REVIEW OF LITERATURE
AT NATIONAL LEVEL

India is a vast country with great diversity in topography and physiography supported by both tropical and subtropical climates. Mosquitoes (Diptera: Culicidae) are the most important source for transmission of many vector borne diseases as compared to other arthropod vectors. Many entomologists have published a large number of papers and monographs in India following their extensive surveys on mosquito fauna. However, most of these publications dealt with only limited and fragmentary areas of taxonomic groups, such as single genus or a few subfamilies of family Culicidae. However, Christophers (1933) and Barraud (1934) were the eminent and pioneer workers to publish extensively importnat literature on tribe Anophelini, Culicini and Magarhirini (Toxorhynchitinae) especially under their magnum opuses, “The Fauna of British India series”. During the last six decades after the publication of above two masterpieces, some of the notable and indispensably referable works of eminent taxonomists like Grassi (1899); Adie (1905), Rothwell (1907), Thomson (1909), Mc Combie (1911), Strickland and Chowdhary (1927); Mc Combie and Abdul (1928), Puri (1948), Wattal and Kalra (1961), Wattal (1963), Roy and Brown (1970), Rao (1984), Das et al. (1990) and Nagpal & Sharma (1995) are of lot of significance and really admirable. All these references dealt with Anophelines only. Later, a comprehensive catalogue of Indian mosquitoes was brought out by Tyagi (2010).

It is the worth to mention here that only four mosquito species were known from India before 1900. Giles (1900) described 242 species of mosquitoes referable to 8 genera viz., Megarhinus Robineau Desvoidy; Anopheles Meigen; Psorophora Robineau Desvoidy; Sabethes Robineau Desvoidy; Culex Linneaus; Aedes Meigen; Corothrella Coquillet and Mochloynyx Loew. Stephens and Christophers (1902) made their first attempt to classify Indian Anophelines into natural groups. James and Liston (1904) wrote a monograph on the Anopheles mosquitoes of India. In this paper, Indian Anophelines have been divided under 10 groups. However, these authors regrouped Anophelines into 13 genera in the 2nd edition of their monograph of 1911. As many as 40 species of Anophelines were also described in this publication. Brunetti (1907 and 1920) published a catalogue of oriental and South Asiatic Nematocera including Indian species.
Later on Christophers (1911, 1913, 1915, 1916, 1916a, 1923, and 1924) published a series of papers on the taxonomy of Indian Anophelinae. He also brought out a synoptic table for the identification of the Anopheline mosquitoes of India in 1931. After two years, Christophers (1933) made major contribution in mosquito’s taxonomy by writing the “Fauna of British India”. This exhaustive taxonomic publication on Anophelines included 42 species and 10 varieties of this group. Not only, pertinent information was provided about taxonomic account of each species, but also useful notes of immense value on breeding habits, bionomics, distribution and relation to diseases provided in this paper. This piece of work proved to be valuable reference material for taxonomists working on Anophelines in this country even after half a century. Iyengar (1922) described the larva of *Anopheles annanddalei* Prashad and studied its main characteristics which differentiate it from other Indian Anophelines. Christophers and Barraud (1923) described the terminology of genitalia of male mosquitoes. In 1931, same authors also studied the eggs of Indian *Anopheles*.

The most eminent Indian worker Barraud (1923, 1923a, 1923b, 1923c, 1923d, 1924, 1924a, 1924b, 1924c, 1924d, 1924e, 1924f, 1927, 1927a, 1927b, 1928, 1929, 1931, 1931a) made a marvelous contribution by publishing a series of papers on mosquito taxonomy. Barraud (1920) provided brief notes on 12 species of mosquitoes from lower Mesopotamia. He revised subfamilies of Culicidae and described many new species. These valuable works eventually led to the publications of the “Fauna of British India”, including Sri Lanka and Myanmar on subfamily Culicinae in 1934. This subfamily is represented by 29 genera and 239 species. Barraud provided detailed diagnosis of each species and included pertinent information on immature stages.

Covell (1927) studied distribution of Anophelinae mosquitoes of India and Ceylon. After four years, Covell (1931) studied distribution of Anopheline mosquitoes of India in detail. Sinton and Covell (1927) studied in detail the morphology of buccal cavity of 52 species of Anophelines under all subgenera except *Chagasia*. Barraud and Covell (1928) recognized the internal morphological features of the female cibarium of some species of Culicidae for taxonomic differentiation.
Puri (1931) studied bionomics, mounting techniques, external morphology of the larvae of Anopheline mosquitoes and also morphology of Anopheline mosquito species in detail. Puri (1928, 1929, 1930, 1937, 1948 and 1948a) also made significant contribution towards the taxonomy of Indian Anophelinae and his major achievement was the publication of a synoptic table for the identification of Indian Anophelinae (Puri, 1954). This publication dealt with description of 43 species and nine varietal forms. Out of these, 40 species have been restricted to present Indian limits. Five synoptic tables for five arbitrary regions viz., Madhya Bharat, Rajasthan, Saurashtra, Uttar Pradesh, Peninsular India, Eastern India, Punjab and Delhi province, Nepal, Myanmar, Thailand, Afghanistan etc. in addition to the main synoptic table were also provided. This publication also dealt with supplementary notes on all Indian species and additional tables for the identification of all varieties and some of the closely related species. Puri (1960) published another synoptic table for identification of 40 species of Anophelines from India, Myanmar and Baluchistan.

Rao et al. (1938) compared Anopheles stephensi type and Anopheles stephensi var. Mysorensis on the basis of ova size. Rao et al. (1952) recorded Anopheline mosquitoes in the district of Shimogea and Hassan, Mysore state. Rao (1957) reported 24 Anopheline species from the districts of Shimoga and Hassan of Mysore State and also provided general but valuable comments on some species. Rao et al. (1973) published a manuscript dealing with general accounts of Haematophagous Arthropods from Western Himalayas, Sikkim and hill districts of West Bengal. In this paper, they described methods of collections and also provided lists of various Arthropods encountered in states of Jammu and Kashmir, Himachal Padesh, Uttaranchal and parts of Sikkim. Rao (1981) made a major contribution towards mosquito studies by providing an exhaustive publication on Anophelines of India. In this publication, he also made an attempt to provide complete list of Anophelines of neighbouring countries of India. He gave full details of each species like name, type locality, repository of type, taxonomy, distinguishing characters, distribution, prevalence, adult bionomics and relation to diseases. Bhombre et al. (1954) studied the seasonable prevalence of Anophelines in western hill tracks of Mysore State provided a list of 23 Anopheline species.
Roy and Siddons (1939) studied the eggs of *Anopheles philippinensis* Ludlow, *Anopheles annularis* Van der Wulp and *Anopheles maculatus* Theobald collected from Midnapur district of West Bengal. Davey (1941) discussed the larva and pupa of *Anopheles brunnipes* Theobald in detail. Sen (1948) studied breeding of *Anopheles* in the rice fields of lower Bengal and recorded a total number of 11 species of Anopheline from rice fields. Srivastava (1955, 1956 and 1956a) studied Anopheline fauna of Utranchal and reported 16 species from the state. Wattal and co-workers (1958) made 18 new records of Culicines from Dehradun and described a new variety. Later on Wattal and Kalra (1961) published pictorial keys to Indian *Anopheles* Meigen. These keys included 32 species of Anophelines. Bhatnagar et al. (1958) studied morphological abnormalities in ornamentation of maxillary palpi, tarsi, hind legs and on wings. They also observed lack of dark coloring or hypomelanism in *Anopheles pallidus* Theobald and incomplete development of sixth wing vein in *Anopheles stephensi stephensi*. Qutubuddin (1960) studied mosquitoes of Indian sub region in detail and also presented an identification keys on the basis of these characters. Al-Tikrity (1963) studied morphology, ecology and geographical distribution of breeding places of *Anopheles apoci* Marsh pupa. Doraisamy (1963) recorded subspecies variation in the larvae of *Anopheles subpictus* Grassi collected from different districts of Madras state and observed variations only in the pilota of the head of larvae.


Hati (1984 and 1984a) studied vector species of mosquitoes in detail. Tewari et al. (1987) reported 31 Anopheline species from hill ranges of Western Ghats. Malhotra et al. (1984). Studied mosquitoes of Mizoram. Bhatt et al. (1987) studied outdoor resting habitat of mosquitoes in Kheda district of Gujarat using the artificial pit shelters and revealed that mosquitoes prefer to rest in pit shelters and these can be used to ecological and behavioral studies. Rajput and Singh (1987) enlisted 23 species of day biting mosquitoes belonging to six genera from Manipur state. They also studied the monthly fluctuations in day biting density of these mosquitoes. Rajput and Singh (1987a) reported *Anopheles minimus* Theobald , an important Malaria vector of North East region from Manipur for the first time. In subsequent publication entitled “Dusk biting mosquitoes of Manipur”. Rajput and Singh (1988) reported 21 mosquito species from human and 22 from bovine bait along with monthly variations. Rajput and Singh (1988a) published a paper regarding the vertical distribution pattern of 90 mosquito species belonging to 10 genera in hill ranges of Manipur.

Malhotra et al. (1987) surveyed the Anopheline fauna from September-October 1980 in Tenga valley from Arunachal Pradesh and collected a total number of 12 species with high density of *Anopheles vagus* Doenitz and *Anopheles maculatus* Theobald. In 1998, they also provided a systematic list of 45 species of Anophelines from North East India and discussed their role in Malaria transmission. Malhotra et al. (2000) described the surface morphology of the eggs of *Anopheles stephensi sensu stricto* with the aid of optical and scanning electron microscope.
Das et al. (1990) a provided pictorial key to the species of Indian Anopheline mosquitoes. Nagpal (1990) observed morphological variations in wings and palpi of 216 specimens of natural populations of Anopheles stephensi Liston 1901, collected from Kutch (Gujarat). Nagpal and Sharma (1983, 1983a and 1987) published a series of papers regarding morphological variations in Anophelinae species on basis of surveys conducted in Assam, Andaman Islands, North Eastern region and Kutch (Gujarat). Nagpal and Sharma in 1995 brought out a major paper entitled “Indian Anophelines” which dealt with the keys for the identification of Indian Anopheles, detailed illustrations of the species, morphological variations, geographical distribution and their role in disease transmission. These authors also provided brief accounts of 58 species of Anophelines including their biology, availability of type form, species complexes, sitting posture, biting time and flight range.

Tewari and Hariyan (1991) described and illustrated the pupa of Anopheles (Anopheles) sintoni Puri for the first time and also compared it to Anopheles sintonoides Ho. Malhotra and Mahanta (1994) provided checklist of mosquitoes of Northeast India. Rattanarithikul and Harbach (1991) found Anopheles maculates (Diptera : Culicidae) from the type locality of Hongkong and two new species of maculatus from the Philippines and provided detail study of these species. Rattanarithikul and Panthusiri (1994). Formulated illustrated keys to the medically important Mosquitoes of Thailand. Kumar et al. (1994) studied the effect of biolarvicide Bacillus sphaericus at the rate of 1g/m² in the main Anopheles stephensi Liston larval habitats in Panji, Goa and observed large decline in habitat productivity. Sagandeep et al. (1994) listed 16 species of mosquitoes representing 4 genera from Punjab and Himachal Pradesh. Sagandeep et al. (2003) did ultra structural studies on mouthparts of four species of genus Culex Linnaeus.

Chakarborty et al. (1998) studied seasonal prevalence of Anopheles stephensi larvae and observed that Anopheles stephensi Liston population in the urban garden in central Calcutta was found to comprise of two forms the type and variety mysorensis.

Prakash et al. (2003) carried out studies on a forest based industrial security camp of Dibrugarh district and developed an effective malaria control strategy. Singh et al. (2003) surveyed outbreak of malaria and observed that 70% of the fever cases had malaria, with 87% of malaria caused by *Plasmodium falciparum* and also found that malaria in Chhindwara increased gradually from 0.31 per 1000 in 1990 to 6.75 per 1000 in 2000. Chaudhary & Gupta (2003) conducted scanning electron microscopic studies on the *An. culicifacies* Giles, a principal vector of malaria in India. Likewise in the next year; they conducted scanning electron microscopic studies on the *An. stephensi* Liston which is also a major vector of malaria in India. Paramavisan and
Mishra (2004) studied West Nile Virus in detail from India. Farooq and Mahajan (2004) examined the drug resistance in malarial parasites and concluded that control of drug resistance in malarial parasites requires reducing the overall drug pressure through more selective use of drugs and improving the way the drugs used. Devi and Jauhari (2007) revealed that phytographically the zones of lower elevation shared higher species abundance of mosquitoes than the higher elevation in the Garhwal region of India. Devi and Jauhari (2008) examined occurrence of Anopheline mosquitoes in seven districts of Uttrakhand, India.

Mokany and Mokany (2006) studied that mosquito species show variances in their oviposition site selection and larval development depending on water depth and drought history. Khalin (2006) described the three-dimensional structure of claspette in male genitalia of Aedes diantaeus Howard, Dyar & Knab under scanning electron microscope. He described the shape, structure and position of claspette’s wing in relation to the claspette’s stem. Khalin (2009) observed the significant 3-D complex structure of the claspettes in the male genitalia of the subgenus Ochlerotatus Lynch Arribalzaga of the genus Aedes Meigen. In the following year, Khalin revealed the fact that 3-D structure of male genitalia of genus Aedes Meigen strongly differs from traditional 2-D pictures, obtained during examination of balsam slides. Pramanik et al. (2006) did a survey of Anopheline mosquitoes and malarial parasite in commuters in rural and urban areas in West Bengal. Singh et al. (2006) studied the conspecificity of Anopheles fluviatilis James species (S) with Anopheles minimus Theobald species (C). Each comprises of at least three sibling species which closely related and are important malaria vectors in Oriental region. Pemola & Jauhari (2006) studied climate factors particularly temperature and rainfall which effect the distribution and breeding of mosquitoes.


Barik et al. (2009) studied bionomics of all five sibling species i.e. *A*, *B*, *C*, *D* and *E* of *Anopheles culicifacies* Giles which is a major vector of malaria in Indian subcontinent and described the effect of climate changes on its major vector species. Mohanty et al. (2009) analysed the phylogenetic relationship of *Anopheles* species, subgenus *Cellia* Theobald (Diptera: Culicidae) and used it to define the relationship of morphologically similar species. Pradya et al. (2009) studied cibarial armature *Anopheles dirus* complex (Diptera: Culicidae) with the aid of Scanning electron microscopy. Sedaghat et al. (2009) studied morphology of the adults, egg, larvae and pupa of *Anopheles persiensis* Linton, Sedaghat and Harbach. Singh (2009) recorded 14 species of Anopheles, 15 of *Culex* and one each of *Armigeres*, *Mansonia* and *Aedes* from Kurukshetra. A few species including *Anopheles pulcherrimus* Theobald, *Anopheles stephensi* Liston and *Mansonia uniformis* (Theobald) have totally disappeared from the area, whereas the population of *Armigeres obturbans* (Walker) is gradually increasing while that of *Anopheles culicifacies* Giles, is on decline.
Manimegalai (2010) studied mosquito prevalence in three areas in Coimbatore city of Tamil Nadu i.e. North Coimbatore, Gandhipuram and Kavundampalayam and observed that *Culex quinquefasciatus* Say was predominant species in North Coimbatore, and *Armigeres subalbatus* (Coquillett), as predominant species both in Gandhipuram and Kavundampalayam areas. Basseri *et al.* (2010) studied that vector density and malaria transmission intensity, display similar patterns in relation to environmental conditions such as rainfall and spatial and seasonal heterogeneity among shelters.

Amala *et al.* (2011) studied diversity of four genera of mosquitoes *Aedes*, *Culex*, *Armigeres* and *Anopheles* in Rajathnikottai village, Dindigul district of Tamil Nadu and concluded that *Anopheles* were most dangerous amongst the four genera and responsible for spreading of malaria. Deepa *et al.* (2011) reported that both *P. falciparum* and *P. vivax* infections provide supporting evidence in favour of an effect of ABO group on disease severity as ‘O’ group provides advantage over non ‘O’ groups. Mandal *et al.* (2011) studied both chlorinated and rain water containers in Kolkata city, India and found that both were positive for *Anopheles stephensi* Liston larvae and reported that these are breeding sites of vector species. Das and Ravindran (2011) collected community knowledge on malaria among febrile patients in an endemic district of Orissa, India.

Adhikari *et al.* (2013) studied diversity and abundance of malaria vectors in Dhekiajuli subdivision of Sonitpur district Assam. Mary *et al.* (2013) studied the effect of larvicidal, pupicidal and repellent activity of synthesized silver nanoparticles using leaf aqueous extract of adiantum capillus-vernis against larva and pupa of malaria vector-*Anopheles sephensi* Liston. Singh and Mohan (2013) examined ommatidia and compound eyes of *Anopheles stephensi* Liston, *Culex quinquifasciatus* Say and *Aedes aegypti* and found that mean number of ommatidia were different in number among adult and pupae in above three species.
REVIEW OF LITERATURE

AT GLOBAL LEVEL

A close look at the review of literature shows that a lot of work has been done at Global level by eminent taxonomists working on mosquito taxonomy. Although a large chunk of this marvelous work was accomplished in early part of twentieth century by some eminent workers like Giles (1900,1901,1901a,1903); Theobald (1901,1901a,1903,1907,1908,1910,1910a) and Cogill (1903).

Edwards (1911,1912,1912a, 1913, 1914, 1917) made important contribution towards the study of African Culicidae. In one of his publication, Edwards (1913) re-described 22 mosquito species and described three new ones. Edwards (1920, 1920a) contributed an important research paper on nomenclature of parts of male hypopygium nomenclature of Diptera and laid particular emphasis on this structure of mosquitoes also. He contributed a publication on nomenclature of parts of male hypopygium of Diptera in (1920a) and laid particular emphasis on that of mosquitoes. Later on, Edwards (1921,1922,1923,1924, 1925,1926,1929,1930,1930a and 1932) gave detailed notes on different species of mosquitoes of Malaysia and Papua New Guinea. In 1924, he studied Australian fauna and gave brief descriptions of 145 species belonging to 16 genera.

Dyar and knab (1919) in their publication entitled “New Species of Tropical American Mosquitoes” provided a report of three new species of Culex Linnaeus from Guiana, one each from Grenada and Guatemala. Dyar (1920a, 1920b, 1920c, 1920d, 1920e, 1921) contributed a series of publications on mosquito taxonomy of Europe, Mexico, California, Panama and Costa Rica and erected many new species belonging to genus Culex Linnaeus. In one of his subsequent publication, Dyar (1922) erected three new species of mosquitoes from Panama, one each from Bolivia and Colombia, besides reporting a new subspecies from Costa Rica. Dyar (1924a, 1924b, 1924c, 1924d, 1924e, 1925) worked a lot on the Sebethid mosquitoes of Brazil, Central America, West Indies, Colombia, Panama and California and reported many new species from above said regions. In 1928, Dyar contributed major publication on the mosquitoes of United States of America. In this manuscript, he discussed all the synonymies and provided keys for adult as well as larvae. Dyar and Shannon (1924)
formulated keys to the genus *Uranotaenia* Lynch Arribalzaga and described new species *Uranotaenia syntheta* to the mosquito fauna of Texas. In another publication, Dyar and Shannon (1924a) while working on subfamily Chaoborinae of American mosquitoes, provided keys upto species level and erected 3 new species, on each from Washington, California and Panama. Dyar and Shannon (1925) while studying the types of Philippine mosquitoes described by Ludlow, erected 2 new genera and also recorded 7 new species.

Carter (1920) described male genitalic armature of *Anopheles maculipennis* Meigen, *Anopheles bifurcates* Linnaeus and *Anopheles plumbeus* Stephens in detail. Macfie and Ingram (1922) explained the genital armature of female mosquitoes of 50 West African species referable to 16 different genera. Root (1924) studied male genitalia of American *Anopheles* mosquitoes. Shannon (1924) examined maxillary teeth of *Anopheles maculipennis* Meigen and observed that number of maxillary teeth higher in the species collected from Northern and non malarial region of North America. Brug (1924 and 1932) made important contributions towards the taxonomy of Indonesian mosquitoes.

Manalang (1930) described morphology and classification of Philippine variety of *Anopheles minimus* Theobald in detail. Gerry (1932) studied morphology of female genitalia of Cuban mosquitoes, which also includes its taxonomic value and significant generic characters. Urbino (1936) studied the eggs of some Philippine *Anopheles* species and provided identification key on the basis of structure of eggs. Chang (1937) examined maxillary teeth on *Anopheles hyrcanus var. sinensis* Wiedemann in Shanghai region and found that *Anopheles hyrcanus var. sinensis* with high maxillary index feeding on man from this region. Chang and Huang (1954 & 1955) studied Anophelinae diversity of Taiwan. They described the characters of adult Anopheline in part I and described characters of larvae in detail in part II. Chang (1957) alone studied maxillary teeth of *Anopheles hyrcanus var. sinensis* Wiedemann and concluded that most of the Anophelines tend to be zoophilic in their choice of blood hosts when different sources of blood were available to them.

Crawford (1938) studied the structure of *Anopheles* pupa and described the pupal stage of 17 species of *Anopheles* in detail. Hurlburt (1938) described two types
of eggs i.e. summer and winter of *Anopheles walkeri* and also presented data on the overwintering of the eggs of *Anopheles walkeri* in winter egg stage under experimentation conditions. King and Bradley (1941) studied general morphology and classification of *Anopheles* species of Nearctic species in detail and also provided keys on the basis of characters of studied species. Michner (1944) explained characters of cibarial armature of some *Culex* species and also differentiated these species on the basis of these structures from Southeastern United States. Causey *et al.* (1946) provided an identification key on the basis of 34 species of Anophelinae on the basis of male genitalic characters from the Northeast and Amazon regions of Brazil.

Coher (1949) studied female genitalia of family Culicidae and formulated a key also. Besides this, the author also studied generic value of this family. Belkin (1952) studied homologies of the pupal and larval hair and revised the criteria which used to determine the larval and pupal hairs. He also observed that larva and pupa lack abdominal hairs IX and XI. Reid (1953) conducted studies on *Anopheles hyrcanus* group from South-East Asia and discussed its classification, distribution, evolution, biology and relation to disease in detail. In 1966, he differentiated *Anopheles indefinites* Ludlow and *Anopheles subpictus* Grassi Hacker which were earlier confused under the name of *Anopheles subpictus* Grassi from Malaya and also discussed their differences on the basis of its nomenclature and distribution.

Hara (1957) studied female terminalia of Japanese mosquitoes and provided a key on the basis of characters of female terminalia. Hara (1959) studied female terminalia of 12 species of genus *Anopheles* belonging to subgenus *Anopheles* and *Myzomia* in detail and also provided identification key to the species. Ohmori (1957) studied four species of *sinensis* group i.e. *Anopheles yatsus- hiroensis*, *Anopheles sinensis* Wiedemann, *Anopheles sineroides* and *Anopheles lesteri* from Japan and found differences on the basis of male hypopygium and ventral side of the side piece and also observed that these all are true species. Stone (1957) published corrections in the taxonomy and nomenclature of Mosquitoes (Diptera : Culicidae). Stone *et al.* (1959) published a catalogue on the world Culicinae which was followed by the publication of the catalogue on systematic of mosquitoes of the world by Knight and Stone in 1977. Menees (1958) described facial areas, labrum, epipharynx, hypopharynx
and mandibles of the larva of *Anopheles quadrimaculatus* Say. In the same year (Menees 1958a), he studied maxilla and labium of the larva of *Anopheles quadrimaculatus* Say and observed that the maxilla made up of palpus, lacinia, galea, stipes, cardo and labium consists of submentum, mentum and prementum.

Gad and Kamel (1967) recorded *Anopheles stephensi* Liston from oil fields in shokier which was not inhibited area before. Hinton (1967) studied the egg shells of 11 species of *Anopheles* with the aid of Stereoscopic Electron Microscope and also explained the difference among them on the basis of biology and taxonomy. Su-Fang (1968) reported comparative morphology on the pupa of different types of *Anopheles (Anopheles) hyrcanus sinensis* from China. Characters of three types of pupa were easily distinguishable. Miyagi et al. (1969) discovered *Anopheles tessellatus* Theobald for the first time from Ryukyu Island and studied in detail its morphologically. Knight (1971) presented mosquito taxonomy Glossary of pupa. In 1978, Knight published a catalogue of the mosquitoes of world, which included one new name of the genus group and 111 new names of the species group.

Aslamkhan et al. (1972) studied 50 genetical and morphological variations in natural population of the malaria mosquito *Anopheles stephensi* Liston from Karachi, Pakistan. White and Muniss (1972) explained taxonomic value of spermatheca size for distinguishing four species of *Anopheles gambia* complex in east Africa. Chen (1972) studied cibarial armature of eight species of Culicinae mosquitoes from Taipei Area of Taiwan and also prepared identification key on the basis of the characters of cibarial armature. Boreham and Baerg (1974) collected female specimens of *Anopheles squamifemur* Antunes and discussed and illustrated its egg, larvae and pupa for first time. Besides this, they also compared it with other species of subgenus *Lophopodomyia*. Siverly and Shroyer (1974) presented an identification key on the basis of male genitalia of mosquitoes of India. Ammen and Talukdar (1974) studied pupal chaetotaxy of five species of genus *Anopheles* viz., *Anopheles subpictus* Grassi, *Anopheles annularis* Van der Wulp, *Anopheles vagus* Doenitz, *Anopheles barbistrostris* Van der Wulp and *Anopheles nigerrimus* Giles from Dacca. Harrison (1972) interpreted affinities on the basis of characters of all life stages within South-East Asian *Anopheles hyrcanus* complex. In 1984, Harrison and Peyton discussed and
illustrated anomalous setae on Anophelinea pupae and also discussed the importance of pupal stage of Anophelines along with its advantages and disadvantages. In 1979, they described and illustrated in detail the adult, pupal and larval stages of a new species *Anopheles (Cellia) dirus* Peyton & Harrison of Leucosphyrus group from Thailand. Peyton (1979) alone divided Leucosphyrus group of the genus *Anopheles* Meigen, subgenus *Cellia* Theobald into three subordinate groups on the basis of relative lengths of female proboscis, maxillary palpus and forefemur.

Manouchehri *et al.* (1976) studied ecology of the *Anopheles stephensi* Liston from southern Iran and observed that this species usually rests indoors and resistant to DDT and Dieldrin in Persian Gulf and Oman sea. Harbach (1978) described and illustrated labiopharynx of 62 species of fourth stage culicid larvae of three genera of Dixinae, two of Chaoborinae and one (Ficalbia) of 34 genera with light and scanning electron microscope. In 1981, Harbach and Knight provided a list of corrections and additions to ‘Taxonomist Glossary of Mosquito Anatomy’ by Harbach and Knight (1980). Harbach (2007) reclassified the mosquitoes and placed them under the suborder Nematocera and family Culicidae which included 3490 species belonging to 44 genera, 145 subgenera, under three subfamilies, namely Anophelineae, Culicinae and Toxorhynchitinae. Beidas and Gillies (1980) described egg of *Anopheles (Cellia) culicifacies adenensis* Christophers from Oman in detail. Savignac and Maire (1981) observed that second and third instar mosquito larva of 34 Canadian species belonging to genera *Anopheles, Culex, Culiseta* and *Wyeomyia* and separated on the basis of absence or presence of thoracic setae, 8-M and J.T. and also on the basis of metathoracic setal support plates. Lee and Craig (1983) explained in detail the cibarial armature of 37 species of mosquitoes under nine genera by using light microscopy and also studied *Anopheles farauti* Laveran, *Aedes aegypti* (Linnaeus), *Culiseta inornata* (Williston) and *Culex declaralon* Dyar and Knab with the aid of scanning electron microscope. Ward (1984 and 1992) published a catalog of the Mosquitoes of the world (Diptera: Culicidae).

Rathor *et al.* (1985) discussed current status of insecticide resistance of two primary and four secondary malaria vectors of Punjab province of Pakistan. Damrongphal and Baimai (1989) studied eggs of species A, B, C and D of the
Anopheles dirus complex with the aid of scanning electron microscopic studies and observed that eggs of species A and C were similar in size and the eggs of species B large than that of species D. Forattini and Sallum (1992) examined female cibarium of 13 species of mosquitoes of the Spissiper section of Culex (Melanoconion) with the help of light and scanning electron microscope and also studied the Culex adamesi with the help of light microscopy. Glick (1992) presented identification key of the 39 species and three subspecies of the female Anopheline mosquitoes of Southwestern Asia and Egypt and also provided tables which included important taxonomic references and geographic distribution.

Linley (1992) described eggs of Anopheles atropos Dyar & Knab and Anopheles darlingi Root with the help of scanning electron microscope. Linley et al. (1995) described the eggs of four species i.e. Anopheles gambiae Giles, Anopheles paralae Sandosham, Anopheles peditaeniatus (Leicester) and Anopheles sinensis Wiedemann of Anopheles (Anopheles) in the hyrcanus complex with the help of scanning electron microscope. Rodriguez (1992) studied the eggs of Anopheles albimanus Wiedemann and observed that eggs of this species are polymorphic in respect to size and shape of their floats but not in their ornamentation.

Amersinghe (1995) provided identification key for the pupal stage of 21 species out of the total 22 species of Anopheline mosquitoes from Sri Lanka. In 2002, Amersinghe et al. presented keys for identification of the fourth instar larvae and females of 24 species of Anopheline mosquitoes includes seven species in subgenus Anopheles Meigen and 17 species in subgenus Cellia Theobald from Pakistan. Chadee et al. (1996) explained the structure of cibarial armature of four species of Anopheles for the first time and also described its role in blood meal haemolysis from Trinidad, West Indies. Amr et al. (1997) reported 19 species of Anophelinae and Culicinae mosquitoes from larval collections made in Northern Jordan and Jordan valley. Out of these species, Culex judaicus, Culiseta annulata and Uranotaenia unguiculata were new records from Jordan. Baimai et al. (1998) studied geographic distribution biting behavior of four species of the Anopheles dirus Complex in Thailand and observed that each species show different biting behavior, seasonal abundance and geographical distribution. Harbach and Kitching (1998) studied Phylogeny and

Sallum et al. (2000) redescribed and compared Anopheles (Kerteszia) laneanu Correa with other species of the subgenus Kerteszia, besides describing pupal stage for first time and its bionomics also. In 2002, they described the ultrastructure of the eggs of Anopheles (Nyssorhynchus) galvaoi Cansey, Deane and Deane and Anopheles (Nyssorhynchus) evansae (Brethes) with the help of Scanning electron microscope. In 2005, these authors revised 20 species of Leucosphyrus group of Neomyzomyia series of Anopheles (Cellia) and included the description of male and female adults, male genitalia, pupa and fourth instar larvae besides providing identification keys for females and fourth instar larvae. Samboon et al. (2000) collected three species i.e. Anopheles flavirostris (Ludlow), Anopheles minimus Theobald and species E (a new sibling species) from different regions and compared them on the basis of SEM studies of cibarial armature and found that these can be clearly differentiated on the basis of cibarial armature. These authors also discussed the previous records of the Anopheles minimus Theobald. In 2009, they examined the structure of cibarial armature of four species of mosquitoes with the help of SEM and found that the species were closely related on the basis of this structure and also explained that these observations are useful for taxonomic identification.

Herrel (2001) studied breeding of Anopheles mosquitoes in irrigated areas of South Punjab, Pakistan and concluded that in South Punjab where rainfall very low it should be possible to reduce Anopheline breeding through water management as larvae develop mainly in water bodies. Mendis et al. (2001) discussed that Plasmodium vivax different parasite from Plasmodium falciparum, both in the pattern of its burden on human populations, transmission and survival and concluded that residual burden of malaria of Plasmodium falciparum around the world increasing than Plasmodium vivax. Alencar et al. (2003) observed the differences in exochorion in relation to tubercles in eggs of Hg. leucoelaenus (Dyar & Shannon) with the aid of scanning electron microscopy and found that it had more resemblance to Hg. equines (Theobald) than Hg. janthinomys Dyar, with greater differences in eggs of Hg. spegazzinii Bretheze and Hg. lucifer (Howard, Dyar & Knab). Reuda et al., (2003)
Review of literature
gave the detailed morphological descriptions, illustrations for *Anopheles (Anopheles) pseudopunctipennis* Theobald, a major vector of human Malaria in Central and South America. They also gave taxonomic and literature records, diagnostic features, distribution and bionomics of the species. Reuda et al., (2007) gave updated distribution records of the *Anopheles (Anopheles) hyrnacus* species group in China. Benedict and Robinson (2003) released transgenic mosquitoes for the study of sterile insect technique. Rubio-Palis et al. (2003) gave taxonomic keys for identification of *Anopheles (Nyssorhynchus) marajoara* and three other sympatric species that occur in Venezuela and gave morphological characters of adult *Anopheles (Nyssorhynchus) marajoara*. Alencar et al. (2005) described the morphology of dorsal and ventral surfaces of both extremities and the micropylar area of eggs of *Haemagogus (Haemagogus) capricornii* Lutz, captured in Brazil. The tubercles presented differences in form, size and distribution. Vythilian et al. (2003) conducted a study on the prevalence of *Anopheles* in three malaria endemic villages in Sekong Province, in the southern region of Lao PDR from August 2001 to October 2001. Apperson et al. (2004) studied host feeding patterns of established and potential mosquito vectors of West Nile virus in the Eastern United States and concluded that vector species from this area may prefer to feed upon avian hosts. Klinkenberg et al. (2004) studied changes in environment of Southern Punjab, Pakistan and observed that *Anopheles stephensi* Liston has increased in prevalence and more common than *Anopheles culicifacies* Giles.

Hueng Chul et al. (2005) recorded 28 species representing seven genera from Jeju Island and described larval habitat characteristics, collection, bionomics and vector potential of each species in detail. Jaichapor et al. (2005) studied morphological variations on wings of *Anopheles minimus* A. in Tak Province from Thailand. Wiwanikit (2005) studied correlation between rainfall and prevalence of dengue and concluded that there was strong correlation between rainfall and the prevalence of dengue in central region of Thailand in 2004. Sedaghat and Harbach (2005) provided a checklist of *Anopheles* species based on data contained in Iranian manuals, reports and information published. Sedaghat et al. (2009) described in detail
the adult, larval and pupal stages of *Anopheles persiensis* Liston with the help of Scanning Electron Microscope.

Amer and Mehlhorn (2006) studied the role of some mosquito organs towards the repellant material and observed that the biting and landing percentages increased significantly in mosquito groups that lacked some organs i.e. maxillary bulbs. However, it was not clear in case of *Anopheles stephensi* Liston that which organ is responsible for perception of repellants. Azari-Hamidian *et al.* (2006) reported *Anopheles pediaenius* (Leicester) for the first time from Iran and studied it in detail. Joseph *et al.* (2006) studied immature stages of *Anopheles arabiensis* and other mosquito species in relation to rice cropping in a rice agro – ecosystem from Kenya. Boza and Vargas (2006) presented detailed description of the cibarial armature of Neotropical mosquitoes *Mansonia titillans*, *Psorophora cingulata*, *Coquillettidia aribalzaza*, *Culex coronator and Limatus duhamii* and descriptions were mainly based on the characteristics of dome, body, transversal bar, lateral flanges and cibarial teeth. Mutuku *et al.* (2006) studied the pupal habitat productivity of *Anopheles gambiae* complex from rural villages of western Kenya and concluded that habitats for pupal production could be treated or eliminated. Mwangangi *et al.* (2006) observed change in species composition and distribution of immature stages of *Anopheles arabiensis* Patton mosquitoes in relation to rice growth cycle in order to generate data for developing larval control strategies in rice ecosystems. Qui *et al.* (2006) collected olfactory information of antennal neurons of the malaria mosquito *Anopheles gambiae* complex and observed that some OR genes are only expressed after the first blood meal. Salako (2006) studied seasonal and temporal variations in the population and biting habit of mosquitoes on the atlantic coast of Lagos, Nigeria. Schaper and Hernandez-Chavarria (2006) studied four larval instars of dengue fever vector *Aedes aegypti* with the aid of Scanning electron microscope and defined morphological changes during larval development.

Helena and Wilkerson (2007) gave records of a newly recognised species in the *Anopheles* (*Nyssorhynchus*) *albitarsis* complex from Puerto-Carreño, Colombia. Walton *et al.* (2007) studied the *Anopheles annularis* group belonging to subgenus *Cellia* Theobald (Diptera: Culicidae) which included 5 currently recognised
species in Southern Asia were identified based on molecular methods. Brochero et al. (2007) reported a new species belonging to *Anopheles (Nyssorhynchus) albitarsis* Complex from Puerto Correno, Colombia and observed that it acts as a vector of malaria. Okech et al. (2007) examined the effect of larval habitat soil substrates in larval development time, pupation rates and vector competence of *Anopheles gambiae* to *Plasmodium falciparum*.

Rueda et al. (2007) updated distribution of *Anopheles hyrcanus* species group in China and observed that *Anopheles sinensis* Wiedemann was widely distributed species and noted their status of type specimen and importance in disease transmission. In 2009, they studied eggs of six species of *Anopheles hyrcanus* group and its related species with the help of Scanning electron microscope (SEM) and described different parts of eggs i.e. anterior and posterior tubercles, decks, plastron, micropyle and floats in detail. Rueda et al. (2010) studied *Anopheles belenrae*, a potential vector of *Plasmodium vivax* in the Republic of Korea in detail. Rueda et al. (2010a) studied species composition, larval habitats, seasonal occurrence and distribution of potential malaria vectors and associated species of *Anopheles* (Diptera: Culicidae) from the Republic of Korea. In 2011, the same author noted distribution, collection and museum records, larval habitats and the vector potential of *Anopheles (Cellia) vagus* Doenitz from Republic of Philippines. Rueda et al. (2014) studied distribution of *Anopheles (Anopheles) hyrcanus* group and associated species in Kyushu Island from Japan.

Yasuoka and Levins (2007) studied the impact of deforestation and agricultural development on Anopheline ecology, epidemiology and demonstrated that the impact of deforestation on mosquito density and malaria were influenced both by agriculture and ecological characteristics of local vector species. Foley et al., (2007) analyzed country occurrence records from the systematic catalog of Culicidae and presented world maps of species richness and endemism. Foley et al., (2008) gave the value of georeferenced collection records for predicting pattern of mosquito species richness and endemism in the Neotropics. In 2009, Foley et al. provided the importance of applying established standards for recording data on mosquito collection events. Foley et al. (2010) prepared mosquito map and the mal-area calculator tools to relate mosquito species distribution with vector borne disease.
Foley et al. (2014) studied Geographic distribution, evolution, and disease importance of *Anopheles albittarsis* Group.

Caillovet et al. (2008) studied water body types harboring the immature mosquitoes in low-lying areas of Haiti and also studied relationship between *Anopheles albimanus* Wiedemann abundance and aquatic predator presence. Ramos et al. (2008) analyzed morphologically three populations of *Anopheles (Nyssorhynchus) nuneztovari* Gabaldon from Colombia and also studied intraspecific variations in wings of all these three species. Turell et al. (2008) conducted studies on arboviral and malaria activity in the Amazon Basin, Loreto department, Peru to determine the relative abundance, species diversity, seasonal and vertical distribution of potential mosquito vectors. Muhammed (2008) studied mosquitoes breeding in rock pools on inselbergs around Zaria, northern Nigeria.

Blanford et al. (2009) studied thermal behavior of *Anopheles stephensi* and concluded that in contrast to locust biopesticides, there is no evidence that thermal behavior by *Anopheles* comprise the efficacy of fungal biopesticides for malaria control. Russel (2009) studied mosquito borne diseases and climate change in Australia and observed that currently climate change not provide great cause for public health concern with mosquito- borne diseases in Australia. Stops et al. (2009) studied bionomics of *Anopheles* species from two ecologically distinct villages of Sukabumi district, West Java, Indonesia from June 2006 to September 2007 and observed a lot of variations in all studied species. Djadia et al., (2009) firstly recorded a new member of *Anopheles hycaninus* group from Iran. This study aimed to provide further evidence on the status of species composition, insecticide resistance and vectorial capacity within the members of *Anopheles (Anopheles) hycaninus* group. Motoki et al. (2009) studied *Anopheles albitarsis* complex with the recognition of *Anopheles oryzalimnetes* Wilkerson and Motoki, and *Anopheles jancronnae* Wilkerson and Sallum, (Diptera : Culicidae). Malkawa et al. (2009) gave first records of *Anopheles balabacensis* Maekawa from Western Sumbawa Island, Indonesia. Violaris and Vasquez (2009) revised list of the mosquito fauna of the Republic of Cyprus. Cuamba and Mendis (2009) studied role of *Anopheles merus* in malaria transmission from southern Mozambique.
Adebote et al. (2009) conducted a study on species of mosquitoes found in Palosai stream of Peshawar. Kim et al. (2009) studied overwintering of Anopheles lindsayi Japonicus larvae from Republic of Korea. Noutcha and Anumdua (2009) prepared entomological indices of Anopheles gambiae sensu lato at a rural community in south-west Nigeria. Oyewole et al. (2009) studied physio-chemical characteristics of Anopheles breeding sites and its impacts on fecundity and progeny development. Wanji et al. (2009) studied distribution, environmental and physiological characterization of Anopheles breeding sites in Mount Cameroon region and suggested that data obtained will serve to analyze the impact of any malaria control measures on the breeding sites, distribution and Anopheles larvae densities and species. William and Savage (2009) examined that the cibarial armature is the way to identify an adult female Culex (Melanoconion) mosquito to species larval and also observed that cibarial armature can be used to identify damaged specimens.

Basseri et al. (2010) studied seasonal abundance and host feeding patterns of Anopheline vectors in malaria endemic areas of Iran and concluded that vectors had tendency to rest in animal shelters after feeding on humans. So, vector control measures should be planned on the basis of feeding pattern, abundance and resting behavior of these vectors. Kong and Wu (2010) studied mosquito proboscis and observed that mosquito does not directly penetrate the victim’s skin with its feeding fascicle but instead, uses a variable frequency micro toothed saw to cut into the tissue of the skin. Reinert (2010) studied egg stage of species of Anophelinae. Scholte et al. (2010) found three invasive mosquito species i.e. Aedes aegypti, Aedes albopictus and Aedes atropalpus from Netherland and reported Aedes aegypti for the first time from Netherland and concluded that these species can pose a potential threat to public health in Europe. Thomson (2010) studied rainfall onset and retreat, climate indices and malaria from Nigeria and observed that rainfall retreat occurs much faster than onset and rate of onset and retreat related to climate indices. Abdolgha (2010) studied seasonal abundance and host-feeding patterns of Anopheline vectors in malaria endemic area of Iran. Dekoninck et al. (2010) studied composition and seasonal activity patterns of mosquito communities collected with malaise traps at Etang de Virelles Nature Reserve which migratory bird sanctuary and possible site for arbovirus transmission in Belgium. Dutta et al. (2010) studied mosquito biodiversity of Dirbu – Saikhowo biosphere reserve in Assam, India. Vujic et al. (2010) studied
species composition and seasonal dynamics of mosquitoes (Diptera: Culicidae) in flooded areas of Volvodina, Serbia. González et al. (2010) recorded Anopheles (Anopheles) calderoni Wilkerson for first time from Colombia and confirmed it by morphology and DNA barcoding.

Amin et al. (2011) conducted a study in three districts of Bangladesh and observed the effects of climate change on public health especially on malaria. Juri et al. (2011) reported Anopheles (Anopheles) neomaculipalpus Curry in North-western Argentina for the first time and concluded that this species could play a role as malaria vector in North-western Argentina. Imbahale et al. (2011) studied larval abundance of Anopheles Meigen mosquitoes and observed that both temporary and permanent habitats were suitable for Anopheles gambiae breeding. Ndoen et al. (2011) investigated dusk to dawn Anopheline mosquito activity pattern, host seeking and resting location in coastal plains, hilly and highlighted areas in West Timor and java.

Chouaia et al. (2012) studied delayed larva development in Anopheles mosquitoes and concluded that Asaia symbionts play beneficial role in the normal development of larvae of Anopheles stephensi Liston. Gadahi et al. (2012) investigated population diversity of mosquito fauna from Tandojam, Pakistan and concluded that Culex population was higher as compared to Anopheline population collected indoor because of preferences of Culex mosquito to urban areas and also depend on distance of breeding habits. Kweka et al. (2012) studied co-habitation between Anopheles gambiae and Culex quinquefasciatus Say and found that co-habitation in semi natural conditions affect mostly body size of Anopheles gambiae. Takken and Verhulst (2012) studied host preferences of blood feeding mosquitoes and observed that many mosquitoes express an opportunistic trait of host choice, but some species were truly host specific. Tisgratog et al. (2012) studied host feeding patterns and preferences of Anopheles minimus in a malaria endemic area of Western Thailand and observed that this species prefers blood feed outdoors as compared to indoors and indicates more anthropophilic feeding behavior. Yaro et al. (2012) studied reproductive depression of Anopheles gambiae in the Sahel and observed oviposition response dropped from 70% during the wet season to 20% in dry season and egg hatch size fall from 173-101.
Gunathilaka et al. (2012) studied blood feeding patterns of *Anopheles* mosquitoes of Sri Lanka and concluded that presence of human blood in mosquito species indicated that possibility of them transmitting malaria. In 2013, they studied breeding habitat diversity of *Anopheles culicifacies* Giles and concluded that *Anopheles culicifacies* adapted to breed in a wide range of water bodies including waste water collections, although they were earlier considered only in clean water. Coetzee et al. (2013) described and named two species of *Anopheles gambiae* complex on the basis of molecular and bionomical evidence. Dabire et al. (2013) investigated swarming behavior of natural population of *Anopheles arabiensis* from March to April and September to October, 2012 in Bobo-Dioulassoba city of West Africa and concluded that this species was most prevalent species in this area. Dadzie et al. (2013) determined the species composition of *Anopheles funestus* Giles population from three ecological areas in Ghana and investigated their role in malaria transmission. Godfray (2013) studied mosquito vector ecology and provided control measures of malaria.

Hii and Rueda (2013) studied malaria vectors of Greater and Mekong sub region and observed that malaria transmission depends on vector behavior, ecology and degree of contact between human and *Anopheles* mosquitoes and also reported *Anopheles dirus* Harrison & Peyton as a vector of *Plasmodium knowlesi* in Vietnam for the first time. Hodge et al. (2013) studied that IRS (Indoor residual spraying) not potential for reducing malaria transmission, although insecticide spray rounds had a dramatic effect on population size of malaria vector *Anopheles gambiae* in an area endemic for malaria. Ilahi and Suleman (2013) studied species compositions and relative abundance of mosquitoes in Swat, Pakistan and observed that rice fields were most favorable site for mosquito breeding followed by river margins and temporary pools and springs.

Kessler et al. (2013) studied behavioral and neurophysiology of *Anopheles gambiae* and found that sucrose stimulates feeding and activates the labellar sucrose neuron and feeding deterrnts inhabits both sucrose and water. Lunde (2013) studied relation between temperature and malaria transmission and observed that global warming effects malaria transmission. Ngo et al. (2013) introduced *Anopheles dangi* as a new species of *hyrcanus* group of subgenus *Anopheles* Meigen, distinguished this
species from *Anopheles crawfordi* Reid on the basis of presence of humeral pale spot on the base of coastal vein of the wing and also distinguished both the species by analyzing nucleotide sequence of the COI, COII and Cyt-b genes of Mt.DNA and D3 gene of rDNA.

Ngom *et al.* (2013) studied spatio-temporal analysis of host preferences and feeding patterns of malaria vectors in Sylvo- pastoral area of Senegal and observed that differences in feeding patterns of malaria vectors were linked to the specific localization of villages and were not influenced by landscape class distribution. Obsomer *et al.* (2013) studied indicator species and environmental influences. These workers observed that indicator value useful to investigate association between different mosquito species and adult mosquitoes but could not be used as best indicator for a particular site. They also concluded that temperature, rainfall and vegetation factors also play important role.

Townson *et al.* (2013) provided integrated morphological and molecular characterization of *Anopheles barbirostris* Van der Wulp and described its adult, larval and pupal stages and compared it with *Anopheles barbirostris* Van der Wulp. Cardo *et al.* (2014) evaluated the effect of urbanization on the distribution of species of mosquito vectors. Faulde *et al.* (2014) recorded *Anopheles stephensi* in Djibouti, Horn of Africa for first time. Zarowiecki *et al.* (2014) hypothesis of ecological speciation for *Anopheles sundaicus* and concluded that Pleistocene climatic variation has proved a homogenizing, rather than diversifying, force for *Anopheles sondaicus* diversity. Danabalan *et al.* (2014) studied host preference of *Anopheles maculipennis* group and concluded that *An. daciae* is widespread in England and Wales, occurs in sympatry with other members of the *An. maculipennis* group, and feeds on humans. Saeung *et al.* (2014) conducted scanning electron microscopy on eggs of *Anopheles hyrcanus* group from Thailand and constructed ultrastructural key for species identification.

It becomes crystal clear from the above detailed review that a lot of work has been done on Culicidae taxonomy, ecology and related issues as compared to very limited research work on these aspects in India.