

Prevalence, population dynamics and host preferences of *Culicoides* spp. (Diptera: Ceratopogonidae) of livestock in Marathwada region of Maharashtra State*

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Abstract

Aim: The present study is a part of a research project on integrated pest management of livestock pests with reference to *Culicoides* spp. Study of prevalence, population dynamics and host preferences are the important benchmarks essential for chalking out the strategies of integrated pest management of *Culicoides*, thus the study was aimed.

Materials and Methods: Light trap collections of *Culicoides* midges and other tiny flies from animal shed from seventeen centers representing entire Maharashtra state were conducted. Similarly, year round collections from host sheds were envisaged to work out host preferences and population dynamics of *Culicoides* spp. locally prevalent. Multiple regression analysis was employed to define the environmental predictors responsible for ups and downs during different seasons occurring in the geographic region of the present study.

Results: Study revealed the prevalence of *Culicoides* spp., *Phlebotomus* spp. and *Simulium* spp. Simultaneous study undertaken by the aid of hand net, collections of fly species from Marathwada region of Maharashtra state yielded additionally, *Tabanus* spp., *Pangonia* spp., mosquitoes and other cyclorrhaphan flies. Some of the species are vectors of livestock diseases hence map of the distribution of these pest species is for to reckon risk areas. Population dynamics study on *Culicoides* spp. in Marathwada region indicated that, (a) *Culicoides* population were persistent throughout the year; (b) Two peaks of population, one in the monsoon (August-September) and another minor peak occurred during post monsoon/beginning of winter (November) of the year. Drastic reduction in the population occurred during the month of May, which is the hottest month in the year. *Culicoides* collections from the sheds of different host species indicated the preferences for feeding in the ascending order of preference as cattle, sheep, buffaloes and then goats.

Conclusion: Prevalence of *Culicoides schultzei*, *Culicoides peregrinus* and *Culicoides actoni* was occurred in the Marathwada region of Maharashtra along with other haematophagus flies. Seasonal population dynamic studies depicted two peaks in the *Culicoides* population, and peak population observed during the monsoon season. Study on the parameters is essential for the preparation of prediction models and forecasting.

Keywords: *Culicoides* spp., host preferences, livestock, Marathwada, population dynamics.

Introduction

Culicoides (Diptera: Ceratopogonidae) are commonly known as biting/bloodsucking midges or gnats (1-3 mm) presenting a huge diversity with more than 1300 species described worldwide [1,2] of which some 96% are hematophagous. These midges are of great concern because they transmit bluetongue (BT) [3,4], African horse sickness virus (AHSV), epizootic hemorrhagic disease virus (EHDV), equine encephalitis virus (EEV), akabane virus, bovine ephemeral fever virus [5] and Schmallenberg disease in 2011 [6,7]. Biting midges are also a source of nuisance through the bites of females. Their presence can, therefore, hinder the economic development of some regions, hampering agricultural and forestry activities, as well as

tourism development [8]. BT is a viral disease causing morbidity and mortality in sheep, cattle and wild ruminants, including deer, sambar and bluebull. BT is endemic in many parts of India and its outbreak in TamilNadu during the monsoon season of 1997-1998 caused the death of 300,000 sheep and goats and occurrence of this disease in many parts of India over the last few decades has affected millions of sheep and goats and other livestock [9]. Although the importance of autochthonous *Culicoides* species in the dissemination of BT virus (BTV) and SV is now generally recognized [10], many aspects of the ecology of native *Culicoides* species are still not fully understood, and there is a lack of information concerning to their dispersal, vectorial capacity, feeding and host-seeking behavior, mating, resting and oviposition are important for understanding disease

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transmission, longitudinal entomological intervention and for control, so that the transmission of the disease during outbreak of BT can be stopped [9,10]. The elucidation of the field biology of *Culicoides* midges is instrumental for the implementation of control measures and disease risk analysis. Though BT disease in several states of India is endemic viz. Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra, Gujarat, Rajasthan, Haryana, Himachal Pradesh and Jammu and Kashmir, until then the knowledge of *Culicoides* spp. as a vector of BT is poorly known in many parts of India [9]. Considering these facts, research on various aspects of epidemiology, biology, bio-control agents and integrated pest management of *Culicoides* spp. prevalent in parts of India is of utmost importance.

In 1994, during a workshop on “Research and Extension needs for Integrated Pest Management (IPM) for arthropods of Veterinary importance” conducted at Lincoln USA, first-time needs of IPM against major pests of livestock were documented and defined [11]. As a result direct losses caused by livestock pests to the certain extent were documented. Realizing the importance and timely need of IPM against livestock pests including *Culicoides* spp., authors conducted detailed research under DBT financed project entitled as development of IPM module against important dipteran pests of livestock with reference to *Culicoides* midges (Diptera: Ceratopogonidae), on various aspects, including species prevalent, population dynamics and host preferences of *Culicoides* spp. in Maharashtra state and is reported in the present paper. It is well-known fact that for undertaking IPM against any pest, sound knowledge of population dynamics and prevalence of pest in a particular geographic area is a must. Thus, during the project work survey across the state were undertaken, for recording the prevalence of *Culicoides* spp. However during light trap collection several other flies were also collected. All such fly species acting as pests of livestock and discharging the role of potent vector are also reported.

Materials and Methods

Survey work of *Culicoides* and other fly species in the Maharashtra state

For the survey of *Culicoides* along with other fly species biting to the livestock, collection work from 16 representative sites were undertaken in the state of Maharashtra. Geographically and politically Maharashtra state is divided into four regions viz. Marathwada, Vidarbha, Konkan and Western Maharashtra. In each region, four places (Four sites representing four regions of the state) were selected for collection. Such 16 collection locations + one location as Parbhani where project work was undertaken. Collection work was completed within 40 days time by provision of special vehicle (Figures 1 and 2) carrying light trap with high power battery as energy source when electric supply was discontinued. Use of light



Figure-1: Light tap collections of *Culicoides* spp. and other flies in buffalo shed.



Figure-2: Light tap collections of *Culicoides* spp. and other flies in goat shed.

traps is considered as the standard method [12,13] for collection of midges. Collection work at each place was undertaken at dawn and dusk time by operating light trap for 10 min. Collected *Culicoides* were preserved in labeled vials containing 70% alcohol glycerin, brought to Parasitology Department. Flies in the vials were subjected to further studies under zoom stereoscopic microscope and were categorized into different fly species along with *Culicoides* spp. Collected flies of different species including *Culicoides* spp., which were primarily identified under zoom stereoscopic microscope by employing the keys [14,15], were also sent in absolute alcohol to NBAIL, Bangalore for molecular identification and DNA bar coding.

Preparation of map of the Maharashtra state depicting areas of prevalence of *Culicoides* and other fly species

Data on identification of fly species were tabulated, and predominance/abundance of the different *Culicoides* species at 17 locations was depicted in the political map of Maharashtra state (Figure-3). Identification of *Culicoides* and other fly species were further confirmed at NBAIL, Bangalore.

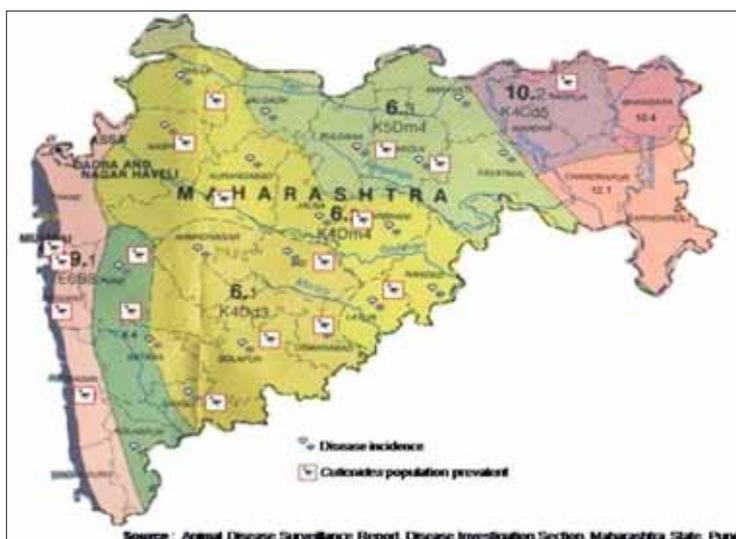


Figure-3: Map depicting prevalence of *Culicoides* spp. in Maharashtra state.

Reporting of fly species from Parbhani and other parts of Marathwada region

Simultaneous studies from Marathwada region were envisaged by collecting large sized flies with the use of hand nets from animal sheds belonging to Veterinary College and animal units of Agricultural University Parbhani. Additional collections were also made from animal sheds belonging to many villages from Marathwada region (places wherefrom farmers have frequently reported the nuisance/abundance of flies). Collected flies were identified in the laboratory, further identified at NBAII, Bangalore and are also reported here.

Seasonal population dynamics of *Culicoides* and its correlation with meteorological data

The *Culicoides* collection were undertaken with the help insect light trap for 5 min in the cattle shed at morning 7.00 am, thrice in a week for twelve months of a calendar year 2010. Insect light trap having ultra violet light were found to be best among the different colored light traps and therefore used for all the collections. The *Culicoides* collected in the trap were examined under zoom stereoscopic microscope, separated according to the species and counted. The environmental data were gathered from meteorology observatory of grade B belonging to Matathwada Agril University Parbhani. Multiple regression analysis was applied to the data and correlation was worked out between year round collections of *Culicoides* spp. and meteorological data.

Host preferences of *Culicoides* spp

Collection work of the *Culicoides* were undertaken from the different sheds in which various species of host animals such as cattle, buffaloes, sheep and goats are maintained. The collections from these sheds were undertaken with insect light trap, with an equal number of collections by allotting 5 min time for each collection, were examined under zoom

stereoscopic microscope, separated according to the species and counted.

Results and Discussion

Identification of *Culicoides* species

Culicoides species collected from 17 locations from Maharashtra state revealed the presence of three species namely [16]:

1. *Culicoides peregrinus* Kieffer, 1910
2. *Culicoides schultzei* Enderlein, 1908
3. *Culicoides actoni* Smith, 1929.

All these three species of *Culicoides* previously recorded from Marathwada region of the state, are found distributed in all the regions of Maharashtra state [17]. Besides *Culicoides* similar sized fly species such as *Simulium* and *Phlebotomus* etc., were also confirmed as detailed in Table-1. The survey of fly species of livestock pests was probably undertaken for the first time in Maharashtra state.

Survey work of *Culicoides* and other fly species in the Maharashtra state

Perusal of Table-1, indicates that three *Culicoides* species, one *Sergentomyia* (*Phlebotomus*), one *Simulium*, one *Aedes* mosquitoes, two species of *Musca* house flies and another scavenger flies were prevalent in the state. The molecular identification has to be confirmed on the basis of morphology for getting accession number. Until now, three *Culicoides* species, *Sergentomyia punjabensis*, *Simulium truncatum*, *Aedes aegypti* mosquitoes, two species of house flies as *Musca formosana* and *Musca domestica* have been confirmed morphologically. The fly marked as *Sergentomyia* contained mixed population of *S. punjabensis* and *Phlebotomus* spp. Other flies yet to be morphologically confirmed. All confirmed species from genus *Culicoides*, *Phlebotomus*, *Simulium*, *Aedes* and *Musca* are potent vectors (mechanical/biological) of one or the other diseases.

Table-1: Details of sites of collection and prevalence of *Culicoides* spp. in Maharashtra state.

Name of district	Collection centre	Name of the unit	Population <i>Culicoides</i>	<i>C. peregrinus</i>	<i>C. schultzei</i>	<i>C. actoni</i>	<i>Phlebotomus</i> sp.*	<i>Simulium</i> [§]	Unknown
Marathwada region Parbhani®	Parbhani	Veterinary College, RK cattle, Buffalo, Sheep, Goat Farm; Agril Dairy, Goat farm of MAU	+++	+++++	+++	++	+++	+++	++
Aurangabad	Paithan	Unorganized private cattle, sheep, goat sheds	+++	+++++	+++	+	+++	++	++
Latur	Udgir	Veterinary College farms	+++	++	++	++	++	++	++
Beed	Ambajogai	Sheep and Goat Government organized farm	++	++	+++	+++	++	++	++
Osmanabad	Tuljapur	Tirth (BK) goat Government Farm	+++	+++	==	+++	+++	++	++
Konkan region Ratnagiri	Maiwan	Unorganized private cattle, sheep, goat sheds	+	++	===	++	+++	==	==
Raigad	Roha	Unorganized private cattle, sheep, goat sheds	+++	++	+++	----	++	++	+
Mumbai	Mumbai	Veterinary College farms	+++	++	+	+++	===	==	+++
Sindhudurga	Kankawali	Unorganized private cattle, sheep, goat sheds	+++	++	===	++	+++	==	==
Western Maharashtra Solapur	Jat/Pandharpur/ Shetphal	Unorganized private cattle, sheep, goat sheds	+++	+++++	+++	+++	++	==	+
Satara	Phaitan	Nimkar Sheep Farm (NARI)	++	++	===	++	++	==	==
Satara	Shirwal	KNP Vety College Farm	++	++	++	==	++	++	++
Nashik	Igatpuri	MAFSU Research Station	+++	+++++	+++	==	++	++	++
Vidarbha region+ Khandesh	Warud	Dairy Technology college farm	+++	===	++	++	++	++	++
Yawatmal	Borgaon Manju	MAFSU Research center	+++	===	+++	+++	+++	==	==
Akola	Nagpur	MAFSU Res. center College farm	+++	+++	+++	+++	==	==	++
Nagpur	Nandurbar	Dr Hedgewar KVK	++	===	++	+++	++	==	==
Nandurbar		Summary of the locations positive for a particular fly species	17	14	13	14	15	09	12

++++=Predominant fly species, +++=Abundant midge population, ++=Midge population moderate, +=Midge population scanty, ==: Midge nil. Total organized farms: 12 Total un-organized private farms: 05. ®from Parbhani region *Tabanus rufrostrer*, *Aedes aegypti*, *Musca formosana*, species of the flies were collected and confirmed on molecular basis. §*Sergentomyia punjabensi*, §*Simulium truncatum*. Collections from the Parbhani and other locations proved the predominance of *C. peregrinus* species, however, at Nadurbar, Mumbai and Osmanabad predominance of *C. actoni* was observed. *C. peregrinus*=*Culicoides peregrinus*, *C. schultzei*=*Culicoides schultzei*, *C. actoni*=*Culicoides actoni*

Importance of studying geographic distribution and plotting of map

The transmission of BTV by the midges involves complicated process, governed by several factors [18,19]. Mere presence of vector and host does not necessarily mean the outbreak of BT disease. However, data of BT disease for 1985-2004 from Maharashtra state, indicates that disease has occurred in the past in almost all districts (except few coastal and some Vidarbha peripheral districts) during 1 or the other year. After correlating the data of BT disease for 1989-2004 and presence of *Culicoides* recorded in the present project across the state, it is abundantly clear that there exist a definite correlation between these two variants. Thus, prepared map depicting the prevalence of any fly (vector) in a particular geographic area is an important benchmark for (a) Deciding the risk areas vulnerable to diseases vectored by these fly species, (b) It helps in chalking out the strategic plan for control measures against vectors and can be considered as prediction-map useful to policy makers, (c) To undertake IPM program against any fly/pest species sound knowledge of epidemiology is prerequisite. The present study will certainly of immense use while formulating IPM module against these flies, and (d) This map of distribution of *Culicoides* species along with other vector species will definitely help to target not only vectors, but also for undertaking management of many vector borne livestock diseases. Probably, this is the first attempt in the country.

Species of *Culicoides* in India

Udupa [20] and Bhoyar *et al.* [21] did the work on various aspects of species at Chennai and Bidar, respectively. In India citing the works of Kieffer (1910, 1911, 1913) [22-26], Sen and Fletcher [27], enumerated 28 *Culicoides* species in India. Of these 28 species, most of them belonged to Calcutta, whereas one species *Culicoides pattoni* was collected from Calcutta, Assam/Puri. Quoting the work of Patel [23], Sen and Fletcher [27] also reported the species of *Culicoides oxystoma* from Bombay Veterinary College. Sen and Dasgupta [15] reported 31 *Culicoides* species and one variety, while Dasgupta [28-31] added few more species from Calcutta. Of these 31 species, *C. pattoni* and *Culicoides indianus* were reported from Coimbatore and Dharwar [15], *Culicoides alatus* from Pune [32], and three species, i.e., *Culicoides fulves*, *Culicoides clavipalpis* and *Culicoides similis* were reported from Madras [33]. In all from India total around 50 species and one variety are documented. These include *C. actoni*, *Culicoides autumnalis*, *C. alatus*, *Culicoides albipennis*, *Culicoides anophelis*, *Culicoides bimaculicosta*, *Culicoides brevimanus*, *Culicoides certus*, *C. clavipalpis*, *Culicoides candidus*, *Culicoides daleki*, *Culicoides dumdumi*, *Culicoides distinctus*, *Culicoides definitus*, *Culicoides fortis*, *C. fulvus*, *Culicoides fulvithorax*, *Culicoides himalayae*, *Culicoides innoxius*, *Culicoides iniquus*, *C. indianus*, *Culicoides imperceptus*, *Culicoides*

inexploratus, *Culicoides kamrupi*, *Culicoides macrostoma*, *Culicoides macfieii*, *Culicoides molestus*, *Culicoides minutus*, *Culicoides magnificus*, *Culicoides nitidulus*, *C. oxystoma*, *Culicoides orientalis*, *Culicoides odiosus*, *Culicoides opacus*, *C. peregrinus*, *Culicoides palpifer*, *Culicoides paivai*, *Culicoides pictiventris*, *Culicoides pseudoturgidus*, *Culicoides paralini*, *C. pattoni*, *Culicoides quadrilobatus*, *Culicoides raripalpis*, *C. schultzei*, *Culicoides shortti*, *C. similis*, *Culicoides setiger*, *Culicoides scapularis*, *Culicoides superfulvus* and *Culicoides turgidus* and one variety as *C. peregrinus* var. *assamensis*. From Darjeeling region of India Wirth *et al.* [34] reported *Culicoides spinulosus* and *Culicoides majorinus* species. In 2006 [9], reported the detailed fauna of Indian *Culicoides* species and their likely role in BT disease transmission.

Other flies reported from Marathwada region of Maharashtra as detailed in Table-2.

Species of Tabanids

Tabanus rufifrater, *Haematopota* and *Pagonia* flies are observed in the Parbhani region of Maharashtra. *T. rufifrater* has been confirmed on the basis of molecular analysis at NBAII Bangalore [35]. However other two species not confirmed to species level.

The family Tabanidae belongs to the sub-order Brachycera and infraorder Tabanomorpha. Members of this family are commonly known as horse flies (*Tabanus*), deer flies (*Chrysops*), and clegs (*Haematopota*). These flies are facultative hematophagous ectoparasites, thus important from medical and veterinary point of view. They are efficient mechanical carriers of various diseases and responsible for transmission of more than 25 animal diseases. Recently Veer [36] reviewed studies carried out on the family Tabanidae from the Indian sub-region with a few additions to Indian fauna by Mitra *et al.* [37], bringing the number of known species/subspecies from India to 244 species/subspecies under 15 genera. Veterinary important tabanids are enlisted from the web-based information entitled as checklist of Indian horse and deer flies (insecta: diptera: tabanidae) by Mitra (Zoological Survey of India, New Alipore, Kolkata-700 053) and Sharma (Zoological Survey of India, Central Zone Regional Centre, Jabalpur-482 002).

Table-2: Fly species reported from Parbhani and other parts of Marathwada region.

Name of the place	Fly species reported
Parbhani and adjoining areas, Sillod (District Aurangabad), Udgir (District Latur)	<i>Tabanus rufifrater</i> , <i>Ades aegypti</i> , <i>Musca domestica</i> , <i>Musca formosana</i> , <i>Haematopota</i> * spp
Parbhani and adjoining areas (Village Kupta), Beed and adjoining areas	<i>Pagonia</i> * spp

*Identified under zoom stereoscope on the basis of morphology, proboscis, wing characteristics etc.

Population dynamics of *Culicoides* spp

Variation in the population occurred during all the three seasons. However, it is clear from the data in Table-3, that (a) *Culicoides* population were persistent throughout the year; (b) two peaks of population, one in the monsoon (August-September) and another minor peak occurred during post monsoon/beginning of winter (November) of the year. Drastic reduction in the population occurred during the month of May, which is the hottest month in the year. In view of the climatological data, the observations in the present project were most expected, because the climatic parameters in the monsoon season are favorable for the growth of not only *Culicoides*, but other various species of insects having aquatic larval and pupal stages. Second the climatic conditions were mostly favorable for growth of bacterial flora and other biological fauna in stagnant water/rain water lodged bodies. These factors contribute to increasing in population of *Culicoides* larvae that consumes bacterial flora as a food for growth and survival. Perhaps this could be a possible reason that, monsoon season happens to be a season of *Culicoides* peak population. Contrary to this, in the region mercury swings between 35 and 45°C during the summer season with very low relative humidity (RH) creating arid environment. Overall bacterial population, biological fauna, etc., are destroyed due to lack of moisture and low RH. This explains the reduction in *Culicoides* population during the summer season. The temperature during the winter season oscillates between 10 and

25°C, critically speaking cannot be regarded as a typical winter season observed in Europe and some other continents of the world. Similarly, winter season in this area is followed by monsoon and can be considered as post-monsoon season during which scattered rainfall and availability of breeding places with favorable/requisite temperature and RH range, makes the *Culicoides* midge survival possible and it reflects in the occurrence of second minor peak. Of all the abiotic factors monitored, the average temperature, RH and wind speed have a major role in the variability of the total number of *Culicoides*. Dynamics of *Culicoides* population is positively correlated with a minimum temperature (11.5-16°C) [38]. Peaks of abundance of *C. oxystoma*, *Culicoides kingi*, *Culicoides imicola*, *Culicoides enderleini* and *Culicoides nivosus* coincide with the rainy season in September and October in Senegal [13]. Thus, Zimmer *et al.* [39] opined that defining the larval habitat shall be considered as essential to understanding population dynamics. Griffioen *et al.* [40] observed a bimodal pattern of activity, with peaks at dawn and dusk. All these observations are in the line of the present study. The highest midge activity was found around sunset, followed by a smaller peak of activity at dawn, stabling of animals at dusk and dawn might curtail the risk of disease transmission as a result of a higher activity of midges during that time of the day. However, midges are also frequently found inside stables [41] and stabling of animals will, therefore, not sufficiently protect animals from midge bites. Precise characterization of

Table-3: *Culicoides* collected during the year 2010 and its relationship with average weather parameters at Parbhani (Marathwada) region of Maharashtra state[®].

Season	Month 2010	<i>C. peregrinus</i>	<i>C. schultzei</i>	<i>C. actoni</i>	Total <i>Culicoides</i> ¹	
Monsoon* (weeks 23-44) 4 th June-4 th November	June	1360	990	367	2730	
	July	1698	1379	257	3347	
	August	4400	2460	518	7402	
	September	5400	3933	772	11020	
	October	2210	1264	225	3742	
	Total	15068	10026	2139	28241	
	%*	70.33	70.71	72.70	71.21	
	%**	53.35	35.50	7.57		
	Winter* (weeks 45-9) 5 th November-4 th March	November	4280	2850	547	7770
		December	303	222	45	570
January		960	700	113	1780	
February		645	290	81	1020	
Total		6188	4062	786	11140	
%*		28.88	28.65	26.72	28.08	
%**		55.54	36.46	7.06		
Summer* (weeks 10-22) 5 th March-3 rd June	March	118	67	13	200	
	April	31	20	03	54	
	May	20	04	01	25	
	Total	169	91	17	279	
	%*	0.79	0.64	0.58	0.70	
	%**	60.57	32.61	6.09		
	Grand total	21425	14179	2942	39660	

*Months and weeks of a calendar year are allotted to each season according to standard meteorological norms designed for Marathwada region. Latitude 17°35' N-20°40' N, Longitudes 70°40'-78°15' E, MSL - 40.9 m, *Percentage workout with grand total mentioned in respective column, **Percentage workout with total mentioned in the respective row.

¹Total *Culicoides* number includes unidentified *Culicoides*, [®]In each month 4 collections were made by employing light trap for 5 min and total number of *Culicoides* were counted. *C. peregrinus*=*Culicoides peregrinus*, *C. schultzei*=*Culicoides schultzei*, *C. actoni*=*Culicoides actoni*

the seasonality of *Culicoides* midges is critical to the creation of accurate and ecologically sound parameter estimates for use in predictive models of the animal diseases transmitted by these midges and, ultimately, to the formulation of logical abatement strategies for their control [42-44]. Precise documentation of temporal changes in the annual abundance and dispersal of *Culicoides* midges is essential for the creation of models to predict BTV infection of livestock and to develop sound abatement strategies [45]. Thus, models need to be developed so as to better understand the influence of environmental and climatic parameters on the distribution and dynamics of *Culicoides* for better evaluation of the risk of diseases transmitted. In view of the importance of such models in the present study multiple regression analysis derived the important predictors of population in a particular season and predicted population equation (Table-4).

Earlier studies conducted for Marathwada region also observed the at par seasonal variation [46,47]. Worldwide, estimating different types of predictors related to the climatic data, many studies were undertaken and such data is used for recording peak and depression in the *Culicoides* population and hence at that precise time control measures can be adapted. Thompson and Connor [48] recommended the environmental information systems such as remote sensing and spatial information technologies for control of arthropod vectors. Baylis *et al.* [49], Baylis and Rawlings [50] used climate data and Satellite imagery model to know the abundance of *Culicoides* in which they estimated normalized difference vegetation index measure of photosynthetic activity and land surface temperature a measure of temperature at earth surface. These two as predictors for estimation of population peaks. Data on seasonal population dynamics not only helps to record period of peak and depression of *Culicoides* flies, but it also helps in forecasting the diseases transmitted by *Culicoides* flies as vector. Sellers [51] described the world wide weather conditions and its correlation in understanding the ecology of vector *Culicoides*. According to his observations *Culicoides* could grow in the temperature range of 10-35°C, and they require adequate

moisture. Movement of the *Culicoides* was found to be affected by mainly wind. In conclusion, author has highlighted two important factors in the *Culicoides* ecology, i.e., temperature and wind. Based on the data author correlated the weather, *Culicoides* distribution and spread of BTV and EHDV. After analyzing the present project data, in view of these observations, it can be concluded that in Maharashtra state and particular Marathwada region control of *Culicoides* midges during monsoon and winter season is important from the point of pest control and control of BT disease.

In addition to the AHSV, *Culicoides* also transmit BTV, EHDV, EEV, Akabane virus, bovine ephemeral fever virus and viruses in the Palyam group [5]. However, the two diseases with the greatest veterinary impact among these are BT affecting ruminants and AHS affecting equines. These two viral diseases has economic impact owing to the fact that their very broad geographical distribution and their potential for spreading rapidly and hence there is necessity of developing prediction models so as to better understand the influence of environmental and climatic parameters on the prevalence and seasonal dynamics of the vector *Culicoides* in a particular geographic area [13,38]. Ilango [9] and Ayllón *et al.* [52] also stressed the need of taxonomic and field biology studies on *Culicoides* and according to them such studies are instrumental for the implementation of control measures and disease risk analysis. Concurring to these studies, observations marked in the present study highlighted the prediction models for *Culicoides* population (Table-4) prevalent in the Marathwada region of Maharashtra state, will certainly help for understanding the distribution of viral diseases transmitted by *Culicoides* midges and for their control.

Host preferences of *Culicoides*

The data in Table-5 indicates the host preferences for feeding of *Culicoides* midges in the order of cattle, sheep, buffaloes and followed by goats. It is also clear from the data (Table-5), that species of *Culicoides* predominant in the region was *C. peregrinus*, however, nonetheless other two species also contributes substantially and hence in IPM programme, control measures shall be undertaken equally against all species.

Table-4: Multiple regression analysis of weather parameters and *Culicoides* population for the year 2010.

Season (2010)	Important predictors of population	Population equation
Monsoon	WV (Km/h) RF in mm T _{min} RD	$Y = -22332.52 + (-)32.65 \times RF + 1276.34 \times RD + 1052.85 \times T_{min} - 220.80 \times WV$
Winter	BSS T _{max} RD	$Y = -1466.78 + 1385.28 \times RD + 130.26 \times T_{max} - 214.36 \times BSS$
Summer	WV (Km/h), BSS hours in a day	$Y = 1222.33 + (-87.66 \times BSS) + (58.33 \times WV)$ Y: <i>Culicoides</i> population

WV=Wind velocity, RD=Rainy days, RF=Rain fall, T_{min}=Temperature minimum, BSS=Bright sunshine, T_{max}=Temperature maximum

Table-5: Host midge relationship of *Culicoides* spp. to four species of hosts in Marathwada (Parbhani) region collected during the year 2010.

Host	<i>Culicoides</i> species						Total
	<i>C. peregrinus</i>		<i>C. schultzei</i>		<i>C. actoni</i>		
	Numbers collected	%	Numbers collected	%	Numbers collected	%	
Cattle	5352	61.66	2983	34.35	347	3.99	8682
Buffalo	3230	55.61	2342	40.32	236	4.06	5808
Sheep	3424	62.10	2022	36.67	67	1.21	5513
Goat	1242	69.15	542	30.17	12	0.66	1796
	13248	60.77	7889	36.18	662	3.03	21799

C. peregrinus=*Culicoides peregrinus*, *C. schultzei*=*Culicoides schultzei*, *C. actoni*=*Culicoides actoni*

Preferential host for *Culicoides* is cattle, which is also a reservoir host for BTV, which is transmitted to sheep via *Culicoides*. Therefore, utmost care is needed to keep these two ruminant hosts at distance during the monsoon season or during the peak period of BT. In this context observations of Jones *et al.* [53] are pertinent to the present study. According to them, during endemic cycle of BTV, vector species do not cause a problem, but during an epizootic cycle where a midge takes blood from an infected animal, after an incubation and multiplication period, infected female transmit virus to any wild or domestic ruminant that it will feed on viz. sheep, goat, cattle, deer, antelope, etc. If a high population of midges is present, the secondary or epizootic cycle may go on repeatedly from year to year. In this context, present study on host preferences focuses mainly that *Culicoides* spp. had shown equal affinity to all four ruminant host species and hence it can be strongly hypothesized that species reported in this region could be possibly responsible for and for completion of circulation of BTV cycle among host species. Host preferences determine which host will be bitten and therefore be potentially infected with vectored pathogenic organisms. Host preferences of *Culicoides* species from Israel based on sensory organs and morphometry [54] and on the basis feeding behavior from Germany were reported by Ayllón *et al.* [52]. Significantly more midges were collected from cattle in the present study, indicating that cattle may be more attractive than sheep for midges, as previously suggested by other authors [55,56]. This has important epidemiological implications, as sheep could be a susceptible target for these vectors when cattle are absent in the vicinity. According to Ayllón *et al.* [52] cattle not only attract midges, but they also constitute important hosts.

Conclusion

Prevalence of *C. schultzei*, *C. peregrinus* and *C. actoni* was reported in the Marathwada region of Maharashtra along with other hematophagus flies viz. *Phlebotomus* spp. and *Simulium* spp. Simultaneous study undertaken by the aid of hand net, collections of fly species from Marathwada region of Maharashtra state yielded additionally, *Tabanus* spp., *Pangonia* spp., mosquitoes and other cyclorrhaphan flies. Population dynamics study on *Culicoides* spp. in

Marathwada region indicated that, (a) *Culicoides* population were persistent throughout the year; (b) two peaks of population, one in the monsoon (August-September) and another minor peak occurred during post monsoon/beginning of winter (November) of the year. Drastic reduction in the population occurred during the month of May, which is the hottest month in the year. *Culicoides* collections from the sheds of different host species indicated the preferences for feeding in the ascending order of preference as cattle, sheep, buffaloes and then goats.

Recommendations

The prevalence of hematophagus flies from Marathwada region of Maharashtra state necessitates the detailed studies on the epidemiology, biology and vector competence of each fly species, all being vectors of livestock diseases in different geographic areas of the country. Prediction map of the distribution of these pest species is required for to reckon risk areas.

Authors' Contributions

BWN being PI of the research project conceptualized and implemented the technical programme with the help of Junior research fellow. BWN collected, processed and analysed the data and submitted it in the form of present research article. PRS being Co-PI was involved in the finalization of technical programme and involved in validation and confirmation of data. PRS being recognised insect taxonomist, based on morphological features confirmed all insect species reported in this article. Both authors read and approved the final manuscript.

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Competing Interests

The authors declare that they have no competing interests.

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