Hemipteran diversity in aquatic ecosystems of Rajasthan and their potential as mosquito bio control agent

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ABSTRACT

Rajasthan has a large diversified aquatic and semi aquatic entomofauna inhabiting water spread areas. They act as pests and vectors for deadly diseases, specifically mosquitoes which are considered most deadly worldwide. Mosquito eggs, larvae, and pupal stages are aquatic, so these are common food source for many aquatic invertebrates. In the present study seven families of Nepomorpha and five families of Gerromorpha, along with five genera of mosquitoes were documented from the aquatic and semi aquatic ecosystems of Rajasthan. According to many experimental studies conducted to understand the interaction between Hemipterans and mosquitoes, found some Hemipteran families like Corixidae (water boatmen), Notonectidae (backswimmers), Belostomatidae (giant water bugs)as predators of Mosquito larvae. The present study lists 50 species of hemipterans from 12 families and a subfamily that indicates the environment of Rajasthan is in favor of their survival and growth, so they can be introduced in the areas where they are not found naturally and can be a major factor in managing mosquito population.

Keywords: Mosquito, Hemiptera, Interaction, Predators
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INTRODUCTION

Despite being a dry region, Rajasthan has plenty of lentic ecosystems; it has large reservoirs, waterlogged areas, ponds, and lakes and has a total of 3 lakh hectares of water-spread areas (Sharma, 2020). Consequently, Rajasthan also has a large diversified aquatic and semi aquatic entomofauna inhabiting water spread areas. A recent study by Prajapat and Meena (2021) documented 878 insect species from Rajasthan; however, furthermore studies are required to get insect biodiversity of Rajasthan state. Insects have important role as supporters and regulators of ecosystem services such as involvement in the flow of nutrients and energy, etc (Crespo-Perez *et al.,* 2020). In addition, they also act as pests and vectors for deadly diseases (Belluco *et al.,* 2023), specifically mosquitoes which are considered most deadly worldwide (Breedlove, 2022).

Mosquitoes bear a cosmopolitan nature. They are distributed all around tropical and temperate areas of the world, so far 3724 species were known, and many more are yet to be found and identified (What's New? | Mosquito Taxonomic Inventory, n.d., January 2024). Mosquitoes have also played considerable role in the process of human evolution as they apply the selective forces by spreading infectious diseases (Yee *et al.,* 2022). Out of the total, 404 species of 50 genera were reported from India under two subfamilies (12 tribes) *viz.,* Culicinae, with 341 species, followed by the subfamily Anophelinae with 63 species (Tyagi *et al.,* 2015).

According to a report from National Center for Vector Borne Diseases Control (NCVBDC) India witnessed 233251 cases of dengue in year 2022, out of which 13491 cases were recorded only from Rajasthan which is the fourth highest in India (Ministry of Health and Family Welfare-Government of India) indicating a large mosquito population in Rajasthan that exhibits notable medical importance. In low-income countries,

mosquito borne diseases are being in top 10 leading causes of death (Kittichai *et al.,* 2023). Mosquitoes were introduced all over the world due to trade and travel, and now they are the most threatening vector of numerous deadly diseases (Van Wilgen, 2017). It is expected that by 2050, approximately half of the world population will be at risk of arbovirus transmission (Kraemer *et al.,* 2019). Apart from their medical importance, they also play an important role in ecological interactions; they are involved in prey-predator interactions with other aquatic insects, especially Hemipterans (Sareein *et al.,* 2019).

Order Hemiptera holds diversity of worldwide 104,000 species belonging to 302 families with 142 extinct and 78 extant families (Szwedo, 2016). India also bears a well-diversified population of Hemipterans in both aquatic and terrestrial habitats, consisting more than 77 families with over 6500 species, which holds 8.6 % of the total known Hemipterans (Belamkar, 2012). Out of these, 2421 are endemic to India, particularly 284 species from 79 genera, and 15 major families were documented as aquatic and semi-aquatic Hemipterans (Z.S.I., 2010).

Generally, Hemipterans are terrestrial but are simultaneously found in aquatic habitats as well (Lancaster and Downes, 2018). They have various feeding mechanisms most of them feed on plants as their mouthparts are of piercing and sucking types (Wang and Dai, 2017), on the other hand they also possess predatory nature and are being used against the pests of agricultural system as bio control agents (Qu *et al.,* 2023). Hemipterans from infraorder Gerromorpha and Nepomorpha, the aquatic and semi-aquatic bugs, respectively (Men *et al.,* 2022b) are more important to be studied because according to a study in waterlogged paddy fields of Barak Valley, Assam by Saha (2019), they were recorded as predators to other insects, Prey-Predator interaction between Hemipteran and Mosquitoes is an aspect that can help to manage the mosquito population (Vinogradov *et al.,* 2022). The present study concludes the possibility, whether mosquito population in Rajasthan can be managed by means of prey-predatory interaction between mosquitoes and Hemipterans by documenting the mosquito and aquatic and semi-aquatic Hemipteran fauna in Rajasthan.

Methodology

A systemic review was commenced by using a method involving the following steps: identifying the time horizon of available studies, database, journal, and article selection, article classification, and raw data was extracted.

The study covers the different time periods as per the different parts of the study and the available literature. Here, the mosquito diversity literature is covered from 1933 to 2023, the Hemipteran diversity literature is recorded from 2002 to 2023, and the interaction between these two has been studied from 1939 to 2022.

For literature surveys, the most commonly used databases have been used, viz., Google Scholar, PubMed, Science Direct. The topics of mosquito biocontrol, Hemipteran and mosquito diversity have been a topic of interest among researchers, but their publications are scattered in different journals. So, to broaden our search and cover all the available publications, a list of specific journals was not selected. Several journals in bio control and diversity domains were gone through. Since, mosquito population management and Hemipetran and mosquito diversity were the topics of interest, broad terms like mosquito biocontrol, Hemipteran diversity in Rajasthan, mosquito diversity in Rajasthan have been used to ensure that no literature was missed. In addition to keyword searches, terms such as mosquito predation, predatory Hemipterans, Hemipterans as bio control agents, aquatic entomofauna of Rajasthan, mosquito abundance were used. Using these terms, articles were selected with relevant context. A total of 61 articles were selected, the final step was categorization of selected articles according to the three different themes, viz., Hemipteran diversity in Rajasthan, mosquito diversity in Rajasthan, and interaction between Hemipterans and mosquitoes.

Here, the literature found related to Hemipteran diversity was primarily from the studies of the

Zoological Survey of India; these studies were done in ecologically important parts of Rajasthan, such as Ranthambhore National Park (Z.S.I., 2010). These studies were included on the basis of their title's relevance to the present study. Other sources of articles related to Hemipteran diversity were the faunal studies of major water bodies in Rajasthan, like the Anasagar Lake of Ajmer (Sharma, 2015), Pushkar Lake of Ajmer (Tak and Srivastva, 2015), Sethani Ka Johra of Churu (Ruksana, 2017), Kot Bandh of Jhunjhunu (Bugalia,. 2020), Pichhola Lake of Udaipur (Naz *et al.,* 2021). Also, some studies were done in the pond ecosystems of Rajasthan. These articles were included on the basis of their in-text information.

Mosquito diversity articles were mostly related to studies of the outbreak of mosquito-borne diseases; along with that, some studies discussing the increasing mosquito population and diversity due to canalization in the western part of Rajasthan were included. Articles focused on biological approaches to mosquito population management, the predatory nature of Hemipterans, and the interaction of mosquitoes and Hemipterans were included. The selected literature was thoroughly studied, and data was extracted.

RESULTS AND DISCUSSION

Hemipteran Diversity

A study was conducted by Prajapat and Meena, (2021) aiming to understand the diversity structure of insects in four different eco-geographical areas of Rajasthan, according to the study, Hemipterans are dispersed across the different geographical divisions of Rajasthan. The highest number of species were recorded from the Eastern Plains. Other studies claims that they were among the most common insects in the Aravalli, Hadoti (Kulshrestha, 2016) and Northeastern plains (Z.S.I.,2010), in a recent study by Lyngdoh *et al.,* (2021), 34 species of aquatic and semi aquatic of Hemipterans from 19 genera were documented.

Different studies in aquatic and semi aquatic ecosystems of Rajasthan have been done, exhibiting a wide range of insect fauna. Studying these online research publications helps in consolidating the data more precisely.According to the information available in literature, in the present study 50 species from 12 families and a sub family (Halobatinae) of aquatic and semi aquatic Hemipteran fauna were documented. From Rajasthan, seven families of Nepomorpha *viz.,* Corixidae (water boatmen), Notonectidae (Backswimmers), Belostomatidae (Giant water bugs), Nepidae (water scorpions), Micronectidae (Pygmy water boatman), Ochteridae, and Pleidae (Pygmy back swimmers) were recorded (Fig 1). The species were as following; Corixidae: *Agraptocorixa hyalinipennis* (Fabricius, 1803) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Lyngdoh *et al.,* 2021), *Corixa lima* (Distant) (Srivastava, 2014; Tak and Srivastva, 2015; Sharma, 2015; Tak, 2015; Rukasana, 2015; Rukasana, 2017; Srivastava, 2018; Bugalia,. 2020; Srivastava, 2020; Srivastava, 2023), *Corixa punctuate* (Illiger, 1807). (Naz *et al.,* 2021), *Sigara pectoralis* (Fieber, 1851) (Rukasana, 2015; Rukasana, 2017; Srivastava, 2018; Srivastava, 2020), *Sigara promontoria* (Distant, 1910) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Lyngdoh *et al.,* 2021), *Sigara seistanensis* (Distant, 1920) (Thirumalai, 2007; Lyngdoh *et al.,* 2021), Belostomatidae: *Diplonychus annulatus* (Fabricius, 1781) (Thirumalai, 2007; Z.S.I., 2010; Lyngdoh *et al.,* 2021), *Diplonychus molestus* (Dufour) (Lyngdoh *et al.,* 2021), *Diplonychus rusticus* (Fabricius, 1781) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Z.S.I., 2010; Lyngdoh *et al.,* 2021), *Lethocerus indicus* (Le Peletier & Serville, 1825) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Z.S.I., 2010; Srivastava, 2018; Lyngdoh *et al.,* 2021), Notonectidae: *Anisops barbatus* (Brooks, 1951) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Lyngdoh *et al.,* 2021), *Anisops bouvieri* (Kirkaldy, 1904) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Lyngdoh *et al.,* 2021), Anisops cavifrons (Brooks, 1951) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Lyngdoh *et al.,* 2021), *Anisops sardeus* (Herrich-Schaeffer, 1849) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Lyngdoh *et al.,* 2021), *Anisops*

cambelli (Brooks, George T., 1951) (Thirumalai, 2007; Z.S.I., 2010; Lyngdoh *et al.,* 2021), *Enithares ciliate* (Fabricius, 1798) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007), *Enithares fusca* (Brooks, 1948) (Lyngdoh *et al.,* 2021), *Enithares mandalayensis* (Distant, 1910) (Lyngdoh *et al.,* 2021), *Enithares unguistris* (Zettel, 2012) (Lyngdoh *et al.,* 2021), *Notonecta glauca* (Linnaeus, 1758) (Srivastava, 2014; Tak and Srivastva, 2015; Sharma, 2015; Tak, 2015; Rukasana, 2015; Rukasana, 2017; Srivastava, 2018; Bugalia,. 2020; Srivastava, 2020; Srivastava, 2023), *Notonecta undulate* (Say, 1832) (Rukasana, 2015; Rukasana, 2017; Srivastava, 2023), *Nychia sappho* (Kirkaldy, 1901) (Lyngdoh *et al.,* 2021), Nepidae: *Laccotrephes griseus* (Guerin-Meneville, 1835) (Thirumalai, 2002; Thirumalai, 2007; Z.S.I., 2010; Lyngdoh *et al.,* 2021), *Laccotrephes maculates* (Fabr., 1775) (Srivastava, 2014: Sharma, 2015; Tak, 2015; Tak and Srivastva, 2015; Srivastava, 2018; Bugalia,. 2020; Srivastava, 2020; Srivastava, 2023), *Laccotrephes rube*r (Linnaeus, 1764) (Thirumalai and Ramakrishna, 2002; Z.S.I., 2010; Lyngdoh *et al.,* 2021), *Nepa cinerea* (Linnaeus, 1758) (Tak and Srivastva, 2015; Sharma, 2015; Tak, 2015; Rukasana, 2015; Rukasana, 2017; Srivastava, 2018), *Ranatra elongate* (Fabricius 1790) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Naz *et al.,*2021; Lyngdoh *et al.,* 2021), *Ranatra filiformis* (Fabricius, 1790) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Lyngdoh *et al.,* 2021), *Ranatra linearis* (Linnaeus, 1758) (Naz *et al.,*2021), *Ranatra nigra* (Herrich-Schaeffer, 1849) (Thirumalai and Ramakrishna, 2002; Srivastava, 2023), Ranatra varipes (Stal, 1861) (Lyngdoh *et al.,* 2021), Micronectidae: Micronecta quadristrigata (Breddin, 1905) (Thirumalai & Ramakrishna, 2002; Thirumalai, 2007; Lyngdoh *et al.,* 2021), Micronecta scutellaris (Stal, 1858) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Lyngdoh *et al.,* 2021), Ochteridae: *Ochterus marginatus* (Latreille, 1804) (Lyngdoh *et al.,* 2021), Pleidae: *Paraplea buenoi* (Kirkaldy, 1904) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2007; Lyngdoh *et al.,* 2021), *Paraplea frontalis* (Fieber, 1844) (Thirumalai and Ramakrishna, 2002).

Infraorder Gerromorpha consists of eight families (Santos *et al.,* 2021), out of which five were reported from Rajasthan *viz.*, Gerridae (Water striders) Hydrometridae (Water measures), Mesoveliidae (Pondweed bugs), Hebridae (Velvet water bug) and Veliidae (Water crickets). The species were recorded as follows; Gerridae: *Aquarius adelaidis* (Dohrn, 1860) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2002; Z.S.I., 2010; Lyngdoh *et al.,* 2021), *Gerris lacustris* (Linnaeus, 1758) (Rukasana, 2015; Naz *et al.,*2021), *Gerris marginatus* (Say, 1832) (Tak and Srivastva, 2015; Sharma, 2015; Rukasana, 2017; Srivastava, 2018), *Gerris remiges* (Say, 1832) (Bugalia,. 2020; Srivastava, 2023), *Limnogonus fossarum* (Fabricius, 1775) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2002; Lyngdoh *et al.,* 2021), Limnogonus nitidus (Mayr, 1865) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2002; Lyngdoh *et al.,* 2021), Limnometra fluviorum (Fabricius, 1798) (Tak and Srivastva, 2015; Sharma, 2015; Srivastava, 2018; Lyngdoh *et al.,* 2021), Onychotrechus rhexenor (Kirkaldy, 1902) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2002; Lyngdoh *et al.,* 2021), Hydrometridae: Hydrometra greeni (Kirkaldy, 1898) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2002; Z.S.I., 2010; Lyngdoh *et al.,* 2021), Mesoveliidae: *Mesovelia vittigera* (Horvath, 1895) (Thirumalai and Ramakrishna, 2002; Thirumalai, 2002; Lyngdoh *et al.,* 2021). Hebridae: *Hebrus pusillus* (Fallén, 1807) (Bugalia,. 2020), Veliidae: *Microvelia diluta* (Distant,1906) (Srivastava, 2014; Tak and Srivastva, 2015; Sharma, 2015; Rukasana, 2017; Srivastava, 2018; Bugalia,. 2020), Microvelia douglasi (Scott, 1874) (Thirumalai and Ramakrishna, 2002; Lyngdoh *et al.,* 2021), Comparative diversity among these recorded families is plotted in Fig 1.

Mosquito Diversity

In context to Rajasthan, for documentation of mosquito fauna different studies were done in different geographical areas of Rajasthan, A

compilation of Mosquito fauna is documented in Table 1.

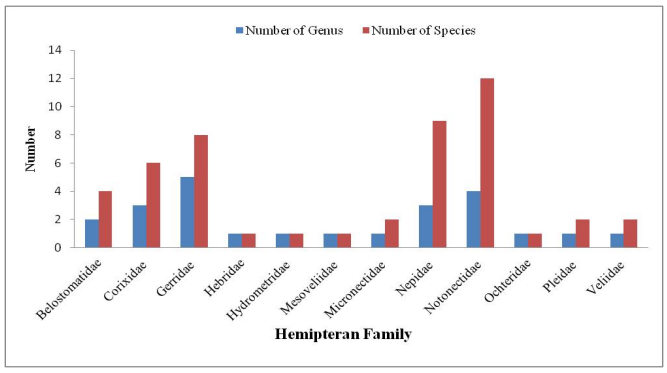

Figure 1. No of Genus and Species from Hemipteran families of Rajasthan on the basis of literature cited from 2002 to 2023.

According to the available literature and published data 32 species from 5 genera viz. *Aedes, Anopheles, Armigeres, Culex* and *Psorophora* were recorded from Rajasthan (Table 1). Most diverse genus was Anopheles with 16 different species followed by Culex with 11 species (Fig.2).

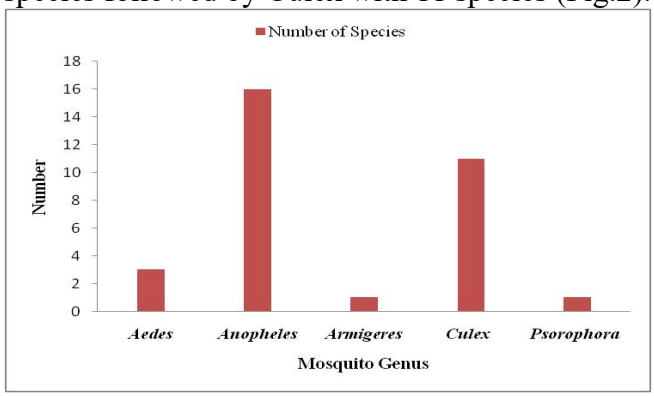

Figure 2. No of species from Mosquito genera of Rajasthan on the basis of literature cited from 1933 to 2023.

From the Table 1 it can be concluded that Rajasthan has a large diversified population of mosquitoes. Invasion and outbreak of Mosquito population has also been recorded from the western part of Rajasthan due to extensive canalization (Tyagi and Chaudhary, 1997). Therefore, management of mosquito population is much needed to avoid outbreak of vector borne diseases.

Interaction of semi-aquatic Hemipterans and Mosquitoes

Insects can be used as biocontrol agents for Mosquitoes (Aditya and Saha, 2006), (Mandal *et al.,* 2008).Hemipteran families have evolved as successful predators due to the accumulation of differential morphological adaptations (Zha *et al.,* 2023). Predatory Hemipterans feed by piercing their stylets into the prey tissues followed by injection of enzymatic venomous saliva for extra oral digestion (Qu *et al.,* 2023). So, their predatory behavior and feeding mechanisms aid in their use as biocontrol agents (Wang *et al.,* 2020).

Mosquito eggs, larvae, and pupal stages are aquatic, so these are common food source for many aquatic invertebrates (Peterson and Rolston, 2022). Since 1939 in New Zealand, the role of Hemipterans as biocontrol for mosquitoes has been recognized (Moirangthem, et. al., 2018). Many studies were conducted to understand the interaction between Hemipterans and mosquitoes including the experimental findings of Lee (1967). Lee concluded that due to fast trembling actions of mosquito pupae only backswimmers among all the included "potential predators" has the exceptional ability to devour the pupae due to their lightning attacking speed.

In addition, according to Ellis and Borden (1970), Notonecta undulate showed a notable behavior by consistently preferring mosquito larvae and pupae over 6 alternate provided prey types. A study has confirmed the effectiveness of artificial mass rearing of predatory Hemipterans and their use as biocontrol agents. Eggs of backswimmers were released in a container that resulted in a reduction of *Cx. quinquefasciatus* larval density in 5 out of 7 samples (Rodriguez-castro, *et al.,* 2006). According to a recent study, Hemipteran family Notonectidae was reported as the aggressive predator family for Anopheles larva in an experiment performed in-vitro (Eba, 2021).

Table 1. Species of mosquitoes recorded from the different areas of Rajasthan

Species	Distribution	References
Aedes aegypti	Jodhpur. Kota, Barmer, Jalore	Joshi *et al.,*(2006), Angel and Joshi (2008), Joshi *et al.,*(2012), Singh *et al.,*(2013), Angel *et al.,*(2014), Charan *et al.,*(2016), Mohanty, (2018), Sharma *et al.,*(2021), Singh *et al.,* (2022), Chittora *et al.,*(2022)
Aedes albopictus	Jodhpur, Kota, Barmer, Jalore	Angel and Joshi,(2008), Singh *et al.,*(2013), Angel *et al.,*(2014), Charan *et al.,*(2016), Sharma *et al.,*(2021), Chittora *et al.,*(2022), (Singh *et al.,*(2022)
Aedes vittatus	Jodhpur, Kota, Barmer, Bikaner, Jalore	Verma *et al.,*(1991), Angel and Joshi,(2008), Singh *et al.,*(2013), Angel *et al.,*(2014), Charan *et al.,*(2016), Sharma *et al.,*(2021), (Chittora *et al.,* 2022), Singh *et al.,*(2022)
Anopheles annularis	Bikaner, Jaisalmer, Kota, Barmer, Jalore	Christophers,(1933), Bansal and Singh,(1993), Tyagi and Chaudhary,(1997), Tyagi and Yadav,(2001), Tyagi,(2004), Joshi *et al.,*(2005), Singh *et al.,* (2013), Prabhakar *et al.,*(2017), Chittora *et al.,*(2022), Singh *et al.,*(2022),
Anopheles barbirostris	Bikaner	(Bansal and Singh,(1993), Tyagi,(2004)
Anopheles culicifacies	Jaisalmer, Pali, Sirohi, Jodhpur, Sri Ganganagar, Bikaner, Barmer, Kota, Jalore	Christophers,(1933), Verma *et al.,*(1991), Mathur *et al.,*(1992), Bansal and Singh,(1993), Tyagi and Chaudhary,(1997), Tyagi and Yadav,(2001), Tyagi,(2004), Joshi *et al.,*(2005), Singh *et al.,* 2013), Prabhakar *et al.,*(2017), Kk *et al.,*(2017), Subbarao *et al.,*(2019), Singh *et al.,*(2021), Singh *et al.,*(2022), Chittora *et al.,*(2022)
Anopheles d'thali	Jaisalmer	(Tyagi and Chaudhary,(1997), Tyagi,(2004)
Anopheles fluvitalis	Kota, Barmer, Bikaner, Jodhpur,	Verma *et al.,*(1991), Tyagi,(2004), Singh *et al.,*(2013), Chittora *et al.,*(2022),
Anopheles maculates	Jalore, Barmer	Singh *et al.,*(2022)
Anopheles minimus	Jodhpur	Singh *et al.,*(2013)
Anopheles multicolor	Jalore, Barmer	Singh *et al.,*(2022)
Anopheles nigerrimus	Sri Ganganagar, Jaisalmer	Tyagi and Chaudhary,(1997), Tyagi and Yadav,(2001), Tyagi,(2004)
Anopheles pulcherrimus	Bikaner, Jalore, Barmer	Bansal and Singh,(1993), Singh *et al.,*(2013), Singh *et al.,*(2022)
Anopheles splendidus	Jaisalmer	(Tyagi and Chaudhary,(1997), Tyagi,(2004)
Anopheles stephensi	Jodhpur, Jaisalmer, Alwar, Kota, Barmer, Bikaner, Jalore	Christophers,(1933), Mathur *et al.,*(1992), Bansal and Singh,(1993), Tyagi and Yadav,(2001), Tyagi,(2004), Joshi *et al.,*(2005), Singh *et al.,*(2013), Kk *et al.,*(2017), Mohanty,(2018), Subbarao *et al.,*(2019), Sharma *et al.,*(2021), Singh *et al.,*(2022)
Anopheles subpictus	Jodhpur, Bikaner, Jaisalmer, Kota, Barmer, Jalore	Christophers,(1933), Verma *et al.,*(1991), Bansal and Singh,(1993), Tyagi and Chaudhary,(1997), Tyagi and Yadav,(2001), Tyagi,(2004), Joshi *et al.,*(2005), Singh *et al.,*(2013), Kk *et al.,*(2017), Prabhakar *et al.,*(2017), Sharma *et al.,*(2021), Chittora *et al.,*(2022), Chittora *et al.,*(2022)
Anopheles sundaicus	Kota, Barmer	Chittora *et al.,*(2022)
Anopheles turkhudi	Jalore, Barmer	Singh *et al.,*(2022)
Anopheles vagus	Kota, Barmer, Jalore	Tyagi and Chaudhary,(1997), Tyagi,(2004), Chittora *et al.,*(2022), Singh *et al.,*(2022)
Armigeres subalbatus	Kota, Barmer, Jodhpur	Sharma *et al.,*(2021), Chittora *et al.,*(2022),
Culex (Lutzia) fuscanus	Jodhpur, Jalore, Barmer	Singh *et al.,*(2013), Singh *et al.,*(2022)
Culex annulus	Kota, Barmer	Chittora *et al.,*(2022)
Culex edwardsi	Kota, Barmer, Jodhpur	Sharma *et al.,*(2021), Chittora *et al.,*(2022))
Culex gelidus	Kota, Barmer, Jodhpur, Bikaner, Jalore	Verma *et al.,*(1991), Singh *et al.,*(2013), Sharma *et al.,*(2021), Chittora *et al.,*(2022), Singh *et al.,*(2022)

Culex malayi	Bikaner, Jodhpur	Verma *et al.,*(1991), Singh *et al.,*(2013),
Culex pseudovishnui	Kota, Barmer, Jodhpur, Bikaner	Verma *et al.,*(1991), Singh *et al.,*(2013), Sharma *et al.,*(2021), Chittora *et al.,*(2022),
Culex quinquefasciatus	Jodhpur, Kota, Barmer, Jalore	Singh *et al.,*(2013), Sharma *et al.,*(2021), Chittora *et al.,*(2022), Singh *et al.,*(2022)
Culex tritaeniorhynchus	Kota, Barmer, Jalore	Singh *et al.,*(2013), Chittora *et al.,*(2022), Singh *et al.,*(2022)
Culex vagans	Kota, Barmer, Jodhpur	Sharma *et al.,*(2021), Chittora *et al.,*(2022)
Culex vishnui	Kota, Barmer, Jodhpur	Sharma *et al.,*(2021), Chittora *et al.,*(2022)
Culex whitei	Kota, Barmer, Jodhpur	Sharma *et al.,*(2021) Chittora *et al.,*(2022)
Psorophora columbiae	Banswara	Jangir,(2023)

*The table represents the diversity of mosquitoes recorded from different parts of Rajasthan. Column 1 represents the recorded species; whereas the column 2 represents the area from where the species were recorded.

According to an investigation by WHO (Sivagnaname, 2009), a reduction in the numbers of *Aedes aegypti* larvae was recorded in the presence of *Diplonychus indicus* (Hemiptera: Belostomatidae). Hemipteran families like Corixidae (water boatmen), Notonectidae (backswimmers), Belostomatidae (giant water bugs) are predators of Mosquito larvae (Vinogradov *et al.,* 2022). Although they are able to control population of mosquito larvae (Culicidae) in phytotelmata and their anthropogenic analogues as reported by Vinogradov *et al.* (2022), they have been little studied as biocontrol agent of mosquitoes. The members of hemipetran families viz. Notonectidae, Corixidae, Belostomatidae are abundant in the aquatic ecosystems of Rajasthan, their abundance indicates that the environment of Rajasthan is in favor of their survival and growth, so they can be introduced in the areas where they are not found naturally and can be a major factor in managing mosquito populations.

Mosquitoes have done notable damage to humankind, and subsequent research has been conducted and methods are used to manage their population, but most of them are not sustainable. In due course of time, Mosquitoes are more resistant to traditional methods. Under IPM, biocontrol of their invasive behavior might be an appropriate option. A diversified aquatic and semi-aquatic Hemipteran population along with predator families like Corixidae, Notonectidae, and Belostomatidae in Rajasthan is the key factor determining the possibilities of use of Hemipetrans as a biocontrol agent of Mosquitoes.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors contribution statement

Mohit Singh contributed to writing the original draft; Vinod Kumari supervised the work and contributed to conceptualizing and driving methodology. Shashi Meena contributed by investigation, conceptualization, and data curation. Rakesh Kumar Lata reviewedthe draft along with helping inwriting and editing.

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