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A review of the geographical distribution of *Aedes aegypti*, *Aedes albopictus* and other *Aedes* species (Diptera: Culicidae) in Pakistan

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Abstract

This study provides information about the geographical distribution of *Aedes* mosquitoes in Pakistan. Data was collected through a literature review to compile a list of the species reported from Pakistan. *Aedes aegypti* and *Aedes albopictus* are the most prevalent species, and their wide geographical distribution and relative abundance need to be studied. Information about Culicidae mosquitoes is still very meager. A complete and up-to-date list of mosquito species present in the country is important for controlling the diseases transmitted by mosquito vectors. Surveillance of mosquitoes provides an early warning system for the risk of transmission of *Aedes* mosquito-borne diseases in an area. This study will contribute to formulating better *Aedes* mosquito control strategies in Pakistan.

Keywords: Culicidae, diptera, *Ae. aegypti*, *Ae. albopictus*, Pakistan

Introduction

Mosquitoes belong to the family Culicidae, order Diptera. The family includes approximately 3,500 species classified into two subfamilies (Anophelinae and Culicinae) and 113 genera. The subfamily Culicinae includes 110 genera classified into 11 tribes. Aedini is the largest tribe of the subfamily with 1,257 species classified into 10 genera^[1]. The genus *Aedes* of this tribe includes 931 species divided in 78 subgenera^[1]. The subgenus *Stegomyia* is a large subgenus that includes 128 species^[2, 3]. The subgenus *Stegomyia* is medically very important. Diseases transmitted by mosquitoes include dengue, malaria, West Nile fever, chikungunya, and Zika virus disease^[4]. Mosquitoes' ability to transmit disease to humans reasons millions of deaths every year^[5]. The major vector-borne diseases combined causes for around 17% of all infectious diseases^[6].

Pakistan is situated in the northwest of South Asia^[7]. Due to its location and favorable climatic conditions for vectors, Pakistan is a hotspot for mosquito-borne diseases^[8]. The mosquitoes *Ae. aegypti* and *Ae. albopictus* are vectors of several globally important arboviruses, including dengue virus, chikungunya virus, yellow fever virus, and Zika virus^[9-12]. *Aedes aegypti* and *Ae. albopictus* are present in Pakistan^[13, 14].

The Pakistan mosquito fauna is not well studied. Although there have been fragmented studies on Culicidae mosquitoes, no studies have been conducted at a national level since the 1970s^[14]. The Fauna of British India, which describes culicine and anopheline mosquitoes, remains a standard reference work. Only three culicine species have been added to the mosquito fauna of Pakistan since 1934. After the partition of India in 1947, Qutabuddin (1960)^[15], Tariq (1967)^[16], Aslamkhan and Baker (1969)^[17], Aslamkhan and Salman (1969)^[18], Aslamkhan (1971 and 1972)^[14, 19], Reisen (1978 and 1982)^[20, 21], Suleman *et al.* (1993)^[22] and Suleman and Khan (1993)^[23] added some evidence regarding the geographical distribution of Culicidae mosquitoes in Pakistan. The confirmed number of mosquito species in Pakistan is 134. Eighty-nine species, 4 subspecies, and 1 variety of culicine mosquitoes belonging to 15 genera and 28 subgenera were reported in Pakistan^[14]. Thus, the aim of this study was to compile a list of all *Aedes* mosquito species present in Pakistan, with their localities, to be considered for future risk assessments.

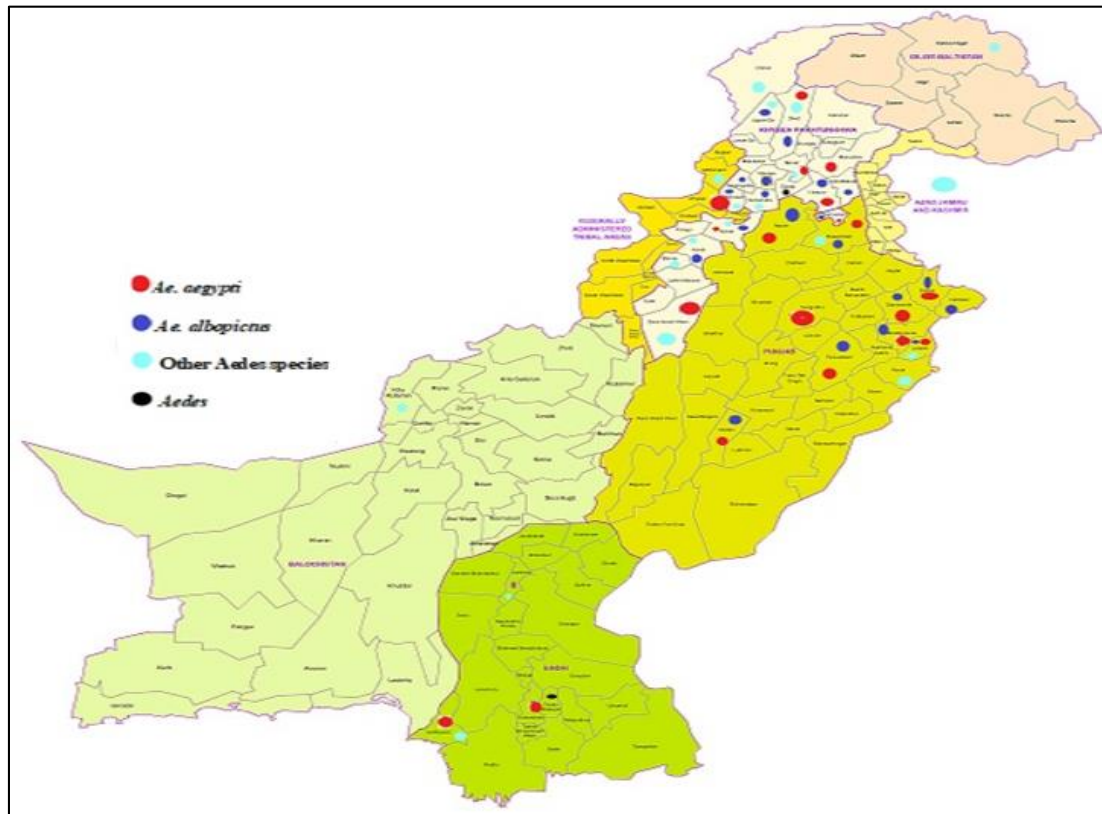
Geographical distribution of *Aedes* mosquitoes from Pakistan

Records were found for the geographical distribution of *Aedes* mosquitoes in 12 districts of Punjab, 17 districts of KP, 4

districts of Sindh, 1 district of Balochistan, and in Islamabad. Twenty-seven *Aedes* species were described in Pakistan (Table 1).

Table 1: Geographical distribution of *Aedes* Mosquitoes in Pakistan

Province	District	<i>Ae. aegypti</i>	<i>Ae. albopictus</i>	Other <i>Aedes</i> species	Ref
Balochistan	Qilla Abdullah	-	-	<i>caspius</i>	[13]
Capital Territory	Islamabad	+	+	-	[24-26]
AJK	Kashmir	-	-	<i>caspius, pulchriventer, sinthoni, versicolor</i>	[13, 19]
Northern Region	Baltistan	-	-	<i>pseudotaeniatus, caspius</i>	[13]
KP	Abbotabad	-	+	<i>albolateralis, pseudotaeniatus, pulchriventer, vittatus</i>	[19, 23]
KP	Bannu	-	-	<i>caspius</i>	[13]
KP	Buner	+	-	<i>pseudotaeniatus, shortii, vittatus</i>	[27]
KP	Chitral	-	-	<i>pulchritarsis</i>	[13, 19]
KP	Charsadda	-	+	-	[28]
KP	Dera Ismail Khan	+	-	<i>caspius, pulverulentus</i>	[13]
KP	Haripur	+	+	<i>shortii</i>	[24, 28, 29]
KP	Karak Khyber	-	+	-	[30]
KP	Karak	-	+	<i>shortii</i>	[31-34]
KP	Khyber Agency	+	-	-	[35]
KP	Kohat	+	+	<i>indicus, micropterus, pallidostratus, pipersalatus, unilineatus, vittatus, w-albus</i>	[15, 36]
KP	Mansehra	+	-	-	[37]
KP	Mardan	-	+	-	[28]
KP	Nowshera	-	+	<i>caspius, pulverulentus</i>	[13, 19, 28]
KP	Peshawar	-	+	<i>caspius, unilineatus, w-albus,</i>	[13, 28, 38, 39]
KP	Swabi	-	-	<i>Aedes</i>	[28]
KP	Swat	+	+	<i>pseudotaeniatus, shortii, vittatus,</i>	[40, 41]
KP	Malakand, Swat	-	-	<i>vittatus</i>	[42]
KP	Upper Dir	-	+	<i>shortii</i>	[43]
Punjab	Attock	+	+	-	[24, 25]
Punjab	Faisalabad	+	+	-	[44-46]
Punjab	Gujranwala	+	+	-	[47]
Punjab	Kasur	-	-	<i>caspius, culicinus, indicus, lineatopennis, w-albus, yusafi,</i>	[18, 20]
Punjab	Lahore	+	+	<i>caspius, culicinus, unilineatus, indicus, lineatopennis, micropterus, pulverulentus, scatophagoides, taeniorhynchoides, thomsoni, vittatus, w-albus</i>	[13, 19, 45-52]
Punjab	Multan	+	+	-	[53]
Punjab	Nankana sahib	+	-	-	[46]
Punjab	Narowal	-	+	-	[54]
Punjab	Rawalpindi	+	+	<i>caspius, chirstophersi, flavopictus, oreophilus,</i>	[13, 19, 24, 25, 55-57]
Punjab	Sargodha	+	-	-	[58]
Punjab	Sheikhupura	+	+	-	[45]
Punjab	Sialkot	+	+	-	[59]
Sindh	Hyderabad	+	-	-	[25]
Sindh	Karachi	+	-	<i>pulverulentus, unilineatus</i>	[13, 24, 60, 61]
Sindh	Larkana	+	-	<i>pulverulentus</i>	[13]
Sindh	Tando Jam	-	-	<i>Aedes</i> mosquito	[62]



Map showing the distribution of the most prevalent *Aedes* species currently and diachronically (1934-2019) in Pakistan

Recent reports related to *Aedes aegypti*, *Ae. Albopictus* and other *Aedes* species from Pakistan

Aedes aegypti and *Ae. albopictus* are very common species in the Indian subcontinent [20]. Several studies reported that *Ae. aegypti* and *Ae. albopictus* were reported from the Punjab districts of Lahore [13, 20, 21, 45-49, 51, 52], Multan [53], Faisalabad [44-46], Attock [24, 25], Rawalpindi [13, 19, 24, 25, 55, 56, 57], Shekhupura [45], Sialkot [59], Norowal [54], Gujranwala [47], Kasur [18, 20], Nankana Sahib [46], and Sargodha [58]. Other studies reported the presence of *Ae. aegypti* in localities of the districts Buner [27], Swat [40,41], Mansehra [37], Landikotal [35], Haripur [24] and Kohat [15, 36]. Several studies reported that *Ae. albopictus* were collected from various localities of the KP districts Upper Dir [43], Karak Khyber [30], Peshawar [28, 38, 39], Karak [31-34], Swat [41], Nowshera [28], Mardan [28], Charsadda [28], Kohat [15, 36], Haripur [24], and Abbotabad [19, 23]. *Aedes aegypti* was reported in various localities of the Sindh districts of Karachi and Hyderabad [13, 24, 25, 60, 61]. *Aedes albopictus* has not yet been reported in Sindh. In another study, *Aedes* mosquitoes were collected from inside and around Tando Jam and Hyderabad [25, 62]. *Aedes aegypti* and *Ae. albopictus* were also reported in different localities of Islamabad [24, 25].

In 1934, Barraud reported *Aedes aegypti* in Karachi, Dera Ismail Khan, Peshawar, Larkana, and Lahore. Qutubuddin reported *Aedes aegypti* from the Kohat Hangu Valley in 1960 and in 2018. Hussain *et al.* (2018) reported *Ae. aegypti* from Kohat. In the southern metropolis of Karachi, *Aedes aegypti* was again reported by Kamimura *et al.* in an entomological survey conducted in 1983. Other studies reported that *Ae. aegypti* were collected from Karachi [24, 61] and a northern border town of Khyber Agency [35].

Aedes shortii was reported in several localities of the districts Upper Dir, Haripur, Karak, Buner, and Swat [27, 29, 31, 41, 43]. *Aedes unilineatus* was reported in Lahore and the Kohat-Hangu Valley [13, 15, 19]. Recent studies reported that it was collected from Karachi (SITE and Gulshan-e-Iqbal) in 2010 and the district of Peshawar in 2013 and 2017 [38, 61].

Aedes w-albus is widely spread in Punjab. Reisen (1978) [20] reported it from Lahore. In 1982, it was reported during an entomological survey conducted in the Changa Manga forest of Punjab [13, 18, 21]. It was reported from the Kohat-Hangu Valley in 1960 [15]. In recent studies, it was reported from various localities of Peshawar [38, 39]. *Aedes pesudotaeniatus* is the commonest species in the hills and plain, extending from the North West Frontier (NWF; present-day Khyber Pakhtunkhwa) to Baltistan [13]. It was reported in different localities in the KP districts of Abbotabad (1993) [23] and Buner (2015) [27]. *Aedes vittatus* was reported in the NWF (1934) and in the Kohat-Hangu Valley (1960) [15]. In different studies it was reported in Abbotabad (1993), Swat (2013), and Buner (2015) [15, 22, 26, 40, 42]. It was reported from three villages of Lahore in 1978 [20].

Aedes micropterus was reported in Punjab and in the Kohat-Hangu Valley in 1960 [15, 20]. *Aedes indicus* was reported in Lahore and Larkana Sindh [13]. It was later reported from Lahore (1978) and the Changa Manga National Forest (1982). *Aedes yusafi* was also reported in Changa Manga [21]. *Aedes piperasaltus* was reported in north-western India and in the Kohat-Hangu Valley (1960) [15]. *Aedes pallidostriatus* was reported in Punjab and in the Kohat-Hangu Valley [15]. *Aedes lineatopinnis* was reported in the district of Lahore (1978) [26] and Kasur (1982) [21]. *Aedes albolateralis* was reported in Abbotabad in 1993 [23]. In 1978, Reisen reported *Aedes caspius*, *Ae. indicus*, *Ae. micropterus*, *Ae. lineatopinnis*, *Ae. pulveutentus*, *Ae. scatophagoides* and *Ae. taeniorhynchoides* from Lahore, Punjab. There is no recent information available on the geographical distribution of *Ae. micropterus*, *Ae. caspius*, *Ae. indicus*, *Ae. yusafi*, *Ae. pulveutentus*, *Ae. piperasaltus*, *Ae. pallidostriatus*, *Ae. lineatopinnis*, *Ae. scatophagoides*, *Ae. taeniorhynchus* and *Ae. albolateralis* in Pakistan.

In 1934, Barraud collected *Aedes* mosquitoes from different localities that presently belong to Pakistan. *Aedes caspius* was reported in Kashmir, Baltistan, Peshawar, Nowshera, Rawalpindi, Bannu, Chaman, and Dera Ismail Khan. *Aedes pulchriverter* was collected from Abbotabad, the Hazara district, and Kashmir. *Aedes sintoni* was reported in Murree and Kashmir. *Aedes falavopictus* was reported in Murree. *Aedes culicinus* was only reported in Lahore. *Aedes pulveutentus* was collected from Nowshera, Karachi, Larkana Sindh, and Dera Ismail Khan. This study shows that *Ae. vexans*, *Ae. pulchriverter*, *Ae. sintoni*, and *Ae. falavopictus* have not been found in Pakistan after 1934.

Conclusion

This is the most complete and updated list compiled after Aslamkhan's work almost 45 years ago. The list will help to improve our knowledge of the presence of *Aedes* mosquito species in Pakistan. There is no available information on the geographical distribution of *Aedes* mosquitoes at the local level in Pakistan. The mosquito fauna of Balochistan Province is unknown. A list of the *Aedes* species with their localities present in the country is important for controlling mosquito-borne disease. Molecular-based methods of mosquito identification would be helpful in refining this list and the geographical distribution of species in the country. Vector surveillance systems should be introduced at the union council level in all provinces. Future research priorities should include further collection of culicine from all provinces of Pakistan.

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