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*Original Article*

# OBSERVATION ON THE ROLE OF TEMPERATURE AND SALINITY ON THE DEVELOPMENT OF *CULICOIDES* SPECIES (DIPTERA: CERATOPOGONIDAE) IN LABORATORY

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## ABSTRACT

This article reviews the influence of various substrate salinity and temperature ranges on oviposition, larval survivability, and adult emergence during laboratory rearing. Habitat selection by the gravid females *Culicoides* spp. (Diptera: Ceratopogonidae) is influenced by physicochemical parameters such as temperature, pH, salinity, moisture, conductivity, and organic and inorganic compounds of substrates. These climatic and habitat related factors influence vectors' life history traits. The species-specific information will be useful in establishing a laboratory colony thereby contributing to our understanding of the vectorial capacity and competenceamongst different species of *Culicoides*.

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**Keywords:** *Culicoides*, salinity, temperature, vectors

## INTRODUCTION

Hematophagous biting midges of genus *Culicoides* Latreille (1809) (Diptera: Ceratopogonidae) are distributed mainly in the tropics and temperate regions of the world, except a few scattered geographical areas. These tiny flies are implicated as vectors of at least 50 arboviruses, several protozoans, and nematodes. The livestock population is affected worldwide by epizootic haemorrhagic disease virus, bluetongue virus (BTV), epizootic hemorrhagic disease virus and African horse sickness virus[1].In India, lack of life history-related data, larval food, captive mating, and artificial blood feeding are the main bottlenecks impeding the studies on vector competence as well as the establishment of successful laboratory colonies of the vector species[2,3]. Naturally, the immatures of these flies prefer areas like muddy fringe areas of stock ponds, shaded muddy pool margins, muddy areas of paddy fields, and cattle manure[4,5,6,7]. Very few species have so far been laboratory-reared, and colonies maintained within the laboratory. Out of the 23 species attempted to rear under laboratory conditions[2,3,8,9,10,11] only colonies exist for only two species of, *Culicoides sonorensis* Wirth and Jones and *Culicoides nubeculosus* (Meigen) are maintained[2]. The rearing procedure and conditionalities of the most prevalent vector species, *Culicoides peregrinus* Kieffer, were performed in the laboratory with a good amount of success[3].The growth and development of this vector species were studied mainly by following habitat-specific temperature ranges and other physicochemical parameters. However, information about species-specific rearing temperature ranges and suitable substrate salinity was unavailable. At different rearing temperature ranges, the rearing of several *Culicoides* spp. was examined, such as *Culicoides variipennis* (Coquillett)[12], *Culicoides arakawae* (Arakawa), *Culicoides maculatus* (Shiraki)[8], *Culicoides brevitarsis* Kieffer[13], *Culicoides (Avaritia) imicola* Kieffer[14]. Besides, the oviposition site selection of these vectors depends on the suitable temperature and the physicochemical factors of these habitats[14,15,16]. Therefore, the peak abundance of these vectors and the appearance of bluetongue disease are related to suitable habitats as well as climatic variations[17]. Thus, in the southern states of India, peak abundance of *Culicoides* and BTD outbreaks was reported in the monsoon period[18], but became low in abundance during post-monsoon[19]. The primary purpose of this article is to explore the tolerance temperature range and substrate salinity of *Culicoides* spp. and how it affects oviposition, larval survivability, and adult emergence. This information provides evidence about the characteristics of the breeding sites and suitable parameters for their adequate survivability.

## MATERIAL & METHODS

Investigation on the influence of rearing temperature was performed in laboratory and on field collected species[19,22,26,27]. In laboratory different temperatures was selected for that purpose[12,13,14,21,23]. To observe the effect of substrate salinity, gravid individuals were placed in oviposition glass vials and oviposition beds were prepared with different concentration of saline water[3,30,33,34,35]. This review was on considered field collected species from different habitat with analysis of physiochemical parameters[15,16,26,27,28,29].

## OBSERVATIONS

### (i) Rearing Temperature

According to the preference performance hypothesis[20], gravid females can detect the ambient temperature to determine maximum larval survivability. It was observed that the development success and duration of different life stages of *C. variipennis* were influenced by rearing temperatures such as larval development was completed within 11-24 days at 25°C, 27°C and 30°C whereas fast development within 8-18 days at higher temperature (35°C). The larval development was delayed (23-48 days) at the low temperature of 20°C[12]. In *C. brevitarsis* more than 80% of fourth instar larval survivability was recorded between 26°C and 30°C[13]. The development and duration of *C. arakawae* and *C. maculatus* were recorded at different rearing temperatures[8]. A higher percentage of pupation was observed in both species at 22.5°C. The duration from egg to adult in both species was prolonged (> 40 days), with a higher mortality rate of 20°C. Larval development ceased for both species in low temperatures (15-16°C), and *C. arakawae* and *C. maculatus* pupation did not occur at 35°C and above 30°C, respectively. The highest percentage of egg hatching and survivability occurred in *Culicoides circumscriptus* Kieffer and *Culicoides paolae* Boorman with a 1:1 sex ratio at 25°C and 30°C, respectively[21]. The most suitable rearing temperature for *Culicoides obsoletus* (Meigen)with the highest developmental success was 24°C, but the sex ratio was 3:1, male: female[22]. This sex ratio became 1:1 at 16-20°C with decreased pupal development. *Culicoides imicola* Kieffer showed the highest larval survivability at a lower temperature 20°C, with delayed development time[14]. Such an experiment was performed with vector species of *C. peregrinus,* and it was noted that 26°C was the ambient temperature for the highest oviposition (70%) and survivability. Duration of pupation was extended (25-39 days) in lower temperatures; 15°C, and 20°C[23]. From these observations, it can be stated that a non-linear relationship exists between rearing temperature and larval survivability. At low-temperature pupation was recorded as 0% and it peaked up to 81% at 26°C later when the temperature increased to 35°C the pupation dropped to 4%. This information could give insight into the possible thermal preference range (20-56°C) of populations to environmental conditions, thereby increasing the understanding of vector distribution and population changes over time. The thermal tolerance in the field conditions may vary greatly depending on the environmental conditions, and geographic location determines the abundance of these vectors.

### (ii) Substrate Salinity

Immature distribution of *Culicoides* spp. depends on habitat availability as well as the physicochemical factors of habitats, i.e., moisture, dissolved oxygen, pH, salinity, organic contents and conductivity[15,16]. Thus, the occurrence of species richness and distribution of *Culicoides* spp. determined by the interactions of the physicochemical parameters. Worldwide *Culicoides* species showed a widespread habitat distribution from freshwater to coastal areas such as *Culicoides crepuscularis* Malloch, and *Culicoides bermudensis*Williams found in freshwater in the United States, but in Bermudas, these species are associated with a salinity range of 1.2 to 36.2 parts per thousand (ppt)[24]. The *Culicoides furens* (Poey) were also reported from salt marsh and freshwater while *Culicoides mississippiensis* Hoffman from salt marsh areas of Florida in low abundance[25]. *Culicoides melleus* (Coquillet), *Culicoides hollensis* (Melander and Brues), and *C. furens* were isolated from the salt marshes of Georgia[26]. The levels of dissolved salts influence the suitability of aquatic habitats for immature populations of the *C. variipennis* complex[15]. However, the highest abundance of the larval habitat of *Culicoides distinctipennis* Austen was in the freshwater lake edges[27]. *Culicoides furens* showed a wider habitat range in both salt marsh and freshwater habitats[25]. The soil chemistry characteristics substrate was examined for*Culicoides pelilioensis* Tokunaga, of Hooghly estuary[28], while a similar investigation was done for *C. variipennis*, *C. sonorensis* and *Culicoides occidentalis* Wirth and Jones throughout their geographic ranges[29] and various *Culicoides* spp.[16]. Habitat parameters show variations within seasons and for species[29,16].

## DISCUSSION

Laboratory-based studies were also reported for the oviposition site preference and the emergence of *Culicoides* are stimulated by different salinity of habitat i.e., in *C. imicola*[30], *C. obsoletus*[31] and *Culicoides impunctatus* Goetghebuer[32]. Salt concentration below 0.06 g 10 $ml^{-1}$ was selected in *C. imicola* as the preferable oviposition substrate[30] whereas *Culicoides variipennissonorensis* (Coquillett) females also chose to oviposit in 0‰ rather than 19‰. Still, it was noticed that no eggs were laid on 34‰[33]. Oviposition and survivability of *C. peregrinus* were gradually affected when exposed to high salinity; 30-40 ppt[34]. Many oviposited eggs were deposited in 0 ppt but reduced sharply in 5 ppt and then continuously decreased to 20 ppt. Oviposited eggs were not observed in 30 ppt to 40 ppt salinity. Egg retention was observed in stressful high saline concentrations. The hatching rate of eggs was highest at 0 ppt (without salt) and gradually decreased with increasing salinity. The hatching duration has not differed with salinity. The larval survivability and pupation recorded maximum in 0 ppt and significantly reduced in 25 ppt[34]. The developmental period from egg to adult was about 18-23 days in the control condition ( without salt)[3], but it became delayed in high salinity with increasing mortality.Similarly, all the immatures of *Culicoides molestus* (Skuse) were died at three to four times the salinity of seawater[35]. They opined that seawater salinity could be an essential factor of habitat suitability for *C. molestus* immatures. The higher saline concentrations of seawater inhibit the survivability and maturation of immatures of *C. molestus*, whereas lower concentrations of natural seawater are more suitable for survivability. A correlation between larval habitat and salinity has been established for several *Culicoides* species[36,37]. *Culicoides circumscriptus* and *C. furens* could survive in hypersaline water, i.e., 1.5 times and three times that of seawater, respectively[38]. The increased larval mortality in higher salinity indicates that salt concentration may be responsible for disrupting the larval osmotic homoeostasis by gain of ions and loss of water.

## CONCLUSION

Substrate parameters and environmental conditions play a vital role in habitat selection and survivability of *Culicoides* spp. The survival of *Culicoides* spp. was maximum during rearing, with temperatures ranging from 20-26°C. During inconducive conditions, the mortality rate increased with an altered sex ratio. In the laboratory alterations in sex ratios affect mating experiments. Likewise, temperature ranges affect the vector species' distribution, ultimately linked to the outbreak of diseases worldwide. Most species adapted to low salinity with increased salinity but very few species tolerated >2 ppt salinity. As larval mortality increased, their survivability was significantly affected in the higher salinity range. Our understanding of these parameters will help establish a laboratory colony, ultimately generating information about disease epidemiology and the vectorial capacity of these vectors. The emergence of bluetongue virus and other *Culicoides*-borne arboviruses are dependent on environmental drivers[39]. Previous studies reported the pattern of *Culicoides*-borne disease in tropical endemic areas related to climatic factors, primarily temperature and rainfall[40]. Besides several other factors like vegetation, physiochemical parameters of habitat and hosts greatly influence the abundance of vector species which are related to the appearance of disease outbreak and vectorial capacity[39].

## REFERENCES

1. Purse BV, Carpenter S, Venter GJ, Bellis G, Mullens BA. Bionomics of temperate and tropical *Culicoides* midges: knowledge gaps and consequences for transmission of *Culicoides* borne viruses. Annu Rev Entomol. 2015; 60: 373-392.
2. Nayduch D, Cohnstaedt LW, Saki C, Lawson D, Kersey P, Fife M, Carpenter S. Studying *Culicoides* vectors of BTV in the post–genomic era: resources, bottlenecks to progress and future directions. Virus Res. 2014; 182: 43-49.
3. Harsha R, Mazumdar A. Laboratory rearing of *Culicoides peregrinus* Kieffer (Diptera: Ceratopogonidae), a potential vector of Bluetongue disease. Med Vet Entomol. 2015; 29: 434-438.

4. Edwards FW. On some Malayan and other species of *Culicoides*, with a note on the genus *Lasiohelea*. Bull Entom Res. 1922; 13: 161-167.
5. Buckley JJC. On *Culicoides* as a vector of *Onchocerca gibsoni* (Cleland and Johnston, 1910). J Helminthol. 1938; 16: 121-158.
6. Das Gupta SK. Breeding habitats of Indian *Culicoides* (Diptera: Ceratopogonidae). Curr Sci. 1962; 31: 465-466.
7. Wirth WW, Hubert AA. The *Culicoides* of South East Asia (Diptera: Ceratopogonidae). Mem Amer Ent Inst. 1989; 44: 228-232.
8. Kitaoka S. Effects of rearing temperature on length of larval period and size of adults in *Culicoides arakawae* and *Culicoides maculatus* (Dipteria: Ceratopogonidae). Natl Inst Anim Health Q. 1982; 22: 159-162.
9. Narladkar BW, Deshpande PD, Shivpuje PR. Bionomics and life cycle studies on *Culicoides* sp. (Diptera: Ceratopogonidae). Vet Parasitol. 2006; 20: 7-12.
10. Barceló C, Miranda MA. Bionomics of livestock-associated *Culicoides* (biting midge) bluetongue virus vectors under laboratory conditions. Med Vet Entomol. 2018; 32: 216-225.
11. Erram D, Burkett-Cadena N. Laboratory rearing of *Culicoides stellifer* (Diptera: Ceratopogonidae), a suspected vector of Orbiviruses in the United States. J Med Entomol. 2019; 57: 25-32.
12. Akey DH, Potter HW, Jones RH. Effects of rearing temperature and larval density longevity, size and fecundity in the biting gnat *Culicoides variipennis*. Ann Entomol Soc Am. 1978; 71: 411-418.
13. Allingham PG. Effect of temperature on late immature stages of *Culicoides brevitarsis* (Diptera: Ceratopogonidae). J Med Entomol. 1991; 28: 878-881.
14. Veronesi E, Venter GJ, Labuschagne K, Mellor PS, Carpenter S. Life-history parameters of *Culicoides (Avaritia) imicola* Kieffer in the laboratory at different rearing temperatures. Vet Parasitol. 2009; 163: 370-373.
15. Schmidtmann ET. Testing the relationship between dissolved salts in aquatic habitats and immature populations of the *Culicoides variipennis* complex (Diptera: Ceratopogonidae). Environ Entomol. 2006; 35: 1154-1160.
16. Uslu U, Dik B. Chemical characteristics of breeding sites of *Culicoides* species (Diptera: Ceratopogonidae). Vet Parasitol. 2010; 169: 178-184.
17. Prasad G, Sreenivasulu D, Singh KP, Mertens PPC, Maan S. Bluetongue in the Indian subcontinent. In Mellor PS, Baylis M, Mertens PPC (eds), Bluetongue. 2009; Paris: Elsevier, pp. 167-195.
18. Sreenivasulu D, Subba Rao MV, Reddy YN, Gard GP. Overview of bluetongue disease, viruses, vectors, surveillance and unique features: The Indian sub-continent and adjacent regions. Vet. Ital. 2004; 40: 73-77.

19. Harsha R, Mazumdar SM, Mazumdar A. Abundance, diversity and temporal activity of adult *Culicoides*spp. associated with cattle in West Bengal, India. Med Vet Entomol. 2020; 34: 327-343.
20. Jaenike J. On optimal oviposition behavior in phytophagous insects. Theor Popul Biol. 1978; 14: 350-356.
21. Barceló C, Miranda MA. Development and lifespan of *Culicoides obsoletus* ss (Meigen) and other livestock-associated species reared at different temperatures under laboratory conditions. Med Vet Entomol. 2020; 35: 187-201.
22. Van den Eynde C, Sohier C, Matthijs S, De Regge N. Temperature and food sources influence subadult development and blood-feeding response of *Culicoides obsoletus(sensu lato)* under laboratory conditions. Parasit Vectors. 2021; 14(1): 300.
23. Banerjee P, Sarkar A, Harsha R, Mazumdar A. Influence of rearing temperatures on oviposition and survivability of developmental stages of *Culicoides peregrinus* vector of bluetongue virus with a note on egg viability. Proc Zool Soc. 2024; 1-8.
24. Williams RW. The biting midges of the Genus *Culicoides* in the Bermuda Islands (Diptera, Heleidae) II. A study of their breeding habitats and geographical distribution. J Parasitol. 1956; 42: 300-305.
25. Kline DL, Wood JR. Habitat preference of coastal *Culicoides* spp. at Yankeetown, Florida. JAMCA. 1988; 4: 456-465.
26. Magnon GJ, Hagan VH. Seasonal abundance of *Culicoides* spp. (Diptera: Ceratopogonidae) in Coastal Georgia. Environ Entomol. 1988; 17: 67-74.
27. Bakhoum MT, Fall AG, Seck MT, Fall M, Ciss M, Garros C, Bouyer J, Gimonneau G, Baldet T. Physicochemical factors affecting the diversity and abundance of Afrotropical *Culicoides* species in larval habitats in Senegal. Acta Trop. 2021; 220: e105932.
28. Ray S, Choudhury A. Population ecology of *Culicoides peliliouensis* Tok. in the Hooghly Estuary, Sagar Island, India. Insect Sci. 1988; 9: 17-25.
29. Schmidtmann ET, Bobian RJ, Belden RP. Soil chemistries define aquatic habitats with immature populations of the *Culicoides variipennis* complex (Diptera: Ceratopogonidae). J Med Entomol. 2000; 37: 58-64.
30. Venter G, Boikanyo S. Preliminary studies on oviposition site preferences of *Culicoides imicola*. Rev Elev MédVét Pays Trop. 2008; 62: 81-180.
31. Harrup LE, Purse BV, Golding N, Mellor PS, Carpenter S. Larval development and emergence sites of farm-associated *Culicoides* in the United Kingdom. Med Vet Entomol. 2013; 27: 441-449.
32. Blackwell A, Lock KA, Marshall B, Boag B, Gordon SC. The spatial distribution of larvae of *Culicoides impunctatus* biting midges. Med Vet Entomol. 1999; 13: 362-371.
33. Linley JR. The effect of salinity on oviposition and egg hatching in *Culicoides variipennis sonorensis* (Diptera: Ceratopogonidae). JAMCA. 1986; 2: 79-82.

34. Banerjee P, Sarkar A, Mazumdar A. Effect of substrate salinity and pH on life history traits of the bluetongue virus vector *Culicoides peregrinus*. Bull Entom Res. 2023; 113(6): 829-837.
35. Brei B, Cribb BW, Merritt DJ. Effects of seawater components on immature *Culicoides molestus* (Skuse) (Diptera: Ceratopogonidae). Aust J Entomol. 2003; 42: 119-123.
36. Kardatzke JT, Rowley WA. Comparison of *Culicoides* larval habitats and populations in central Iowa. Ann Entomol Soc Am. 1971; 64: 215-218.
37. Lardeux FJ, Ottenwaelder T. Density of larval *Culicoides belkini* (Diptera: Ceratopogonidae) in relation to physicochemical variables in different habitats. J Med Entomol. 1997; 34: 387-395.
38. Becker P. Observations on the life cycle and immature stages of *Culicoides circumscriptus* Kieffer (Diptera, Ceratopogonidae). Proc R Soc Edinb. 1961; 67: 363-387.
39. Chanda MM, Carpenter S, Prasad G, Sedda L, Henrys PA, Gajendragad MR, Purse BV. Livestock host composition rather than land use or climate explains spatial patterns in bluetongue disease in South India. Sci Rep. 2019; 9: 1-15.
40. Geoghegan JL, Walker PJ, Duchemin JB, Jeanne I, Holmes EC. Seasonal drivers of the epidemiology of arthropod-borneviruses in Australia. PLOS Negl Trop Dis. 2014; 8: e3325.

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