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Species Composition and Relative Abundance of Mosquitoes in Swat, Pakistan

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ABSTRACT: A comprehensive survey of mosquitoes (Diptera: Culicidae) was conducted in Swat Pakistan, from April to September during 2000. The survey involved the sampling of both, adult and immature stages of mosquitoes, and recovered a total of 21 species in five genera. Sampling of adult mosquitoes involved Pyrethrum spray collections, Man-biting collections, and Animal-biting collection. Immature stages of mosquitoes were collected from variety of habitats including springs, irrigation channels, rice fields, marshes, temporary pools, construction pools, agriculture pools, river margins, ditches, waste water drains, wells and tree holes. During the study most of the species built up their populations in June, July and August, while a few increased their populations in September. During the survey of immature stages, from a total of 138 samples taken, *Cx. quinquefasciatus* showed maximum frequency of occurrence (recovered from 48 samples) followed by *An. maculatus* (17 samples), *Cx. pseudovishnui* (14 samples), *An. annularis* and *An. stephensi* (13 samples each), *Cx. bitaeniorhynchus* (11 samples), *An. splendidus* (5 samples) and *Cx. theileri* (4 samples). The rest of the species occurred infrequently. The observations on habitat specificity of different species of mosquitoes showed the rice fields as the most favorable site for mosquito breeding (harboring 12 species) followed by river margins (five species) and temporary pools and springs (four species each). During this study *Ae. aegypti* was recovered from tyres in Mingora; it was not reported earlier from Swat.

KEYWORDS: Diptera, Culicidae, Immature stages, Frequency of occurrence, Habitat specificity.

ABBREVIATION: *An, Anopheles; Cx, Culex; Ae, Aedes; Ar, Armegere, Cu, Culiseta.*

1 INTRODUCTION

Mosquitoes are slender biting insects of the order Diptera, sub order Nematocera and family Culicidae, with about three and half thousand species [1]. In the modern classification of Culicidae as adopted by knight and Stone [2], there are three sub families: Culicinae (with thirty genera), Anophelinae (with three genera) and Toxorhynchitinae (with one genus). Sub family Culicinae, being the largest and most diversified is further divided into a number of tribes: Aedini, Culicini, Culisetini, Mansoniini, Ficalbiini, etc. The tribe Aedini consists of several genera including Aedes and Armigeres. The sub family Anophelinae includes the most important genus "Anopheles" several species of which are malaria vectors.

Mosquitoes may serve as hosts for a variety of different organisms including viruses, sporozoans, nematodes etc; but humanity is fortunate in the sense that not all the above mentioned parasites are essentially pathogenic to man [3]. Even then certain parasites are constant threats to man by manifesting different diseases including malaria, filariasis, dengue, yellow fever and certain other mosquito- borne viral diseases. Malaria is one of the most vicious diseases of man. According to WHO 2008 report [4], 247 million cases of malaria led to nearly 881000 deaths during 2006. A number of countries in the Indian Subcontinent including India, Pakistan, Bangladesh and Sri Lanka continue to report endemic malaria transmission to the World Health Organization [5]. According to the World Health Organization 2009 report, 140 million people in Pakistan are at risk for malaria infection with 18% living in high risk situations [6].

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Being a sub-tropical country, Pakistan has a rich fauna of vectors including mosquitoes, sand flies and other Dipterans. Presence of vast agricultural lands, open networks of irrigation channels, rivers and several water dams for power generation in the country provide plenty of breeding sources for mosquitoes. In Pakistan 23 species of Anopheles have been reported; out of these two species, *Anopheles culicifacies* and *Anopheles stephensi* are considered the important malaria vectors in Pakistan. The main malaria vector of rural areas is *Anopheles culicifacies* ([7]-[11]) and of urban areas is *Anopheles stephensi* [12]. Two other species, Anopheles *pulcherrimus* and *Anopheles fluviaitlis* are suspected to be involved in malaria transmission in the mountainous areas of Punjab and Khyber Pakhtunkhwa, Pakistan [13].

Imported cases of human filariasis have been reported from Sindh province [14]. In 2001, confirmed cases of tropical pulmonary eosinophilia (TPE) in indigenous patients as a result of infection with *Wuchereria bancrofti* were reported. The disease is very rare in Pakistan [15]. The only endemic mosquito-borne arbovirus infection of man known to occur in Pakistan is the West Nile Virus ([16]-[17]).

In Khyber Pakhtunkhwa, Pakistan, a few studies have so far been made on mosquitoes. Relative abundance of the mosquitoes in Peshawar valley has been described by Suleman et al.1993 [13]. An ecological study on mosquitoes of Swabi District [18], and yellow fever mosquito introduced into Landi Kotal [19] are among the studies carried out in Khyber Pakhtunkhwa, Pakistan. Recently survey for the determination of species composition of mosquitoes in Palosai Peshawar was conducted by Ali and Rasheed [20].

The present work constitutes the first study on mosquitoes in Swat, Khyber Pakhtunkhwa, Pakistan. This work describes species composition, relative abundance and seasonal variation of mosquitoes recovered as adults or immature and also describes the habitat preferences for breeding in Sherpalam and in some other areas of Swat Valley. The data generated in this study helps in understanding habitat specificity of different mosquito species, which is imperative for devising an effective mosquito control program. Sound knowledge of disease vectors is the foundation on which we can hope to devise effective control measures.

2 MATERIALS AND METHODS

2.1 DESCRIPTION OF SWAT VALLEY

Swat belongs to the Malakand division of NWFP, Pakistan and lies between 34^0 34" and 35^0 55" north latitudes and 72^0 08" and 72^0 50" east longitudes. The total area of the district is 5337sq Km. Swat is located in the lap of mountainous ranges, which are the offshoots of Hindukush; so the larger part of Swat is covered with mountains and hills. True plain is not found in Swat, yet local people call some areas plain surfaces. These plain surfaces receive water from river Swat and its tributaries for irrigation which provide sufficient breeding grounds for mosquitoes. The climate of Swat is somewhat warm in the lower parts but cool and refreshing in the upper parts. Summers are short and moderate, temperature seldom rises above 37^0 C. Annual rainfall ranges from 800 to 900 mm, and snowfall during winter is the constant feature of upper Swat.

2.2 STUDY AREA

Sherpalam (at 1115m altitude) was the main focused area for mosquito survey; Sherpalam is one of the Field Assistant (FA) circles of Tehsil Matta and District Swat which covers an area of approximately 16790 ha. The settlement of Sherpalam is situated 19Km north of Mingora City and 3Km south of Matta and can broadly be divided into the hill terrain of village Amlookband (at 1170m altitude), hamlet Bawrai and the low lying undulating plains of Sherpalam village (the whole area is called Sherpalam). The village Amlookband and hamlet Bawrai lie on the eastern face of Neelawi extension of Hindu Raj Mountain making the western boundary of Sherpalam settlement. The hill tract has springs, which serve as a source of drinking and irrigation water for the residents; however, this tract is mostly rain dependent. These springs create breeding sites for mosquitoes during summer. The low-lying undulating plains of Sherpalam village are located on the right side of Swat River in south and Harnoi River in north. These plains have perennial streams originating either from Harnoi River or Swat River which provide a network of water channels for irrigation, thus creating maximum breeding sites for mosquitoes.

2.3 SAMPLING METHODS AND SITES

2.3.1 ADULT MOSQUITOES

Sampling of adult mosquitoes involved Pyrethrum spray collections, Man-biting collections, and Animal-biting.

2.3.1.1 PYRETHRUM SPRAY COLLECTION

Ten fixed sampling sites representing six human dwellings (HD) and four cattle sheds (CS) were selected for collection of adult mosquitoes fortnightly at Sherpalam. Commercially available flit was used for knocking down the indoor-resting mosquitoes. The collections were usually made three to four hours after sunrise. The rooms were opened after 10-15 minutes of spray and the mosquitoes were collected from the sheets (spread before spraying) in the light of electric bulb and torch with the help of entomological forceps. Collection from each room was kept in a separate test tube containing silica gel for desiccation, which was labeled accordingly.

2.3.1.2 MAN-BITING COLLECTION

Landing/biting mosquitoes on man were captured at night hours (7-12pm) in a human dwelling and during daytime (4-6pm) in a dense orchard of apples. The author worked as insect collector while a volunteer served as bait who was directed to put off his shirt ad roll up his paint up to knee joints.

2.3.1.3 ANIMAL-BITING COLLECTION

Animal-bait collections of landing/biting mosquitoes were made with a suction tube (mouth aspirator) at night hours (8-11pm) in a cattle shed during the study period.

2.3.2 IMMATURE STAGES (LARVAE & PUPAE)

Sampling sites in the hill terrain of Amlookband included springs, agricultural pool and construction pool. Maximum potential breeding habitats of mosquitoes were found in the low laying plains of Sherpalam which included rice fields, irrigation channels, marshes, waste water drains, ditch, temporary pools, well and tree holes. Some attempts were made occasionally for sampling of immature stages of mosquitoes from various breeding sites at other localities of Swat Valley which included Madyan, Behrain and Kalam which are cold and high altitude areas.

Larvae /pupae were picked with the help of a large mouthed glass dropper either from the habitat surface or from water sampled with a 300ml plastic dipper. From enclosed water habitats such as tree holes and tires, larvae/pupae were collected with the help of a medium sized spoon. The immature stages were then transferred to plastic jars labeled accordingly. The jar openings were closed with net cloth. Small quantity of water (up to 200 ml) was collected along with the larvae from the collection spot to ensure food supply. A collection form was used for each sample to record data pertaining to the habitat (locality, ecology, etc.), individual rearing and identifications. The jars containing larvae were brought to the laboratory and reared to adulthood. The adult mosquitoes emerged from the pupae were collected with the help of aspirator and were killed with a cotton swab of chloroform in an airtight container. Specimens were placed in test tubes containing silica gel before identification. In addition to the study of adults, permanent slides of 4^{th} instar larvae were also prepared. Binocular microscope was used for taxonomic study and identification was made up to species level with the help of taxonomic keys provided in the literatures ([21]-[22]).

3 RESULTS

From Sherpalam a total of 4587 specimens (Females+Males) comprising 19 species in 5 genera were collected as adult or immature from a variety of habitats. During occasional surveys in some other localities of Swat, a total of 918 (females+males) adults in 9 species were recovered from larvae/pupae which included *Ae. aegypti* L from tires in Mingora city and *Ae. shortti* Barraud from rock pools in Kalam which were not found in Sherpalam. From the whole area (Sherpalam+ other localities) the total number of adults and species recovered reaches to 5505 and 21 respectively. Of all the sampling methods used, collection of immature stages proved most productive as it yielded the maximum number of species (19), indoor-resting collection yielded 13 species, while man- biting and animal-biting collection, yielded 8 and 6 species respectively. Altogether, Anopheles were represented by 8 species (1351specimens) constituting 24.6% of the total fauna captured. Genus Culex was represented by 7 species (3625 specimens) constituting 66.2% of the total fauna. The largest number of specimens belonging to a single genus was Culex. The remaining three genera viz; Aedes, Armigeres and Culiseta contributed a small proportion in the total collection (Table 3.1).

Table 3.1. Overall species composition and relative abundance of mosquitoes (females+males) recovered as adults or immature from Sherpalam and other localities of Swat

Species	Total	Percentage
An. maculatus Theobald	530	9.6
An. annularis van der- Wulp	241	4.37
An. splendidus Koizumi	53	0.9
An. fluviatiis James	268	4.8
An. stephensi Liston	245	4.45
An. *d' thali* Patton	6	0.1
An. *culicifacies* Giles	5	0.09
An. pallidus Theobald	4	0.07
An. *quinquefasciatus* Say	2970	53.9
An. pseudovishuni Theobald	148	2.6
An. bitaeniorhynchus Giles	315	5.72
Cx. theileri Theobald	75	1.36
Cx. mimeticus Noe	70	1.27
Cx. perexiguus Theobald	38	0.69
Cx. tritaeniorhynchus Giles	39	0.7
Ae. vittatus Bigot	110	1.99
Ae. pseudotaeniatus Giles	244	4.43
Ae. shorti Barraud	21	0.38
Ae. Aegypti Linnaeus	69	1.25
Ar. Subalbatus	48	0.87
Cu. longiareolata Macquart	6	0.108
Total : 21 species	**5505**	**99.648**

Data on monthly variation in species composition and relative abundance of indoor-resting mosquitoes (Human dwelling + Cattle sheds) sampled in Sherpalam is summarized in table 3.2. Most of the species built up their populations in June, July and August, while a few increased their populations in September. Sampling of immature stages (larval/pupal) yielded 16 species. The species composition, relative abundance and monthly variation of Anopheline and Culicine mosquitoes recovered from all the aquatic habitats of Sherpalam surveyed during April- September (2000) is summarized in table 3.3. The breeding potential was highest in July followed by August, June and September.

Table 3.2. Monthly variation in species composition and relative abundance of indoor-resting mosquitoes. Each value represents percent abundance of a mosquito species.

Species	April	May	June	July	August	September	Total
An. maculatus	0	0	0.56	0.25	0.25	0.25	1.31
An. annularis	0	0	1.39	3.186	0.154	0.154	4.8
An. splendidus	0	0	1.33	0.051	0.25	0.411	2.04
An. fluviatilis	0	0	0	1.07	2.46	8.63	12.16
An. stephensi	0	0	0	8.42	0.308	0.308	9.04
An. d'thali	0	0	0	0	0	0.25	0.25
An. culicifacies	0	0	0	0	0	0.205	0.205
Cx. quinquefasciatus	0	1.38	10.38	17.52	26.88	2.98	59.14
Cx. pseudovishnui	0	0	0.668	1.64	0.051	0.051	2.41
Cx.bitaeniorhynchus	0	0	0.668	4.31	0	0	4.98
Cx. theileri	0	0	0.616	1.43	0	0	2.05
Cx. mimeticus	0	0	0.102	0.205	0	0	0.31
Ae. pseudotaeniatus	0	0	0	0	0	0	0.102

During the survey of immature stages, from a total of 138 samples taken, *Cx. quinquefasciatus* showed maximum frequency of occurrence, as it was recovered from 48 samples followed by *An. maculatus* (17 samples), *Cx. pseudovishnui* Theobald (14 samples), *An. annularis* and *An. stephensi* (13 samples each), *Cx. bitaeniorhynchus* (11 samples), *An. splendidus* Koizumi (5 samples) and *Cx. theileri* Theobald. The rest of the species occurred less frequently (Table 3.4).

The observations on habitat specificity of different species of mosquitoes based on total larval collections from various aquatic habitats are summarized in Table 3.5. The rice fields appeared as the most favorable habitat for mosquito breeding, since the highest numbers of species (12) were recovered from this category of sites.

The river margins were the second most important breeding sites, since they harbored 5 species. The springs and temporary pools harbored 4 species each. Altogether *Cx. quinquefasciatus* was found breeding in 14 different habitats, *Cx. bitaeniorhynchus* and *An. maculatus* in 4, *Cx. pseudovishnui* and *A. annularis* in 3, while the rest of the species were found restricted to one to two particular habitats.

4 DISCUSSION

This study describes species composition, relative abundance, seasonal variation and habitat specificity of mosquitoes in Swat, Pakistan. Mosquito fauna was represented by eight species of Anopheles, seven of Culex, four of Aedes and one each of Armigeres and Culiseta. Majority of the species (19) were recovered as larvae/pupae while three species (*An. d'thali* Patton, and *An. culicifacies* Giles recovered as adults were not found as immature. Of the 19 species recovered from larval/pupal collections, eight species viz; *An. pallidus* Theobald, C*x. perexiguus* Theobald, *Cx. triataeniorhynchus*, *Ae. vittatus* Bigot, *Ae. aegypti* L, *Ae. shorti* Barraud *Armigeres subalbatus* Coquillett, and *Cu. longiareolata* Macquart were not recovered from the indoor-resting collections. *Ar. subalbatus* was recovered both as larvae and adults (during man-biting collection). Eleven species that were found both in indoor-resting collections and in larval/pupal collections included: *An. maculatus*, *An. annularis*, *An. splendidus*, *An. fluviatilis* James*, An. stephensi, Cx.quinquefasciatus, Cx. pseudovishnui* Theobald*, Cx.bitaeniorhynchus, Cx. theileri* , *Cx .mimeticus* and *Ae. Pseudotaeniatus* Giles.

Among Aedes, *Ae. aegypti* was found only from tires in Mingora City and *Ae. shortti* from rock pools in Kalam (high altitude and cold area). The absence of *Ae. shortti* in low altitude localities (840-1360 m) and presence at Kalam of high altitude (2000m) during survey represents its affinity with high altitude and cool climate.

The present study was the first in Swat. However, in other areas of the country, some studies on mosquitoes have been conducted. Qutubuddin (1960) [23] recorded 23 Anopheline and 12 Culicine species. One Anopheline, *An. pallidus* and five culicine viz; *Cx. pseudovishnui*, *Cx. perexiguus, Ae. pseudotaeniatus, Ae. shorti* and *Cu. longiareolata* found in the present study were not encountered by Qutubuddin [23].

Aslamkhan and Salman (1969) [24] found 29 species of mosquitoes in Changa Manga National forest. Species found in the present study but not encountered by Aslamkhan and Salman (1969) [24] included *Ae. vittatus*, *Ae. pseudotaeniatus*, *Ae. shorti*, *Ae. aegypti*, *Cx. pseudovishnui*, *Cx. mimeticus*, *Cx. perexiguus*, *An. maculatus*, *An. splendidus*, *An. pallidus*, *An. fluviatilis*, *An. d'thali*.

Reisen (1978) [25] surveyed seven villages in Lahore area, using four collection methods (indoor-resting, outdoor-resting, bovid biting and light traps) recorded 43 species of mosquitoes, comprising 12 species of *Aedes*, nine of *Anopheles*, 16 of *Culex* and one each of *Coquilletidia*, *Culiseta*, *Minomya*, *Mansonia*, *Orthopodomya* and *Uranotaenia*. Seven species of Culicines viz. *Cx. perexiguus Cx. mimeticus*, *Ae. aegypti*, *Ae. shorti*, *Ae. pseudotaeniatus*, *Ar. subalbatus*, *Cu. longiareolata* and three species of Anopheles viz. *An. maculatus*, *An. splendidus*, and *An. d'thali* encountered in the present study were not reported by Reisen (1978) [25].

Table 3.3. Monthly variation in species composition and relative abundance of mosquitoes recovered from Larvae/pupae. Each value represents percent abundance of a mosquito species.

Species	April	May	June	July	Aug	Sep	Total
An. maculatus	0	1.9	3.3	6	3.57	4.8	19.57
An. annularis	0	0.49	0.646	1.52	2.28	0.456	5.39
An. Splendidus	0	0.114	0.038	0.608	0.076	0.076	0.912
An. fluviatilis	0	0	0	0.076	0.836	0	0.912
An. stephensi	0	0	0	0.988	1.52	0	2.508
An. pallidus	0	0	0	0.152	0	0	0.152
Cx. quinquefasciatus	3.192	8.89	11.43	16.112	9.728	0.722	50.07
Cx. pseudovishnui	0.342	0.722	0.874	0.912	0.988	0	3.838
Cx. bitaeniorhynchus	0	0	0.988	3.192	2.964	0.19	7.334
Cx. theilersi	0	0.228	0.304	0.646	0.152	0	1.33
Cx. mimeticus	0	0.038	0.38	0.798	0.722	0	1.938
Cx. perexiguus	0	0	0	0.988	0.456	0	1.44
Cx.tritaeniorhynchus	0	0	0	0	0.722	0	0.722
Ae. Vittatus	0	0	0	0	4.18	0	4.18
Ar. Subalbatus	0	0	0	0	0.418	0.38	0.798
Cu. longiareolata	0	0	0	0.228	0	0	0.228

Pal and Aziz (1985) [26] while carrying out a survey of incidence of malarial parasites in selected human population at Rawalpindi and Islamabad captured seven *Anopheline* species using mechanical aspirator from cattle sheds and human dwellings. Four species of Anopheles, *An. maculatus, An. splendidus, An. pallidus* and *An. d'thali* found in the present study were not recovered by them.

In 1983 a field study team of encephalitis in Karachi area sponsored by the Japanese Ministry of education and science, surveyed the area widely and collected adult mosquitoes by flit method [27]. They found five common species of mosquitoes including *Cx. tritaeniorhynchus*, *Cx. quinquefasciatus*, *An. subpictus* and *Ae. aegypti*. All the species except *An. subpictus*, found by them were also encountered in the present study.

Suleman et al. (1993) [13] found 31 species of mosquitoes in Peshawar Valley. These 31 species included 10 species of Anopheles, 8 of Aedes, 9 of Culex, 2 of Culiseta and one each of Armigeres and Mansonia. Two Aedine species (*Ae. aegypti* and *Ae. shortti*), two of Culex (*Cx. pseudoushnui* and *Cx. perexiguus*) and one Anopheline species (*An. d'thali*) encountered in the present study were not reported by Suleman et al. (1993).

Table 3.4. Frequency of occurrence and relative abundance of mosquitoes (females+males) recovered from larvae/pupae

Species recovered	Frequency of occurrence	Number of adults recovered
An. maculatus	17	487
An. annularis	13	142
An. splendidus	5	22
An. fluviatili	3	24
An. stephensi	13	53
An. pallidus	1	4
Cx. quinquefasciatus	48	1315
Cx. pseudovishnui	14	101
Cx. bitaeniorhynchus	11	193
Cx. theileri	4	35
Cx. mimeticus	1	51
Cx. perexiguus	3	38
Cx. Tritaeniorhynchus	1	19
Ae. vittatus	1	110
Ar. Subalbatu	2	21
Cu. langiareolata	1	6
Total=16 species	138 samples	2621 specimens

Then in 1996 Suleman et al. [19] reported two species of mosquitoes viz; *Cx .quinquefasciatus* and *Ae. Aegypt* from tires at Landi Kotal which were also recovered in the present study from tires in Mingora City. Distribution of *Ae. aegypti* in the recent past was apparently restricted to the port city of Karachi and its recent distribution to Landi Kotal was attributed to tires imported via Karachi to Landi Kotal [19]. The presence of *Ae. aegypti* in Mingora Swat detected in the present study may be attributed to its recent dissemination from Landi Kotal via Peshawar along the trade route. Nevertheless, it has not yet reached Khwazakhela and Matta (surveyed in the present study).

Mukhtar et al. (2003) [28] studied the role of waste water irrigation in mosquito breeding in south Punjab, Pakistan. They found four species of Anopheles and two species of Culex. Aedes were not identified to species level. The species diversity of mosquitoes recovered from Swat is richer as compared to the study of Mukhtar et al. (2003) [28]. Akram et al. (2009) [29] observed mosquito activities from February to mid-December at various collection sites and found high populations of Culex, Anopheles and Aedes species. During the survey they found that mosquito activity was suspended during June and July because of high relative humidity (70%); a result of the monsoon rains in August, with temperature ranging from 38 to 42°C, the populations of Culex, Anopheles and Aedes began to increase (36.8, 32.1 and 26.3%, respectively). This study indicated that in Swat most of the species built up their populations in June, July and August, while a few increased their populations in September.

Table 3.5. Habitat specificity of different mosquito species recovered from different habitats at Sherpalam and in some other localities of Swat. X represents the presence of a species in a habitat.

Species	Spr	IR	RF	Mar	TP	CP	AP	RP	RM	DIT	CD	Well	Tire	FWP	TH
An. maculatus	X	X	X						X						
An. annularis	X		X						X						
An. splendidus			X												
An. fluviatili			X		X										
An. stephensi			X		X									X	
An. pallidus			X												
Cx. quinquefasciatus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Cx. pseudovishnui			X	X					X						
Cx. bitaeniorhynchus		X	X						X		X				
Cx. theileri			X												
Cx.mimeticus			X												
Cx. perexiguus	X		X												
Cx. tritaeniorhynchus				X										X	
Ae. vittatus						X									
Ae. Shortti								X							
Ae. Aegypti													X		
Ae. Pseudotaeniatus								X					X		
Ar. Subalbatus															X
*Cu. l*ongiareolata					X										
Total Species 19	4	3	12	3	4	2	1	3	5	1	2	1	3	3	2

AP-agriculture pool, Cd- cemented drains, CP-construction pool, DIT-ditch, FWP-fresh water pond, IR-irrigation channels, Mar-marches, RF-rice fields, RM-river margins, RP-rock pools, Spr-sprigs, TH- tree holes, TP-temporary pool.

Recently survey for the determination of species composition of mosquitoes in Palosai Peshawar was conducted by Ali and Rasheed (2009) [20] and found three species of Culex and six species of Anopheles. The present study is richer in collection methods, habitats surveyed and in species composition as compared to the study of Ali and Rasheed (2009).

In the present study, habitat specificity of different species of mosquitoes based on total larval collections from various aquatic habitats was observed. The rice fields appeared as the most favorable habitat for mosquito breeding, since the highest numbers of species (12) were recovered from this category of sites. The river margins were the second most important breeding sites, since they harbored 5 species. The springs and temporary pools harbored 4 species each. Different species of mosquito vary in their habitat requirements [30]. The characteristics of water bodies play a major role in determining which mosquito species inhabits an area [31]. The main factor limiting the numbers of mosquitoes in any area is the availability of their breeding places which is directly affected by environmental factors. Various environmental factors control the population dynamics of mosquitoes inhabiting natural breeding places [32].

5 CONCLUSIONS AND RECOMMENDATIONS

In Swat, mosquito fauna is diverse and represented by Anopheles, Culex, Aedes, Armigere and Culiseta. The genus Anopheles includes the known malaria vectors, *An. stephensi* and *An. culicifacies* and the suspected malaria vectors, *An. fluviaitlis*. The genus Culex includes *Cx. perixiguus* which is not reported from other areas of Pakistan. The genus Aedes includes a high altitude species, *Ae. shortti* and recently disseminated dengue vector, *Ae. aegypti*. This research was conducted during April-September 2000 when rice was cultivated on maximum area of upper Swat. Rice fields and associated ditches, ponds, pools (perennial and temporary), water channels and marshes constituted the most important breeding sites for mosquitoes including malaria vectors. But in the present time, most fields of upper Swat have been occupied by peach orchards, as a result marshes have been converted into dry lands and most of the water channels, ditches and drainages remain dry, but still cases of malaria have not been reduced. Therefore, further study is required to compare this data with the new findings, to investigate the influence of landscape changes on the species composition of mosquitoes, and to explore

the adaptation of malaria vectors to other breeding sites. This will help in understanding relationship between landscape components and mosquito population, which is a priority in foreseeing the influence of land-cover changes on malaria vector occurrence and in shaping control strategies for the future.

REFERENCES

[1] A.N.Clement, "The biology of mosquitoes", Champman and Hall, London, vol. 1, 1992.

[2] K.L. Knight and A. Stone, "A catology of the mosquitoes of the world (Diptera: Culicidae)", Thomas Say Foundation. E.S. A, vol.6, 1977.

[3] M. Bates, "The Natural History of Mosquitoes" Harper: NewYark, 1949.

[4] WHO "World Malaria Report 2008", WHO Press, World Health Organization, Geneva Switzerland, 2008.

[5] R.H. Behrens, Z. Bisoffi, A. Bjorkman, J. Gascon, C. Hatz, T. Jelinek, F. Lergos and N. Muhlberger, "Malaria prophylaxis policy for travelers from Europe to the Indian Sub-Continent". *Malaria Journal,* vol.5, pp.7, February 2006.

[6] WHO "World Malaria Report 2009", WHO Press, World Health Organization, Geneva Switzerland, 2009.

[7] G. Covell, "The Present State of the Knowledge Regarding the Transmission of Malaria by different Species of Anopheline Mosquitoes", Records of the Malaria Survey of India, vol.2, pp1-48, 1931.

[8] E.P. Hick and S.A. Majid, "A Study of the Epidemiology of Malaria in a Punjab District. Records of the Malaria Survey of India", 7, pp.1-35, 1937.

[9] W.K. Reisen and P.F.L. Boreham, "Estimates of Malaria vectorial capacity for *Anopheles culicifacies* and *Anopheles stephensi* in Rural Punjab Province", Pakistan *Journal of Medical Entomology*, 19 (1), pp.98-103, January 1982.

[10] F.R. Mahmood, K. Sakai and K. Akhtar, "Vector Incrimination Studies and Observation on Species A & B of The Taxon Anopheles culicifacies", *Transactions of the Royal Society of Tropical Medicine and Hygiene,* vol.78, pp. 607-616, 1984.

[11] S.D. Pervez and I.H. Shah, "Role of *Anopheles stephensi* as Malaria Vector in Rural Areas of Pakistan", *Pakistan Journal of Health*, vol. 3, pp. 35-42, 1989.

[12] M. Rehman and A. Mutalib, "Determination of Malaria Transmission in Central Part of Karachi City and Incrimination of *An. stephensi* as the Vector", *Pakistan Journal of Health,* vol. 17, pp.73-84, 1976.

[13] M. Suleman, S. Khan and M. Khalid, "Ecology of mosquitoes in Peshawar Valley and adjoining areas: species composition and relative abundance", *Pakistan Journal of Zoology*, vol. 25, n°.4, pp.321-328, December 1993.

[14] M.S. Wolfe, & M. AslamKhan, " Filariasis survey in Karachi. *Transactions of the Royal Society of Tropical Medicine and Hygiene,"* vol. 63, pp.147, 1969.

[15] M.A. Beg, A. Naqvi, V. Zaman and R. Hussain, "Tropical Pulmonary Eosinophilia and Filariasis in Pakistan", Southeast Asian Journal of Tropical Medicine and Public Health, vol.32, n°.1, pp.73-75, March 2001.

[16] H.C. Barnett, "Taxanomic complexes of arbovirus vector". *Japanese Journal of Medical Science Biology*, vol.20, pp.19-21, 1966.

[17] M.I. Burney and A.H. Munir, "Role of Arthropode-borne viruses in human disease in Rawalpindi and Peshawar Area II. Isolation of West Nile virus from human blood and culicine mosquitoes in Rawalpindi Area", Pakistan *Journal of Medical Research*, vol.5, pp.271, 1966.

[18] A.Z.K. Yousafzai, "Ecological studies on mosquitoes in a rural village of Swabi district", M.Sc. Thesis, Department of Zoology, University of Peshawar, Pakistan, 1994.

[19] M. Suleman, M. Arshad and K. Khan, "Yellow fever mosquito (Diptera: Culicidae) introduced into Landikotal, Pakistan by tire importation", *Journal of Medical Entomology*, vol. 33, n°.4, pp.689-693, July 1996.

[20] N. Ali and S.B. Rasheed, "Determination of Species Composition of Mosquitoes found in Palosai Stream, Peshawar", *Pakistan Entomologist*, vol. 31, n°.1, 2009.

[21] P.J. Baraud, "The fauna of British India, including Ceylon and Burma, Diptera, family Culicidae, Tribes Megarhinini and Culicini", Taylor and Francis, London, XXVIII, pp.463. 1934.

[22] R.E. Harbach, "The mosquitoes of the Subgenus Culex in South West Asia and Egypt (Diptera: Culicidae)", Contributions of the American Entomological Institute, vol.24, n°.1, 1988.

[23] M. Qutubuddin, "The mosquito fauna of Kohat-Hangu Valley, West Pakistan", Mosquito News, vol. 20, pp. 355-361, 1960.

[24] M. Aslamkhan and C. Salman, "The bionomics of the mosquitoes of the Changa Manga National Forest, West Pakistan", *Pakistan Journal of Zoology,* vol. 1, pp.183-205, 1969.

[25] W.K. Reisen, "A quantitative mosquito survey of seven villages in Punjab province, Pakistan with notes on bionomics, sampling methods and the effects of insecticides", *Southeast Asian Journal of Tropical Medicines and Public Health*, vol. 9, pp.587-601, 1978.

[26] A.R. Pal and A. Aziz, "A survey of malaria parasite and anopheline mosquitoes in Rawalpindi-Islamabad area", *Journal Pakistan Medical Association*, pp.69-71, March 1985.

[27] K. Kamimura, T. Takasu, A. Ahmad and A. Akhtar, "A survey of Mosquitoes in Karachi Area, Pakistan", Journal of Pakistan Medical Association, vol. 36, n°. 7, pp.182-8, July 1986.
[28] M. Mukhtar, N. Herrel, F.P. Amerasinghe, J. Ensink, W. van der hoek and F. Konradsen, "Role of waste water irrigation in mosquito breeding in South Punjab, Pakistan", *Southeast Asian Journal of Tropical Medicine and Public Health*, vol. 34, n°. 1, March 2003.
[29] W. Akram, F. Hafeez, Naeemullah, Y.K. Kim, A. Hussain, and J.J. Lee, "Seasonal distribution and species composition of daytime biting mosquitoes", *Entomoogical Research,* vol. 39, pp. 107–113, March 2009.
[30] WHO, "Manual on environmental management for mosquito control", Geneva: WHO Offset publication, pp.661982.
[31] WHO "Geographical distribution of arthropod-borne diseases and their principal vectors". *WHO/VBC/89.96, 1989.*
[32] R.H. Wharton, "The biology of Mansonia mosquitoes in relation to the transmission of filariasis in Malaya", *Institute* for *Medical Research* (*Malaysia*), vol. 11, pp. 114, 1962.