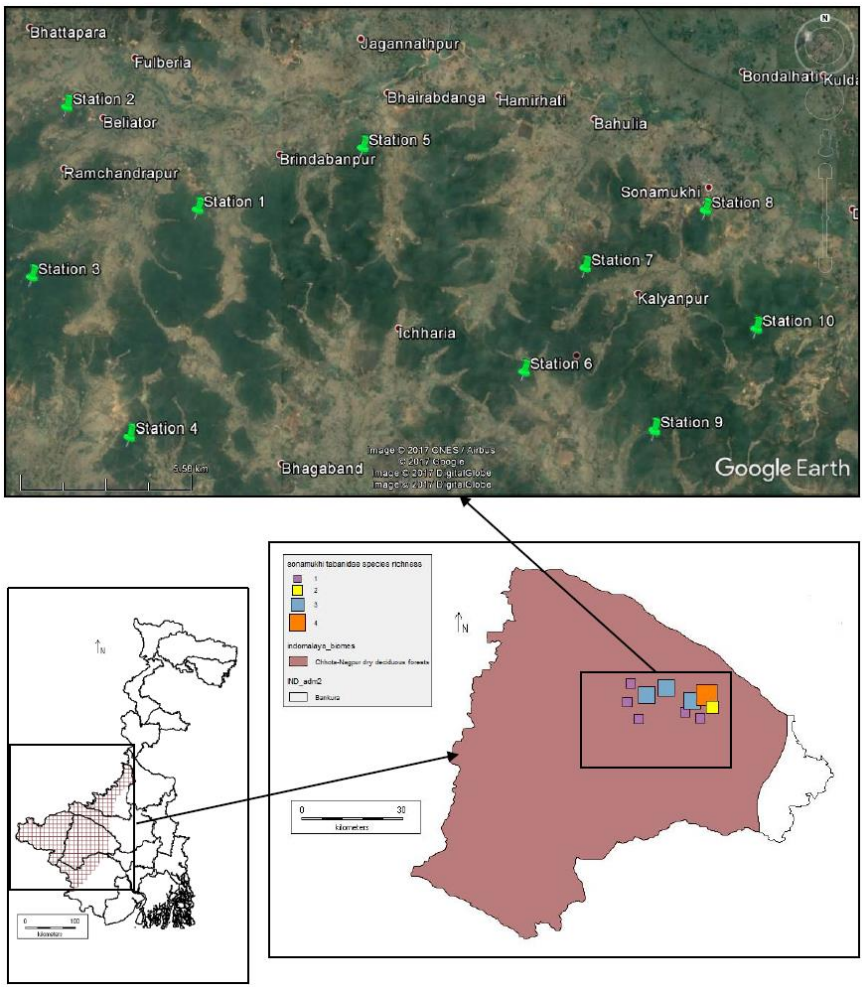


Plate 2. Habitus of three species of Tabanidae, i.e. A: *Haematopota javana* Wiedemann, 1821; B: *Haematopota marginata* Ricardo, 1911 and C: *Hippocentrodes desmotes* Philip, 1961.



Map 1. GIS map showing distribution and richness of family Tabanidae in Sonamukhi protected forest, on the basis of eco-regions in Indo-malayan biome of arid region of west Bengal below and satellite map of all the stations showing study sites of Tabanidae above.