

REVIEW OF THE LITERATURE



General: Dove and Hall (1932) and Tokunaga (1937) were found to be most useful for a general understanding of the biology and importance of Culicoides. Dove and Hall (1932) deal with the history of the name "sand fly", which has generally, and more correctly, been applied to the biting flies of the genus Phlebotomus (Family Psychodidae). The name has also been applied to other Diptera, such as Hippelates, Stomoxys and Chrysops, although less frequently. Dove and Hall (1932) also gave early records of Culicoides biting activity in the Southeastern United States. Tokunaga (1937) also reviewed the use of the name "sand fly" in the Japanese and Chinese literature, and restricted the use of the term to the biting midges of the family Ceratopogonidae (genera Culicoides, Leptoconops and Iasiocheles). According to Tokunaga (1937) detailed systematic studies of Culicoides date from 1906 when Kieffer subdivided the Ceratopogonidae into nineteen genera. This system served as a basis for the modern taxonomic studies of Malloch (1915), Goetghebuer (1920) and Edwards (1926). Malloch's observation on the humeral pits of Culicoides permitted reliable separation of that genus from the closely related genus Ceratopogon. The small size and relative neglect of Culicoides by entomologists has caused the erection of many synonyms, as revealed by the synonymy listed in Wirth and Hubert (1961), and by others.

Taxonomy of Asian Culicoides: Most of the references to Asiatic Culicoides are taxonomic in nature, and relatively little has been published on the biology control or disease importance of the Asiatic species. Edwards (1922) reported on some Malayan Culicoides, including

a species (C. anophelis) which sucked blood from the abdomen of engorged Anopheles mosquitoes. During work on Kala-azar in Bengal Smith (1929) collected a number of Culicoides species, and described two of them as new. Also in India, Mukerji (1931) gave a key for some of the Culicoides species, and described an additional species, based on collections in the Calcutta area. Smith and Swaminath (1932) reported on Culicoides from Assam, and noted a diminution in numbers during the hot months of April and May.

Macfie (1934, 1937) reported on a number of Culicoides species and species of related genera collected by workers in Malaya, Java, Borneo and Thailand. One of the most comprehensive early publications on Asian Culicoides was that of Tokunaga (1937) on the sand flies of Japan. The earliest work which dealt extensively with the Culicoides of Thailand was published by Causey (1938) who described nineteen species collected by him in the country from August 1931 to July 1935. Sen and Das Gupta (1958) published a short note on the male of C. anophelis and outlined its distribution. An important contribution on the Asian Culicoides was published by Wirth and Hubert (1959) who erected the subgenus Trithecoides for Culicoides in which the females had three well developed spermathecae and a long second radial cell. The authors included extensive notes on the distribution of the various species in the subgenus. In 1961 Wirth and Hubert also published on the Culicoides of Taiwan, including a review of previous collections on the island made by Sauter, Shiraki, Tokunaga and others. Eighteen species were recorded from Taiwan in this paper. Hubert and Wirth (1961) also published a key to the Culicoides of Okinawa, with

descriptions of two new species, based chiefly on light trap collections made on Okinawa by Captain C. Nibley.

Morphology : There are four stages in the life history of Culicoides-egg, larva*, pupa* adult*. The eggs are elongated and slightly curved, and deposited in masses. The larvae are aquatic; free-swimming and oel-like forms without prolegs. The body segments* are short thick cylinders, each segment carrying a pair of lateral setae. The last segment bears three pairs of anal setae, short and light in color. The larval head is well sclerotized*, simple and nearly as wide as the body. The head* is provided with anterior protruding mouthparts.* The mandibles* are slightly curved, and there is pharyngeal skeleton equipped with combs. The morphology* of the larval stage is discussed in Tokunaga (1937), Thompson (1937) and Foote and Pratt (1954).

The pupal stage was described by Lawson (1951), Tokunaga (1937) and Foote and Pratt (1954). The pupa is free from the larval exuvium, and the integument is dark brown and well sclerotized. The cephalothorax* is usually equal in length to the abdomen*, which is motile and supplied with a variable number of apical* and lateral spiracles. The operculum* is either with or without spines. The anal segment has one pair of apicolateral spines which are sometimes darkened at their tips.

The adults have been characterized by Foote and Pratt (1954). The anterior radial cells* are very characterized, and are usually approximately equal, though one or both may be considerably narrowed in some species. The costa* from one -sixteenth to two thirds the wing length. The wing* membrane provided with microtrichia. At least a few, and sometimes many, macrotrichia* present. Wing coloration

* discussed in Torre-Bueno (1937).

various, from almost unicolorous to heavily pigmented. Generally with a pattern of discrete white spots and darkened areas. Mesonotum unicolorous, or more usually with a pattern of dark lines or spots on a grey or brown background. Mesonotum with a pair of sensory pits located postero-laterally from the humeri.

The female* with spermathecae* of varying size and shape. From one to three functional spermathecae. Antenna of female with first segment obscured. The second unit, torus*, larger than the succeeding segments. First eight flagellar units round or oval, segments 11 to 15 elongated.

Male* with terminal flagellar units of antennae* longer, with more plumose* setae. Terminalia with ninth tergite rounded or truncate, generally with apicolateral processes of varying development. Ninth sternite emarginate, parameres* twisted. Sclerotized aedeagus* present. Anal segment membranous, with seta bearing paired cerci.

First tarsal* segment at least twice as long as the second. Both sexes with simple claws. Empodium very small. The mouthparts of the female have been described in detail by Tokunaga (1937). They consist of a labium*, labrum*, paired mandibles and paired maxillae* and maxillary palps. The palps are five-segmented and the third segment may have scattered sensillae* or sensory pits.

Biology: The biology of *Culicoides* was reviewed in detail by Kettle (1962). The following is an outline of the biologies of the various stages.

Egg: Eggs are deposited in moist situations in groups usually

* discussed in Torre - Bueno, (1937)

smaller than one hundred. The eggs usually hatch in a few days, although some may be delayed for up to several months.

Larvae - Larvae may be found in a wide variety of moist environments, such as ponds, creeks, lakes, tree-holes, slime-covered bark, rotting forest litter, rotting banana stalks. Larvae are generally found in the mud or other organic material. They may swim from time to time, but more generally will be found burrowing, or partially extending from the mud. The larvae feed on organic and inorganic material in an apparent random manner on the mud surface. Various microorganisms such as algae, fungi, bacteria, sporangia, ciliates and flagellates are ingested. Larvae may be reared in the laboratory on culture media rich in organic matter, such as cow or horse dung, mixed with mud and water. (Megahead 1955) Some larvae are predatory or cannibalistic (Thompson, 1937). The larval stage is the longest part of the life cycle, and may persist for several months if the larvae enter diapause.

Pupae- Pupae are found at the edge of the pond or other habitat, on the surface of the substrate, above the waterline. The larvae will not pupate if they are kept covered with water (Kettle, 1962). The pupae are generally quiet, but they are capable of violent movement if disturbed. The pupal stage may last from 4 to 7 days.

Adults-The adults are generally most active at dawn and dusk (Kettle, 1962). Their flight and other activities are strongly influenced by temperature and wind and other meteorological conditions. They may appear in large numbers in random flights in search of food, but the presence of a host may stimulate active seeking of the host. The females require a blood meal, although the males feed only on nectar

or plant juices. Each species has a range of vertebrate hosts on which it will feed, but generally one or more of these are fed upon in larger numbers. Feeding may occur at various times of the night or day, but most species are crepuscular. Very few Culicoides rest in houses. The resting places are usually in damp cool situations, such as algae, the base of trees, moss, grass or dead leaves (Kettle, 1962).

Some species are reported to be parthenogenetic, but mating is required for fertile egg production in most species. Most mating occurs by the flying female entering male swarms, but in some species mating may take place on the host while the female is feeding.

(Megahead, 1955) Egg development is rapid, and eggs are deposited a few days after feeding. The adult longevity had been studied in only a few species. It is influenced by meteorological conditions, and may be ten days or less in the laboratory. The entire life cycle in Culicoides nubeculosus may be completed in as little as three weeks, although four to eight weeks is more usual (Megahead, 1955). In colder regions the life cycle may occupy several years, while in temperate regions there may be one or two generations a year, and in tropical regions there may be several a year (Kettle, 1962).

Disease Importance: Culicoides are known or suspected vectors of a number of human and animal disease organisms. These include- filariae, viruses, protozoa. Lavoipierre (1958), published a lengthy review of the filariae, including a number transmitted by Culicoides. These include: Mansonella ozzardi (Manson), Acanthocheilonema perstans Manson and Dipetalonema streptocerca (Macfie and Corson) of man;

Onchocerca reticulata (Deising) and O. gibsoni Cleland and Johnson of large domestic animals. The microfilariae are ingested by the Culicoides while feeding on infected animals, and penetrate through the alimentary tract of the midges. They develop to the infective form in the Culicoides tissues (generally the flight muscles) and enter a new host when the Culicoides feeds. The adult worms are found in the tissues of the vertebrate host. Causey (1938) found unidentified microfilariae in Culicoides peregrinus at Nakornsrihamarat in Thailand, but the observation has not been repeated, and its importance is unknown.

Several important virus diseases are believed to be transmitted by Culicoides. These include Bluetongue disease of sheep in Africa and the United States (Price and Hardy, 1954), and South African Horse Sickness which is known from several localities in Africa and Asia (Du Toit, 1944). This disease is characteristic of dry climates, but there is at least a possibility that it could be introduced into Thailand.

Protozoa of the genus Haemoproteus have been shown to be transmitted by Culicoides in Canada (Fallis and Wood, 1957), and it is probable that a number of species of this avian parasite genus are transmitted by Culicoides (Bennett and Fallis, 1960).

Control-

The control of Culicoides has proved to be a difficult matter in the past, due largely to the inaccessibility of the immature stages. Some success was had with larval control with insecticides in Florida and Panama, but larvae developed resistance so rapidly that this is no longer recommended (Anonymous, 1963). The nature of some larval breeding sites is such that the control of water level, such as alternate flooding and drying, might offer some help in control, where the biology of the species involved is well understood. At present, however, larval control seems to be out of the question except in special circumstances.

The use of insecticidal fogs may reduce local populations of Culicoides and offer temporary protection for large outdoor gatherings (Kettle, 1962). However, the midges tend to infiltrate the area rapidly as soon as the fog or mist of DDT or other insecticide has dispersed.

Protection of individuals from bites may be the best course of action in prevention of human disease. This may be by use of clothing or head nets, or by the use of insect repellents, such as Diethyltoluamide (Anonymous, 1963). Window screens may be painted with 5% DDT or 8% malathion to keep these small flies from entering through the mesh (Anonymous, 1963).