

land is provided in Table 1. A checklist of the 436 species of Culicidae that are included in this study is presented in Table 2. A list of the appropriate references for each genus and subgenus is presented in Table 3. The distribution and larval habitats of these genera and subgenera are provided in the following sections. Table 4 provides a summary of the known larval habitats for the different genera and subgenera.

### Zoogeography

The Kingdom of Thailand lies roughly between 6 and 21 degrees north latitude, and between 98 to 105 degrees east longitude. The country is located in the center of the mainland of Southeast Asia, and has an area of 198,115 mi<sup>2</sup> (513,115 km<sup>2</sup>). Surrounding countries include Myanmar to the west, Lao PDR to the north and east, Cambodia to the southeast, and Malaysia in the south. The Gulf of Thailand is to the south and the Andaman Sea is to the southwest of peninsular Thailand. Thailand is divided into 76 provinces and 926 districts. Bangkok, the capital of Thailand, is in the south-central area just above the Gulf of Thailand. A map of Thailand that includes the provinces is presented in Fig 1.

The number of subregions recognized in Thailand has vacillated between five and six during the last 89 years. Kloss (1915) initially recognized six subregions based on orography, precipitation and floral patterns: North, Northeast (Khorat Plateau), Central Valley, Western Mountains, Southeast, and South (Peninsular). Pendleton and Kingsbury (1962) combined the North and Western Mountain regions and only recognized five subregions. Bunnag (1977) advocated six subregions, but combined the Western mountains and Central Valley into one subregion and split the South into two subregions. At the same time Lekagul and McNeely (1977), working on mammal distributions, recognized the initial 6 subregions of Kloss (1915). We follow Kloss (1915) and Lekagul and McNeely (1977) in recognizing six subregions in Thailand, as presented in Fig 2. These subregions are characterized by unique geographic, precipitation, floral, and faunal features that have significantly affected the zoogeography of the mosquito fauna in the country. Certain genera and subgenera are found throughout the country, whereas others are reported from only certain subregions (Fig 2). Beside the influence of the six subregions on the distributions of the mosquito fauna, other major factors influence species composition. For example, the location of Thailand in the heart of Southeast Asia has had considerable impact on the mosquito species that occur there. Thailand serves as a crossroads for natural as well as unnatural (human) dispersal of flora and fauna from at least three different subregions of the Orient [Indian, Chinese, Sundaic (= Malaysia and Indonesia)] (Harrison and Scanlon, 1975). Also present are introduced species from other

continents (eg, *Aedes aegypti* L.). The above factors must be considered when interpreting the mosquito fauna of Thailand. Detailed descriptions of the six subregions we recognize are provided below.

**Northern Subregion (Subregion 1).** The Northern Subregion encompasses nine provinces in the extreme northern part of the country. This subregion is mountainous with intervening fertile valleys. These mountains are relatively low and covered primarily by tropical deciduous forest, with teak (*Tectona grandis* Linnaeus) being one of the dominant large trees. A few of the tallest mountains such as Doi Inthanon (2,585 m, the highest point in the country) and Doi Pui (1,683 m) have pine-oak forests at higher elevations. The ranges of hills and mountains in the northern subregion are separated by river systems (eg, the Ping, Wang, Yom, and Nan Rivers). These rivers flow southward through narrow valleys and into the plains of the Central Valley where they merge to form the Chao Phraya River (Thailand's major river).

**Western Subregion (Subregion 2).** The Western Mountains Subregion begins due west of Bangkok. This subregion extends from Prachaup Kiri Khan Province in the south (approximately 11 degree north latitude), and northward along the Thai-Myanmar border to approximately 18 degrees north latitude. It encompasses five provinces. The mountains in this subregion are more or less contiguous from the Thanon Thongchai range in the north to the Tanao Sri range in Kanchanaburi Province, which in turn extends southward to the southernmost border of Myanmar. The region has a few large valleys and plains, many caves and waterfalls, considerable forest, many protected areas (eg, Huay Kha Khaeng and Kaeng Kra Jan Dam National Parks), and gives rise to many rivers (eg, Kwae and Mae Klong Rivers). Because this region is largely undisturbed, many new species of mosquitoes have been discovered there.

**Peninsular Subregion (Subregion 3).** Southwest of Bangkok the country narrows and forms peninsular Thailand. This area encompasses 14 provinces. The topography of the peninsula varies from rolling hills to mountainous regions with little flat land. The more northern portion of the Peninsular Subregion consists of coastal plains to the east with a western range of low hills along the Myanmar border. The rivers on the peninsula have produced extensive tidal flats with mangrove thickets. Although most of these rivers drain into the Gulf of Thailand, the mangrove thickets are most abundant on the west coast, with much smaller groves on the gulf side of the peninsula. Midway down the peninsula there are mountains along the Myanmar border that reach approximately

1,500 m elevation. Narrow passes in these mountains link Thailand and Myanmar. Slightly further south these ranges separate the Andaman and South China Seas at the Isthmus of Kra, and further south there are numerous large islands including Phuket on the west coast and Koh Samui on the east coast. The area between Nakhon Si Thammarat and Satun is connected by the Santakiri mountain range. The extreme southern part of Thailand is an overlapping region that contains fauna and flora from both Thailand and Malaysia (Whitmore, 1984).

**Southeastern Subregion (Subregion 4).** To the southeast of Bangkok there is a narrow coastal plain with interspersed mangrove thickets, with inland hills and rather isolated mountains which approach the coast at points, particularly near the Cambodian border in Chantaburi and Trat Provinces. This area represents the southeastern subregion of Thailand and contains seven provinces. The generally rolling countryside of the southeast has high hills in the center and along the eastern boundary with Kampuchea (Cambodia). This region has extensive rubber plantations, fruit orchards and cassava farms, in addition to world famous sapphire mines. These provinces still have areas of tropical evergreen and semi-evergreen forest, and in many ways resemble the Southern Peninsular Region adjacent to Malaysia. The highest peaks are Khao Soi Dao (1,668 m) and Khao Khieo (797 m). A number of coastal hills extend to the sea in some areas and create a markedly indented coastline fringed with many islands.

**Central Subregion (Subregion 5).** The Central Valley subregion encompasses 22 provinces. This is a broad expanse of relatively flat land that has low limestone hills interspersed throughout the area, especially to the west and east. This area forms the extensive Chao Phraya River basin that is the cultural and economic heartland of Thailand. The Central Valley is a plain consisting of two portions: heavily dissected rolling plains in the north and the flat, low-lying floodplain of the Chao Phraya River in the south. Much of the population of Thailand, and most of the industry and manufacturing, is located on the broad central alluvial plain near Bangkok. This is the main agricultural region of Thailand and is used extensively for irrigated rice crops of a number of different varieties. During the rainy season, this subregion becomes an immense inland sea of rice fields and is a major source of mosquitoes. This valley is also used for fruit plantations and a variety of other agricultural crops such as vegetables, sugar cane, and corn. Interspersed throughout the central valley are numerous small villages that are usually only several kilometers from a neighboring village. Nearly all of the forest in this subregion has been eliminated, except at the tops of the limestone hills and in several national parks. At the

southern extreme of the central valley is Bangkok, a city of over 12 million people that is nestled beside the Chao Phraya River, which empties into the Gulf of Thailand only a few kilometers south of the city. The delta floodplain of the Chao Phraya River forms numerous small channels that are joined by other rivers, most notably the Pa Sak, as the Chao Phraya River flows towards the Gulf of Thailand.

**Korat Plateau Subregion (Subregion 6).** One of the most striking geographical features of Thailand is the Korat Plateau to the northeast of Bangkok. This region encompasses 19 provinces. The southern edge of this plateau consists of an east to west line of hills and mountains that form the boundary with Cambodia. To the north and east is a vast area of cultivated land (primarily rice fields) with scattered deciduous forests that form part of the drainage basin of the Mekong River. To the northwest of the plateau are the Phu Kradung (1,351 m) and Phu Rue (1,375 m) mountains. Lower mountains and hills extend south to form the western edge of the plateau. The plateau is generally drier than the rest of Thailand, except for the peaks and slopes of the southern mountain chain, which have areas of evergreen cloud forest. Wet monsoon rains in the degraded forests of the flat central region of the plateau produce rapid runoffs, and the two primary rivers (the Mun and Chi) frequently flood. Rivers in this region generally flow to the southeast and drain into the Mekong River, which forms the boundary between Thailand and Lao PDR. The Mekong River is studded with islands and is broken up by impassable rapids in this region.

### **Climate**

Besides its location in the tropical monsoon zone of mainland Southeast Asia, the major influences on the fauna of Thailand are topography, precipitation, and flora (Whitmore, 1984; Lekagul and McNeely, 1988). According to Ayurakit and Griffith (1962), the climate in the northern half of Thailand can be divided into three seasons: (1) the cool-dry season from late November to early February; (2) the hot-dry season from late February to May; and (3) the rainy season from late May to mid-November. Between November and February the dry northeast monsoon brings cool air masses in a southwesterly flow and creates a seasonably cooler climate for much of the country. Between late February and early May stagnant air is associated with a distinct hot and dry period. Beginning in late May, the warm, humid air masses of the southwest monsoon flow northeastward over the region from the Indian Ocean, depositing great quantities of precipitation, with rainfall reaching a maximum in September. More southern areas of Thailand primarily have the two monsoon seasons, with rain interspersed between them when the air is more stagnant.

## **Deforestation**

Forests are disappearing at an alarming rate in Thailand. Forest cover has dropped from a little over 50% of the total land area of the country in 1960 to about 18% in 1990 (Ganjanapan, 2000). A great loss of forest cover was caused by concessions provided by logging companies that made it easier for villagers to clear forested areas to produce cash crops. In addition, an increase in the amount of land for resettlement projects has significantly altered the environment in several areas. Due to the extent of deforestation, the Royal Forest Department has begun to pay more attention to the conservation of the forests. Many areas are now protected – these include national parks, wildlife sanctuaries, and watershed areas.

## **Bionomics**

There are a number of biological, physical, and chemical factors that must be considered when conducting surveys for both adult and immature mosquitoes. Although there are numerous unique factors that can influence the collection of specific species, some of the common factors to be considered when conducting mosquito surveillance are discussed below.

### **a. Factors affecting mosquito distribution**

The following factors commonly affect adult mosquito distribution:

- Association with specific biogeographical regions
- Terrain
- Seasonality
- Elevation
- Temperature
- Abundance and types of vegetation
- Daily activity/feeding patterns (diurnal or nocturnal)
- Blood host abundance
- Host specificity or the use of certain specific collection methods
- Abundance of and proximity to larval habitats

The following factors commonly affect larval mosquito distribution:

- Association with specific biogeographical regions
- Terrain
- Elevation