



Review Article

A Checklist of Mosquitoes (Diptera: Culicidae) of Guilan Province and their Medical and Veterinary Importance

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ABSTRACT

Background: Mosquitoes (Diptera: Culicidae) are the most important arthropods in medicine and health because of the burden of diseases which they transmit such as malaria, encephalitis, filariasis. In 2011, the last checklist of mosquitoes of Guilan Province included 30 species representing 7 genera.

Methods: Using the main data bases such as Web of Science, PubMed, Scopus, Google Scholar, Scientific Information Database (SID), IranMedex and Magiran which were searched up to August 2018 and reviewing the literature, the available data about the mosquito-borne diseases of Iran and Guilan Province were extracted and analyzed. Also the checklist of mosquitoes of Guilan Province was updated.

Results: One protozoal disease (human malaria), two arboviral diseases (West Nile fever, bovine ephemeral fever), two helminthic diseases (dirofilariasis, setariasis) and one bacterial disease (anthrax) have been found in Guilan Province which biologically or mechanically are assumed to transmit by mosquitoes. The updated checklist of mosquitoes of Guilan Province is presented containing 33 species representing 7 or 9 genera according different classifications of the tribe Aedini.

Conclusion: There is no information about the role of mosquitoes in the transmission of bovine ephemeral fever and anthrax in Iran and Guilan Province. Also the vectors of dirofilariasis and setariasis are not known in Guilan Province and available data belong to other provinces. It seems that the role of arthropods in the epidemiology of anthrax is not important.

Keywords: Checklist, Mosquito-borne disease, Mosquito-borne Infection, Mosquito-borne pathogen, Mosquito-borne virus, Mobovirus

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Introduction

About 16% of the global burden of infectious and parasitic diseases belong to the vector-borne diseases. After diarrhoeal diseases, HIV/AIDS, tuberculosis, mosquito-borne malaria shows the fourth highest burden among infectious and parasitic diseases (1). The transmission of malaria as well as other diseases including filariasis, encephalitis etc. and their biting nuisance makes mosquitoes (Diptera: Culicidae) the most important arthropods in medical and health entomology (2).

Mosquitoes includes two subfamilies Anophelinae and Culicinae and the latter subdivided into 11 tribes. The family

composes 41 or 113 genera (according to the classification of genera in the tribe Aedini) and 3559 species (3).

The most important taxonomic change in the classification of mosquitoes during recent years is the elevation of many subgenera to the generic rank in the tribe Aedini by Reinert et al. (4-7), thus they included 82 genera in the tribe. However Wilkerson et al. (8) and Wilkerson and Linton (9), using the equal weighting of data set of Reinert et al. (4-7), made a different conclusion and included ten genera in the tribe Aedini. Two parallel classifications are mentioned and used in many references (e.g. 10, 11).

The present article tries to provide a comprehensive and systematic review of mosquito-borne diseases in Guilan Province and an update checklist of mosquitoes of Guilan Province in the Caspian Sea littoral of northern Iran.

Methods

This investigation reviewed the articles indexed in Web of Science, PubMed, Scopus, Google Scholar, Scientific Information Database (SID), IranMedex and Magiran databases which were searched up to August 2018. First, the main textbooks or chapters of textbooks of medical and veterinary entomology pertaining mosquitoes (e.g. 2, 10, 12, 13) were reviewed to extract mosquito-borne diseases. Also the aforementioned databases were browsed to obtain literature that indicates mosquito-borne diseases, using keywords like “mosquito-borne diseases”, “mosquito-borne infections”, “mosquito-borne pathogens” and “mosquito-borne viruses”. Then, mosquito-borne disease names were extracted from identified literature. Afterwards, the databases were browsed to obtain literature reporting occurrence of mosquito-borne diseases in animals and humans in Guilan Province, Iran or a wider geographic range such as the Middle East, southwestern Asia or the World Health Organization Eastern Mediterranean Region. Harbach (14) and World Health Organization (15) were consulted for the definition of the regions. At last, the main keywords were browsed as “extracted mosquito-borne disease names, Iran, Iranian, Guilan, Gilan” and “extracted mosquito-borne pathogen names, Iran, Iranian, Guilan, Gilan”. The main mosquito-borne disease names were ‘malaria, avian malaria, bird malaria, West Nile (WN) fever, dengue (DEN) fever, Rift Valley fever (RVF), Sindbis (SIN) fever, bovine ephemeral fever (BEF), avian pox (AP), poultry pox, dirofilariasis, dirofilariosis, setariasis, setariosis, dipetalonemiasis, filariasis, lymphatic filariasis, wuchereriosis, tularemia, tularaemia, anthrax’ and the mosquito-borne pathogen generic names were ‘*Plasmodium*, *Dirofilaria*, *Setaria*, *Deraiphonema*, *Dipetalonema*, *Wuchereria*, *Francisella*, *Bacillus*, *Flavivirus*, *Alphavirus*, *Phlebovirus*, *Ephemerovirus*, *Orthobunyavirus*, *Avipoxvirus*, *Orbivirus*, *Orthonairovirus*’. In addition, the references of the selected literature were also reviewed to increase the coverage of search. With few exceptions, only data from books or peer-reviewed articles were included in the final analysis. Regarding infectious agents of diseases (pathogens), mosquito-borne diseases are divided into four categories of protozoal diseases (protozooses), arboviral diseases, helminthic diseases (helminthoses) and bacterial diseases. Ashford’s article (16) was consulted for the current usage of nomenclature for some parasitic diseases especially arthropod-borne ones. Also, other names of mosquito-borne diseases (if they were applicable) were extracted and mentioned from the literature. Concerning each disease, data related to infectious agents (pathogens), distribution, reservoir or host (human and animals) and disease prevalence (if there were available) in Guilan Province were extracted and presented from the literature. At last, an update checklist of mosquitoes of Guilan Province was presented. The abbreviations of genera and subgenera of mosquitoes followed Reinert (17).

Mosquito-Borne Diseases in Guilan Province

Protozoal Diseases (Protozooses)

Malaria (Plasmodiosis or Plasmodial Infection): Human malaria causes the highest global burden of vector-borne diseases and the fourth highest burden among infectious and parasitic diseases (1). Other names of the disease are ague, paludism, marsh fever and intermittent fever (12). The disease is reported in 91 countries of the world with at least 216 million infection cases and about 445000 deaths per year with about 90% of them from tropical Africa (18). Four species of *Plasmodium* (*P. falciparum*, *P. malariae*, *P. ovale*, *P. vivax*) are usually responsible for human malaria and which are biologically transmitted only by some anopheline mosquitoes (10). At the present time, Iran is in the eliminating stage of the World Health Organization for malaria control. The indigenous cases of malaria have declined from 1847 to 81 between 2010 and 2016 (18). Before starting malaria control program in Iran, Caspian Sea region of northern Iran, including Guilan Province, was one of the foci of malaria in the country with meso- to hyper- endemicities. One of the first scientific investigations on malaria in Iran was carried out by Latychev in 1921 in Rasht and Bandaranzali of Guilan Province. The most prevalent *Plasmodium* is *P. vivax* in the province (19). At the present time, though, up to 6 imported human cases of malaria per year have been reported in Guilan Province in recent years, there is no indigenous case of the disease in the province from 2006 (20). So, the province is considered as the zero indigenous malaria cases (free of malaria). Out of 475 formally recognized species and more than 50 unnamed members of species complexes of *Anopheles* Meigen (3), about 70 species are known the vectors of malaria and 40 species are more important vectors (2). Seven species of the genus *Anopheles* (*An. maculipennis* Meigen s.l., *An. sacharovi* Favre, *An. culicifacies* Giles s.l., *An. dthali* Patton, *An. fluviatilis* James s.l., *An. stephensi* Liston, *An. superpictus* Grassi s.l.) are known as malaria vectors in Iran and *An. maculipennis* s.l. in Guilan Province (21). Also, *An. hyrcanus* (Pallas) was introduced as a possible vector of malaria using a nested polymerase chain reaction (PCR) assay in Fooman of Guilan Province (22).

Arboviral Diseases

Mosquito-Borne Viral Infections (Mosquito-Borne Viruses or Moboviruses)

West Nile Fever: West Nile virus and its subtype Kunjin, a member of the Japanese encephalitis (JE) serogroup (Flaviviridae: *Flavivirus*), is distributed in Eurasia, Africa, North and Central America and Australia. Mosquitoes, especially ornithophilic species including different species of *Anopheles*, *Aedeomyia* Theobald, *Aedes* Meigen, *Coquillettidia* Dyar, *Culex* Linnaeus, *Mansonia* Blanchard and *Mimomyia* Theobald, are the principal vectors of the virus and some virus isolations have been reported from soft and hard ticks (Parasitiformes: Ixodida: Argasidae and Ixodidae). Wild birds, especially wetland species, are the principal vertebrate hosts. The virus has also been isolated from mammals and frogs. Rabensburg virus is the synonym of WNV (23-26). Guilan Province, with vast wetlands, is one of the foci of WNV where infections are found in humans (1.4–10%) (27-29), horses (2.2-25%) (29, 30) and birds (especially the common coot, the main reservoir) (62.7%) (31). Recently, Shahhosseini et al. (32) found the virus in *Cx. pipiens* Linnaeus in Guilan Province.

Bovine Ephemeral Fever: Bovine ephemeral fever virus (Rhabdoviridae: *Ephemerovirus*) infects a wide range of wild and domestic ruminants especially cattle and water buffalo in Africa, Asia and Australia. Other names of the disease are three-day sickness, stiff sickness, dengue fever of cattle, bovine epizootic fever and lazy man's disease. Mosquitoes of the genera *Anopheles*, *Aedes* and *Culex* and biting midges (Diptera: Ceratopogonidae) are probably the main vectors (33-35). In Iran, bovine ephemeral fever virus is found in cattle and water buffalo using molecular sequence and serological assay in different provinces such as Razavi Khorasan (36) Khuzistan (37), Fars, Tehran, West Azerbaijan (38) and Qazvin (39). Also, there is unpublished data about the occurrence of BEF in the provinces of Bushehr, Guilan, Ilam, Mazandaran, Qom, Semnan and Yazd (39, 40). There is no information about the vectors of BEF in Iran.

Helminthic Diseases (Helminthoses)

Mosquito-Borne Filariases

Dirofilariasis (Dirofilariosis): Dirofilariosis is a disease caused by at least 27 species of the nematode genus *Dirofilaria* (Spirurida: Onchocercidae: Dirofilariinae), especially *D. immitis* (canine or dog heartworm) and *D. repens*, which are transmitted by mosquitoes. The disease is cosmopolitan. The reservoirs of the nematodes are many different mammals (at least 111 species), especially canids. Currently human dirofilariosis is classified as an emerging disease in some areas because of dramatic increases in the number of reported cases (41-43). More than 77 species of *Anopheles*, *Aedes*, *Culex*, *Coquillettidia*, *Mansonia*, *Psorophora* Robineau-Desvoidy and *Culiseta* Felt are assumed to play a role in transmission of dirofilariosis (44). Azari-Hamidian et al. (45) reviewed all published documents on dirofilariosis in Iran by 2005. Thus the review included references that have not been cited herein. It seems that Guilan Province is one of the foci of dirofilariosis, where *D. repens* infection is found in humans (Three cases) (45, 46) and *D. immitis* found in 4.4% (47) to 51.4% of local dogs (48, 49). *Culex theileri* Theobald is a known vector of *D. immitis* in Ardebil Province (44), but there is no information about the vector of infection in Guilan Province.

Setariasis (Setariosis): Setariasis caused by 43 species of *Setaria* (Nematoda: Spirurida: Onchocercidae: Setariinae) is a worldwide disease and infects a wide range of ruminants. Setariasis is transmitted by the mosquito genera of *Anopheles*, *Aedes*, *Armigeres* Theobald, *Culex* and *Mansonia* and probably stable-fly (Diptera: Muscidae) (41, 50). Five species of *Setaria* (*S. digitata*, *S. equina*, *S. labiatopapillosa*, *S. marshali*, *S. cervi*) have been reported in Iran using Knott's method and microscope observation. They are found in horse, cattle, water buffalo, sheep, goat, donkey and wild sheep in the provinces of East Azerbaijan, Guilan, Hamedan, Khuzistan, Mazandaran, Qazvin, Sistan and Baluchistan, Tehran, West Azerbaijan and Zanzan (51-62). Baharsefat et al. (52) reported lumbar paralysis (cerebrospinal nematodiasis) in sheep due to *S. labiatopapillosa* in Guilan Province for the first time in Iran. *Anopheles maculipennis* is known the vector of *Setaria* in

Ardebil Province (44), but there is no information about the vector of infection in Guilan Province.

Bacterial Diseases

Anthrax: anthrax is a worldwide infection caused by the bacterium *Bacillus anthracis*. Other names of the disease are charbon, malignant pustule, malignant carbuncle, splenic fever, milzbrand and woolsorter's disease. The main ways of transmission to human are direct contact of infected carcasses or the handling of contaminated products from morbid animals. Horseflies, stable-fly and mosquitoes (experimentally in *Aedes*) mechanically transmit the bacterium. Also, ants, coprophagous and necrophagous beetles (e.g. Dermestidae), blow-flies (Diptera: Calliphoridae) and house-fly (Diptera: Muscidae) are believed to be implicated in transferring spores. But it seems that arthropods have a minor importance in the epidemiology of the disease (13, 63, 64). Human cases of anthrax have been reported from 106 to 179 per year during 2006-2011 from at least 25 Iranian provinces (20). One rare case of human cutaneous anthrax was found in Guilan Province (65). During 2006-2011, from 4 to 21 cases of human anthrax were reported from Guilan Province. The province as well as Charmahal and Bakhtiari, Fars, Isfahan, Kurdistan, Razavi Khorasan and West Azerbaijan Provinces show high rate of human cases in Iran (20). There is no information about the role of arthropods in transmission of anthrax in the country.

A checklist of mosquitoes (Diptera: Culicidae) of Guilan Province

In 2007, the most recent checklist of Iranian mosquitoes included 64 species representing seven genera (66). After that, four minor modifications were carried out in the nomenclature of Iranian mosquitoes which were noted during providing keys to them (67). Those two aforementioned articles listed most of the literature that pertained to the records of mosquitoes in Iran by 2007. After that five species were added to the Iranian mosquito fauna (22, 68-71).

The last checklist of Iranian mosquitoes (66) included the species of tribe Aedini in two genera of *Aedes* and *Ochlerotatus* Lynch Arribalzaga according to elevation of subgenus *Ochlerotatus* to generic rank by Reinert (72). At the present time, based on the system of classification of aedine species, 12 verified species of Iranian Aedini (66, 69, 71) are classified in one genus (with five subgenera) (8, 9) or five genera (4-7). So, the checklist of Iranian species includes 69 species representing seven or eleven genera.

Azari-Hamidian (73) listed 30 species of mosquitoes representing seven genera in Guilan Province. Since, two species new to the province fauna, *Ae. pulcritarsis* (Rondani) and *Cx. perexiguus* Theobald, and a genus and species [*Orthopodomyia pulcripalpis* (Rondani)] new to Iranian fauna were reported from Guilan Province (70, 74), thus there are 33 species representing seven or nine genera in the province. A checklist of mosquitoes of Guilan Province is presented as follow:

Family Culicidae Meigen, 1818

Subfamily Anophelinae

I) Genus *Anopheles* Meigen, 1818

- Subgenus *Anopheles* Meigen, 1818
- 1- *An. (Ano.) algeriensis* Theobald, 1903
 - 2- *An. (Ano.) claviger* (Meigen, 1804)
Maculipennis Group
 - 3- *An. (Ano.) atroparvus* Van Thiel, 1927
 - 4- *An. (Ano.) labranchiae* Falleroni, 1926
 - 5- *An. (Ano.) maculipennis* Meigen, 1818
 - 6- *An. (Ano.) melanoon* Hackett, 1934
 - 7- *An. (Ano.) messeae* Falleroni, 1926
 - 8- *An. (Ano.) persiensis* Linton, Sedaghat and Harbach, 2003
 - 9- *An. (Ano.) sacharovi* Favre, 1903
 - 10- *An. (Ano.) plumbeus* Stephens, 1828
Hyrceanus Group
 - 11- *An. (Ano.) hyrcanus* (Pallas, 1771)
 - 12- *An. (Ano.) pseudopictus* Grassi, 1899
Subgenus *Cellia* Theobald, 1902
 - 13- *An. (Cel.) superpictus* Grassi, 1899
Subfamily Culicinae
- Tribe Aedini
- II) Genus *Aedes* Meigen, 1818
Subgenus *Aedimorphus* Theobald, 1903
 - 14- *Ae. (Adm.) vexans* (Meigen, 1830) [*Aedimorphus vexans*]
Subgenus *Dahlia* Reinert, Harbach and Kitching, 2006
 - 15- *Ae. (Dah.) echinus* (Edwards, 1920) [*Dahlia echinus*]
 - 16- *Ae. (Dah.) geniculatus* (Olivier, 1791) [*Dahlia geniculata*]
Subgenus *Ochlerotatus* Lynch Arribalzaga, 1891
 - 17- *Ae. (Och.) caspius* (Pallas, 1771) s.l. [*Oc. caspius* s.l.]
 - 18- *Ae. (Och.) pulcritarsis* (Rondani, 1872) [*Oc. pulcritarsis*]
Tribe Culicini
 - III) Genus *Culex* Linnaeus, 1758
Subgenus *Culex* Linnaeus, 1758
 - 19- *Cx. (Cux.) pipiens* Linnaeus, 1758
 - 20- *Cx. (Cux.) torrentium* Martini, 1925
 - 21- *Cx. (Cux.) perexiguus* Theobald, 1903
 - 22- *Cx. (Cux.) theileri* Theobald, 1903
 - 23- *Cx. (Cux.) mimeticus* Noe, 1899
 - 24- *Cx. (Cux.) tritaeniorhynchus* Giles, 1901
Subgenus *Maillotia* Theobald, 1907
 - 25- *Cx. (Mai.) hortensis* Ficalbi, 1889
Subgenus *Neoculex* Dyar, 1905
 - 26- *Cx. (Ncx.) territans* Walker, 1856
Tribe Culisetini
 - IV) Genus *Culiseta* Felt, 1904
Subgenus *Allotheobaldia* Broelemann, 1919
 - 27- *Cs. (All.) longiareolata* (Macquart, 1838)
Subgenus *Culicella* Felt, 1904
 - 28- *Cs. (Cuc.) morsitans* (Theobald, 1901)
Subgenus *Culiseta* Felt, 1904
 - 29- *Cs. (Cus.) annulata* (Schränk, 1776)
 - 30- *Cs. (Cus.) subochrea* (Edwards, 1921)
Tribe Mansoniini
 - V) Genus *Coquillettidia* Dyar, 1905
Subgenus *Coquillettidia* Dyar, 1905
 - 31- *Cq. (Coq.) richiardii* (Ficalbi, 1889)
Tribe Orthopodomyiini
 - VI) Genus *Orthopodomyia* Theobald, 1904
 - 32- *Or. pulcralpis* (Rondani, 1872)
Tribe Uranotaeniini
 - VII) Genus *Uranotaenia* Lynch Arribalzaga, 1891
Subgenus *Pseudoficalbia* Theobald, 1912
 - 33- *Ur. (Pfc.) unguiculata* Edwards, 1913

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Ethical consideration

None.

Conflicts of interests

Authors declared no conflict of interest.

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