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# Spatio-Temporal Assessment of Mosquito Dynamics in Relation to Meteorological Variables in Baramulla District of North Kashmir, India

**Bilal Ahmad Malla*** **and Jebanesan A.**

Department of Zoology, Annamalai University, Annamalai Nagar, Tamil Nadu, India

**Corresponding Author*

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**Abstract:** The present investigation was an attempt to find out the mosquito fauna diversity and distribution in relation with meteorological factors across three study localities/sites of Baramulla district (Kashmir division), India. The study period between May to October of 2019 and 2020, encountered a total of 701 mosquito specimens with maximum number of individuals recorded from Sopore (n=250) followed by Rafiabad (n=242) and Zaingeer (n=209). The mosquitoes seasonally reported were mostly found abundantly in summer (n=418). Monthly collections illustrated that number of mosquitoes were recorded maximum in August and September (n=381) and minimum in May and June (n=76). *Culex quinquefaciatus* was abundantly encountered and represent the highest percentage occurrence of 38.088% whereas *Anopheles gigas* contributed a minimum percentage occurrence of 5.563% among all species reported during the study period. In August 2019, maximum temperature and humidity recorded was 29.6 C/87% and minimum temperature and humidity was 17.5 C/66%. Precipitation observed was 155.5 mm. The maximum temperature and humidity observed during August, 2020 was 31.2 C/85% and minimum temperature and humidity was 18.6 C/69%. Overall study period suggested that maximum temperature and relative humidity supported the prevalence of mosquitoes. The precipitation recorded was 153.2 mm. In May 2019 and May, 2020, the rainfall observed was 150.9 mm and 138.0 mm, respectively, but the fluctuation in temperature and humidity does not favour the mosquito growth, thereby least density was observed. In other words, the requirement of an ideal temperature, rainfall and humidity is an essential variable for survival of mosquitoes in aquatic habitats.

**Keywords:** Mosquito, Meteorological factors, Temperature, Humidity, Precipitation

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## Introduction

Animal fauna comprising mosquitoes are most recognizing group of Culicids with slender proboscis, elongated–oval shaped wings, distinct abdominal segments and long-legged insects belonging to order Diptera (Han *et al.,* 2019). Mosquitoes harboring lentic biotic communities are able to adjust their biology to a wide variety of ecological conditions for breeding, growth and survival (Overgaard *et al*., 2002; Becker *et al*., 2012). The early stages (egg, larvae and pupae) being purely aquatic are crucial determinants of adult distribution and abundance (Paaijmans *et* *al*., 2007). Adult mosquitoes inhabiting terrestrial environments are not only the major sources of nuisance causing forms but also the causal agents of deadly and debilitating diseases through pathogen transmission. *Anopheles* mosquitoes used to transmit the pathogens in humans causing malaria. *Aedes aegypti* and *Aedes albopictus* infected female mosquitoes are major contributors responsible for transmitting dengue and chikungunya. Lymphatic filariasis (LF), a debilitating, neglected tropical disease (NTD) is transmitted by *Culex*, *Mansonia* and *Downsiomyia* genera of mosquitoes. Japanese encephalitis, an arboviral disease caused by *Culex*, *Anopheles* and *Mansonia* species through a zoonotic cycle between animals (pigs and/or water birds) and humans (Bhattacharyya *et al*., 2014; Attaullah *et al*., 2015). Both genera of *Aedes* and *Culex* are frequently associated with arbovirus transmission to humans (Tabachnick, 1991). Bhattacharyya *et al*. (2014) reported that 32 species of mosquitoes are responsible for causing dangerous vector borne diseases in India.

The influence of climate is significantly important in the propagation of both mosquitoes and mosquito borne diseases with detrimental impact on human populations. Mosquito-borne diseases are major contributors of morbidity and mortality by means of complex dynamism between environmental variables and social factors (Monaghan *et al.,* 2018) The climatic attributes govern mosquito life cycle events possibly by altering their activity, proliferation, longevity and survival in transient and permanent breeding habitats (Abai *et al*., 2016). Air temperature being an important extrinsic limiting climatic variable possibly not only facilitate the growth and development of many mosquito species but also regulates the various abiotic characteristics and biotic activities of an aquatic environment (Piyaratnea *et al*., 2005). The fluctuation in solubility of gases with increase in temperature (above 30 C) might be detrimental for many species (Clements, 1992; Bellingham, 2013). An upsurge in temperature generally leads in reducing interval between blood meals (Baba *et al*., 2013), shorten incubation periods (Githeko *et al*., 2000) and increase in biting frequency (Gimnig *et al*., 2002) in mosquitoes. Paaijmans *et al.* (2010) revealed that mean daily water temperature is generally higher than mean air temperature, which eventually assist in growth of immature forms. During summer periods, the rise in temperature results in gradual decrease in breeding sites and hugely impact larval and subsequent generation (Chovatiya, 2010). Chirebvu and Chimbari (2015) described that the tall plants covering aquatic environments reduces the exposure of light intensity, thereby induces a microbial growth (in turn produce a high variety of producers) and significantly may be highly detrimental for mosquito larvae population. Rainfall either increase or decrease the population of larvae by providing more breeding sites (in case of small habitats) or may flush them out (in case of large habitats), thereby maintain their variability. Previously colonized aquatic habitats inhabited by pathogens, competitors and predators may be flushed out by means of heavy rainfall and could increase the rate of mosquito survival ability and oviposition (Paaijmans *et al.,* 2010). Precipitation results in the availability of new breeding sites which enhance mosquito egg laying, feeding, metabolic rate and survivorship by maintaining a balancing relative humidity (50 to 60%) (Reiter, 2001; WHO, 2014). Humidity is a critical determinant to accomplish mosquito flight activity and host seeking behaviour. In dry atmospheric conditions, mosquitoes desiccate easily resulting in depletion of adult vectors. A relative humidity of at least 50 to 60% ensures prolonged mosquito survival and breeding sites for the mosquitoes to lay eggs (Asgarian *et al*., 2021). Furthermore climatic variables alter interactions among the mosquito species and subsequently result in an increase or decrease of their population in particular areas (Weicheld, 2015). Mosquito studies regarding their diversity and distribution in Kashmir valley have been conducted by previous workers from time to time in order to update the mosquito species prevalence across the Kashmir division of Jammu and Kashmir, union territory, India (Christophers, 1933; Barraud, 1934; Rao *et al*., 1973; Bhat and Kulkarni, 1983; Rao, 1984; Dar, 2018). There is a scarce information regarding mosquitoes abundance and distribution in relation to meteorological variables in Kashmir division (Jebanesan *et al*., 2012). At regional levels, India is drastically experiencing the wave of change in climate which is interlinked with global-scale alterations not only in its tropical and subtropical areas, but also in temperate areas. The Kashmir division falling in north-western Himalayan ranges is facing the challenge of variability in atmospheric temperature and precipitation in the last few decades (Zaz and Romshoo, 2013).The observations analyzed by them from 1980 to 2016 with prominent dynamics in air temperature and precipitation revealed increased trend in temperature during winter and autumn periods and considerable dip in precipitation during autumn season in high altitude regions of the valley.

The aim of the present study was to find out the impact of climatic characteristics (air temperature, precipitation and relative humidity) on the distribution and fluctuation patterns of mosquito species in selected localities of their breeding habitats in Kashmir. Moreover, a good understanding and knowledge regarding environmental variables might lead to find out the approach for the management and control strategies of mosquito population dynamics.

## Materials and Methods

*Study area:*

The present study was carried out in Baramulla district (altitude-1593, area-4,588 km$^2$, population- 1,008,039 and geographical coordinates- 34°19′80′′N latitude and 74°36′36′′E longitude) of Kashmir division situated in the lap of north-western Himalayas and both sides of the Jehlum river. It is endowed with unique habitat heterogeneity and unique topography, reservoir of important river tributaries including streams, ponds and lakes and variation in biological diversity. More than 80% of the population lives in rural areas due to which agriculture farming become the main source of livelihood. The climate is temperate and characterized to exhibit four distinct seasons notably spring (March-May), summer (June- August), autumn (September-November) and winter (December-February) (Zaz and Romshoo, 2013).

*Study site and period*:

The study sites/locations were mainly selected due to the availability of mosquito breeding points. The outdoor collections of immature mosquitoes were carried out from three sites-, Zaingeer, Sopore and Rafiabad in Baramulla district twice monthly from May to October, (2019 and 2020) including two different seasons namely summer and autumn.

*Larval sampling*:

*Mosquito culture and Identification*:

The properly labelled mosquito specimens (larvae and pupae) collected from different breeding sites were brought and maintained under ideal and controlled laboratory conditions in separate plastic and enamel culture trays (ambient temperature of 27±2 C, natural photoperiod cycle of 14L:10 D and 75%-85% Rh). Until adult emergence, larvae culture was fed brewer's yeast and dog biscuits (artificial food in 3:1 ratio) on regular basis. The pupae were noticed regularly and transferred to plastic jars kept in a wooden framed cage (40×40×40 cm) with front side enclosed with muslin cloth. The emerged adults were provided 10% sucrose soaked in cotton pad (placed in a petri plate at bottom edges of mosquito cage). Simultaneously, adults were picked with the help of mouth aspirator, narcotized and pinned on corks in glass vials for further investigation (Vanlalruia *et al*., 2014). During field collection trips, a few genera of mosquitoes were identified macroscopically. The larvae of *Anopheles* simply float horizontally to the surface of water and lack respiratory siphon; *Culex* bear a slender respiratory tube and create a certain angle to the water surface; respiratory tube of short stature with a certain angle to the surface of water, likely to be *Aedes*. Adults were

Table 1: Collection of total mosquito individuals across the localities of Baramulla district

| Baramulla | | 2019 | | 2020 | | Total Individuals |
|---|---|---|---|---|---|---|
| | | Summer | Autumn | Summer | Autumn | |
| **Mosquito species** | *Aedes aegypti* | 19 | 16 | 26 | 17 | **78** |
| | *Aedes albopictus* | 11 | 11 | 19 | 13 | **54** |
| | *Anopheles gigas* | 14 | 8 | 9 | 8 | **39** |
| | *Anopheles stephensi* | 17 | 13 | 21 | 15 | **66** |
| | *Culex mimeticus* | 17 | 11 | 17 | 10 | **55** |
| | *Culex quinquefasciatus* | 76 | 49 | 87 | 55 | **267** |
| | *Culex tritaeniorhynchus* | 19 | 15 | 16 | 12 | **62** |
| | *Culex vagans* | 23 | 13 | 27 | 17 | **80** |
| **Total** | | | | | | **701** |

counted and observed under Stereo zoom binocular microscope following systematic taxonomic keys (Christophers, 1933; Barraud, 1934; Tyagi *et al*., 2015).

*Meteorological data*:

The data regarding climatic variables namely temperature, rainfall and relative humidity was procured from Indian Meteorological Department, Meteorological center, Rambagh, Srinagar.

## Results

In the present faunistic study, mosquito immature collection tours were carried out across the selected localities/sites of Baramulla district between May to October, 2019 and May to October, 2020. A total of 701 mosquito individuals were reported from all the breeding points (permanent, semi-permanent and transient) studied (Table 1). The mosquitoes seasonally reported were mostly found abundantly in summer (n=418). Monthly collections illustrated that number of mosquitoes were recorded maximum in August and September (n=381) and minimum in May and June (n=76), respectively (Table 2, Fig. 1). Likewise at all the study sites, it was found that maximum number of mosquitoes (n=369) were reported in May to October, 2020 and the rest (n=332) during May to October, 2019.

The maximum density of mosquito specimens were recorded from Sopore (n=250) followed by Rafiabad (n=242) and Zaingeer (n=209) study localities (Figs. 2, 3, 4). Moreover, the taxonomical identification revealed eight mosquito species in the study area belonging to genus *Culex*, *Aedes* and *Anopheles*. Among all genera, the *Culex* genus dominated with four species, followed by *Aedes* and *Anopheles* with each two species. Among all species, the highest percentage occurrence of *Culex quinquefasciatus* (38.08%) and lowest percentage occurrence of *Anopheles gigas* (5.56%) were reported from all mosquito breeding environments. Furthermore, the impact of climatic variables is important extrinsic factor in assisting growth and density of mosquito vectors in lentic aquatic environments. Minimum population of mosquitoes were recorded in August, 2019 (n=100) and maximum in August, 2020 (n=106). In August, 2019 maximum temperature and humidity was 29.6 C/87% and minimum temperature and humidity was 17.5 C/66% and precipitation observed was 155.5 mm (Table 3). The maximum temperature and humidity observed during August, 2020 was 31.2 C/85% and minimum temperature and humidity was 18.6 C/69%. The precipitation recorded was 153.2 mm. In May 2019 and May 2020, the rainfall observed

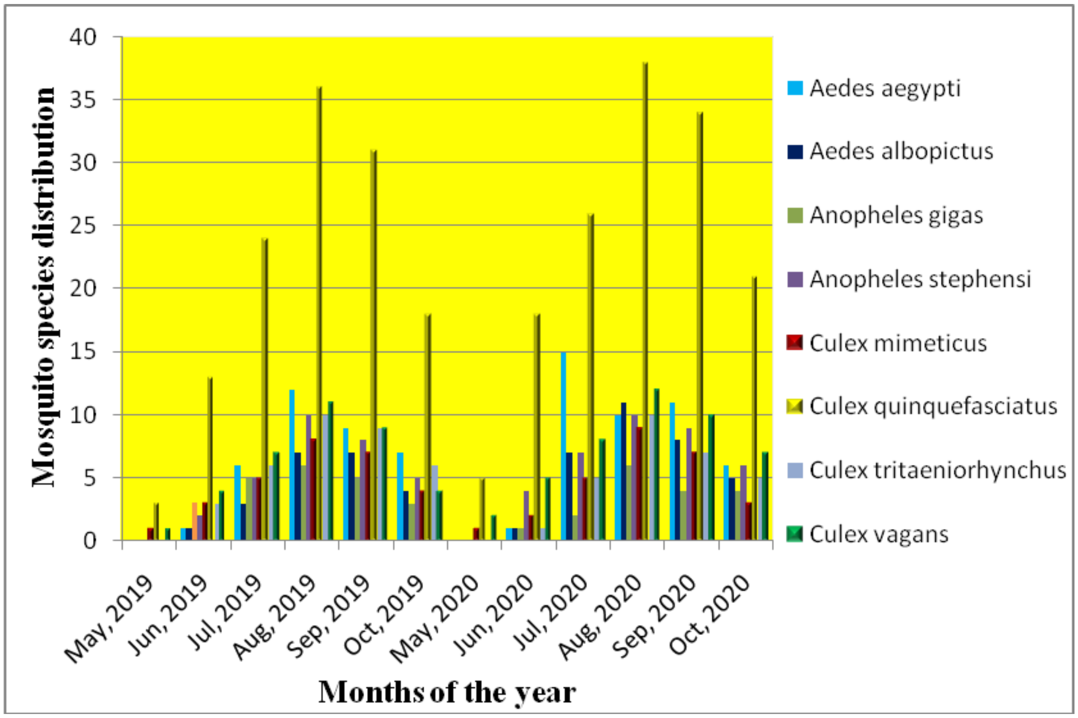


Fig 1: Monthly collection of individual mosquito species in study localities of Baramulla district.

Table 2: Monthly collection of individual mosquito species in study localities of Baramulla district

| **Mosquito species** | **Monthly distribution of mosquitoes** | | | | | | | | | | | | **Species percentage composition (%)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | May, 2019 | May, 2020 | Jun, 2019 | Jun, 2020 | Jul, 2019 | Jul, 2020 | Aug, 2019 | Aug, 2020 | Sep, 2019 | Sep, 2020 | Oct, 2019 | Oct, 2020 | |
| *Ae. aegypti* | 0 | 0 | 1 | 1 | 6 | 15 | 12 | 10 | 9 | 11 | 7 | 6 | 11.12 |
| *Ae. albopictus* | 0 | 0 | 1 | 1 | 3 | 7 | 7 | 11 | 7 | 8 | 4 | 5 | 7.70 |
| *An. gigas* | 0 | 0 | 3 | 1 | 5 | 2 | 6 | 6 | 5 | 4 | 3 | 4 | 5.56 |
| *An. stephensi* | 0 | 0 | 2 | 4 | 5 | 7 | 10 | 10 | 8 | 9 | 5 | 6 | 9.41 |
| *Cx. mimeticus* | 1 | 1 | 3 | 2 | 5 | 5 | 8 | 9 | 7 | 7 | 4 | 3 | 7.84 |
| *Cx. quinquefasciatus* | 3 | 5 | 13 | 18 | 24 | 26 | 36 | 38 | 31 | 34 | 18 | 21 | 38.08 |
| *Cx. tritaeniorhynchus* | 0 | 0 | 3 | 1 | 6 | 5 | 10 | 10 | 9 | 7 | 6 | 5 | 8.84 |
| *Cx. vagans* | 1 | 2 | 4 | 5 | 7 | 8 | 11 | 12 | 9 | 10 | 4 | 7 | 11.41 |

Table 3: Month-wise meteorological Variables of district Baramulla during Study period of May to October (2019 and 2020)

| Year | Months | Monthly Average Temperature (C) | | Average Humidity (%) | | Total Precipitation (mm) |
|---|---|---|---|---|---|---|
| | | Max | Min | 08:30 h | 17:30 h | |
| 2019 | May | 24.5 | 8.1 | 72 | 39 | 150.9 |
| | June | 24.9 | 12.9 | 75 | 41 | 242.4 |
| | July | 30.1 | 18.1 | 84 | 45 | 111.4 |
| | August | 29.6 | 17.5 | 87 | 66 | 155.5 |
| | September | 28.1 | 14.0 | 68 | 43 | 20.6 |
| | October | 20.8 | 7.32 | 69 | 40 | 54.9 |
| 2020 | May | 23.7 | 12.2 | 71 | 41 | 138.0 |
| | June | 25.4 | 17.4 | 74 | 32 | 35.0 |
| | July | 31.2 | 18.5 | 84 | 65 | 23.0 |
| | August | 29.8 | 18.6 | 85 | 69 | 153.2 |
| | September | 29.0 | 15.3 | 61 | 46 | 59.1 |
| | October | 25.0 | 3.0 | 71 | 43 | 1.4 |

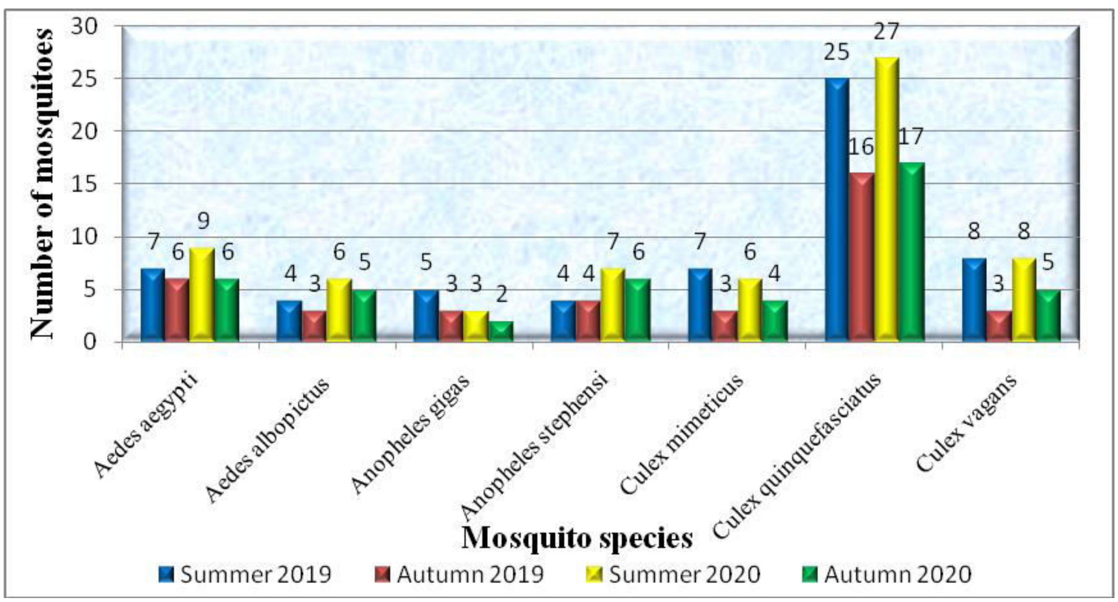


Fig. 2: Collection of mosquito individuals across the Zaingeer localities of Baramulla district.

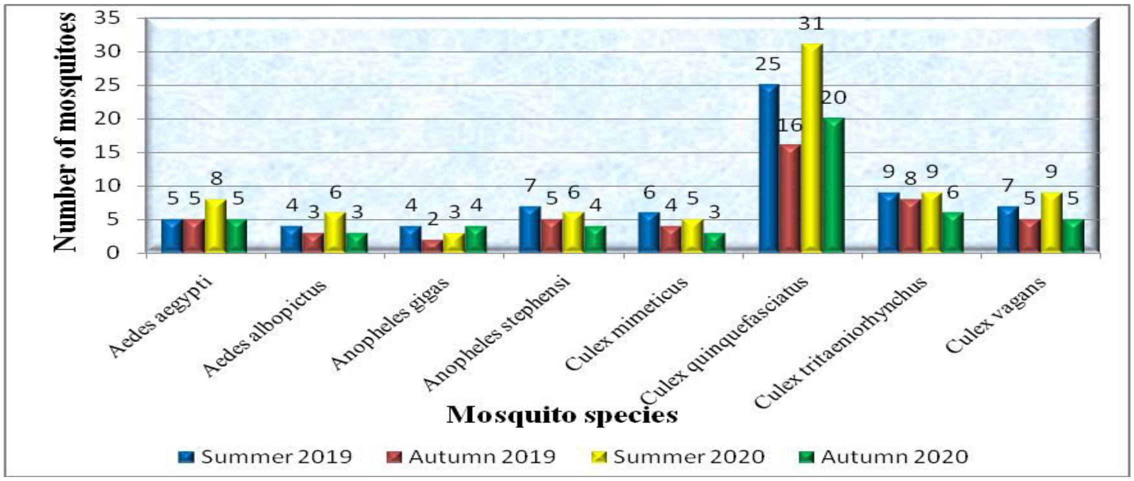


Fig. 3: Collection of mosquito individuals across the Rafiabad localities of Baramulla district.

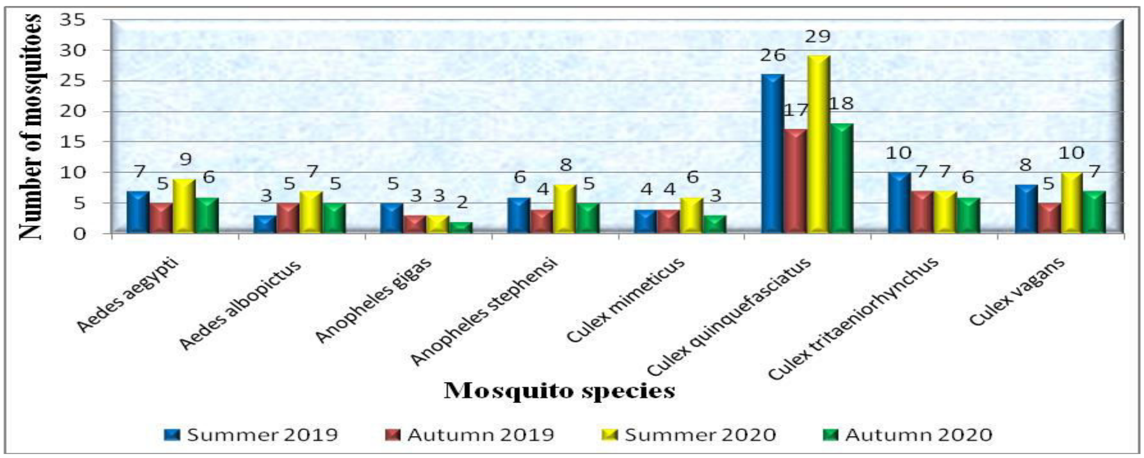


Fig. 4: Collection of mosquito individuals across the Sopore localities of Baramulla district.

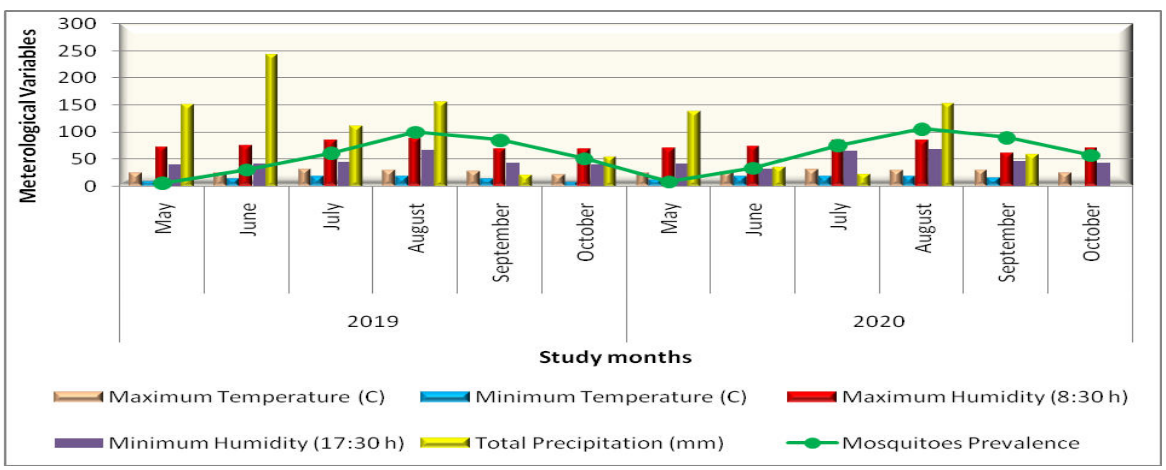


Fig. 5: Mosquito abundance reported in relation with meteorological variables during study period in Baramulla district.

was 150.9 mm and 138.0 mm, respectively, but the fluctuation in temperature and humidity does not favour the mosquito growth, thereby least density was observed (Fig. 5). In other words, the requirement of an ideal temperature, rainfall and humidity is an essential variable for survival of mosquitoes in aquatic habitats.

## Discussion

Mosquitoes evolved successfully on the planet earth over millions of years due to a broad range of habitat preference. In respect to medical and veterinary concern, mosquito diversity surveys have been carried out spatially and temporally in order to update the prevalence mosquito vector species involved in disease transmission (Devi and Jauhari, 2004; Vanlalruia *et al*., 2014; Selvan *et al*., 2015). The findings of the present study reported eight mosquito species belonging to three genera across the study area. The abundantly found *Culex* genera represent four species and the results are consistent with the previous work carried out on mosquito species composition in Virudhunagar, district, Tamil Nadu, India (Wilson *et al*., 2014). Across the study period, maximum number of mosquitoes increase their population in summer seasons (July and August) and tend to decrease subsequently in Autumn (October) season. Similar observations were studied by Ilahi and Suleman (2013) who investigated that mosquito collections were obtained maximum in June, July and August months. Jebanesan *et al*. (2012) also reported that the breeding potential and growth of mosquito vectors tend to increase in warmer months and the oviposition may take place in mid-June, July, August and September.The extrinsic factors (meteorological variables) govern mosquito life cycle stages possibly by altering their activity, proliferation, longevity and survival in transient and permanent breeding habitats (Abai *et al*., 2016) and influence the spread of mosquito vectors (Roiz *et al*., 2014). The present study reveals that the temperature recorded in the month May and June in 2019 (24.5 C) and 2020 (23.7 C), supported a low population of mosquitoes and is in accordance to the findings of Impoinvil *et al*. (2007) who studied mosquito dynamics in relation to fluctuation in temperature by affecting the hatching time of mosquito eggs. The present study highlighted that the maximum mosquitoes were recorded in between the temperature 28.1 C to 31.2 C and coincides with the study carried out previously by Simon-Oke and Olofintoye (2015). It has been studied that larval and adult mosquito population are highly modulated by the alteration in relative humidity. The suitable relative humidity between 61% to 87% was recorded in July, August and September and in turn prolong mosquito abundance and growth. Studies of Selvan *et al*. (2020) support our findings who have reported that mosquito survival rate increases with increase in relative humidity. Although it has been studied that high hatching rates are enhanced by high humidity and shows negative impact when humidity is relatively low (Hanson and Craig, 1994). Precipitation results in the availability of new breeding sites which enhance mosquito egg laying, feeding, metabolic rate and survivorship by maintaining a balancing relative humidity. The high amount of rainfall recorded during the present study supported maximum number of immature mosquito forms by providing more aquatic habitats. Gimnig *et al*. (2002) studied that previously colonized aquatic habitats inhabited by pathogens, competitors and predators may be flushed out by means of heavy rainfall and could increase the rate of mosquito survival ability and oviposition. Furthermore rainfall increases or decreases the population of immature stage mosquitoes by providing more breeding sites in case of small habitats or may flush them out in case of large habitats (Selvan *et al*., 2020).

## Conclusion

The present study investigates both seasonal and month-wise larval mosquito collections from different aquatic habitats and the impact of environmental factors on diversity and abundance of mosquito communities. Seasonal mosquito species composition discloses that the summer accommodates maximum number of mosquito individuals and it might be due to the availability of more aquatic environments. The mosquito peaks were recorded maximum during August and minimum in May. Moreover the genus, *Culex* was found abundantly and occupied most of the mosquito breeding habitats. The temperature, humidity and rainfall are important and inter-related variables enhancing mosquito survival rate and growth. Mosquitoes tend to decline in number with an increase in air temperature. Moreover high peaks of humidity coincided with higher amounts of precipitation relatively increases the incidence of mosquito population. It is important to mention that we are witnessing a global climate change and local seasonal variability of mosquito vector findings associated with meteorological factors might be effective in order to predict the status of dynamics in mosquitoes.

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