

inhabit brackish water, eg, *Cx. (Cux.) sitiens*, and polluted water, eg, *Cx. (Cux.) quinquefasciatus*. *Lutzia* are found in freshwater habitats similar to those occupied by *Culex* species, however they occur principally in tropical regions of the world.

Feeding behavior

Most records of *Culex* and *Lutzia* from Thailand refer to nocturnal feeding on mammals, eg, humans, cows, and dogs. The periodicity of nocturnal feeding varies greatly depending on the species. *Culex (Cux.) quinquefasciatus*, for example, are fairly abundant in urban areas throughout the year and are commonly found resting during the day in shade outdoors, and on walls, dark corners, in cabinets, bathrooms, and under chairs and tables in houses. Females are vicious biters at night indoors and outdoors and feed principally on blood of man and dogs from sunset until dawn. Many species of *Culex* have been collected in large numbers at night in cowsheds, in light traps or animal-baited traps, and biting cows, pigs, and occasionally humans. Infrequently, *Cx. (Eum.)* species, *Cx. (Lop.) infantulus*, *Cx. (Lop.) rubithoracis*, and other *Cx. (Lop.)* species, as well as *Lt. (Mtl.) fusca*, are caught attacking humans. Little is known about the adult biology and medical importance of species in subgenera *Culiciomyia*, *Eumelanomyia*, *Lophoceraomyia*, and *Oculeomyia* of *Culex*, and *Metalutzia* of *Lutzia*.

THE GROUPS, SUBGROUPS, COMPLEXES, AND SPECIES OF GENERA *CULEX* AND *LUTZIA*

A brief account of the classification and biology of the *Culex* and *Lutzia* in Thailand is given below. A complete listing of the species belonging to each species group, subgroup, and complex, and their distributions, is provided in Table 1. The known habitats of the Thai species are listed in Table 2.

Culex (Culex)

Subgenus *Culex* is important because many species have been incriminated as vectors of Japanese encephalitis and filariasis. The species occur everywhere from cities and lowland tropical forests to higher elevations in mountains. Immature stages occur in a variety of ground-water habitats, and artificial and natural containers. Nineteen species belonging to eight subgroups occur in Thailand.

Pipiens Group. This group includes three species in Thailand, each belonging to a different subgroup.

Pipiens Subgroup. *Culex quinquefasciatus* is the only species of this subgroup in Thailand. It is the most common domestic species, occurring abundantly in houses and in practically all types of human and animal shelters in urban communities. Larvae thrive in a wide range of habitats containing clear, turbid, or polluted fresh to brackish water in ground pools, ditches, pits, wells, drains, and containers.

Trifilatus Subgroup. *Culex hutchinsoni* is the only member of this subgroup in Thailand. It is apparently a rather uncommon species. Adults have been collected from light traps and animal-baited traps. Immature habitats include various types of ground pools, such as ponds, swamps, marshy depressions, ditches, rock pools, pits, wells, rice fields, footprints, wheel tracks, and artificial and natural container habitats, eg, cans and tires.

Univittatus Subgroup. *Culex fuscocephala* is the only member of this subgroup in Thailand. Adults are abundant and frequently collected outdoors among herds of domestic animals such as cows, water buffaloes, and pigs. Females prefer to feed on cows and pigs. The immature stages have been collected most frequently from general ground-water habitats and various kinds of artificial and natural containers.

Sitiens Group. This is a large group with 16 species representing five subgroups in Thailand.

Barraudi Subgroup. Two rare and closely related species, *Cx. barraudi* and *Cx. edwardsi*, belong to this subgroup. These species have been collected in ditches, sand pools, ground pools, stream margins, rice fields, and rock pools at high elevations in Chiang Mai and Udon Thani Provinces. *Culex edwardsi* have been collected from stream pools, marshy seepage bogs, seepage pools, and animal footprints. The biology of the adults and their feeding habits are unknown.

Gelidus Subgroup. The *Gelidus* Subgroup, as defined by Sirivanakarn (1976), is monotypic. Sirivanakarn removed three species previously included in this subgroup by Edwards (1932) and Bram (1967).

Culex gelidus is one of the most common and best known species in Thailand. Breeding sites include ponds, swamps, marshy depression, ditches, pits, wells, stream margins, seepage pools, rice fields, wheel tracks, and footprints. Larvae have also occasionally been found in artificial containers such as tanks, water jars, pots, and coconut shells. The species is closely associated with humans and domestic animals such as cows, water buffaloes, and pigs in rural and urban areas. Adults have been collected in light

traps, animal-baited traps, and biting humans.

Mimeticus Subgroup. This group includes 11 species, 10 in the Oriental Region and one in the Australasian Region. *Culex mimeticus* is widely distributed in the Oriental Region and also extends into the Middle East. Sirivanakarn (1976) recognized two species complexes within this taxon, the Mimeticus and Mimulus Complexes. Members of the subgroup breed in bodies of freshwater that usually contain green algae, mosses, grasses, and other aquatic vegetation. Adult females enter human habitation, but they are not known to bite humans.

- **Mimeticus Complex.** Two species of the Mimeticus Complex (seven species) occur in Thailand. These species, *Cx. jacksoni* and *Cx. mimeticus*, appear to be restricted to certain localities at high elevations. Larvae have been collected in ground pools near streams, stream pools, stream margins, seepage-springs, rice fields, and rock pools. The biology of the adults is unknown.

- **Mimulus Complex.** Two species of the Mimulus Complex (four species) are known to occur in Thailand, *ie*, *Cx. mimulus* and *Cx. murrelli*. These two species are fairly common locally and are frequently encountered in hilly and mountainous areas. Larvae occur in a variety of ground-water habitats, including ponds, pits, wells, swamps, marshy depressions, ditches, ground pools, stream pools, stream margins, seepage-springs, rice fields, footprints, wheel tracks, and crab holes. They also occur in natural containers (rock pools, rock holes) and artificial containers. Adults of the two species are sometimes captured together in houses and light traps.

Sitiens Subgroup. The Sitiens Subgroup includes seven species in the Oriental, Australasian, and Afrotropical Regions. Four of these species occur in the Oriental Region and three of these occur in Thailand. Sirivanakarn (1976) divided the subgroup into three complexes, the Sitiens and the monotypic *Annulirostris* and *Whitmorei* Complexes. Although it is probable that *Cx. annulirostris* and *Cx. whitmorei* are complexes of species, we prefer not to recognize them as complexes until they are definitely known to comprise more than one species. *Culex whitmorei* and two members of the Sitiens Complex are the only species of the Sitiens Subgroup that are known to occur in Thailand.

***Culex whitmorei*.** Larvae of this species have been collected in a variety of ground-pool habitats, including swamps, ditches, pits, wells, grassy pools, ground pools, flood pools, stream pools, stream margins, rice fields, footprints, and wheel tracks. Females

are commonly collected in light traps and animal-baited traps.

• **Sitiens Complex.** This complex is represented in Thailand by two coastal, brackish water species, *Cx. alis* and *Cx. sitiens*. *Culex sitiens* larvae are very adaptable and exhibit a high tolerance for salinity, occurring in fresh, brackish, and even seawater. Larvae have been collected in ponds, pits, ditches, ground pools, stream margins, crab holes, and rock pools in salt marshes, and in mangrove and *Nipa* swamps. They have also been found in artificial containers such as jars, cans, and the bottom of boats. Adults have been captured biting humans and in light traps and cow-baited traps. *Culex alis* is less common than *Cx. sitiens*. Larvae of this species have been found in ground pools, rice fields, crab holes, rock pools, and rock holes at or near coastal beaches. Nothing is known about the adult biology of *Cx. alis*.

Vishnui Subgroup. The Vishnui Subgroup includes eight species that are largely restricted to Southeast Asia and adjacent tropical areas. The distributions of two species, *Cx. pseudovishnui* and *Cx. tritaeniorhynchus*, extend into the Middle East. Sirivanakarn (1976) divided the subgroup into three complexes, the Vishnui and the monotypic *Tritaeniorhynchus* and *Whitei* Complexes. As in the case of *Cx. annulirostris* and *Cx. whitmorei* of the Sitiens Subgroup, because there is no evidence that *Cx. tritaeniorhynchus* and *Cx. whitei* consist of more than one species, we prefer not to recognize them as complexes. These two species and four members of the Vishnui Complex are known to occur in Thailand.

Culex tritaeniorhynchus. This species is very common and widespread in Thailand. Its breeding sites are ground-water habitats containing fresh or polluted water with abundant grasses, rice plants, and other aquatic vegetation. Immature stages sometimes also occur near or along the margins of slow moving streams. Adults have been collected in animal-baited traps and light traps, and females have been captured biting cows, pigs, and occasionally humans.

Culex whitei. This species is apparently uncommon but it is broadly distributed from India through Southeast Asia. Immature stages have been collected from swamps, marshy depressions, pools in stream beds, elephant footprints, seepage-springs, and stream margins. Nothing is known about the feeding habitats of adult females.

Vishnui Complex. This complex is represented in Thailand by *Cx. alienus*, *Cx. perplexus*, *Cx. pseudovishnui*, and *Cx. vishnui*. Breeding sites of these species are gen-

eral ground pool habitats: wells, marshy depressions, ditches, pits, sand pools, ground pools, stream pools, rice fields, footprints, wheel tracks, and rock pool/hole natural containers. *Culex perplexus* and *Cx. alienus* are uncommon forest species whereas *Cx. pseudovishnui* and *Cx. vishnui* are common and widespread species frequently found in association with *Cx. tritaeniorhynchus*. Large numbers of *Cx. pseudovishnui* and *Cx. vishnui* have been collected in animal-baited traps and light traps, and in biting collections from cows, pigs, and occasionally humans. Nothing is known about the biting habits and adult biology of *Cx. alienus* and *Cx. perplexus*.

Culex (Culiciomyia)

Members of this subgenus occur principally in the Oriental Region. Sixteen species are recorded from Thailand. Species of *Culiciomyia* are common in tropical forests from lowland areas to higher elevations in mountains. Most species are distributed throughout the country but *Cx. barrinus*, *Cx. harrisoni*, *Cx. lampangensis*, *Cx. termi*, and *Cx. viridiventer* have only been collected in the north. Larvae of *Culiciomyia* occur in a variety of ground-water habitats and natural and artificial containers, including pits, ponds, swamps, stream pools, seepage pools, footprints, wheel tracks, rock pools, tree holes, hole in stumps, coconut shells, and leaf axils, eg, palm and *Nipa*. Larvae of *Cx. bailyi*, *Cx. dispectus*, *Cx. fragilis*, *Cx. nigropunctatus*, *Cx. pallidothorax*, and *Cx. spathifurca* have also been collected from bamboo internodes, bamboo stumps, split bamboo, and bamboo pots whereas *Cx. barrinus*, *Cx. harrisoni*, *Cx. lampangensis*, *Cx. scanloni*, *Cx. termi*, and *Cx. thurmanorum* have only been found in natural ground-water habitats and rock pools. Adult females of *Cx. nigropunctatus*, *Cx. pallidothorax*, and *Cx. spathifurca* have been collected in light traps and occasionally attacking humans. The host preferences and bionomics of other species of *Culiciomyia* are poorly known.

Culex (Eumelanomyia)

This subgenus was reviewed by Sirivanakarn (1972). Most species of *Eumelanomyia* occur in the Oriental Region and have been recorded mainly in Thailand and Malaysia. Ten species belonging to two groups are found in Thailand. Species of this subgenus are common in tropical forests in mountainous areas but also occur in lowland areas from plains and valleys to higher elevations. Immature stages are found in a range of habitats from ground pools of different sizes to tree holes and bamboo.

Protomelanoconion Group. This group is represented in Thailand by two very closely related species. *Culex brevialpis* is a common species found in tree holes, bamboo,

and artificial and natural containers, eg, water jars, rock pools, and coconut shells, and occasionally in ponds, ditches, ground pools, and stream margins. *Culex phangngae* is only known to occur in southern Thailand. The immature stages of this species are found in the same types of sites as *Cx. brevipalpis*.

Mochthogenes Group. This is one of the largest groups of *Eumelanomyia*. Eight species representing five subgroups are recognized in Thailand.

Foliatus Subgroup. This subgroup includes two species in eastern areas of the Oriental Region, but only the more widespread *Cx. foliatus* occurs in Thailand. The immature stages occur in a variety of habitats, including swamps, ditches, pits, wells, ground pools, stream pools, stream margins, seepage-springs, footprints, crab holes, and rock pool/hole natural containers. Immatures have been found in bamboo habitats and *Pandanus* axils. Adults have been captured in light traps and infrequently attacking humans.

Hinglungensis Subgroup. This subgroup includes four species in the Oriental Region, but only *Cx. hinglungensis* occurs in Thailand. Nothing is known about the biology of this species. Adult males have been collected in light traps next to streams in mountainous areas.

Malayi Subgroup. The Malayi Subgroup includes two Philippine species and *Cx. malayi*, which is widely distributed in the Oriental Region, including Thailand. The immature stages of *Cx. malayi* have been found mainly in ponds, swamps, ditches, pits, wells, sand pools, ground pools, flood pools, stream pools, stream margins, seepage pools, rice fields, wheel tracks, crab holes, and rock pools. Adults have been collected in light traps.

Otachati Subgroup. This subgroup includes *Cx. otachati*, known only from Cambodia and the northeast of Thailand, and an undescribed species from the Philippines. *Culex otachati* appears to be a rare species. Adult males were collected (along with *Cx. kiriensis* of the Tenuipalpis Subgroup) while resting on vegetation along stream margins under heavy forest shade in hilly and mountainous areas. Nothing more is known about the biology of this species.

Tenuipalpis Subgroup. Four species of this subgroup, *Cx. kiriensis*, *Cx. oresbius*, *Cx. richei*, and *Cx. tenuipalpis*, occur in Thailand. A fifth species occurs in the eastern Palaearctic and a sixth is known from peninsular Malaysia. Larvae of the species occurring in Thailand have been found in ponds, swamps, marshy depressions, stream pools,

stream margins, seepage-springs, elephant footprints, and rock pools. *Culex tenuipalpis* is recorded from localities in the north of the country whereas *Cx. kiriensis*, *Cx. oresbius*, and *Cx. richei* are recorded from both northern and northeastern localities. *Culex richei* and *Cx. oresbius* also occur in the south. Adults of *Cx. kiriensis*, in association with *Cx. otachati*, were collected while resting on low vegetation near a stream in mountain forest. Other than this, nothing is known about the biology of these species.

Culex (Lophoceraomyia)

Subgenus *Lophoceraomyia* has a wide distribution in the Oriental, Australasian, and eastern Palaearctic Regions. The majority of species occur in Southeast Asia. Sirivanakarn (1977c) reviewed the subgenus in the Oriental Region. Thirty-one species belonging to three groups are recorded from Thailand. The immature stages occupy a variety of ground-water and both natural and artificial container habitats, at altitudes ranging from the low central valleys to high mountains. Habitats are restricted to humid tropical forests and open cultivated lands such as rice fields and plantations. Adults have been captured in sweep nets, animal-baited traps, and light traps. Females of some species are known to attack humans, but wild birds are probably the preferred hosts (Colless, 1959).

Fraudatrix Group. Twenty-three species of this group occur in the Oriental Region. These species are divided between two subgroups, the *Fraudatrix* and *Minutissimus* Subgroups. The two subgroups are represented in Thailand by 13 species.

Fraudatrix Subgroup. This subgroup, which includes 68 species in the Oriental and Australasian Regions, is the largest group of the subgenus. It is represented in the Oriental Region by 20 species, which Sirivanakarn (1977c) classified into seven complexes. However, since the *Alphus*, *Inculus*, and *Seniori* Complexes are monotypic, we prefer to recognize the name-bearing members as unassigned species within the subgroup. *Culex seniori* is only known from the type locality in India. *Culex inculus* occurs in Cambodia and peninsular Malaysia, but is not recorded from Thailand. *Culex alphus* and 10 species belonging to four complexes occur in Thailand.

Culex alphus. This species, apparently rare, occurs in the south of the country. Immature stages have been collected in ponds, swamps, and wells. Nothing is known about the bionomics of the adults.

- **Cinctellus Complex.** This complex includes *Cx. fulleri* in the Philippines and the

widespread *Cx. cinctellus*. Larvae of *Cx. cinctellus* have been collected in swamps, marshy depressions, ground pools, and stream margins. Adults have been collected in light traps and animal-baited traps.

- **Quadripalpis Complex.** The Quadripalpis Complex includes six species in the Oriental Region. Three of these species, *Cx. aculeatus*, *Cx. quadripalpis*, and *Cx. reidi* occur in Thailand. The immature stages occur in ground-water habitats such as ditches, stream pools, seepage, and rock pool/hole natural containers. *Culex reidi* is occasionally found in crab holes in *Nipa* swamps, and in water held in fallen palm leaves. Females of *Cx. quadripalpis* occasionally attack humans (Colless, 1965), but nothing else is known about the biology of these species.

- **Rubithoracis Complex.** This complex includes three species, but only the widespread *Cx. rubithoracis* is known to occur in Thailand. *Culex rubithoracis* is a common species found in ponds, swamps, marshy depressions, ditches, pits, wells, ground pools, and rice fields. Adults have been taken in light traps and resting on vegetation.

- **Variatus Complex.** The Variatus Complex includes seven species in the Oriental Region. Five of these species, *Cx. gracicornis*, *Cx. macdonaldi*, *Cx. paioji*, *Cx. variatus*, and *Cx. whartoni*, occur in Thailand. Larvae are found in various types of ground-water habitats. Larvae of *Cx. variatus* are found in bamboo, coconut shells, and palm axils. Females of this species occasionally attack humans (Colless, 1965). Nothing more is known about the biology of these species.

Minutissimus Subgroup. This subgroup includes three species, two of which occur in Thailand. *Culex infantulus* is a common species that breeds in various types of ground-water habitats and natural and artificial containers. Adults of this species have been collected in light traps. Larvae of *Cx. minutissimus* have been found in pits, wells, ground pools, flood pools, stream margins, seepage pools, coconut shells, and leaf axils. Adults of this species have been captured in sweep nets, but nothing is known about their biology.

Mammilifer Group. The Mammilifer Group (Sirivanakarn, 1977c) is largely confined to the Indomalayan part of the Oriental Region. A few species also occur in the Papuan part of the Australasian Region. Two subgroups are recognized for the Oriental species, the Brevipalpis and Mammilifer Subgroups. These two subgroups are represented in Thailand by 15 species.

Brevipalpis Subgroup. The Brevipalpis Subgroup includes 10 species, but only two of these occur in Thailand. Sirivanakarn (1977c) recognized five complexes within this group, the Brevipalpus, Curtipalpis, Hewitti (monotypic), Jenseni (monotypic), and Navalis Complexes. One of the Thai species belongs to the Brevipalpus Complex and the other to the Curtipalpis Complex.

- **Brevipalpis Complex.** This complex is represented by *Cx. lucaris* in the south of the country. Larvae have been collected from pitcher plants (*Nepenthes gracilis*). Nothing is known about the biology of the adults.

- **Curtipalpis Complex.** The only species of this complex in Thailand, *Cx. curtipalpis*, occurs in the south of the country. Larvae have been collected from tree holes and pitcher plants (*Nepenthes gracilis*). Nothing is known about the biology of the adults.

Mammilifer Subgroup. This subgroup includes 22 species in the Oriental Region, which Sirivanakarn (1977c) classified into eight complexes: the Flavicornis, Ganapathi, Impostor (monotypic), Mammilifer, Minor, Peytoni, Pholeter (monotypic), and Traubi Complexes. The Thai species include *Cx. pholeter* and 12 species that belong to the Ganapathi, Mammilifer, Minor, Peytoni, and Traubi Complexes. We do not recognize the Pholeter Complex of Sirivanakarn because it is monotypic.

Culex pholeter. Larvae of *Cx. pholeter* have been found in tree holes and split bamboo, as well as stream pools, wheel tracks, footprints, and crab holes. Nothing is known about the biology of the adults.

- **Ganapathi Complex.** This complex includes *Cx. ganapathi* and *Cx. spiculosus*, which occur in Thailand. These are common species throughout the country. Larvae have been collected from container habitats, eg, tree holes, bamboo, coconut shells, and plant axils. Nothing is known about the biology of the adults.

- **Mammilifer Complex.** The Mammilifer Complex includes three species, but only two, *Cx. mammilifer* and *Cx. demissus*, are known to occur in Thailand. Larvae of the former have been collected in a variety of ground-pool habitats, artificial containers, and rock pools, and on occasion from bamboo and leaf axils. *Culex demissus* are found in tree holes, root holes, stump holes, bamboo, and *Pandanus* axils. Nothing is known about the biology of the adults.

• **Minor Complex.** Five of the eight species belonging to this complex are known from Thailand. *Culex bengalensis*, *Cx. bicornutus*, and *Cx. minor* are common species that breed in various types of ground-water and natural container habitats. The habitats of *Cx. minor* include ditches, ground pools, flood pools, stream pools, stream margins, seepage pools, foot prints, wheel tracks, and crab holes. These records may be based erroneously on misidentifications of *Cx. bicornutus*, but it is possible that *Cx. minor* occurs in several of these habitats. *Culex incomptus* has been found in tree holes and *Cx. tuberis* has been collected from crab holes and rocks pools. No data are available on the feeding behavior of these species. The adults may possibly attack humans (Colless, 1965).

• **Peytoni Complex.** This complex includes two species, *Cx. eukrines* and *Cx. peytoni*. Both of these species occur in Thailand. The immature stages are found in natural container habitats. *Culex eukrines* occasionally occur in flood pools, footprints, and crab holes. Nothing is known about the biology of the adults.

• **Traubi Complex.** This complex includes three species, but only *Cx. traubi* is known in Thailand. Larvae of this species have been found in tree holes and bamboo stumps. No data are available on the feeding behavior of females, but they may possibly attack humans (Colless, 1965).

Wilfredi Group. This group includes three closely related species, *Cx. hirtipalpis*, *Cx. pilifemoralis*, and *Cx. wilfredi*. All three of these species occur in Thailand. The breeding sites of *Cx. hirtipalpis* are unknown. *Culex pilifemoralis* and *Cx. wilfredi* occur at high elevations in mountainous areas and the immature stages typically occur in ground-water habitats such as ponds, pits, wells, ground pools, flood pools, stream pools, seepage pools, stream margins, footprints, and wheel tracks, and also rock-pool containers. *Culex wilfredi* occurs throughout the country whereas *Cx. pilifemoralis* has only been collected in northern and western Thailand.

***Culex* (*Oculeomyia*)**

Six species of subgenus *Oculeomyia* are widely distributed in Thailand. These species belong to two complexes, *Bitaeniorhynchus* and *Sinensis*. The immature stages of *Oculeomyia* occupy a variety of ground-water habitats that contain clear freshwater with green algae and other aquatic vegetation.

• **Biteniorhynchus Complex.** The Biteniorhynchus Complex includes six Oriental species. Five of these species occur in Thailand. *Culex biteniorhynchus* and *Cx. infula* are widely distributed in the country, *Cx. pseudosinensis* occurs in the south, and *Cx. longicornis* and *Cx. sp* near *infula* are known only from the north. Breeding sites include stagnant pools such as ponds, swamps, marshy depressions, ditches, pits, wells, sand pools, ground pools, flood pools, seepage pools, rice fields, footprints, rock pools, stream pools, and stream margins with still or slow running water. Adults of *Cx. biteniorhynchus* and *Cx. infula* have been captured in light traps and biting humans.

• **Sinensis Complex.** The Sinensis Complex includes three species in the Oriental Region. Only one of these species, *Cx. sinensis*, occurs in Thailand. Larvae of this species have been collected in freshwater ground pools, flood pools, stream pools, stream margins, rice fields, ponds, ditches, and pits/wells. Adult females have been captured in light traps and biting humans.

Lutzia (Metalutzia)

Three species of subgenus *Metalutzia*, *Lt. fuscana*, *Lt. vorax*, and *Lt. halifaxii*, occur in the Oriental Region, and are widely distributed in Thailand. These species are larger than species of *Culex*, and are easy to recognize for this reason. Larvae are predaceous, principally on larvae of other mosquito species. These species are sympatric and found predominantly in ground-water habitats, including rice fields, small ponds, roadside ditches, jungle pools, shallow wells, footprints, and wheel tracks. The preferred habitats are apparently elephant footprints and rock pools. Larvae of *Lt. halifaxii* are found infrequently in tree holes, root holes, stump holes, bamboo cups, and coconut shells. Adult females have been collected in light traps and baited nets. They seldom attack humans.

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