Technical Bulletin 228

April 1958

The Mosquitoes of Minnesota

(Diptera : Culicidae : Culicinae)

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The Mosquitoes of Minnesota

(Diptera : Culicidae : Culicinae)

A. Ralph Barr[1]

Part I. Introduction

MOSQUITOES are extremely important to the economy of the state of Minnesota. Their primary importance at the present time does not concern their ability to carry diseases but rather lies in their nuisance value. Hardly a community in the state, from the plains of the southwest to the forested region of the northeast, does not have a pest mosquito problem at some time during the warmer part of the year.

The species causing such problems are, however, not always and everywhere the same. Different areas have different pest species and in each area control measures must be adapted to the peculiarities of the most important pests present. It is for this reason that a manual is needed to aid in identification of the various species and to bring together the salient features of their biologies. The present publication is intended to fulfill that need as well as to serve as a vehicle for observations gathered by the author during the years 1952 to 1957. It is hoped that the present work will also stimulate further studies by pointing out a few of the myriad of problems, both taxonomic and biological, which remain to be solved in this area.

ACKNOWLEDGMENTS

Thanks are due the Chamber of Commerce of the City of Virginia and the State Entomologist's Office for cooperation in fieldwork in the spring of 1953, and the University of Minnesota Forestry and Biological Station at Itasca State Park for the use of their facilities during the springs of 1954 and 1957. The State Entomologist's Office also provided a quantity of light trap material which proved to be valuable. Lastly, thanks are due Dr. Alan Stone of the United States National Museum for many services, Dr. R. C. Wallis of the Connecticut Agricultural Experimental Station and Dr. R. D. Price of the University of Minnesota for valuable material, Dr. E. F. Cook of the University of Minnesota for working directly with the editors and printer on matters which distance prevented the author from taking care of in person, and Sylvia Barr who provided all illustrations and performed a large part of the technical work on which this publication is based.

Part II. Historical

THE FIRST ACCOUNT of mosquitoes in Minnesota was given by Lugger (1896) who mentioned three species found in the state: *Culex consobrinus* (= *Culiseta inornata*), *C. pungens* and *Anopheles quadrimaculatus*. "*Culex pungens*" is considered to be a synonym of *pipiens* but the larva figured by Lugger is clearly *restuans*. The identity of "*quadrimaculatus*" is questionable; it is probably either *earlei* or *walkeri* or both. Riley (1940) says that Lugger's Grand Rapids record refers to *walkeri*. Lugger also gave a rather general account of the biology, anatomy, and control of mosquitoes.

Washburn in 1902 (1902b) added "*Culex impiger*" to the list given by Lugger and stated that *pungens* (= *pipiens*) was probably the most abundant and troublesome species in the state. Although *pipiens* was probably a good deal more abundant in those days than it is now, due to the availability of breeding places at that time, it hardly seems likely that it was the most "troublesome" mosquito. Possibly other forms such as *Aedes vexans* were mistakenly classified as "*pungens*". The identity of "*impiger*" is questionable; it is probably one of the *Aedes* with a golden mesonotum such as *intrudens* or *abserratus*. There is a

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very old specimen of *Aedes triseriatus* in the University collection identified as "*impiger*".

The results of a partially successful campaign to control mosquitoes were also given by Washburn in 1902 (1902a) and in 1903 he added *Culex stimulans, C. restuans,* and *Wyeomyia smithii* to the state list bringing the total to seven. His "*stimulans*" was probably *Aedes vexans;* old identifications in the University collection bear out this impression. "*Anopheles quadrimaculatus* (= *maculipennis*)" was found to be abundant at Basswood Lake (practically on the Canadian border) which indicates that the identification certainly did not refer to *quadrimaculatus.*

In 1905 Washburn recorded 16 species of mosquitoes and chaoborids from the state. To the previous list of seven he added *Culex tarsalis, nemorosus, canadensis, cantans, triseriatus,* and *dyari, Grabhamia curriei, Taeniorhynchus perturbans,* and *Anopheles punctipennis.* "*Culex stimulans*" was no longer listed, hence that identification was changed, probably to "*sylvestris*" (= *Aedes vexans*) although the possibility that it was to "*cantans*" cannot be discounted. The latter name refers to one or more of the *Aedes stimulans* group of mosquitoes, most probably *excrucians. Culex tarsalis* is probably correct as are *canadensis, triseriatus, T. perturbans,* and *An. punctipennis.* "*Culex nemorosus*" probably refers for the most part to *Aedes communis* and "*G. curriei*" to *Ae. dorsalis.* "*Culex dyari*" was probably a mixture of *Culiseta morsitans* and *minnesotae.* Washburn in 1906 added "*Culex frickii*" (= *C. territans*) to the list bringing the total to 17.

C. W. Howard in 1916 revised the state list and made a number of changes in nomenclature. He recognized a total of 12 species which he had studied and listed an additional six which he had not found. Three of his species, *Aedes auroides, fuscus,* and *trivittatus* had not previously been recorded from the state. He did not recognize one previous state record, that of "*Culex consobrinus*", and apparently was unaware of Washburn's 1906 record of "*Culex frickii*". Howard probably believed that Lugger's "*consobrinus*" was *pipiens* but the latter's remarks concerning "*consobrinus*" obviously refer to a *Culiseta;* there are very old specimens of *Culiseta inornata* in the collection which are identified as "*consobrinus*". Howard's new record of *Ae. trivittatus* was probably correct, as was his identification of "*fuscus*" (= *cinereus*). The identity of "*auroides*" is problematic but since "*impiger*" and "*nemorosus*" are also listed, this species is probably *punctor.* The adult was said to have a broad stripe on the thorax which would indicate either *punctor* or *dianteus;* his description of the larva does not agree with either of these species and was probably erroneously associated with the adult.

Among the previously recognized species, Howard gave remarks on *Culex pipiens, restuans,* and *tarsalis, Aedes sylvestris* (= *vexans*) and *canadensis, Mansonia perturbans,* and *Anopheles punctipennis.* "*Aedes abfitchii*" of this work probably corresponds to Washburn's "*Culex cantans*" and is *Aedes excrucians,* at least for the most part. "*Aedes impiger*" of this work is probably *intrudens.*

Dyar in 1922 (1922a) added *Aedes aurifer, campestris, flavescens, impiger* (= *implicatus*), *spencerii,* and *trichurus* to the state list and in 1923 *riparius* (1923c). In 1928 he reported *Aedes nigromaculis* and *Culex salinarius* as being present.

Owen in 1937 listed a total of 37 species from the state and straightened out the *Anopheles* and the *stimulans* and *communis* groups of *Aedes.* Riley and Chalgren (1938) added one species ("*Psorophora posticata*", = *P. horrida* not *ferox*) to this list as did Sandve (*Culiseta melanura*) in 1946 and Knight (1951; *Aedes abserratus*). A new *Culiseta* was added by Barr (1957b; *minnesotae*), a new *Aedes* by Rueger (1958; *barri*), and three new records are introduced in the present work (*Psorophora ciliata, Culex erraticus,* and *Aedes pionips*) bringing the total for the state to 45.[2]

Riley and Chalgren (1938) collected mosquitoes by light-trapping and by hand in Hennepin County in 1937 and 1938. The most striking result of their study was that the light-trap catches were 89 to 98% *Aedes vexans* as were 66% of the hand catches. Other species that were fairly numerous were *Culex tarsalis* and *Aedes dorsalis, cinereus,* and *stimulans.* Chalgren, McCartney, and Riley (1940) surveyed the anophelines of central Minnesota (Stearns, Todd, Wadena, Crow Wing, Morrison, Mille Lacs, Benton, and Sherburne Counties) using light-traps, hand-catches, and resting station and larval collections. Of the specimens captured in "resting places" 95% were anophelines and 94% were *An. earlei;* most of these were taken under bridges and in hog houses, barns, and privies. Too few hand catches were made for meaningful results but the light-trap catch was 60% *Aedes vexans,* 12% *Anopheles walkeri,* 8% *An. earlei,* and 8% *Ae. cinereus.* The most common anopheline larva taken was *earlei.* It was concluded

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[2] Since the above was written, Price and Abrahamsen (1958) have found two more species, *Anopheles barberi* and *Orthopodomyia signifera,* in Minnesota.

that *earlei* was the dominant anopheline of central Minnesota; the techniques used, however, were probably not adequate for sampling *An. walkeri.*

Part III. Biology of mosquitoes

THE MOST COMPREHENSIVE works on the biology of mosquitoes are by Howard *et al.* (1913a), Bates (1949), Muirhead-Thomson (1951), and Horsfall (1955). All of these works are useful and complement rather than supplant each other. The first-named work summarized most of what was known up to 1912 and quotes much of the earlier work *verbatim;* included are extended accounts of morphology which do not appear in most later works. Bates' book summarizes what is known of the several phases of the life history of mosquitoes and attempts to synthesize this material. Muirhead-Thomson reviews at some length his own work and that of others which is related to his own; although the scope of the work is limited, the material and presentation are excellent. Horsfall's recent book indicates most of what is known of the biology of each species.

ZOOGEOGRAPHY

The most characteristic physiographic features of Minnesota are the plains areas of the southwestern part of the state and the forested areas of the northeastern part. Between these is a broad and changing intermediate region. The southwestern edge of the forested region is predominantly hardwood but this grades imperceptibly into coniferous forest toward the northeast.

Many species of mosquitoes show a good correlation with these two broad regions of the state although there is much overlap in intermediate areas. The plains species include *Aedes nigromaculis, flavescens, dorsalis, spencerii,* and probably *campestris.* Species practically always found in or near wooded areas include *Wyeomyia smithii, Culiseta minnesotae,* and *Aedes cinereus, excrucians, stimulans, fitchii, canadensis,* and most of the *communis* group. Some species such as *Aedes vexans* and *Culiseta inornata* are able to utilize both habitats successfully.

OVIPOSITION

Larvae of mosquitoes are invariably aquatic; there are few types of naturally occurring water in which larvae are not regularly found. A particular species, however, tends to occur more regularly in some types of water than in others. It was once believed that mosquitoes scattered their eggs more or less indiscriminately; the absence of a given kind of larva from a certain habitat was thought to be due to the unfavorability of that habitat for larval survival. It is now realized, however, that the distribution of larvae in nature is more related to the oviposition habits of the female of the species; it has been shown, for example, that females of a number of species will not lay their eggs in dilute saline solutions even though the larvae are perfectly capable of developing in such solutions. Larvae, then, are found only where females lay eggs, although their absence in a breeding place may be due to predation as well as to a lack of oviposition.

Oviposition is a subject which badly needs study; practically all of our knowledge of this activity derives from laboratory experiments or is inferred from the distribution of larvae in nature. Oviposition is rarely observed in the field since most mosquitoes appear to oviposit only at reduced light intensities. With a strong red light and patience a good deal could probably be learned.

Mosquitoes can, in general, be divided into two classes depending on whether or not their eggs enter into a period of dormancy. In Minnesota, those species laying "non-dormant" eggs are included in the genera *Anopheles, Culex, Culiseta, Mansonia, Uranotaenia, Orthopodomyia,* and probably *Wyeomyia* while species of *Aedes* and *Psorophora* lay eggs which become dormant. Dormant eggs are usually much more resistant to drying than are non-dormant ones.

In those species laying non-dormant eggs, the female usually lays her eggs directly on the water surface and such eggs are usually adapted for floating. Some of these species lay their eggs in rafts (*Culex* (fig. 10), *Culiseta, Mansonia, Uranotaenia*) in which case the female must stand on the water surface (or very close to it) while ovipositing. In those cases where eggs are laid singly (*Anopheles,* figs. 1-7), the female may stand on the water or hover over it while ovipositing.

These non-dormant eggs usually develop to the point of hatching and then hatch in a very short time; the length of time required for the egg stage is dependent almost entirely on temperature. At room temperature (about 23° C.) this incubation period is usually about 2 days. The incubation period of such eggs can usually be reduced to about 1.5 days by higher temperatures and can, of course, be greatly lengthened by lower temperatures. Non-dormant eggs

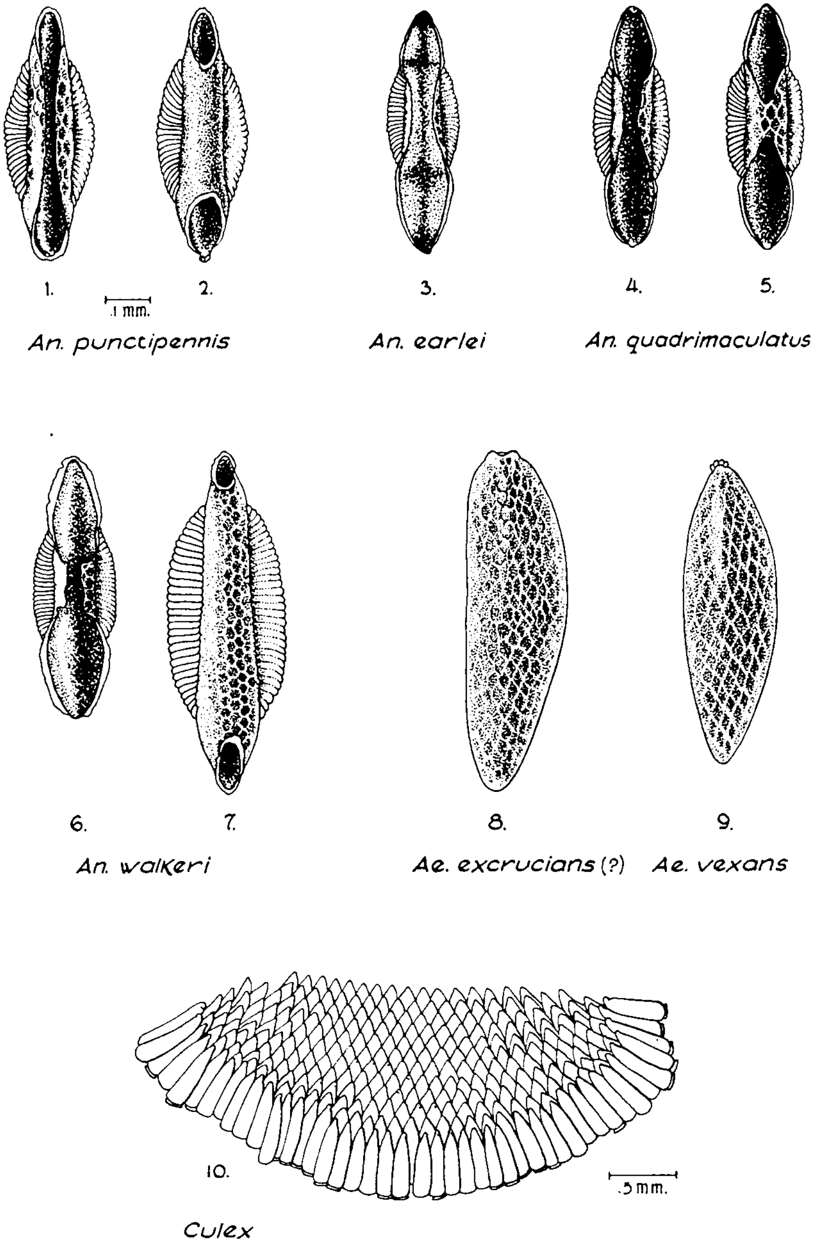

PLATE 1 (figs. 1-10). Eggs of *Anopheles*, *Culex*, and *Aedes*.

are, as a rule, easily killed by drying although they can usually survive "stranding" for at least a day or so under very humid conditions. In the latter case the caps of the eggs may pop open but the larvae usually stay inside until placed in water; in some cases the larvae will emerge and creep around on a moist surface.

Species having non-dormant eggs usually have several generations a year, the number depending, of course, on the length of the breeding season. These species, then, tend to be found for the most part in more permanent waters where one generation succeeds another throughout the breeding season. Some species such as *Anopheles quadrimaculatus* and *Culex erraticus* are usually found in water which would be classified as permanent while others such as *Anopheles punctipennis* or *Culex pipiens* or *restuans* are generally found in more temporary water although the generalization still holds that species with non-dormant eggs tend to breed in permanet or semi-permanent water.

Species of *Aedes* and *Psorophora,* on the other hand, exhibit a very different kind of behavior. Females of these genera lay their eggs (figs. 8, 9) not on water but on the moist sides of breeding places. The eggs undergo a certain amount of development but do not normally hatch after completing their development; instead they enter a period of dormancy and will then hatch when the proper conditions ensue. Although a great deal of work has been done on this part of the cycle of *Aedes* mosquitoes there is still much to be learned.

Most of our knowledge of oviposition of *Aedes* mosquitoes derives from work done on *Aedes aegypti,* the yellow fever mosquito; few other species have been colonized. In rearing *aegypti* we provide a bowl of water, the sides of which are lined with filter paper, for oviposition. The females readily lay their eggs on the moist filter paper near the water line. The eggs must then be allowed to remain in contact with moisture (or at a high humidity) for a day or two, after which they may be dried (but should not be desiccated). After this "conditioning" the eggs are rather resistant to low humidities and may be stored for long periods of time although the percentage which will hatch begins to fall off within a few months. The eggs may then be hatched by merely putting them in tap water and adding some food; if one wants larvae all of the same age he can put the eggs in water in a partial vacuum which quickly removes most of the oxygen dissolved in the water and promotes uniform hatching. Under these conditions many eggs will hatch within a few minutes.

Other species of *Aedes* and *Psorophora* react similarly. Most species which develop in ground pools will not, however, lay their eggs readily on a surface as smooth as filter paper (Beckel, 1955). This is probably because they prefer to insert them into irregularities in moist soil (Barr and Azawi, 1958). The eggs of these species are probably not as resistant to drying as is *Ae. aegypti* since their eggs are normally protected by soil moisture. Yates (1945), for example, found that the eggs of *Ae. lateralis* (= *sticticus*) and *vexans* hatched very poorly after the soil had been excessively dried or after removal from soil.

In multivoltine species of *Aedes* and *Psorophora* dormant eggs may be stimulated to hatch by lowering the oxidation-reduction potential of the water in which the eggs are placed (Gjullin *et al.*, 1941; Horsfall, 1956a). This technique, however, does not suffice with univoltine forms (Barr and Azawi, 1958); it appears that these forms must be exposed to low temperatures before they will hatch (Beckel, 1954c; Beckel and Copps, 1955).

BREEDING PLACES OF LARVAE

As has been noted above, certain types of larvae tend to be found in certain types of breeding places more often than in other types. Some species show a high degree of specificity in this regard while others are much more indiscriminate. In general it would appear that the more abundant a particular species is in a particular locality, the wider variety of breeding places its larvae will inhabit in that locality.

Many systems for the classification of breeding places have been developed but mosquitoes usually show less regard for such distinctions than do culicidologists; a particular species of larva is usually found in several classes of breeding places in such systems. To put it differently, it is very difficult to characterize the breeding places selected by a particular species of mosquito. The reason for this is that we do not as yet understand the various factors which influence the oviposition of mosquitoes. Although a few such factors have been investigated in the laboratory, little field work has been done. A fuller discussion of this problem is given by Bates (1949).

The author uses the following sketchy classification of breeding places in field work:

Temporary water
Semi-permanent water
Permanent water
Specialized breeding places

In general, *Aedes* and *Psorophora* larvae tend to be found in temporary or semi-permanent waters. The hatching of the eggs of such species depends on wide fluctuations in the water level, which limits the breeding of these species in more permanent breeding places. Some *Aedes* such as *vexans, sticticus,* and *spencerii* are most abundantly found in extremely temporary breeding places while others such as *fitchii, excrucians,* and *trichurus* are usually taken in water which is semi-permanent. An important point is that with many species (*stimulans* group, most of the *communis* group) the eggs are laid one year but larvae do not appear till the next. A breeding place may be temporary one year and permanent the next depending upon the amount and distribution of precipitation, heat, etc. To put it differently, we judge a breeding place by its condition at the time we find larvae but the critical factor is the condition of such a breeding place at the time that females were ovipositing, which may have occurred as long ago as a year or more.

Mosquitoes which lay "non-dormant" eggs, as noted above, tend to occur most commonly and most abundantly in semi-permanent or permanent waters; temporary waters often dry so quickly as to wipe out such species whereas more permanent waters allow continuous breeding throughout the summer. The breeding places of these species are likely to be more temporary earlier in the summer and more permanent later in the summer, due perhaps to the disappearance of the former type of breeding place in the fall; permanent breeding places also offer little vegetation for the protection of larvae early in the year although such vegetation is abundant later in the year.

The category of specialized breeding places encompasses such places as tree-holes, rock holes, pitcher plants, and artificial containers where species with very restricted oviposition habits often breed. Larvae of *Wyeomyia smithii,* for example, are taken nowhere except in pitcher plants; larvae of *Aedes triseriatus,* on the other hand, are most commonly taken from tree holes although they are often collected in various sorts of wooden containers and, more rarely, in metal or glass ones.

LARVAL GROWTH

The growth rate of larvae of mosquitoes is affected by many factors such as temperature, crowding, availability of food, etc. At laboratory temperatures most species will complete larval development in about a week; species which occur in very temporary breeding places may require less time. Some species, however, have a very prolonged development, even at higher temperatures. Laboratory data may be very misleading when applied to field conditions. In Minnesota, larvae (particularly of *Aedes* species) are often found in the field as early as March although emergence does not generally occur on a large scale till the middle of May. Such larvae are regularly encountered in waters with a temperature near the freezing point in the field; their breeding places regularly become coated with ice at night or in cloudy weather and may remain ice-covered for a week or so without damaging the larvae. It is probable that such larvae are rather resistant to freezing. Under such conditions larval development may be very slow; the aquatic stages often require a month or two or even more. The resulting adults are, of course, somewhat larger than is customary among mosquitoes.

In 1953 the author found a breeding place of *Aedes trichurus* in northern Minnesota. At the time of its discovery in March, the breeding place contained a few first instar larvae. On April 22 the larvae were mostly in the third instar; large numbers were present but they were not overcrowded. The site was examined daily till pupation began on May 9. During most of this time the weather was cloudy and cold; the breeding place often contained ice and the water temperature was usually below 5° C. Even under these conditions the larvae were not particularly sluggish and spent most of their time at the surface. When disturbed they would drop to the bottom but most returned to the surface in a few minutes. It is probable that most of our truly northern *Aedes* are well adapted to developing in such extremely cold water and generally have a very prolonged developmental period.

An interesting observation concerning this breeding place is that when "middle-aged" fourth instars or younger larvae were removed to a warm laboratory, they invariably developed poorly and most eventually died. Later in the year, however, all of the larvae in the breeding place developed to late fourth instars. These larvae when taken into the warm laboratory pupated overnight and produced viable adults. In the field, however, the larvae appeared to develop up to the point of pupation but would not pupate until the weather warmed considerably. Such larvae, of course, did not suspend development but continued to feed and become larger, waiting, as it were, until the proper conditions for pupation occurred. When the larvae were examined in late April there was a good deal of variability in size and stage of development but just before pupation the larvae were much more uniform in these respects. In May there were one or two warm, sunny days and practically all of the larvae pupated at once; a few stragglers, probably abnormal individuals, were encountered for a week or two thereafter. This seeming "stimulus for pupation" may indicate a temperature threshold for pupation but, to the knowledge of the writer, such has never been recorded. It is also possible that sunlight, *per se,* could stimulate pupation. Nielsen and Haeger (1954) presented evidence to show that larvae of *Aedes taeniorhynchus* usually pupated around nightfall; their thesis is that larvae could "speed up" pupation so that it would occur at this time of day or, alternatively, could delay the process so that it would occur the following evening.

The data on other phases of larval growth is scanty. Crowding is known to retard larval growth even in the presence of abundant food. This is probably due at least in part to excessive activity on the part of the larvae. Scarcity of food usually appears to be a negligible factor in the field; even when larvae are overcrowded, which is not commonly seen in the field, retardation of growth usually seems to be due more to excessive movement than to scarcity of food.

Larvae of practically all mosquitoes are indiscriminate in their feeding habits, taking a large variety of diatoms, desmids, other algae of various sorts, protozoans, debris, etc. *Psorophora ciliata* is the only true mosquito in the state which is predaceous in the sense that it eats good-sized aquatic animals.

NATURAL FACTORS IN CONTROL OF MOSQUITO LARVAE

It appears to the author that in Minnesota there are two important factors regulating the survival of mosquito larvae. The most important is the drying of breeding places. This is particularly important in the early spring when large numbers of larvae are found in water collections on frozen ground. The permanence of such breeding places seems to be dependent almost entirely upon temperature and rate of evaporation; if the ground beneath such a breeding place thaws too rapidly the larvae are stranded and are killed either by drying or predation; the latter is probably particularly important since larvae disappear very quickly from such breeding places. Even rainfall often does not prevent the drawdown of water in such breeding places since drainage is good after thawing of the ground. The author has rarely found a breeding place of *Aedes spencerii* which persisted long enough for pupation of the mosquitoes to occur, even though larvae have often been found abundantly. The customary scarcity of adults of this species is probably due to the high death rate of larvae which are killed when their breeding places dry. Under exceptional conditions the species could probably become a veritable scourge in the early spring.

Although predators of mosquito larvae are almost as ubiquitous as the larvae themselves, they usually appear to be of little value in the control of larvae. In the marsh which contained *Aedes trichurus* larvae mentioned above, predaceous insects were rather abundant; the author often sat and watched them chase larvae. The larvae stayed in a small, open place surrounded by vegetation so that the entire population could be easily estimated. During the entire time that the marsh was under observation, the larvae never materially decreased in numbers. Similar observations have been made by the author on other occasions.

Under some conditions, however, predation becomes an important factor. (1) Where small fish are present larvae are able to survive only in dense vegetation or flotage. (2) When a breeding place becomes very small due to drying, predation becomes very efficient. The author has examined many such breeding places which contained practically nothing but predators even though the ponds had previously contained numbers of larvae. (3) As noted above, stranded larvae usually disappear very quickly, probably due to predation. The most conspicuous predators present aside from fishes are dytiscids, larval hydrophilids, and odonate naiads. The author has observed a planaria-like turbellarian taking early instar *vexans* larvae.

The role of parasites in limiting the development of larvae is not known. Larvae are often taken covered with suctorians but do not appear to be seriously inconvenienced by them. In the laboratory heavy growths of these organisms are often associated with high larval mortalities; the two events probably are not causally related to one another but are due to a third event. Usually such pans show a high bacterial growth, scum formation on the surface, and a reduction in dissolved oxygen. The growth of larvae in well oxygenated water largely prevents this condition from developing.

Parasitic fungi of the genus *Coelomomyces* have been observed in *Anopheles earlei* and *walkeri* larvae collected at Itasca State Park, and in *Aedes vexans* larvae from the Twin Cities Area. Dr. Price of the University of Minnesota has also found them in larvae of *Culiseta morsitans* from Itasca State Park. They were also observed in larvae of *Psoro-*

phora ciliata collected by A. G. Peterson in Mississippi.

PUPAL STAGE

The pupal stage of most mosquitoes requires about 2 days at room temperatures; this interval can usually be shortened by half a day or so at higher temperatures and may be prolonged for a week or longer by lower temperatures. The length of the stage appears to depend almost entirely on temperature since the pupa does not feed. It would appear that emergence follows pupation automatically after a certain time interval at a given temperature, the adult being unable to "speed up" or delay emergence (Nielsen and Haeger, 1954). Pupae of most mosquitoes appear to be rather tolerant of drying; emergence is usually successful even though pupae have been stranded for most of the pupal stage. The pupae of males are usually decidedly smaller than those of females; the two sexes in a given lot can usually be easily separated on this basis, especially if doubtful pupae are discarded. This method does not work well with some anophelines (Barr, 1954a) and mixed lots of pupae are often impossible to separate by size.

MATING

Male mosquitoes in a given lot practically always begin emerging before females and the bulk of the males of such a lot practically always emerges a few hours to a day or so before the bulk of the females of that lot. The length of the aquatic stages of males thus averages a day or so less than that of females. Since the pupal stages of the two sexes appear to be of about the same length, the shortening in development of males takes place primarily in the larval stages, especially in the last instar; pupal and adult males are therefore of a correspondingly smaller size.

Mating of most northern mosquitoes takes place in a "swarm" formation. Under certain conditions males begin a peculiar dancing flight which appears to be necessary for mating in most of our mosquitoes. Such a "swarm" may consist of only one or a few males or several thousands of them. The swarms usually form at low light intensities, in the evening or morning and sometimes during cloudy weather. A female usually pairs immediately upon entering such a swarm; copulation usually requires only a minute or so although it is prolonged for hours in some species (*Culiseta inornata*).

As a rule mating probably takes place soon after emergence since biting females are practically invariably inseminated even when taken near a breeding place. The author has dissected wild-caught, biting females of *Aedes vexans, cinereus, canadensis* and several other species and has rarely found an uninseminated female; in culicines usually 2 of the 3 spermathecae contain spermatozoa.

FEEDING OF ADULTS

Adults of both sexes of practically all mosquitoes will feed on nectar from various kinds of plants. It is thought that this is probably the only food which most male mosquitoes take in the field. The role of such juices in female mosquitoes is, however, not understood. It is known that females will live longer when fed such juices than when not fed at all but beyond this, the function of plant feeding in females has not been elucidated. In the spring of 1957 the author found that *Aedes* females which had taken blood survived much better when given raisins than when given no food at all; this was especially true at low temperatures. In view of the fact that females taken feeding on flowers are frequently gravid, nectar may be an important dietary supplement while eggs are being matured, especially at low temperatures.

With very few known exceptions, females must have a blood meal before they can mature eggs. In Minnesota the only known exceptions to this are *Aedes atropalpus* and a form of *Culex pipiens*, both of which can lay eggs "autogenously" (without blood) but will take blood on occasion. Although it is widely stated that northern mosquitoes may not require a blood meal for maturation of the eggs, the concept has arisen from the apparent scarcity of vertebrates in regions in which vast numbers of these mosquitoes occur. There is a single mosquito (*Aedes communis*) in such regions which is known to develop its eggs autogenously (Hocking, 1954) and this mosquito is thought never to feed on blood; such a condition is certainly very much the exception and not the rule.

The factors attracting mosquitoes to feed are not well understood although warm temperatures, high humidities, and dark colors seem to be attractive to most mosquitoes (Brown, 1951); CO_2 in the proper concentration seems to attract some species (Reeves, 1953). A reduction in light intensity appears to be an important stimulus for the feeding of females of most northern mosquitoes; practically all of our mosquitoes feed predominantly between dusk and dawn. The lower saturation deficiency which prevails at this time is probably the critical factor but the activity of the adults often appears to be triggered by light intensity rather than humidity. Biting activity is also increased by cloudiness.

A good deal has been written about feeding preferences of mosquitoes and it is difficult to generalize from, or even summarize, this work. Most mosquitoes appear to be able to oviposit after feeding on a variety of vertebrates and few appear to be limited in their feeding to a single kind or even a few kinds of vertebrates. Some mosquitoes appear to have habits which bring them into close association with a particular kind of animal and so usually feed on this kind of animal; "domestic" mosquitoes such as *Aedes aegypti* or *Anopheles gambiae* thus are closely associated with man and feed to a large extent on him. Such habits, of course, heighten the probability of the mosquito's being an efficient disease vector. We are fortunate in having no highly domestic species in the state although many species (such as *Culex pipiens*) will enter houses readily. Many species are attracted to light at night and will readily enter poorly screened houses. At Itasca State Park the author has been particularly troubled by *Aedes intrudens* and *Mansonia perturbans* in this respect; at times hundreds of mosquitoes were killed indoors in a single evening although there was no obvious deficiency in the screening. Those species which hiberate as adults are especially sly in gaining entrance to shelters, even well screened ones; these include species of *Anopheles*, *Culex*, and *Culiseta* in particular. In the matter of feeding, northern *Aedes* and *Anopheles* probably prefer to attack mammals while *Culex* probably prefers to attack birds, although no strict lines can be drawn.

Engorgement with blood by a female usually requires a minute or so and the development of eggs is a variable process. Most mosquitoes appear to be able to develop a clutch of eggs on a single blood meal although a number of exceptions have been described. As a rule a mosquito will first oviposit (when kept at room temperature) about 4 to 5 days after feeding although many exceptions are known; in many mosquitoes this period may be reduced to as little as 2 days at higher temperatures. In northern Minnesota the evenings are usually very cool, especially in the spring when the *Aedes* females or overwintered *Culex*, etc., are developing their eggs; under these conditions the preoviposition period is upwards of a week as a rule. A female usually deposits a clutch of eggs after each engorgement; the preovipisition period of the second and later clutches may be somewhat shorter than that of the first clutch, as a rule around 3 days at room temperature. In determining the length of the preoviposition period under laboratory conditions it is well to remember that a female does not necessarily lay her eggs as soon as she is able; she may retain them for prolonged periods of time until the proper conditions for oviposition prevail. Oviposition usually occurs in the evening hours; since biting also usually takes place at this time, the interval between biting and ovipositing is as a rule a matter of so many complete days. A species may show a three day biting cycle at one temperature but at a lower temperature the cycle will lengthen to four days in most individuals.

The number of clutches a mosquito will lay depends to a large extent on its longevity. Little has been learned in field studies of this important phase of the biology of mosquitoes although it is known that most species can lay several clutches of eggs after a single insemination.

As previously stated, probably the most-critical factor in the survival of adult mosquitoes is humidity. All mosquitoes tend to be very susceptible to high saturation deficiencies when compared with many other kinds of insects. For this reason mosquitoes are generally most active at low saturation deficiencies; these conditions usually prevail at low light intensities so most mosquitoes show a correlation of activity with such light intensities. It is at this time that mating, feeding, migration, and oviposition occur in most species. Some mosquitoes, however, appear to be better adapted to survive high saturation deficiencies than others; most of the plains species (*dorsalis*, *campestris*, *nigromaculis*) can be taken in bright sunlight under conditions where other kinds of mosquitoes are rarely or never taken. Forest mosquitoes, on the other hand, are also often taken in the daytime but not in exposed, sunlit places; in wooded areas, of course, the saturation deficit is perpetually lowered, as is the light intensity.

Dispersion is a subject fraught with difficulty since adequate techniques for the measurement of the length of flight have not been developed except under unusual conditions. Most studies of the flight range of mosquitoes involve such a low recovery rate that generalizations cannot be drawn. Some species of mosquitoes do, however, appear to wander a great deal further than do others.

Longevity is again a subject about which little is known due to the lack of adequate techniques. Since it has been shown (MacDonald, 1952) that even small variations in the longevity of mosquitoes may produce large variations in the ability of such mosquitoes to transmit disease, it is hoped that techniques will soon be developed for estimating average longevity of mosquitoes under a given set of conditions. A beginning has been made in this direction by Draper and Davidson (1953), Davidson and Draper (1953), and Davidson (1954).

Much has also been written about predators of adult mosquitoes but again this factor is difficult to evaluate.

HIBERNATION

It would appear that mosquitoes have developed efficient overwintering mechanisms only in the egg and adult stages. Although two of our mosquitoes (*Wyeomyia smithii* and *Mansonia perturbans*) are known to overwinter in the larval stage, no group of mosquitoes which overwinters by this method has been really successful in colonizing northern regions.[3] (It seems likely that the probability of either of these species' undergoing adaptive radiation in northern climates is low since one (*Wyeomyia*) is, at least at the present time, confined to a plant with a restricted distribution, and the other (*Mansonia*) is dependent upon marshy areas for its survival.)

Hibernation in the egg stage is probably practiced by all of our northern *Aedes* mosquitoes and by our *Psorophora* spp. but none of the latter has been successful in invading northern regions. One wonders why the one genus has been successful and not the other when both use the same method of overwintering; even among the *Aedes*, only the subgenus *Ochlerotatus* has been really successful.

Among the mosquitoes which overwinter as adults only the *Culiseta* is really characteristic of northern regions. *Anopheles* and *Culex* are most abundantly found in warm regions and only the nominate ("typical") subgenera have successfully invaded northern regions. Studies on the physiology of hibernation of these mosquitoes, although numerous, are confusing and badly need attention; overwintering and hibernation are usually considered to be synonymous, as they probably are in this region, but in warmer areas nothing could be farther from the truth.

SEASONAL DISTRIBUTION

For a discussion of the seasonal distribution of mosquitoes the following classification is useful:

early spring *Aedes*
summer *Aedes*
species hibernating as adults

Generally the first sign of mosquito activity in the spring is the appearance of *Aedes* larvae in melted snowpools. These are larvae of the early spring *Aedes* and the time of their appearance is dependent on the beginning of the spring thaw which usually takes place in March or April although exceptionally it may occur earlier or later. The adults usually begin emerging in early May but again this varies a great deal from year to year; peak populations of these mosquitoes usually occur in late May or early June and disappear within a couple of weeks or so dependent of course on temperature and humidity at that time.

As implied above, the early spring *Aedes* are single-generation species (at least in this latitude); these include the *stimulans* group and most of the *communis* group of mosquitoes. It is significant that of the *Aedes* in Minnesota, only the truly northern ones appear to be restricted to a single generation a year; all of the Minnesota *Aedes* which also occur in southern areas (except *stimulans* and *canadensis*) appear to have more than one generation a year.

In the observations of the author the earliest species to appear in the spring was always *spencerii* although it was quickly followed by *intrudens*, *trichurus*, *implicatus*, *communis*, *punctor*, and *dianteus*, approximately in that order. Somewhat after these species, *excrucians* and *fitchii* adults began to appear. The last groups to emerge were the summer species, *cinereus* and *canadensis* and lastly *vexans*. In different seasons the order of all of these species appears to be about the same, although the period of time from first to last may be rather long or may be as short as a couple of weeks.

The summer *Aedes* (*vide supra*) are the last to emerge in the spring and may be taken throughout the summer months. *Aedes canadensis* is usually abundant only in the spring although fresh specimens can usually be taken throughout the summer. *Ae. cinereus* may be as abundant throughout the summer as in the early spring, especially in wooded areas. *Ae. vexans* is likely to be much more abundant in the summer than in the spring.

Those species which overwinter as adults (most *Anopheles*, *Culex*, *Culiseta*, *Uranotaenia*) are usually the first adults seen in the early spring; these, of course, are hibernating females seeking a host. With the passing of

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[3] *Anopheles barberi* and *Orthopodomyia signifera*, which only recently have been taken in Minnesota, also overwinter as larvae.

these females it is generally difficult to find adults for a month or so although adult populations may be building up during that time. The largest numbers of individuals of these species usually occur in late summer or fall at which time the species may be abundant.

The abundance of biting mosquitoes thus follows a fairly predictable pattern. In the early spring there is a small amount of annoyance due to overwintered females. In May the population usually increases tremendously due to the emergence of *Aedes;* annoyance is likely to be at a maximum at this time of year, particularly in wooded areas. In the early summer annoyance usually subsides somewhat; at this time the most abundant species are the summer *Aedes* and those genera which overwinter as adults. In areas where annoyance is exceptionally high during the summer, the summer *Aedes* are generally common; large numbers of biting females of *vexans* usually occur about two weeks after peaks of rainfall. Towards fall these same species are the common ones with those which overwinter as adults (the *Culex, Culiseta,* etc.) becoming increasingly more common. The latter usually reach a peak in the fall except when that season is uncommonly dry; in such years their peak may occur in late summer. The last sign of adults in the fall is the activity of females seeking hibernating quarters. In such places females may be taken throughout the winter months although there is often a high mortality in such places.

Part IV. Techniques

EQUIPMENT

For general field work involving the aquatic stages of mosquitoes the worker needs as a minimum a dipper or net with which to sample the water, a pipette for transferring the mosquitoes, and a series of jars for transporting them. The dipper should be white so that larvae are easily seen; a saucepan will do for a larger sample. The author prefers a rather large pipette with a long tube. The kind of jars used is not critical but they should be provided with covers so that mosquitoes can not splash out. At times it is convenient to transfer a quantity of water to a white enamelled pan which can then be scrutinized in a leisurely fashion, particularly when the water is dark, muddy, etc.; in some cases an aquatic net also is useful. One would be well advised to carry along some type of portable seat such as a camp-stool since the ground around breeding places is often too wet for sitting. Other useful pieces of equipment include a wax pencil, data book, thermometer, pH indicators, yard stick, and a camera to make a permanent record of the breeding place. Breland (1954) has recently summarized the field techniques he uses.

In the laboratory a variety of tools are needed. Small dissecting needles can be made by inserting *minuten nadeln* into the ends of softened glass rods; the needle should first be pushed point first into a cork for ease in handling. Larger and stouter needles may be made from insect pins if the butt of the needle is first bent in a crook and this crook is then twisted into a softened glass rod. Small spatulas can be made by flattening the tips of such dissecting needles. A large spatula can be made by flattening one end of a straightened paper clip, cutting off the clip to the desired length, inserting it into a wooden handle, and then tempering the blade with heat. A small aspirator for handling *Aedes* eggs in water can be made from small diameter glass tubing drawn at the tip; a length of rubber tubing may be added for flexibility. A large aspirator for catching adults is made from a length of glass tubing of the desired diameter. A wisp of cotton is placed in one end which is then covered with gauze and inserted into a length of rubber tubing; a glass mouthpiece may be added if one objects to the taste of rubber. If adult mosquitoes are to be dissected they are most easily killed by catching them in the aspirator and drawing cigarette smoke through the tube; this method does not harm malaria parasites, filarial larvae, etc., which might be damaged by ether or chloroform.

EGGS

Mosquito eggs may be found while dipping for the aquatic stages. Those of *Anopheles* are very small and easily overlooked but may be found by diligent search (Aitken, 1948). Egg rafts are larger and more easily seen; the author has collected them by pressing down vegetation around the edges of breeding places with the hands so that the rafts float over the hands. The eggs of *Aedes* are not generally encountered in field work but may be collected by taking sod samples from around breeding places; Gjullin (1938) and Horsfall (1956b) have devised machines for isolating eggs from such samples. Eggs of this genus may also be obtained by allowing females to feed in the field and then transporting them to the laboratory where the eggs are laid on moist cotton several days later. Such females can be kept in test tubes closed with gauze (Barr and Azawi, 1958).

Mosquito eggs may be put in vials on damp filter paper for storage; for preservation the filter paper should be treated with formalin (Lawlor, 1940). The author knows of no method of making good permanent mounts of entire mosquito eggs (but see Craig, 1955). Live eggs may be safely sent through the mail by just wrapping them in waxed paper and dropping them in an envelope if the envelope is carefully postmarked by hand.

LARVAE

In collecting larvae one should make certain the samples contain no predators. Some authors use a system of dipping whereby they can calculate the number of mosquitoes per dip for the evaluation of the importance of a breeding place (Belkin, 1954). It is difficult to devise such a system that will give consistent results.

For killing larvae the author prefers to use warm water; therefore, field collected larvae are usually carried back to the laboratory. If this is not possible the larvae may be pipetted into vials; excess water is then removed with a pipette and 95% alcohol added to the vial of larvae in water till the concentration of alcohol is 70 to 80%. To prevent damage of the larvae by shaking, the smaller vials can be completely filled with alcohol, stoppered with cotton, and dropped into a jar of alcohol; if the jar is to be stored for any length of time, a small amount of glycerine should be added to prevent damage in case of excessive drying. Larvae should always be mounted as soon as possible since they darken and harden with age and generally lose many of their characters (hairs, anal papillae, antennae, etc.).

If larvae are carried back to the laboratory alive they should be examined to see how many kinds are present. An attempt should be made to rear some of each kind so that the larval identifications can be compared with those of the adults which emerge. Larvae are killed with warm (about 50° C) tap water; if the heat is excessive the larvae will be darkened. After death the larvae are transferred by means of a spatula to 95% alcohol which fixes and dehydrates them; delicate larvae (such as *Wyeomyia*) may have to be run through a graded series of alcohols but most kinds can be transferred directly to 95% alcohol without severe shrinkage taking place. Larvae are usually left for an hour or so in alcohol and are then transferred directly to beechwood creosote where they clear, usually in a few minutes. If it appears that the larvae are becoming distorted in creosote they should be pierced with a needle to allow the creosote to enter more readily; it is a good idea to do this routinely when the larvae are ready to be transferred to creosote. A larva is then transferred to a drop of thin balsam on a glass slide, the terminalia are dissected off with needles and laid on their side, and a small coverslip is added; bubbles migrate to the edge of the coverslip freely if the balsam is not too thick. The author prefers tearing off the terminalia with needles since cutting usually jars the larva so much as to break off the hairs. The coverslip can be supported with pieces of broken coverslips or slides but this is usually not necessary. Larger larvae may need to be cleared in KOH before dehydration but such treatment should be avoided since it causes a loss of characters (hairs and anal papillae). Foote (1952) and Burton (1954) have recently discussed other methods of mounting larvae.

The above technique gives excellent permanent preparations and reduces the handling of larvae to a bare minimum; larvae should be handled as little as possible. Creosote is an excellent clearing medium since it obviates the use of absolute alcohol, thus reducing by one the number of times larvae must be handled.

Some larvae of each species should be mounted as above. Others of the same species should be reared and the larval and pupal exuvia saved so that the adult can be associated with certainty with its immature stages. Exuvia are poor for studying the morphology of larvae but are useful in associating a larva with the correct adult; Yamaguti and LaCasse (1951) say that exuvia are also useful for studying the larval mouthparts. For mounting, exuvia are dehydrated and cleared according to the schedule given above except that very little time is required. The two exuvia (larval and pupal) should be mounted on the same slide. The coverslip for the larval exuvium should be supported by pieces of broken coverslips so that the air tube and head capsule will not be crushed. The pupal skin is transferred to a small drop of thin balsam on a slide and then the cephalothoracic bar with the attached abdomen (fig. 47) is teased away from the remainder of the cephalothorax and mounted dorsal side up. The remainder of the cephalothorax is then turned over so that its ventral side is up, and dissected so that it will lie flat; as little balsam as possible should be used so that the coverslip will flatten the preparation; it is wise to use a large coverslip which also aids flattening. The larval and pupal exuvia should be given the same number as the adult so they can be quickly located.

PUPAE

Entire pupae are useless for taxonomic purposes. If pupae are collected they should be reared and the pupal exuvia mounted as above.

ADULTS

Adults may be taken by hand or may be trapped with bait (live animal) or light. If specimens are being taken for taxonomic study it is best for the collector to get into a favorable location and catch them one by one by hand as they come to feed. The author prefers to use a small vial with cyanide as the killing agent. A few small pieces of tissue paper in the vial will help to prevent the specimens from being excessively damaged. It must be remembered that mosquitoes are covered with tiny scales and their identification is based largely on the color, shape, and distribution of these scales; rubbed specimens are often unidentifiable. After killing, the adults should be mounted as soon as possible; in an emergency they may be stored in cardboard pillboxes (metallic boxes often prevent the escape of water, thus causing the specimens to mold).

If one wishes to work with live females they may be caught by aspirator or with test tubes either before or after feeding. They may be stored in test tubes or vials or transferred to cages where they usually survive somewhat better. They should be provided with a high humidity and maintenance food of some type (prunes, raisins, apple slices, etc.). Adults may also be reared from immature stages but most species will not mate in captivity. A light trap may be modified so that it will blow the mosquitoes into a large bag where they will remain alive.

Some authors calculate landing rates or attack rates for a location at a given time. These figures are used to compare mosquito densities at different places or different times. They are very unstable and vary not only with time and place but also with light intensity, time of day, humidity, temperature, attractiveness of subject, species of mosquitoes, age and nutritional status of the mosquito, air movement, etc. A refinement of this method is the use of a bait trap where some vertebrate is used as bait and the trap is a cage with a series of baffles which allow mosquitoes to enter but not to leave. These methods, of course, attract only females.

Mosquitoes may also be taken in their resting places either by means of an aspirator or a sweeping net. Such collections often include blooded females which can be used in precipitin test studies to determine the host of the mosquito. Males may also be taken in resting places.

Adults may also be taken by sweeping vegetation. A light, rather stiff net (nylon) is preferable so that the mosquitoes will not be badly rubbed. Both males and females can often be taken feeding on flowers or resting in grass or shrubbery.

The last and one of the most widely used methods of collecting adults is by means of light traps. A trap consists essentially of a light suspended above a funnel leading to a killing jar or cage. The trap may utilize a portable light source. A fan is often directed down into the killing jar to blow the mosquitoes in and prevent their flying out again. The trap may be supplied with solid carbon dioxide to increase its effectiveness for certain species (Reeves, 1953).

Light traps are useful because they trap large numbers of mosquitoes, both male and female, and require so little effort. They take many kinds of mosquitoes which are weakly or not at all attracted to man (*Uranotaenia sapphirina, Culex* spp., *Culiseta* spp.). There is a standard (New Jersey) light trap on the market. As a method of sampling, light traps are of limited value since some kinds of mosquitoes are more highly attracted to light than others. Other important variables include the location of the trap, weather, the age and nutritional status of the mosquito (Nielsen and Nielsen, 1953), the variability in performance of the trap, etc. Such traps are, however, particularly useful in trapping large numbers of males.

Adults may be pinned in many ways but the author prefers to mount them on cardboard points with lacquer. A pinned specimen should bear at least a locality and date as well as its identification. Male terminalia are prepared for examination by clipping them from the specimen with iridectomy shears, softening (but not clearing) in 10% KOH, and mounted by the schedule given for larvae. A more detailed discussion of this important subject is given in the next paragraph. Female terminalia (Gjullin, 1937) as well as the mouthparts and thoraxes of adults may be mounted in the same fashion; a study of the thorax is particularly instructive since thoracic bristles are used in the classification of genera.

If these are first seen on slide mounted material, they can be more easily located on pinned specimens.

The terminalia of *Aedes* mosquitoes are somewhat more difficult to mount than are those of most mosquitoes of this region. The technique of the author is as follows: The terminalia of the specimen should be clipped off through the eighth abdominal segment and dropped into alcohol (70% or so), so that they will not float when put into the macerating solution. The terminalia are placed in hot 10% potassium hydroxide (KOH) for about 3 minutes. KOH is used to soften the specimen allowing it to regain its normal shape and making dissection possible; the author does not allow the specimen to stay in KOH long enough for it to "clear" appreciably. The specimen should be examined periodically under a dissecting scope to avoid over- or under-treatment. When the specimen has relaxed into its normal, undistorted shape it should be taken out of KOH and neutralized in a weakly acidic solution. (This step is not entirely necessary but appears to give somewhat better results.) Acetic acid is usually used. The specimen is then washed in water and dehydrated in 95% alcohol and cleared in beechwood creosote. A minute or two in each of these solutions is all that is required although they may be left longer; excessive exposure (longer than a day) to any of these solutions should be avoided.

The mounting of *Aedes* male terminalia is a variable procedure with different culicidologists since there is no single way to mount specimens so that all salient characters can be seen. Some insist that the terminalia should be dissected apart entirely so that all structures are exposed. The author is of the opinion that in the vast majority of cases the terminalia should be mounted intact. The reason for this is that the general configuration of the terminalia is an important character in identifying specimens; this character is destroyed by dissection. If the general configurations of the terminalia of *Aedes stimulans, excrucians, barri,* and *flavescens* (figs. 88, 78, 80, 87) are studied, it will be seen that they are very similar, and are, at the same time, quite different from other species occurring in Minnesota. If this configuration is learned, the terminalia of this group of species will be immediately recognized when in creosote. Identification is then simply a matter of checking the basal spine and the shape of the claspette filament, both of which may easily be seen while the specimen is still in creosote. If there are details which cannot be seen under the dissecting microscope, the specimen can be put in a drop of creosote on a microscope slide and examined under the low or even high (43x) power of a compound microscope without using a cover-slip; the shape of the claspette filaments may usually be seen by tilting the specimen sideways at this time.

When the specimen is ready for mounting its identity is usually already known. Place a small drop of thin balsam on a clean microscope slide and transfer the specimen to this drop. The eighth segment should then be dissected off, care being taken not to destroy the ninth tergal lobes. Two or three pieces of broken cover-slips should be arranged around the specimen to insure its not being distorted by the cover-slip; these pieces may be stacked up for thicker terminalia. A clean cover-slip is then used to cover the specimen. A small amount of orientation may be done by pushing the top of the cover-slip and moving the entire balsam-specimen mass. Specimens mounted in this manner retain the normal shape of the terminalia and are, for the most part, easily identified. In those species in which the claspette filament must be examined for identification (*trichurus, stimulans, sticticus, spencerii, fitchii, trivittatus*) this examination can be made while the specimen is in creosote. Although the author routinely mounts male terminalia in this fashion, he also dissects a few specimens of each species to better examine other structures (claspette filaments, aedeagus, etc.). A variety of mounting methods should be used so that all details of the terminalia are clearly seen, but there seems to be little to recommend the very common practice of merely squashing the entire terminalia under a cover-slip.

COLONIZATION AND REARING

Probably the best single method of learning something about the biology of mosquitoes is to keep a colony for a number of generations. All that is needed is a few pans for rearing the larvae, food for the larvae, pipettes for handling the immature stages, a cage for the adults, and a source of blood for the adults. In rearing *Culex pipiens* for instance, one provides a bowl of water in which females can oviposit. The egg rafts are transferred to rearing pans where at room temperature they hatch in about 2 days. The larvae can be fed small amounts of dog biscuits, dried alfalfa pellets, etc. If they develop poorly, a little brewer's or fresh yeast may be given. Aeration of the pans will help to prevent excessive bacterial growth. The larvae should pupate in a week or so at which time they are pipetted into clean water and put in the cage. About two days later the adults emerge. They can be given a little sucrose solution, apple slices, raisins, or other nutriment to maintain them until they are ready to engorge. Adults do well when kept at 20 to 25° C. and a fairly high relative humidity (60 to 70%). The best method of feeding *Culex pipiens* as a rule is to use a chicken which is immobilized and placed in the cage overnight. The females which feed will then develop their eggs in a week or so.

Aedes aegypti is another mosquito easy to rear in the laboratory and it has the advantage that its eggs may be dried and stored so the colony does not have to be continuous. This mosquito is especially convenient to use since it feeds readily on humans. Trembley (1955) has recently reviewed the literature on laboratory rearing of mosquitoes.

The species occurring in Minnesota which have been colonized include *Anopheles quadrimaculatus, punctipennis,* and *earlei, Culex pipiens, tarsalis,* and *salinarius, Aedes atropalpus* and *triseriatus,* and *Culiseta inornata.*

In rearing field-collected larvae it is important not to transfer them immediately to a markedly higher temperature; the temperature should be gradually raised stepwise so that the larvae have an opportunity to acclimate.

Part V. Systematic treatment

KEY TO GENERA

Adult females

1. Maxillary palpi about as long as proboscis (fig. 11); scutellum rounded (fig. 13); thorax and abdomen with few or no scales (tribe Anophelini) ---------- *Anopheles* (p. 34)

1. Maxillary palpi less than half as long as proboscis (fig. 12); scutellum tri-lobed, a tuft of bristles on each lobe (fig. 14); thorax and abdomen densely covered with scales (tribe Culicini[4]) ---------- 2

2. Post-notum with a tuft of setae (fig. 15); upper sternopleural bristles absent (not prealars, fig. 18 ---------- *Wyeomyia smithii* (p. 45)

2. Post-notum without a tuft of setae; upper sternopleural bristles present (fig. 18) ---------- 3

3. Wings with cell R_2 (second submarginal) not half as long as its petiole (fig. 19); with lines of brilliant blue scales on head, thorax, and wings ---------- *Uranotaenia sapphirina* (p. 46)

3. Wing with cell R_2 at least as long as its petiole (fig. 20); without brilliant blue scales ---------- 4

4. Spiracular bristles present (not post pronotals, fig. 18) ---------- 5

4. Spiracular bristles absent ---------- 6

5. Post-spiracular bristles present (fig. 18); tip of abdomen narrow, pointed, cerci evident (fig. 17) ---------- *Psorophora* (p. 57)

5. Post-spiracular bristles absent; tip of abdomen rounded, cerci concealed (fig. 16) ---------- *Culiseta* (p. 46)

6. Post-spiracular bristles present (fig. 18); tip of abdomen narrow, pointed, cerci evident (fig. 17) ---------- *Aedes* (p. 60)

6. Post-spiracular bristles absent; tip of abdomen rounded, cerci not evident (fig. 16) ---------- 7

7. Wing scales conspicuously dark and light intermixed (fig. 21) ---------- 8

7. Wing scales dark (fig. 22) ---------- *Culex* (p. 124)

8. Hind tarsi with pale rings covering the apex of one segment and the base of the next (fig. 24); mesonotum dark, with single rows of bright, bluish-white scales forming a distinctive pattern ---------- *Orthopodomyia signifera* (p. 53)

8. Hind tarsi with pale rings at the bases of the segments only (fig. 23); mesonotum without well-defined pattern ---------- *Mansonia perturbans* (p. 54)

Male terminalia
(Modified from Ross, 1947)

1. Dististyle with a contorted mass of branches as in fig. 33; with three long hairs on basistyle lateral of phallosome ---------- *Wyeomyia smithii* (p. 45)

1. Dististyle either unbranched or with only one or two simple lobes; basistyle without hairs as above ---------- 2

2. A pair of subcylindrical arms (claspettes) arising from dorsum of capsule, each tipped with a sclerotized filament (fig. 36) ---------- *Aedes* (subgenera *Ochlerotatus* and *Finlaya*) (p. 60)

2. Claspettes absent or not as above; if a filament is present, there is a cluster of setae associated with it (figs. 71, 72) ---------- 3

3. Basistyle with an apico-mesal shoulder (subapical lobe) bearing a cluster of specialized, blade-like or spatulate spines, which are fre-

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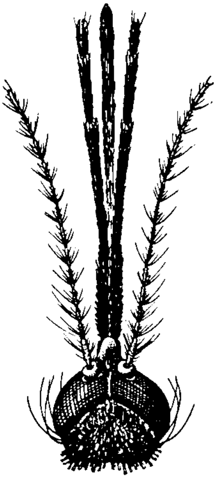
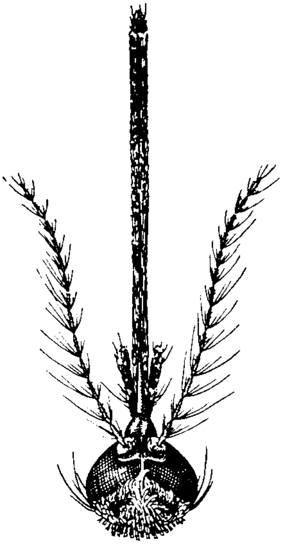
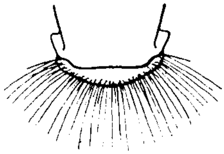
[4] Some authors divide the tribe Culicini of Edwards (1932) into two tribes, the Culicini and Sabethini.



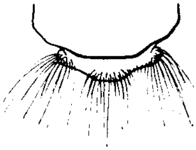
11. *An. walkeri*



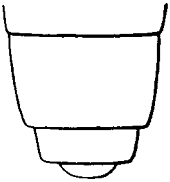
12. *Ae. vexans*



13. *An. walkeri*

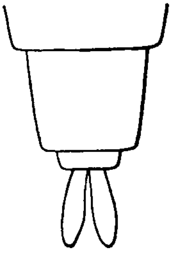


14. *Ae. punctor*



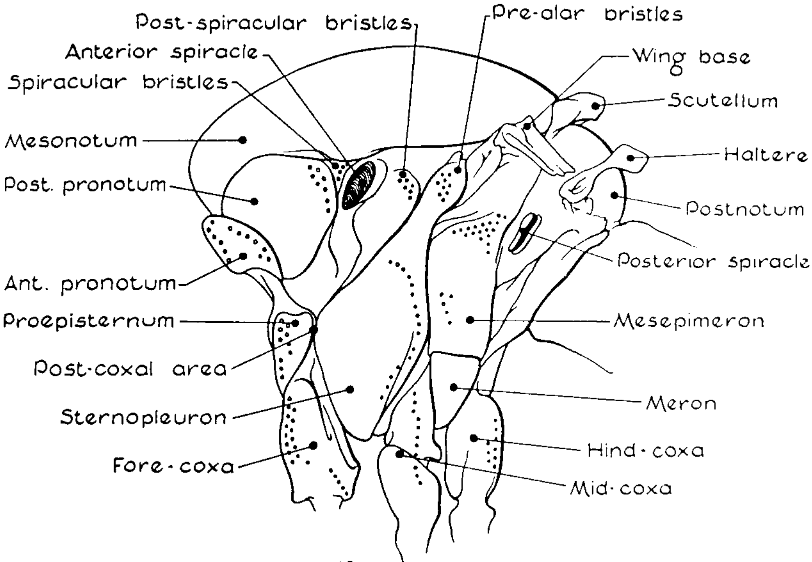
16. *M. perturbans*

15. *W. smithii*

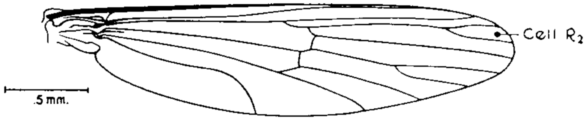


17. *Ae. punctor*

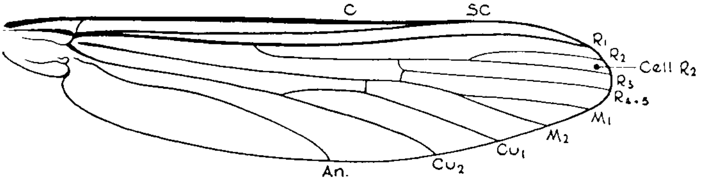
PLATE 2. Details of adult female mosquitoes. Figs. 11, 12. Heads of adult female *Anopheles* and *Aedes*. Figs. 13-15. Scutella of *Anopheles*, *Aedes*, and *Wyeomia*. Figs. 16, 17. Tip of abdomen of *Mansonia* and *Aedes*.



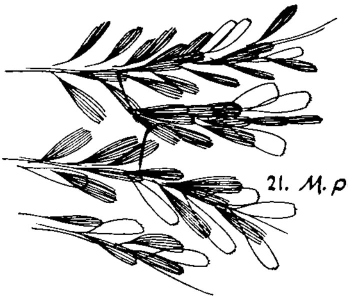
18.



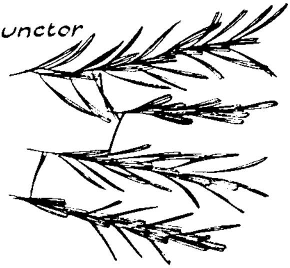
19. *Urano. sapphirina*



20. Generalized wing



21. *M. perturbans*



22. *Ae. punctor*

PLATE 3. Details of adult female mosquitoes. Fig. 18. Generalized thorax. Figs. 19, 20. Wings of *Uranotaenia* and generalized mosquito. Figs. 21, 22. Wing scaling of *Mansonia* and *Aedes*.

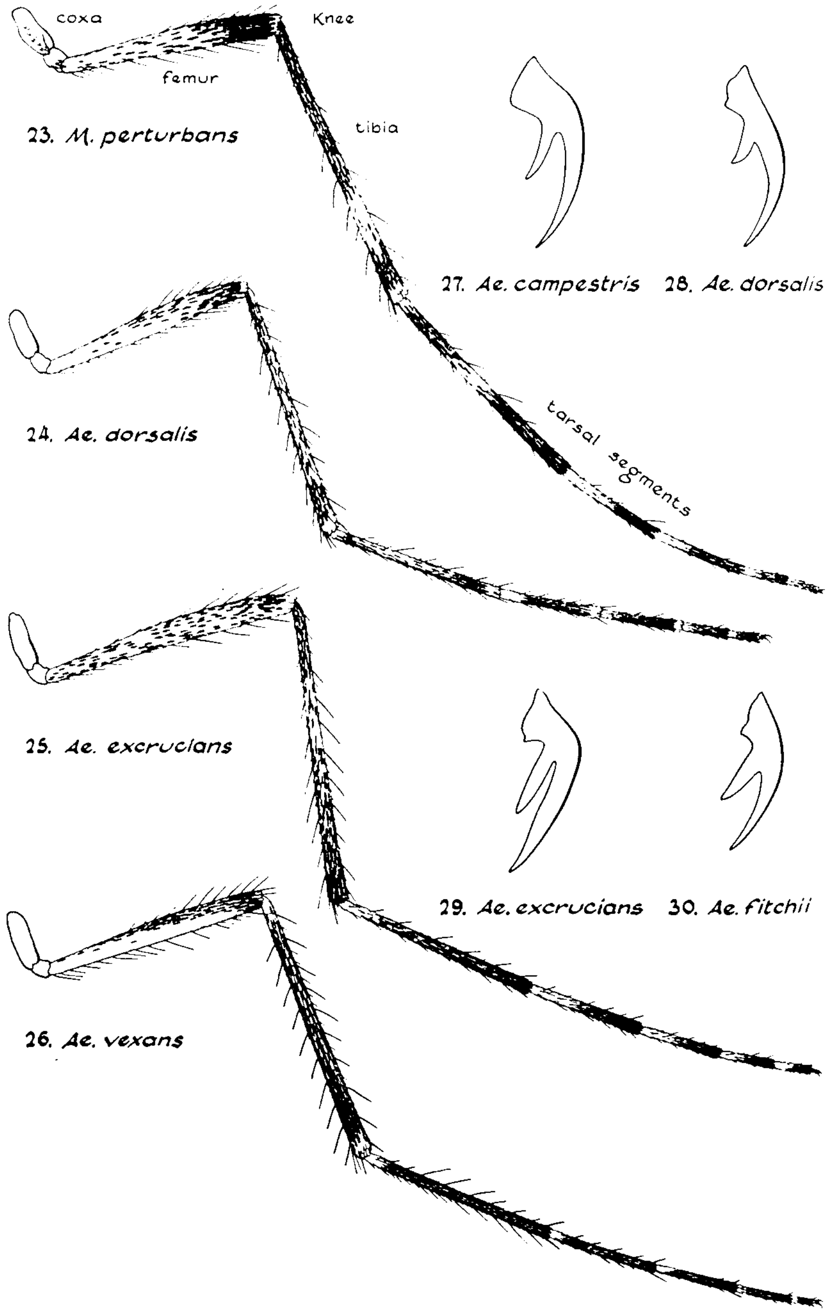


PLATE 4 (figs. 23-30). Legs and tarsal claws of *Mansonia* and *Aedes* females.

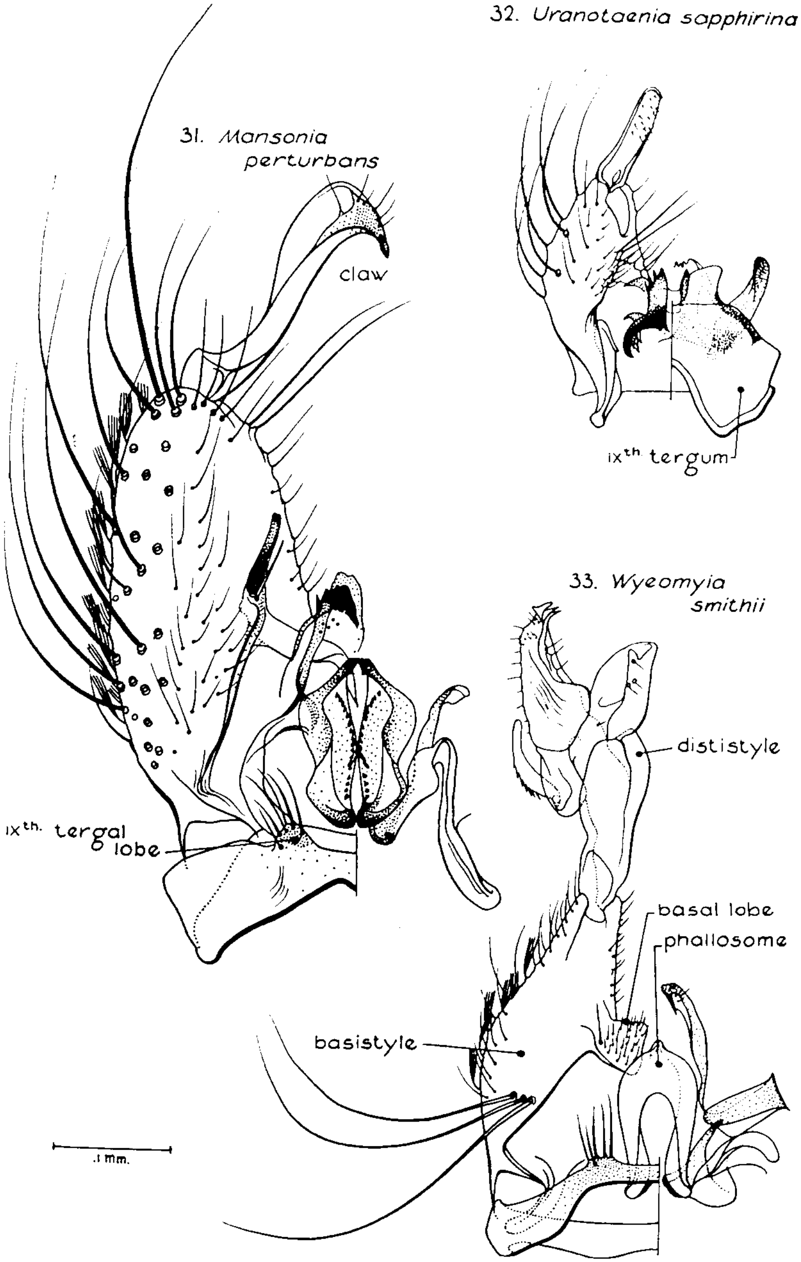
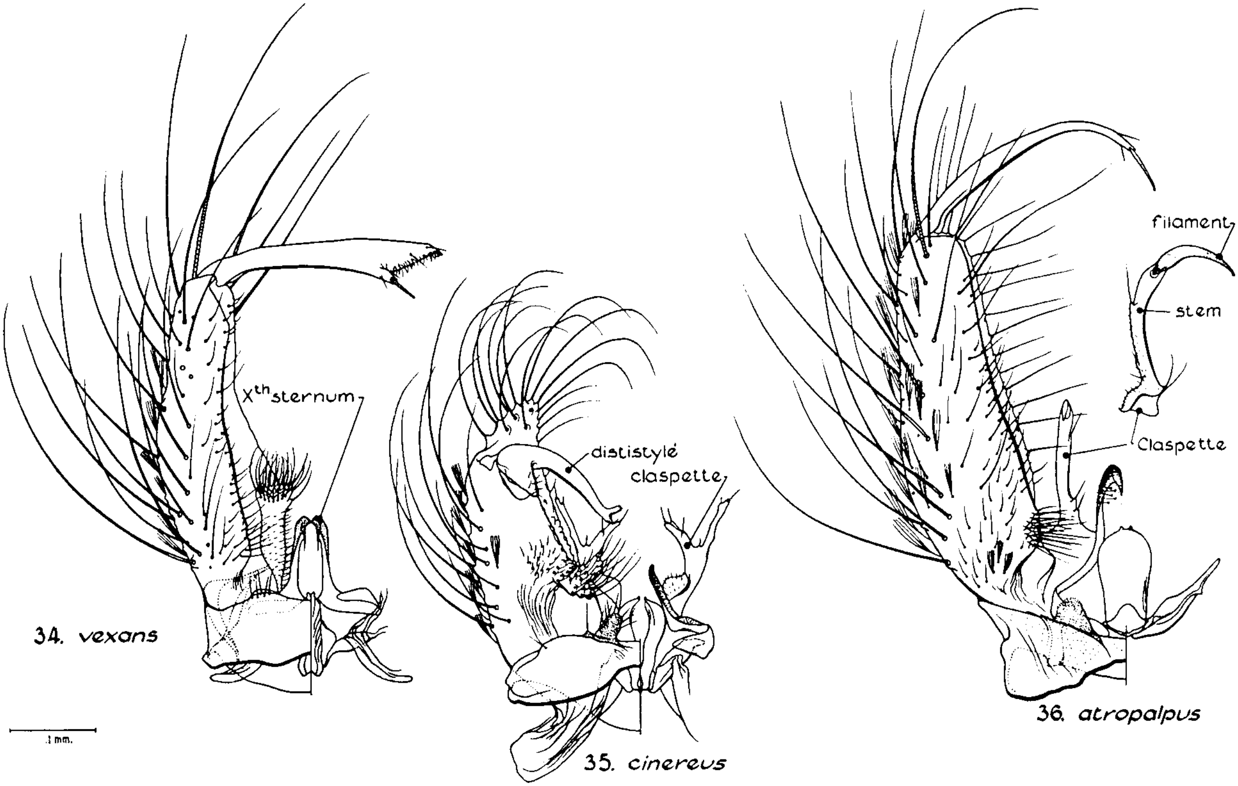


PLATE 5 (figs. 31-33). Male terminalia of culicine mosquitoes.

PLATE 6 (figs. 34-36). Male terminalia of *Aedes*.



34. *vexans*

35. *cinereus*

36. *atropalpus*

quently complex in structure (figs. 121-126); 10th sternum with a dense crown of spines ---------- *Culex* (p. 124)

3. Basistyle either without a sub-apical lobe or the lobe bearing only narrow spines; tenth sternum variable ---------- 4

4. Apex of basistyle continuing as a pointed lobe beyond insertion of the dististyle as in fig. 35, (dististyle furcate at base, the longer portion again shallowly furcate at apex; without a large spine (claw) at apex of dististyle) --- *Aedes (Aedes) cinereus* (p. 87)

4. Dististyle inserted approximately at apex of basistyle; basistyle without prominent apex extending posteriorly beyond the insertion of the dististyle ---------- 5

5. Claw of dististyle inserted before apex, forming a thumb-like projection as in fig. 34; (claspette filament absent, stem with a crown of spines) ---------- *Aedes (Aedimorphus) vexans* (p. 88)

5. Dististyle with claw at apex or almost so, the claw not forming a thumb-like projection ---------- 6

6. Claspettes each with a stalk-like base, and with a comb-like cluster of spurs or setae at apex (figs. 71, 72) in addition to a twisted filament ---------- *Psorophora* (p. 57)

6. Claspette absent or plate-like, without filament ---------- 7

7. Claw of dististyle split distally into a number of teeth, as in plate 7 ---------- *Orthopodomyia signifera* (p. 53)

7. Claw of dististyle a peg, rod, or hair, not split into numerous teeth as above ---------- 8

8. Basistyle with a stout, peg-like rod on mesal face near middle; dististyle with apical half very wide, its apical claw forming a stout, spur-like tip (fig. 31) ---------- *Mansonia perturbans* (p. 54)

8. Basistyle frequently with one or more stout setae on mesal face, but never with a rod-like structure; dististyle not enlarged at apex or with a peg-like or hair-like apical claw ---------- 9

9. Basistyle short and ovate, with a pair of large, stout spines dominating the ventral aspect of the basal portion as in fig. 44; phallosome usually with leaflets; lateral of the phallosome are claspette lobes which bear a series of spines (fig. 40) ---------- *Anopheles* (p. 34)

9. Basistyle either long and slender (figs. 64 to 67) or without a pair of isolated stout spines on basal portion of ventral aspect (fig. 32); phallosome without leaflets; claspette lobes absent ---------- 10

10. Ninth tergum a large, bilobed, sclerotized plate which is nearly as long as the basistyle (fig. 32); lobes of ninth tergum without setae; basistyle very short, rounded; dististyle short, wide ---------- *Uranotaenia sapphirina* (p. 46)

10. Ninth tergum a much narrower plate (figs. 64-67), lobes with many large spines or setae; basistyle linear; dististyle long, rather evenly tapered ---------- *Culiseta* (p. 46)

Pupae

The pupae of mosquitoes have not been extensively studied. The system of chaetotaxy proposed by Belkin (1953) is shown in fig. 47 which was labelled through the courtesy of Dr. Belkin. The different systems of chaetotaxy which have been proposed are discussed by Foote (1953). A key to the genera of North American mosquito pupae is given by Darsie (1951); descriptions are also given of the known culicine pupae.

Larvae

1. Siphon absent, instead there is a sessile spiracular plate (fig. 53) ---------- *Anopheles* (p. 34)

1. Siphon present (fig. 55) ---------- 2

2. Siphon with pecten (fig. 55) ---------- 5

2. Siphon without pecten (figs. 59, 61) ---------- 3

3. Siphon attenuated distally, triangular (fig. 59); head wider than long ---------- *Mansonia perturbans* (p. 54)

3. Siphon not attenuated, elongate; head at least as long as wide ---------- 4

4. Siphon with a single pair of highly branched tufts; inner tuft of dorsal brush of anal segment strongly multiple (plate 7) ---------- *Orthopodomyia signifera* (p. 53)

4. Siphon with many single hairs; inner tuft of dorsal brush of anal segment a long, single hair (fig. 61) ---------- *Wyeomyia smithii* (p. 45)

5. Upper and lower head hairs peg-like (fig. 58); comb scales borne on a plate which is often indistinct; head ovoid, longer than wide ---------- *Uranotaenia sapphirina* (p. 46)

5. Upper and lower head hairs hair-like, not peg-like; comb scales usually not on plate (fig. 60); head usually subquadrate, not longer than wide (fig. 60) ---------- 6

6. Air tube with a ventral hair tuft at the base (fig. 60) ---------- *Culiseta* (p. 46)

6. Air tube without a ventral hair tuft at the base (fig. 55) ---------- 7

7. Anal segment ringed by the dorsal saddle (fig. 62) ---------- 8

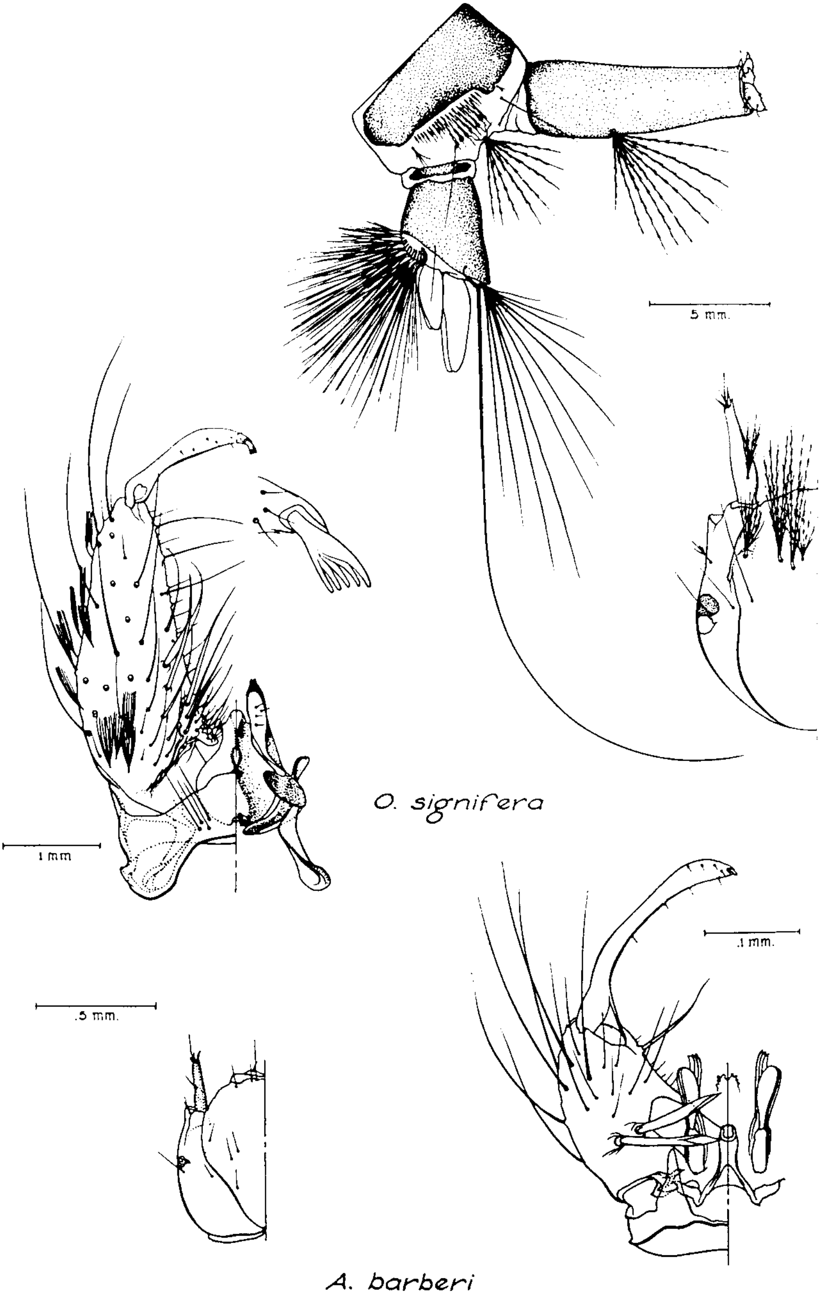
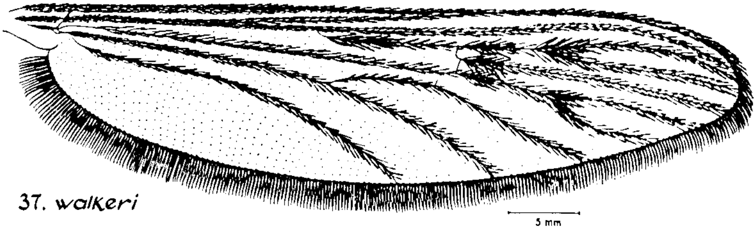
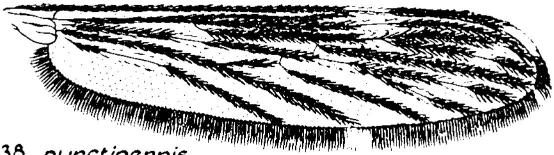


PLATE 7. Larvae and male terminalia of *Orthopodomyia signifera* and *Anopheles barber*

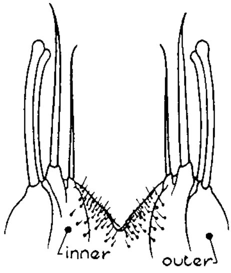


37. *walkeri*

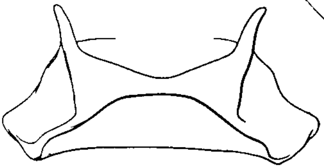


38. *punctipennis*

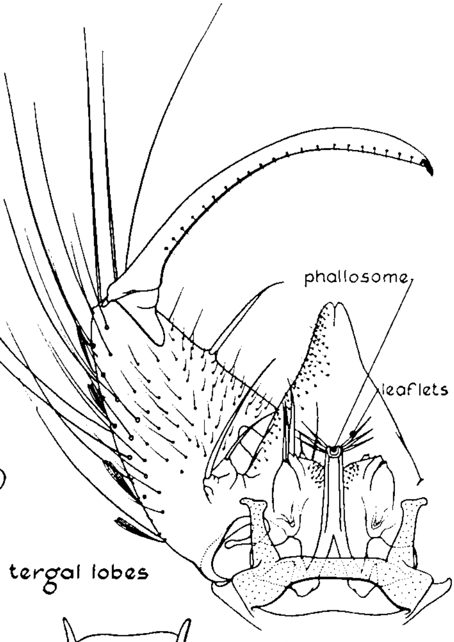
39. *earlei*



40. *walkeri*

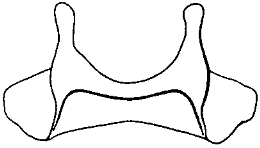


41. *walkeri*

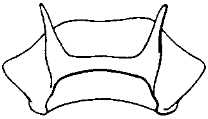


IX^th^ tergal lobes

44. *earlei*

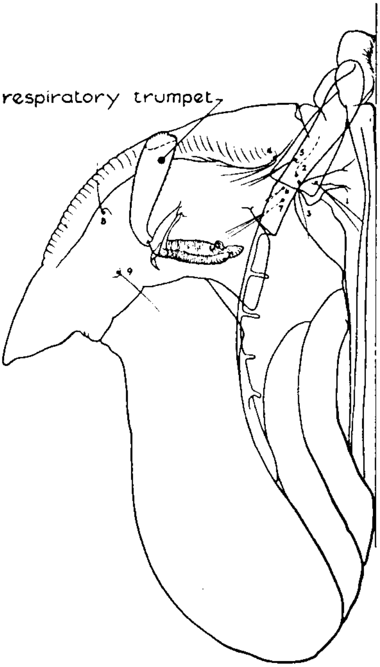


42. *quadrimaculatus*

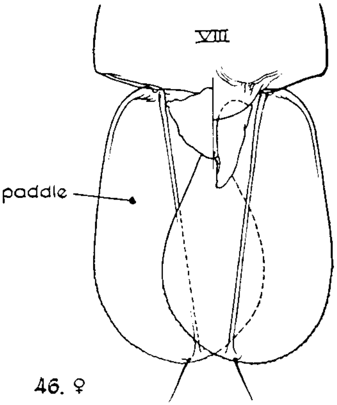


43. *punctipennis*

PLATE 8 (figs. 37-44). Wings and structures of male terminalia of *Anopheles.*



45. Cephalothorax



46. ♀

47. Abdomen

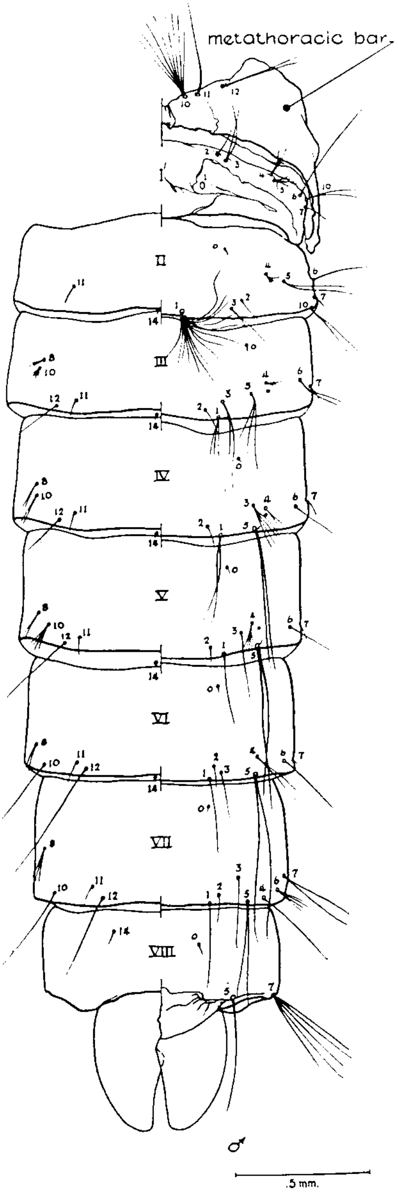


PLATE 9 (figs. 45-57). Pupa of *Aedes implicatus.*

48.

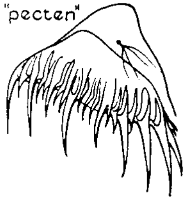
49.

quad. punct.

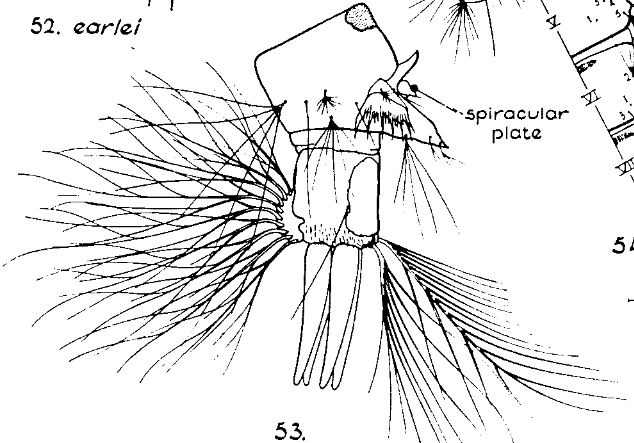
50.

51.

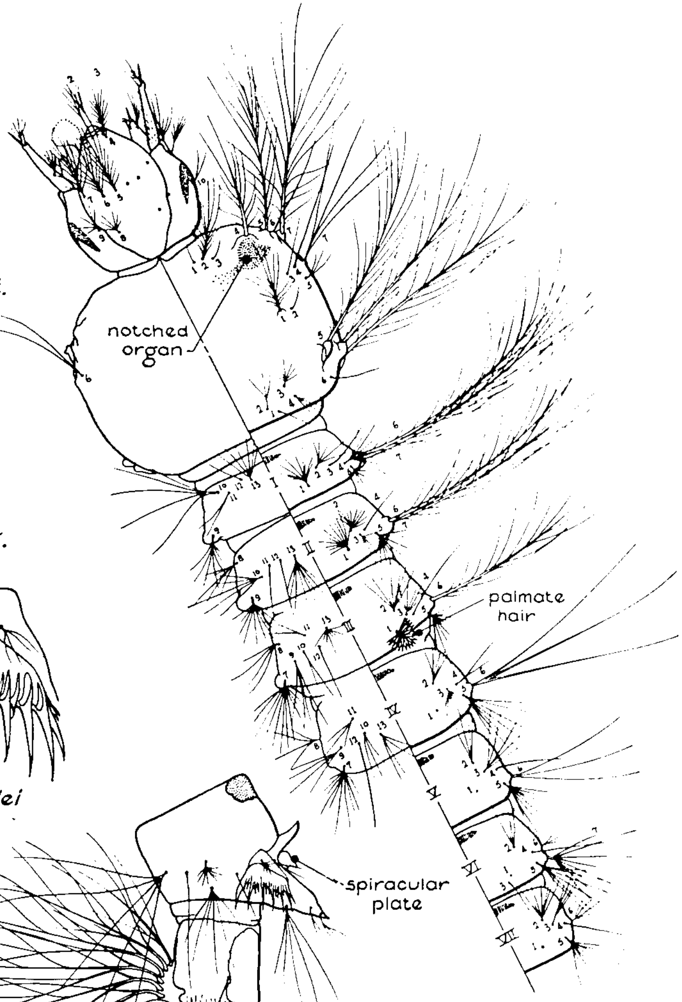
earlei walk.



52. *earlei*



53.



54.

PLATE 10. Details of *Anopheles* larvae. Figs. 48-51. Inner anterior clypeals (head hair 2). Fig. 52. Pecten. Figs. 53, 54. *Anopheles earlei.*

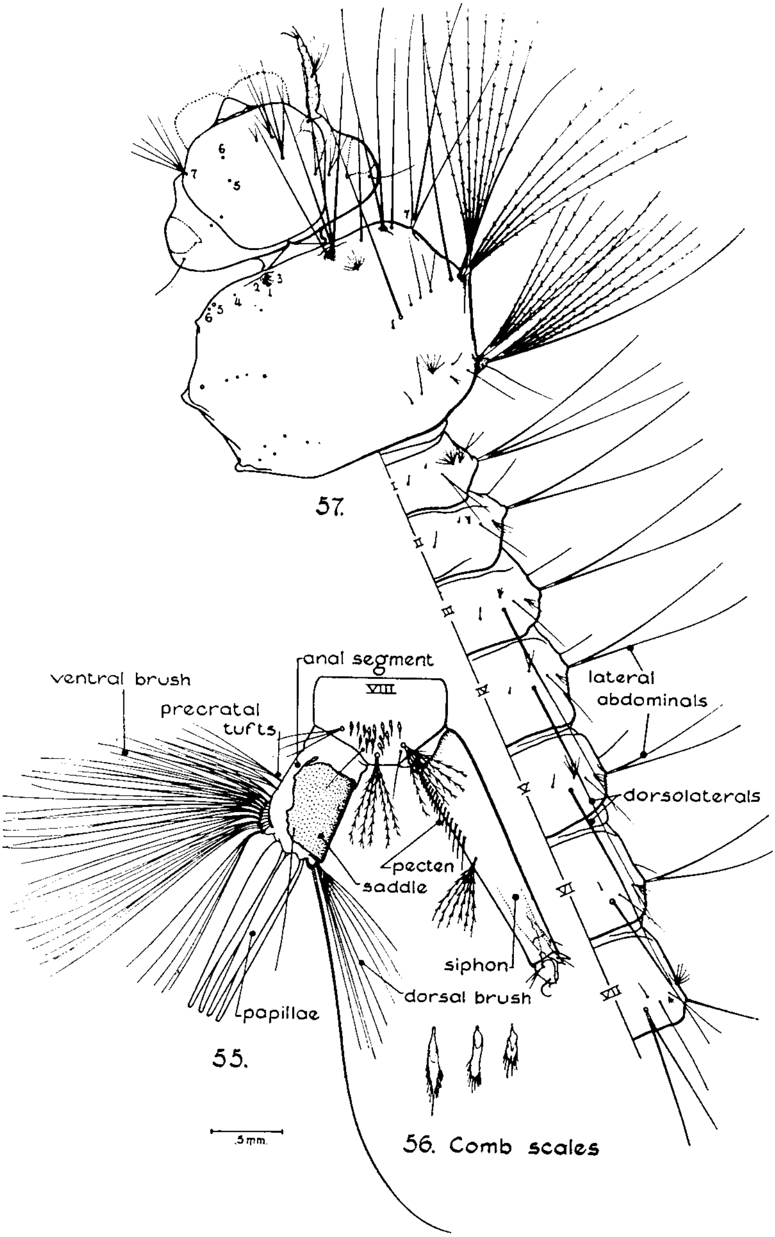
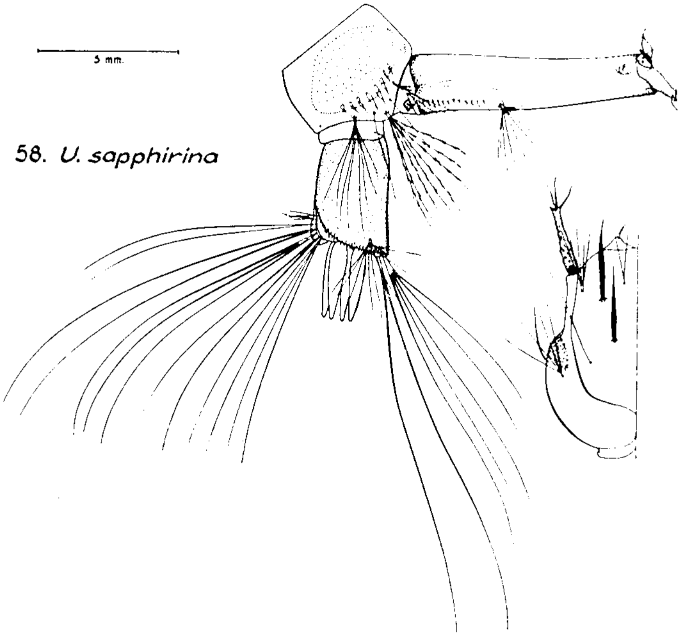
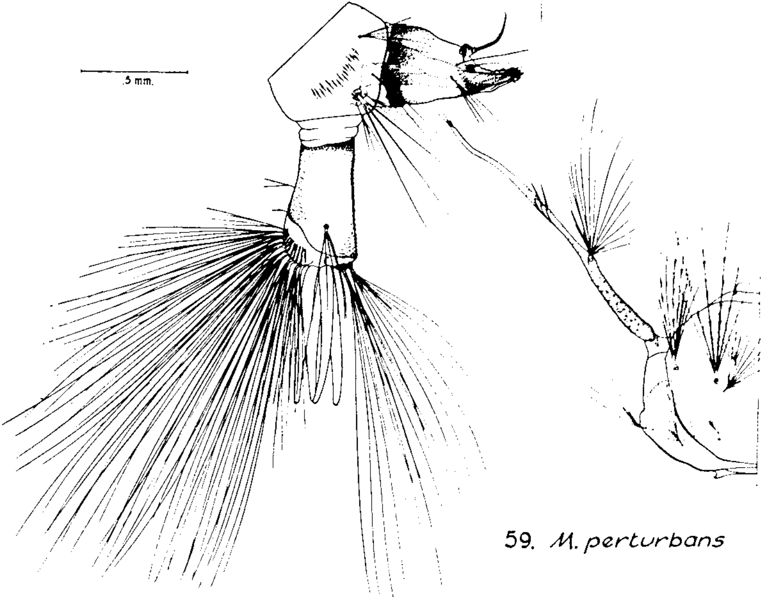


PLATE 11 (figs. 55-57). Larva of *Aedes fitchii.*



58. *U. sapphirina*



59. *M. perturbans*

PLATE 12 (figs. 58, 59). Larvae of *Uranotaenia* and *Mansonia*.

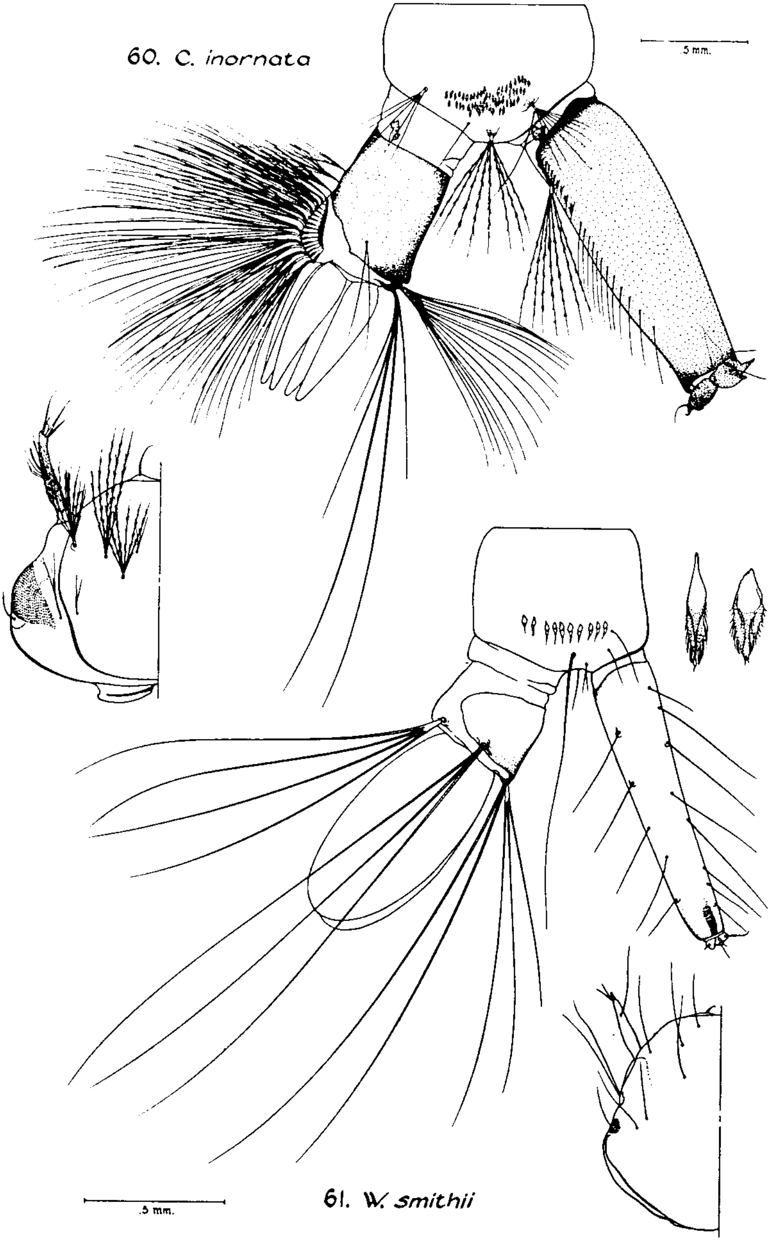


PLATE 13 (figs. 60, 61). Larvae of *Culiseta* and *Wyeomia.*

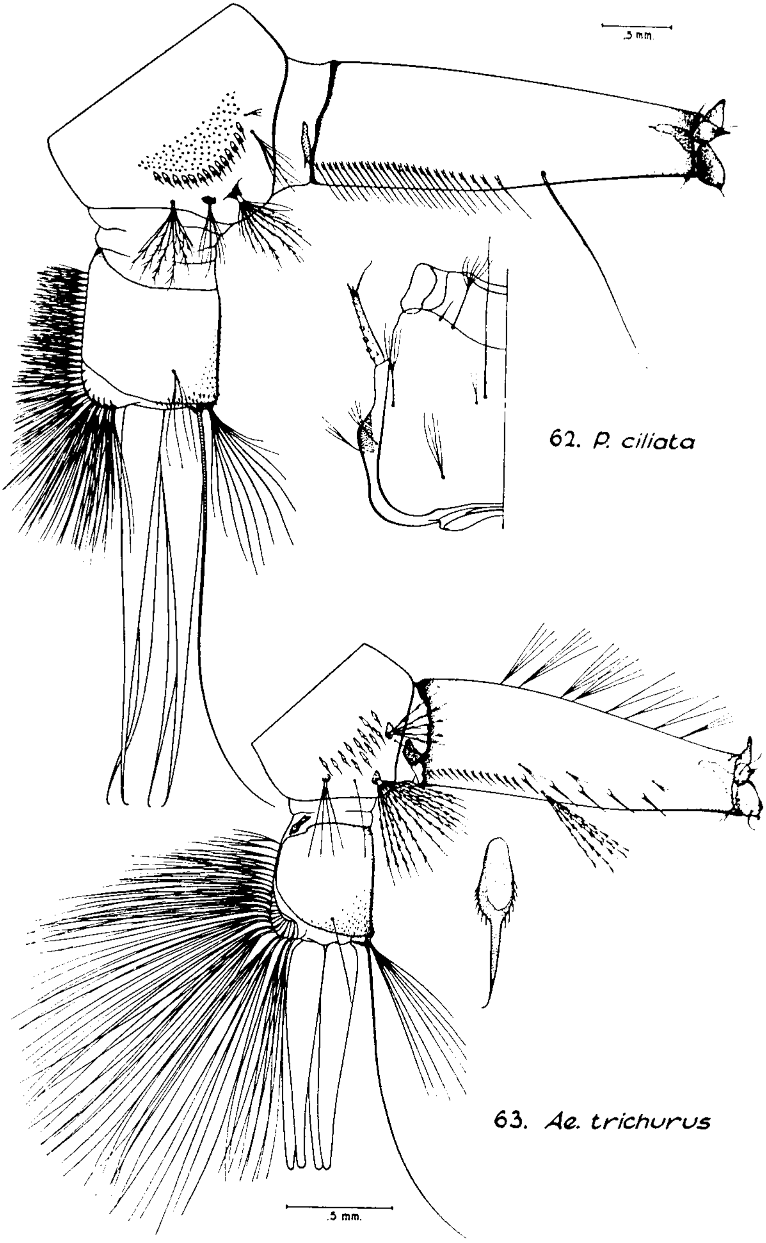


PLATE 14 (figs. 62, 63). Larvae of *Psorophora* and *Aedes*.

7. Anal segment not ringed by the dorsal saddle, the sides do not extend to the mid-ventral line of the anal segment (fig. 55) ------ 9
8. Anterior tufts of ventral brush piercing the mid-ventral line of the saddle (fig. 62) ---------------------------*Psorophora* (p. 57)
8. Anterior tufts of ventral brush posterior of, not piercing, the saddle which encircles the anal segment (figs. 95-97) ------------ 9
9. Many hair tufts or hairs on the siphon, none placed between the spines of the pecten (figs. 127-132) ------------------*Culex* (p. 124)
9. A single pair of large hair tufts on the siphon, usually close to or associated with the pecten (fig. 55); (*A. trichurus* (fig. 63) has a number of smaller siphonal tufts) ----------------------------- *Aedes* (p. 71)

GENUS *ANOPHELES*

The five species of *Anopheles* in Minnesota are in the subgenus *Anopheles*. Their classification is clear-cut only in the adult female and then only in unrubbed specimens. Males can usually be separated by using a combination of the wings and terminalia. The pupae are quite variable although typical specimens of the various species are different; only the pupae of *walkeri* and *barberi* are unmistakable. The majority of larvae can be separated but atypical specimens are not uncommon and may be unidentifiable. A comparative study of the eggs has not been made although figures of all except *barberi* are reproduced (figs. 1-7). In this genus identifications of the various stages should be based on series of individuals whenever possible; in some cases associated material may be necessary.

Key to *Anopheles* Females

1. Wing with several patches of white or yellowish white scales (fig. 38) ------------------------------- *punctipennis* (p. 36)
1. Wing with only one or no patches of light scales (figs. 37, 39) ------------------ 2
2. Wing with a single patch of light scales at the apex (fig. 39) ----------- *earlei* (p. 35)
2. Wing without apical patch of light scales (fig. 37) -------------------------- 3
3. Apices of segments of maxillary palpi with pale rings (fig. 11) -------- *walkeri* (p. 42)
3. Apices of segments of maxillary palpi without pale rings ---------------------- 4
4. Wings with aggregations of dark scales forming spots (fig. 37) -- *quadrimaculatus* (p. 38)
4. Wings without aggregations of dark scales-------------------------- *barberi* (p. 35)

Key to Male Terminalia of *Anopheles*

1. Phallosome without leaflets (plate 7) ------------------------------ *barberi* (p. 35)
1. Phallosome with leaflets -------------- 2
2. Ventral claspette lobes with a pair (or series) of blunt, more or less capitate spines (fig. 40) ------------------------------------ 3
2. Ventral claspette lobes without blunt, more or less capitate spines; the spines usually sharp, occasionally rounded but not capitate (fig. 44) ----------------------------------- *punctipennis* (p. 36), *earlei* (p. 35)[5]
3. Lobes of ninth tergum narrow, usually tapered at apex[6] (fig. 41) ----- *walkeri* (p. 42)
3. Lobes of ninth tergum wider, apex usually expanded, capitate, or truncate[6] (fig. 42) ------------------ *quadrimaculatus* (p. 38)

Key to *Anopheles* larvae

1. With practically all dorsal head hairs single, none highly branched; most dorsal head hairs also reduced in size (plate 7); in tree holes ---------------------------- *barberi* (p. 35)
1. With practically all dorsal head hairs branched; the postantennal and upper and lower head hairs large, plumose; not in tree holes ------------------------------- 2
2. Tubercles of inner anterior clypeals (hairs 2) separated by at least the diameter of one tubercle; inner anterior clypeals usually simple, without feathering or branching (fig. 48); usually with well-developed palmate hair on abdominal segment II------------------------- *quadrimaculatus* (p. 38)
2. Tubercles of inner anterior clypeals usually separated by less than the width of one tubercle (fig. 49); inner anterior clypeals variable, often feathered or branched; palmate hairs on II weakly developed at most (fig. 54) ------------------------- 3
3. Inner anterior clypeals simple (fig. 49); antepalmate hair on abdominal segment IV usually 2- to 3-branched-------------------------------- *punctipennis*[7] (p. 36)
3. Inner anterior clypeals not simple, either feathered toward tip (fig. 51) or branched

---

[5] These males are readily separated by the pattern on the wings.

[6] This separation is not entirely satisfactory.

[7] The separation of *punctipennis* is not always satisfactory.

(fig. 50); antepalmate hairs on abdominal segment IV variable 4

4. Inner anterior clypeals with feathering toward tips, without definite branching (fig. 51); antepalmate hair on abdominal segment IV usually single or double; pecten usually with 9 or 10 strong spines...*walkeri* (p. 42)
4. Inner anterior clypeals forked or branched (fig. 50); antepalmate hairs on abdominal segment IV usually with 3 or more branches (fig. 54); pecten usually with not more than 8 strong spines (fig. 52)......*earlei* (p. 35)

Anopheles (Anopheles) *barberi* Coquillett

This species has only recently been taken in Minnesota by Price and Abrahamsen (1958). Minnesota specimens not seen by the author.

FEMALE — This is a small species and the only anopheline in the state with unmarked wings. The adult is said (Carpenter and LaCasse, 1955) to have very long bristles on the mesonotum. The mesonotum is exceptionally shiny in rubbed specimens.

MALE TERMINALIA (plate 7; drawn from specimens from Douglas County, Kansas) — This is the only anopheline in the state in which the phallosome lacks leaflets. The spines of the ventral claspette lobes are bulbous but frequently distorted when mounted in resinous media. Ninth tergal lobes indistinct.

PUPA — Described by Penn (1949) and Darsie (1949).

LARVA (plate 7; figured from Kansas and Mississippi specimens) — Found in tree holes and artificial containers. Most of the dorsal head hairs of this species are small and simple; head hairs 3, 5, 6, and 7, which are all highly branched in other species, are usually simple. Shaft of antenna smooth, not spinose. Inner anterior clypeals (2) very widely separated, simple.

EGG — Described by Howard *et al.* (1917; see also Vargas, 1942), according to whom the membranous frill acts as a float and completely encircles the egg.

BIOLOGY — Reviewed by Jenkins and Carpenter (1946) and Horsfall (1955). Hibernation is by the larval stages, the mechanism apparently similar to that of *Ae. triseriatus* (*q.v.*) which is also found in tree holes.

DISTRIBUTION — Eastern North America; north to New York and Minnesota; west to Nebraska, Kansas, Texas; south to Mexico. In Minnesota, has been taken only in Scott County.

IMPORTANCE — Of no known importance except as a local pest. The species can transmit malaria in the laboratory but has not been shown to be of importance in the field due, probably, to its small numbers and nondomestic habits.

Anopheles (Anopheles) *earlei* Vargas

This is the *maculipennis* or *occidentalis* of many authors. *An. maculipennis* (*s.s.*) appears to be restricted to the palaearctic region (but see Frohne, 1956) while *occidentalis* is thought to be found only on the western coast of North America (Pratt, 1952). The relation between *earlei* and *occidentalis* is not yet clear but most authors consider the two forms to be specifically distinct.

ADULTS — Wings with aggregations of scales forming four spots (fig. 37); fringe scales at apex of wing pale (fig. 39), other wing scales dark. The pale spot on the tip of an otherwise dark wing is diagnostic for this species in Minnesota; rubbed females may be inseparable from *quadrimaculatus* which, however, occurs only in the southern part of the state.

MALE TERMINALIA (fig. 44; the transparent, triangular anal lobe is ventral, not dorsal of the claspette lobes and phallosome) — Ventral claspette lobe with sharp spines only, as in *punctipennis;* an occasional spine is rounded at the tip but not capitate. Lobes of ninth tergum sometimes as in fig. 44 as described by Rozeboom (1952) but very variable. Although the terminalia of *punctipennis* and *earlei* are rather similar, the two species are easily separated by their wing markings.

PUPA — Described and figured by Penn (1949) and Darsie (1949). The author has examined a series of Minnesota specimens which agree well with Darsie's description.

LARVA (fig. 49) — Inner anterior clypeals (head hair 2) branched, not feathered (fig. 50). (Occasionally one is simple and rarely both; Rozeboom (1952) found that 4 of 87 larvae from Montana had both simple.) Tubercles of inner anterior clypeals usually separated by less than the diameter of a single tubercle (fig. 50). Outer clypeals (3) with definite stalk. Postclypeals (4) usually with average of 4 or more branches. Outer occipitals (9) usually with average of 6 or more branches. Metathoracic hair 3 is a 5- to 7-branched tuft much like hair 4; metathoracic 6 usually simple. On the abdomen, the antepalmate (2) of segment I usually has an average of 5 or fewer branches; 13-I strong, over half as long as and usually about as long as 11-I. The "palmate" (1) of II is a distinct tuft, without a flattening of the filaments as in the other palmates. On IV, 11 is anterior and medial of 12; 10 is medial of a line connecting 11 and 12. The antepalmate hairs (2) of IV and V with 3 or more branches. Six-V usually with 2 or 3 branches. "Pecten" usually with 6 to 8 strong spines.

The separation of *earlei* from *quadrimaculatus* and *walkeri* seems to be complete when a combination of characters is used; larvae with simple inner anterior clypeals would key to *punctipennis* from which they can usually be differentiated by the post-clypeals, metathoracic hairs 3 and 6, 13-I, 1-II, and the position of 10-IV. Pratt (1955) says *earlei* larvae can be differentiated from other anophelines in Minnesota by having 4 rather than 2 tergal plates on each abdominal segment.

Egg — The egg laid by Minnesota females is banded as described by Rozeboom (1952) for the Montana form. This banding (fig. 3, redrawn from Rozeboom) is diagnostic for *earlei* in the state. The egg has 17 to 21 float ridges (Rozeboom).

Biology — The adult females hibernate in caves, houses, and in other protected situations (McLeod and McLintock, 1947). Matheson and Belkin (1943) report finding females with large fat bodies in New York on September 19. There may be a high mortality of the females during the winter months (Owen, 1937) and the population is undoubtedly at its lowest strength in the early spring. Females leave their hibernating quarters to seek a blood meal in the early spring; they are said to attack mostly at dusk (Matheson and Belkin, 1943). The date for terminating hibernation is variable but usually is in May (late April to early June) in Minnesota. Females are readily taken in hand catches or light traps at this time. Host preferences of this species have not been investigated but the females attack man avidly. They have been taken in pig pens and chicken coops. Philip (1943) was unable to take them in numbers feeding on flowers. Pletsch (1946) dissected two females and found they contained 97 and 126 developing eggs. The author fed 2 females which, after being held 5 days at room temperature (about 23° C.) laid 348 eggs. The eggs had finished hatching within 2 days producing 322 larvae (92% viability).

The earliest larvae usually occur in June but are rare at this time. They are found in aquatic vegetation along the margins of streams or semipermanent or permanent ponds (Mail, 1934; Poston, 1942). They are likely to be associated with other kinds of larvae which breed in permanent water (*Anopheles, Culex, Mansonia, Uranotaenia*). The larval population tends to increase throughout the summer so that it should be at its peak in the late fall; in late summer, however, there is often a simultaneous drying of breeding places. For this reason the peak larval population is likely to occur in July (Rempel, 1950, 1953). Breeding usually falls off in September and the males die shortly thereafter.

An. earlei has been colonized by Rozeboom (1952) but the colony was subsequently lost. Mating occurred readily even in small cages.

Distribution — *An. earlei* is found in the northern part of North America; south to British Columbia, Idaho, Colorado, Nebraska, Iowa, Wisconsin, Michigan, New York, and Connecticut (Carpenter and LaCasse, 1955). In Minnesota it is fairly common in the northern forested region and may be locally abundant there. Rempel (1950) noted that it was rare in plains areas of Saskatchewan although common in woodland areas. Chalgren *et al.* (1940) found this species to be the dominant anopheline of Central Minnesota. Daggy *et al.* (1941) rarely found it in southeastern Minnesota and Poston (1942) found it common in St. Paul but it decreased in abundance further south.

Importance — The relation of *earlei* to malaria has not been studied but there is no epidemiological evidence indicating that it may be an important vector. The species is usually not so common as to be an important pest; it may prove to be an efficient vector of heart worms (*Dirofilaria immitis*) of dogs (Yen, 1938).

Anopheles (Anopheles) punctipennis Say

Adults — Wing with a series of patches of white scales, one on the costa about a third of the distance from the tip (fig. 38). Specimens with reduced wing spotting have been taken in Florida but are unknown from Minnesota.

Male terminalia — Rather similar to those of *earlei* (*q.v.*); the lobes of the ninth tergum (fig. 43) are variable in both species. Yamaguti and LaCasse (1951a) separate the two species by the heavy sclerotization of the ventral claspette lobe of *punctipennis* but the author could not. The terminalia have been figured by many authors including Carpenter and LaCasse (1955) and Ross and Roberts (1943).

Pupa — Described and figured by Penn (1949) and Darsie (1949). The author has 4 Minnesota specimens which agree reasonably well with Darsie's description except that CT-8, 6-V (of Belkin), and the terminal paddle hair are usually branched.

Larva — Inner anterior clypeals (hairs 2) simple (rarely branched); usually separated by less than the width of a single tubercle (fig. 49). Outer clypeals (3) with stalk at base. Postclypeals (4) usually with average of 3 or fewer branches. Outer occipitals (9) usually with average of 6 or more branches. Metathoracic hair 3 is an abortive palmate with definitely flattened leaves; metathoracic hair 6 is branched. On the abdomen the antepalmate (2) of I usually with an average of 5 or fewer branches; 13-I weak, less than half as long as 11-I. Palmate hair on II with flattened leaves but poorly developed. On IV hair 11 is anterior and medial of 12; 10 is lateral of a line connecting 11 and 12. Antepalmates (2) of IV and V usually double. Six-V usually double. Figured by many authors including Ross and Roberts (1943) and Carpenter *et al.* (1946). An occasional specimen is similar to *earlei* (*q.v.*); Roth (1945a) discusses larval aberrations.

Egg (figs. 1, 2; redrawn from Mitchell, 1907 and Lawlor, 1940) — Herms and Frost (1932) describe the eggs as being 534 to 578 micra long with 16 to 22 float chambers. The length of the floats (Herms and Freeborn 1920) is about 320 micra which is more than half the length of the egg. Characters for separating the eggs of *punctipennis* and *quadrimaculatus* are given by Mitchell (1907).

Lawlor (1940) described an "unusual" type of egg (fig. 2) laid by *punctipennis* females captured in January and February in Georgia. Morphologically this egg bears the same relationship to the normal egg of *punctipennis* as the winter egg of *walkeri* (*q.v.*) does to the summer egg of that species; *i.e.*, the exochorion covers the dorsum of the egg in the middle. According to Lawlor one female captured in February laid the usual type of eggs but all the rest laid the unusual type. Later in the season the eggs tended to be of an intermediate type. There was no difference in the size or number of float chambers in the two types of eggs. The capability of these eggs to overwinter has not been established although it is known that females do hibernate; the possibility exists that eggs also may overwinter.

Biology — Reviewed by Boyd (1930c) and Horsfall (1955). Adult females overwinter in caves, houses, and other protected situations. Their winter activities have not been studied in Minnesota except for a few collections by Owen (1937) but they have been extensively studied in the southern United States. In North Carolina, Boyd and Weathersbee (1929) found that the species wintered primarily in vacant houses and hollow trees. At that latitude there was no real hibernation; on warm days the females would move about and feed. They were unable to fly at temperatures below 8° C. Later studies (Boyd, 1930a) indicated that breeding probably took place throughout the winter months and the same was later demonstrated in Georgia (Zukel, 1949a, b). This species undoubtedly undergoes a much more complete hibernation in Minnesota; there are no records of females biting in the winter. Owen (1937) found that they would feed soon after being taken into the laboratory. He also noted a high mortality of hibernating females during the winter; the species is undoubtedly at its lowest numbers in the spring.

On warm days in the early spring the females leave their hibernating quarters to feed; this usually occurs in May (April to June) in Minnesota. The peak of biting activity appears to be in the evening. Studies on the host preferences of this species (Boyd, 1930c) indicate that it is largely zoophilic, feeding mostly on domestic mammals; *punctipennis* will feed on man although he is not the preferred host.

After the female has fed for the first time she will lay her eggs in 3 to 7 days according to Mitchell (1907). The process of oviposition has been described by Herms and Freeborn (1920); it was initiated at reduced light intensities. There was a total of 6,700 eggs in 33 layings with an average of 203 and a range of 83 to 321; in later studies (Herms and Frost, 1932) an average of 202 eggs was laid.

Mitchell (1907) found that a female may deposit more than 2,000 eggs during a single breeding season with but a single fertilization. Six or 7 was the most frequent number of clutches laid by a female although some laid up to 9.

Herms and Freeborn found the incubation period of the eggs to be 3.2 days at 20 to 25° C. (range 2 to 6 days). Mitchell reported an incubation period of 2 to 58 days (generally 10 to 18) in the winter. Owen hatched eggs in the laboratory in 4 days.

The larvae have been found in an unusual variety of breeding places but in Minnesota are most often taken in algal mats along the edges of streams or semipermanent ponds (Owen, Poston). Since larvae are also taken in temporary rainpools and occasionally in artificial containers, there may be a correlation between rainfall and breeding of this species.

The distribution of larvae was studied by Coggeshall (1926) in Georgia. Dissections of larvae showed that they exhibited no selection in choice of food, taking everything from plankton to their own exuvia. Boyd and Foot (1928) continued work on the distribution of larvae in relation to food supply in North Carolina. They found that *punctipennis* was more commonly found than was *quadrimaculatus* in all situations except ponds. In breeding places where *quadrimaculatus* alone occurred there tended to be a larger variety of plankton than where *punctipennis* alone was found; breeding places containing a mixture of these species tended to have an intermediate variety of plankton. It was concluded that the distribution of the two species could not be explained on the basis of food supply.

The work was extended by Boyd (1929) who included water temperature in his analysis. *An. punctipennis* larvae were shown to be found in cooler water on the average than were those of *quadrimaculatus*; however, their breeding places were also subject to a wider diurnal fluctuation in temperature. The preference of *punctipennis* for cooler water was related to the larger spring and fall populations of that species in contrast to its much reduced summer populations; the optimum temperature for larvae may be 7 to 10° C. (Boyd, 1930c). Boyd (1930a) points out that there is not an extensive emergence of adults in the summer which may indicate estivation of the species. This midsummer depression of the population was noticed in Minnesota by Poston (1942). Owen (1937) found larvae most commonly in June and July. Ross (1947) in Illinois found larvae in open, sunlit water in the early spring but in shaded pools and creek beds in the summer. Masters (1953) showed that in Ohio, *punctipennis* larvae were found more abundantly in the less polluted of a series of five tanks which contained water polluted with horse manure.

The development of the larvae, according to Mitchell, takes 18 to 25 days in the winter (in the laboratory) and the pupal stage 2 to 4 days. Boyd (1930a) found that there was a slight preponderance of females over males.

The species was colonized by Boyd and Mulrennan (1934) in the southeastern United States but Hardman (1946) was not able to do the same in California. He believed the difficulty was that the species would not mate in captivity; the former authors apparently were using a room-sized cage. It is interesting to note that Knab (1907) described mating swarms of this species in Maryland; they were 7 to 8 feet from the ground, 5 to 6 feet high, and contained less than a hundred individuals. Mating pairs were observed dropping out of the swarm.

DISTRIBUTION — This is the most widely distributed anopheline in North America, being found from coast to coast from southern Canada to Mexico except in the Rocky Mountains (Matheson, 1944); it reaches its greatest abundance in the southern states (Carpenter *et al.*, 1946). In Minnesota it is most common in the southern half of the state; it has been taken in the northern plains regions but not in the coniferous forest (Owen, 1937). Daggy *et al.* (1941) found it to be common in the southeastern part of the state; in the Mississippi River Valley it was outnumbered by *quadrimaculatus* and probably by *walkeri*, but in "inland" collections (away from the river) it constituted 86% of the anopheline adults captured in resting places and 99% of the adults reared from larvae.

IMPORTANCE — Although this species is readily infectible with human malaria (King, 1916) it has not been implicated as a vector. This is probably due to the female's not entering houses as readily as does *Anopheles quadrimaculatus*. In Minnesota the species is usually unimportant due to its scarcity although it may become troublesome at times. It may prove to be an efficient vector of heartworms of dogs (Yen, 1938; Phillips, 1939).

Anopheles (Anopheles) quadrimaculatus Say

ADULTS — Adults (fig. 37) lack the white patches of wing scales of *punctipennis* and the pale wing tips of *earlei*. The female lacks the white palpal bands of *walkeri* but this character is not present in the male. The mouthparts of the male have been described in detail by Vizzi (1953).

MALE TERMINALIA — Ventral claspette lobe with a series of rounded, usually capitate spines (fig. 40). Lobes of the ninth tergum variable but usually capitate as in fig. 42. These lobes are generally narrower and more acute at the tip in *walkeri*. Ross (1947) believes this character gives a reliable separation in Illinois and the same seems to be true in Minnesota. The terminalia are figured by many authors including Ross and Roberts (1943) and Carpenter & LaCasse (1955).

PUPA — Described and figured by Penn (1949) and Darsie (1949). Penn and Coleman (1949) give an analysis of 100 pupae. Burgess (1946) gives characters for separating living pupae of *quadrimaculatus* and *punctipennis*.

LARVA (based on specimens from a colony from Alabama; Minnesota specimens not examined) — Inner anterior clypeals (2) usually without branches or feathering, their tubercles separated by a distance which is several times the width of one tubercle (fig. 48). Outer clypeals (3) with stalk at base. Postclypeals (4) usually with average of 3 or fewer branches. Outer occipitals (9) usually with average of 6 or more branches. Metathoracic hair 3 with flattened leaves, metathoracic hair 6 is branched. On the abdomen the antepalmate (2) on I usually averages 5 or fewer branches; 13-I strong, over half as long as 11-I. The palmate (1) of II usually well-developed, never tuft-like. On IV hair 11 is anterior and medial of 12; 10 is usually lateral of a line connecting 11 and 12. Antepalmates (2) of IV and V usually single; 6-V usually averages 4 or fewer branches. "Pecten" usually with 7 to 9 large spines.

The separation of this larva appears to be fairly complete when a combination of characters is used but abnormal specimens may be difficult or impossible to identify (Roth, 1945a).

Measurements of the head widths of all instars have been made by Knowles (1943) and Jones (1953). The latter also gives a method of estimating the age within each of the first three instars. Coggeshall (1941) was able to select strains of larvae which possessed or lacked the white line on the dorsum of the abdomen.

EGG (figs. 4, 5; redrawn from Mitchell (1907) and photographs by the author) — Jones (1953) gives the length as being .56 ± .02 mm., width .21 ± .01 mm., and length of floats .29 ± .02 mm.; a number of other measurements are also given. An unusual variant is shown in fig. 5 (drawn from a photograph by the author).

BIOLOGY — The literature on *quadrimaculatus* is voluminous and has been summarized by Boyd (1930c) and Horsfall (1955). The winter is passed by the inseminated adult female. Hibernation begins in September or October in New Jersey according to Smith (1904a) and the females do not feed before hibernating. Mayne (1926) found that gravid females were adversely affected by cold; presumably they are not able to hibernate. In many parts of the southern United States breeding is interrupted for only a short period during the winter (Boyd, 1927); in those areas the females do not hibernate completely but move about and feed on warm days (Boyd and Weathersbee, 1929). According to Bradley and Fritz (1945) females are not active in winter in more northerly areas; they either perish or enter hibernation in the fall and remain inactive until May. Hibernating females have large fat bodies (Boyd, 1930a) and in New Jersey (Smith, 1904a) are found in cellars, barns, hollow trees, and other places sheltered from direct winds. Atchley *et al.* (1955) found that larval breeding is interrupted at temperatures around 5° C.

Early in the spring the females leave their hibernating quarters to seek a blood meal. Willis (1947) found that the odor of humans was attractive to females but carbon dioxide was not. In laboratory tests on the biting of *quadrimaculatus*, Burgess and Young (1944) found that females would not engorge on blood till 48 hours after emergence (18-20 hours according to Keener, 1945). Maximum feeding occurred at 49 to 72 hours when the females had previously been allowed to feed on sugar solution (see also Keener, 1945). A higher proportion of females engorged when allowed to feed on a sugar solution first. These authors were not able to show a correlation of biting with temperature between 20 and 32° C. Feeding took place more readily at reduced light intensities; Keener (1945) found there was a peak of feeding in the early morning hours although females would feed all through the night. Burgess and Young (1944) and Terzian and Stahler (1949) noticed that *quadrimaculatus* females were reluctant to feed if unmated. Linduska and Morton (1948) describe tests on the permeability of fabrics to the biting of females of this species. Females take about 3 mm^3 of blood on the average (Keener, 1945).

The feeding preferences of the females have been intensively investigated and are summarized by Boyd (1930c). The species cannot be characterized as being anthropophilic but does feed readily on humans. Most females which have been tested have fed on bovine, equine, or human blood. Some humans are consistently more attractive to *quadrimaculatus* females than are others (Bull and Reynolds, 1924). Among cattle and horses the individual is likely to be more important than the species in attractiveness (Bull and Root, 1923). Hogs, sheep and dogs are also important hosts but fowls and rabbits are not particularly attractive according to Bull and Reynolds. King and Bull (1923) showed that in smaller populations of females, a higher proportion had fed on humans than was the case in larger populations. Boyd (1930a) noted that the females had a remarkable tendency to remain in the vicinity of the host after feeding. The fed females are likely to move around a good deal at night during the preoviposition period. Fed females are more resistant to desiccation than unfed ones (Bang *et al.*, 1943).

Keener (1945) found that there was a peak of oviposition in the evening at reduced light intensities; since the peak of biting is in the mornings females can oviposit and then feed again the same night. Wallis (1955) has described the oviposition behavior of this species.

In the experience of the author the peak of oviposition occurs 4 to 6 days after a blood meal in laboratory colonies (about 20 to 25° C.; see also Keener, 1945; Trembley, 1955). DeCoursey *et al.* (1953) found that females laid 46 ± 59 eggs in a clutch (219 ± 12 according to Keener, 1945). Keener found that females averaged about 660 eggs in a lifetime; they averaged about 66 eggs per blood meal and some laid 9-12 times. Bellamy (1950) found that his most fertile females average 1,007 eggs; the viability of the eggs varied from 85 to 97% among different females.

The optimum temperature for incubation of the eggs is 33.3° C. according to Huffaker (1944). The incubation period of the eggs has been given by many authors; at room temperature it is about 2.5 days. Huffaker found a time of 33 hours at the optimum temperature and Hurlbut (1943) constructed a curve showing the relation of temperature to incubation period in this species. Mayne (1926) hatched the eggs in 24 hours at 35° C. and in 30 hours at 34° C. Farid (1949) determined the median lethal temperature (after 5 minutes exposure) of the eggs to be 45.9° C.

A number of investigators have subjected *quadrimaculatus* eggs to drying. Mayne (1926) found that some eggs would hatch after being on drying mud for 16 days. Darrow (1949) determined that eggs could survive drying only if they had completed 20 to 30 per cent of their development. Such eggs when dried would continue to develop in a saturated atmosphere but under drier conditions their development was suspended; some could survive 54 hours of desiccation. Kartman and Repass (1952) found that eggs from wild-caught females were more resistant to the effects of drying than were those from laboratory colonies. (See also Wyckoff, 1951).

The percentage hatch of the eggs is very variable but in the experience of the author averages about 80% in laboratory colonies; in one experiment (Barr, 1954a) 63.5% of 9,610 eggs hatched (see also Love, 1954).

Larvae are most numerous in late June and July in Minnesota according to Owen (1937). Larval breeding places have been studied very intensively by many authors (Coggeshall, 1926; Boyd and Foot, 1928; Watson and Spain, 1937; Goodwin and Lenert, 1943; Eyles, 1948). Larvae were taken particularly in warm water; Boyd (1929) in North Carolina found that they did not become widespread until available breeding places had mean temperatures of 21° C. or higher and declined as the temperature fell below this limit in the fall. The water also had to have a minimal diurnal fluctuation in temperature. Larvae are usually taken in sunlit water (Boyd, 1930c) but this is probably a reflection of the warmer temperatures of such water. They are also usually found in water where there is no perceptible current (Boyd, 1930c). Streams often breed *punctipennis* abundantly while flowing and *quadrimaculatus* later in summer when they become ponded.

The larvae tend to be associated with a large variety of plankton (Coggeshall, 1926; Boyd and Foot, 1928) but this is probably an effect of the still, warm water. Boyd (1929) found that they were taken in neutral or alkaline water (mean pH 7.06 ± .81); no breeding occurred in the absence of dissolved oxygen and the larvae tended to be associated with rather high concentrations of dissolved carbon dioxide. Masters (1943) usually found *quadrimaculatus* larvae in waters with a rather high specific gravity. The importance of a high surface tension in breeding places is stressed by Fair *et al.* (1951).

Larvae are invariably associated with aquatic vegetation or floating debris which gives protection from predators. Hess and Hall (1943) stress the relation between the numbers of larvae and amount of "intersection line" in an area; the latter is the line of intersection of plant, water, and air surfaces, i.e., the amount of meniscus present. In general, larger populations of larvae are found in places with a high intersection line than in those with a low one. Emergent vegetation usually makes for a large amount of intersection line while floating-leaved plants such as water lilies have low values.

The larvae are indiscriminate in their feeding according to Coggeshall (1926) and Boyd and Foot (1928). They may be cannibalistic in the later larval stages (Howard *et al.*, 1913a). Knowles (1943) found that growth of the head width of *quadrimaculatus* larvae fitted "Dyar's Law."

The optimum temperatures for the larval stages according to Huffaker (1944) are 32.5, 32.3, 31.0, and 30.0° C. respectively; his "optimum" is apparently the temperature at which development is fastest. The lengths of time required for development of the larval stages at their "optimum" temperatures are said by Huffaker to be 30, 26, 30, and 55 hours respectively but these values are based on the fastest 50% of the larvae and are thus somewhat lower than the average. He found an overall time of 176 hours (7.6 days) for the development of the larval and pupal stages at the overall optimum temperature of 31° C. Hurlbut (1943) found that larvae required 12 days for development at 28° C.; he gives a curve relating temperature to velocity of development. Huffaker presented evidence to show that development proceeded faster at variable than at constant temperatures.

The threshold for development of larvae is about 7° C. according to Huffaker. When kept at 12.1° C. only 2% were able to survive to emergence; at 29.6° C. 92% emerged, and at 34.4° C. only 44% emerged. Farid (1949) determined the median lethal temperatures (5 minute exposure) of the larval stages to be 43.8, 43.5, 43.7, and 43.0° C. respectively (see also Barr, 1952).

Desiccation of larvae has been discussed by Darrow (1949) and is an important factor in water level management (Bishop *et al.*, 1947; Hall, 1951).

The optimum temperature of the pupal stage according to Huffaker (1944) is 30.5° C. at which the adults emerge in 35 hours. Hurlbut (1943) constructed a curve relating temperature to velocity of development of the pupa. The median lethal temperature (5 minute exposure) is 42.5° C. according to Farid (1949); the termal death time at 42° C. (Barr, 1952) is 4.7 minutes. The discrepancy in the two measurements is probably due to different criteria of survival. The latter author showed that the pupa was more resistant to heat than was the larva which immediately preceded it.

Resistance to desiccation of the pupa was studied by Darrow (1949). She found that pupae survived drying if in a saturated atmosphere; the adults, however, experienced difficulties in emerging on mud. Keener (1945) found that males emerge before females on the average and the proportion of sexes in a lot was roughly equal.

Boyd (1927) in North Carolina states that the first generation of adults of the summer occur about 20 to 30 days from the last frost and subsequent broods occur at intervals of about 20 to 30 days. According to Bradley and Fritz (1945) high densities of *quadrimaculatus* occur at the very beginning of the active season in more northerly areas and abruptly disappear at the end of the season. They also found that the species may be more abundant in northern latitudes than farther south where the active season is of much longer duration. A deficiency in rainfall may depress summer populations in the south.

Mating probably takes place in this species within a short period after emergence. The species (at least laboratory strains) will mate in small cages but the behavior of the males in such colonies suggests that swarming normally takes place in the field (Boyd, 1930b; Bellamy, 1950). Copulation has been described by Roth (1948) who found that the males were sexually active only at times when the antennal hairs were erect; normally these hairs are recumbent on the antennae. The males were noted to be active in the evening and in the morning. They were also sensitive to vibrations of a particular frequency. Goodwin (1949) found greater numbers of males than females near breeding places; they appear to disperse, but only over a limited range near the breeding place.

There is a considerable amount of literature on the resting places of this species since densities of populations are usually gauged by the numbers found in such places. The resting places usually used for such counts are dark, cool places in houses, barns, stables, privies, beneath houses, etc. Artificial resting places may also be used; Smith (1942) used empty nail kegs and Goodwin (1942) boxes. The latter author found that females preferred boxes within three feet of the ground and red ones contained more females and were easier to use than black ones. King *et al.* (1944) describe the nocturnal activity of the females as follows: "The daily flight or dispersal period begins just at dusk and continues for a half hour or so. During the remainder of the night, flight is probably limited for the most part to local forays in search of a host. Another period of activity begins just at daylight and ends with a general shift to the daytime resting places." Goodwin (1949) has shown that the movements at night are general for the females, even fed ones tended to move around a great deal.

Eyles and Bishop (1943) studied the microclimate of resting places in some detail. They found that the egress from resting places was greatest during the 20 minutes following sunset and that it could only be correlated with a change in light intensity; egress tended to occur earlier on cloudy days. The time of egress was delayed by artificially illuminating the females. The ingress of mosquitoes into the resting places at dawn was a more gradual process and could not definitely be correlated with any single factor; after their period of activity the mosquitoes may have gone to rest in many different places and only returned to their daytime resting places after each nighttime resting place became unfavorable. The authors also showed that favored daytime resting places had moderate temperatures and evaporation rates.

The flight range of *quadrimaculatus* has been extensively studied and is reviewed by Eyles (1944) and Eyles *et al.* (1945). It is well known that females are rarely taken further than a mile away from their breeding places even when there is a high population density; this fact has been used extensively in the management of *quadrimaculatus*. Longer flights are occasionally recorded such as the eight mile one recorded by Clarke (1943a) but this is definitely exceptional. Eyles *et al.* describe a situation in which females were regularly dispersing over two miles and they conclude that *quadrimaculatus* females will probably, within limits, fly as far as necessary to find blood. In this particular situation there was a lack of hosts within the usual one mile limit (see also Gartrell and Orgain, 1945). There is no evidence for "homing" in this species. King *et al.* (1944; also Gartrell and Orgain, 1945) state that there may be long prehibernation flights in the fall.

The longevity of *quadrimaculatus* in nature has not been studied but Boyd (1927) suggests that the normal longevity may be considerably less than two weeks with few individuals surviving longer. He also suggests that rain may be an important cause of mortality among adults (see also Darsie *et al.*, 1953).

The density of adults in an area is difficult to measure but under special circumstances has been estimated (Eyles and Cox, 1943). Bradley (1943) discusses the relative merits of light traps and counts in resting places as indices of the density of adults. Extremes of rainfall may affect adult populations in different ways; Atchley *et al.* (1955) found high populations when reservoirs were above their normal level. The author has found in Kansas that this species may be most abundant in dry years.

Techniques for rearing laboratory colonies of this species have been given by many authors (Boyd *et al.*, 1935; Crowell, 1940; Goodwin, 1945; Peffly *et al.*, 1946; Casanges *et al.*, 1949; Trembley, 1955). No basic work has been done on the parasites and predators of mosquitoes even though Brooke and Proske (1946) have described a precipitin test for determining the predators in breeding places.

DISTRIBUTION — Eastern United States from New England to Mexico; west to Minnesota, Kansas, Oklahoma, and Texas (Matheson, 1944). In Minnesota *quadrimaculatus* is usually common only in the southeast. Owen (1937) gives a single record from Carlton Co. in the northern part of the state but the record has not been verified. Riley and Chalgren (1939) did not take this species in the Crystal Bay Area of Hennepin County, and Chalgren *et al.* (1940) did not find it in central Minnesota. Daggy *et al.* (1941) found it to be the most numerous anopheline in the Mississippi River Valley in southeastern Minnesota as judged by captures in resting places; Poston (1942) came to the same conclusion but stated that near St. Paul it was definitely beginning to be supplanted by *earlei*.

IMPORTANCE — This species is the principal vector of human malaria in the eastern United States and is always to be regarded with suspicion. In Minnesota, as in practically all of the United States, there is little or no human malaria but the vector is present and may reach dangerous proportions from time to time. Malaria in Minnesota has been discussed by Riley (1930).

***Anopheles (Anopheles) walkeri* Theobald**

Peters made a comprehensive study of the biology of this species in Wabasha as a doctoral dissertation (1942), a part of which was subsequently published (1943).

ADULTS — Wing lacks patches of white scales as in *punctipennis* or pale wing tips as in *earlei*. Papal segments of female with light rings apically (fig. 11).

In southern regions this species can be distinguished from *quadrimaculatus* by its pale halteres (Bang *et al.*, 1943). Peters (1942) remarked that in Wabasha he was able to separate the two on this basis; however, he also examined specimens of *walkeri* from Wisconsin which had had dark halteres. Stone (1953) has recently pointed out that specimens from northern areas often have dark halteres. The writer was not able to separate specimens of these two species in the University of Minnesota collection by the color of the halteres; he is inclined to agree with Ross (1947) who found the separation was poor on old specimens since the colors appear to change with age. In 1954 a long series of *walkeri* adults was collected at Itasca State Park, Clearwater Co., in June and July, all of which had dark halteres. The degree of darkness of the halteres varied but none of the specimens had the very pale halteres characteristic of *walkeri* in southern areas.

Comparisons of Minnesota specimens with a series from Orlando, Florida, showed that the latter were smaller, much darker, and with palps much more extensively marked with white. The ringing of the palps in Minnesota specimens is often very light; the scales themselves usually do not appear to be white as in Florida specimens, merely pale. This form should be studied more extensively in northern regions (such as Itasca), more central regions (such as Wabasha or further south), and in Florida to see whether these forms are biologically similar. Unfortunately the writer was never able to examine eggs from northern specimens.

MALE TERMINALIA — Ventral claspette lobe with a pair of rounded capitate spines (fig. 40). Lobes of the ninth tergum similar to fig. 41; those of *quadrimaculatus* (*q.v.*) are usually broader, blunter, and more swollen (capitate) toward the apex. The terminalia have been figured by many authors including Ross and Roberts (1943) and Carpenter *et al.* (1946).

PUPA — Described and figured by Penn (1949) and Darsie (1949); paddle described and figured by Peters (1943). The paddle is unique among Minnesota anophelines because of the large cog-like teeth on its outer margin.

LARVA — Inner anterior clypeal (2) usually feathered toward tip (fig. 51); the feathering may be so inconspicuous that it can only be seen with the 4 mm. objective of a compound microscope but appears to be rather constant (but see Ross, 1947). Tubercles of inner anterior clypeals usually separated by less than the diameter of a single tubercle. Ross separates this species on the branching of the outer clypeals (3); in *walkeri* they are usually branched so close to the base that no stalk is visible. The character, as far as the writer can determine, is reliable but the bases of these hairs are obscured by the mouthbrushes in most specimens examined. Postclypeals (4) usually with average of 3 or fewer branches. Outer occipitals (9) usually with average of 3 or fewer branches. Metathoracic hair 3 with flattened leaves; metathoracic hair 6 is branched. On the abdomen the antepalmate (2) of I averages 6 or more branches; 13-I strong, over half as long as and usually about as long as 11-I. The palmate of II usually weakly developed but with flattened leaves, occasionally tuft-like. On IV 11 is anterior and usually lateral of 12; 10 is lateral of a line connecting 11 and 12. Antepalmates (2) of IV and V usually single or double; 6-V usually triple. Pecten usually with 9 or 10 strong spines (9-11). The larva has been figured by Ross and Roberts (1943), Carpenter *et al.* (1946), and Rempel (1950) among others.

EGG (figs. 6, 7; redrawn from Peters, 1942) — In this species there are summer and winter eggs and all stages intermediate between the two. The summer egg is .62 ± .02 (SD) by .19 ± .01 mm. with floats .29 ± .01 mm. long and with 22.4 ± 1.5 float chambers according to Hurlbut (1938); Peters (1942) found the eggs in Wabasha to be .66 mm. in length. The winter egg, according to Hurlbut, is larger, measuring .76 ± .05 by .27 ± .01 mm. with floats .49 ± .06 mm. long and with 31.4 ± 1.5 float chambers; Peters found them to be .76 mm. long. The latter also found transitional eggs measuring .69 to .74 mm. in length. According to Peters the summer egg of *walkeri* is grossly similar to that of *quadrimaculatus* but larger; a detailed comparison is given.

BIOLOGY — The hibernation of *walkeri* appears to be unique to our anopheline fauna. Adults of *walkeri* are not known to overwinter in northern regions unless we accept statements in the older literature which were made before the overwintering egg was known; *e.g.*, Owen (1937) says: "*Anopheles walkeri* Theobald spends the winter in the adult stage like the other members of this genus to be found in Minnesota. The adults doubtless come out of hibernation early in May, although the earliest record in this study is May 23." Certainly there are no records of hibernating females in the University of Minnesota collection, although it does contain hibernating females of our other three species of anophelines known to hibernate as adults.

Hibernation, then, appears to take place in the egg stage in Minnesota. Peters (1942), working in Wabasha, found summer eggs during the summer; transitional eggs were first found on August 4 and winter (hibernating) eggs on August 19. The factors causing these eggs to be laid in the fall are not known but Matheson and Hurlbut (1937) found that females which were reared in the laboratory in August developed such eggs; these females had developed from summer eggs. The same authors found that a female could lay different types of eggs at different times.

Hurlbut (1938) found that winter eggs would not hatch at room temperature even though the summer eggs did so in about the same length of time as with other anophelines. Apparently a few winter eggs hatch under these conditions but the majority do not. Hurlbut dissected some eggs which had been kept at room temperature for three weeks and found that the larvae were fully developed. The fate of the eggs in the field in winter has not been extensively investigated but Peters took them in every month of the winter. They were sometimes taken from blocks of ice but at least 50% always hatched. He also found that the eggs were able to survive a temperature of -21° C. for at least 72 hours. The eggs would not hatch at 5° C. but would at 10°; hatching was very prompt, taking place in a few minutes.

In Wabasha, Peters took only eggs on March 29. Winter eggs and a few first instar larvae were taken on April 9 when the water temperature was 9° C. Adults were first taken in light traps on May 20. Summer eggs first appeared on June 1. There appeared to be four overlapping generations that year (1941) in Wabasha. The last summer eggs were taken August 20.

The incubation period of the winter eggs is variable and depends to a large extent on circumstances. Hurlbut (1938) records eggs being laid on September 5 to 23 and then hatching on April 14 to May 10. Four of 568 eggs hatched shortly after laying; 201 hatched the following spring. Summer eggs, on the other hand, hatched in 3 days at an average temperature of 21° C.

The larval breeding places of this species are discussed by many authors (Poston, 1942; Peters, 1942; Bang *et al.*, 1943; Eyles, 1948); cattail marshes and the marshes on the edges of rivers are particularly important breeding places in Minnesota. Larvae are likely to be found where the water is shaded (Peters, 1942) and are usually rather rare; this rarity may be more apparent than real (Daggy *et al.*, 1941; Poston, 1942) since the larvae appear to be well dispersed in their breeding places so that concentrations are not found. The period of larval and pupal development according to Peters was 58 days at 15° C., 42 days at 20°, 31 days at 25°, and 21 days at 30°; larvae died in 3 days at 35°. The pupal stage required about 3 days at 20° C.

It is interesting to notice how many authors regard this species as being rare. This is particularly true if one bases his opinion on the numbers of larvae found or the numbers of females in "resting places." Daggy *et al.* (1941) found larvae to be uncommon and females were usually not taken in resting places; light traps and hand catches, however, were likely to abound with *walkeri.* The explanation for the rarity of larvae may be as given above. The rarity of adults in resting places is almost certainly due to the fact that adults are sought in *quadrimaculatus* resting places (houses, barns, vacant buildings) rather than in *walkeri* resting places. The females of this species tend to rest on emergent vegetation just over the surface of the water (Peters, 1942; Bang *et al.*, 1943); Poston (1942) records taking large numbers of females resting on the concrete foundations of barns at dusk or on damp, cloudy days. Light traps and hand catches, on the other hand, may also give biased estimates of the relative abundance of species since *walkeri* appears to be more highly attracted to light than are many other species (Daggy *et al.*; Bang *et al.*; Huffaker & Back, 1943; Eyles and Burgess, 1945), and the females seem to bite much more readily in daylight. The rarity of *walkeri* and the abundance of *quadrimaculatus* in buildings may be a reflection of the different hibernating habits of the two species.

There seems to be no information available on the mating habits of this species or on its feeding preferences. It will feed readily on man and has been taken feeding on various domestic animals (Bang and Simpson, 1942). Bang *et al.* have produced evidence to show that *walkeri* females are able to fly 1.5 to 2 miles. The adults appear to be very susceptible to desiccation. Newkirk (1955) found a maximum of 114 eggs laid by the females; Ellis (1944) an average of over 150.

DISTRIBUTION — Eastern North America from Canada to Mexico; west to Nebraska (Carpenter *et al.*, 1946). It reaches its greatest abundance in the north central states. In Minnesota the distribution is incompletely known except that it has not been found in the extreme western part; most of the state records are from the Mississippi basin and the transitional forest region; there are few records from the coniferous forest region. Riley and Chalgren (1939) found it to be the most common anopheline in light traps and hand catches in the Crystal Bay Area (Hennepin Co.). Daggy *et al.* (1941) found it to be common in light traps in some areas of southeastern Minnesota but not in others; it was also commonly taken in hand catches. Poston (1942) also found this species common at times in the southeastern part of the state.

IMPORTANCE — This species is believed to be of no importance in the transmission of malaria; this is probably due to its non-domestic habits. In the state it may be common locally but is usually not important as a pest.

GENUS *WYEOMYIA*

Wyeomyia (Wyeomyia) smithii (Coquillett)

ADULTS — There is a tuft of setae on the postnotum (fig. 15) which is not easily seen but is diagnostic for the genus in Minnesota. Small; dorsum of abdomen covered with dark, metallic scales, with lighter ones ventrally. Mesonotum with dark, metallic scales; sides of the thorax with pale scales. Legs dark above, light below. There are few bristles on the sides of the thorax; post spiraculars and lower mesepimerals absent, with a single postpronotal and sternopleural; spiraculars present, upper sternopleurals absent. The female has been figured by Headlee (1945) and Carpenter & LaCasse (1955). The antennae of the male are similar to those of the female. Roth (1946) has described the female genitalia.

MALE TERMINALIA (fig. 33) — The dististyle has a number of lobes and is unique among Minnesota mosquitoes. Basistyle with three long setae and with basal lobe.

PUPA — Described and figured by Darsie (1951) according to whom the most characteristic features are the extreme development of hairs 7 on VII and VIII and the extreme length of hairs CT-2 and 5 on IV to VI.

LARVA — The larva may be differentiated from others in the state by the air tube, which is of normal shape but lacks the pecten (fig. 61) and has many hairs. Head at least as long as wide; body exceptionally hairy; anal segment lacks ventral brush and has only one pair of papillae apparent; air tube with many single or double hairs in no definite pattern. Found only in leaves of pitcher plants. Howard *et al.* (1913b) figure the entire larva.

EGG — Described by Smith (1902).

BIOLOGY — There has been practically no work done on the biology of this species. The larvae are found only in the leaves of the pitcher plant, *Sarracenia purpurea*, which is said to be insectivorous. Smith (1902) describes the life history in New Jersey as follows: "The insect winters in the larval stage, freezing and thawing as often as need be during the season. It pupates late in May and becomes adult a week or ten days later. Eggs are laid singly or in small groups; fastened to the sides (of the leaves) or floating on the surface. The summer broods mature in about a month, and there are probably three if not four series; but the broods overlap so much that the breeding is practically continuous. Late in the season the adults select the new leaves for oviposition even if they are yet dry."

Oviposition may also occur above the water line in older leaves (Carpenter and LaCasse, 1955). The larvae have been taken in winter frozen in solid blocks of ice (Smith, 1901). Owen (1937) froze larvae taken in the summer and found that "although larvae can withstand freezing they are destroyed by temperatures near -14° C. The data suggest also that pupae are more susceptible to low temperatures than are larvae." The larvae may be active even at very low temperatures (Haufe, 1952).

The development of the larvae appears to be very erratic; in the laboratory, at least, the larval stages may be very prolonged and may require months for development, even at elevated temperatures. Howard *et al.* (1913a) record the resistance of larvae to starvation for nearly a year.

The larvae are said to remain under water feeding for extended periods of time, rarely coming to the surface for air (Smith, 1901). This probably indicates that not all of the oxygen used for respiration is taken at the surface of the water.

DISTRIBUTION — According to Carpenter *et al.* (1946) this species is found in south Canada and the eastern United States south to South Carolina and Alabama. Dodge (1947) has described the southern form from North and South Carolina as *haynei*. It was taken from *Sarracenia purpurea venosa*: *Wyeomyia smithii* presumably is found only in the "typical" form of the pitcher plant.

In Minnesota this species has been found wherever pitcher plants occur; they have been found primarily in black spruce and tamarack swamps in the northern part of the state. An interesting record of *smithii* is from the Eloise Butler Flower Garden in Glenwood Park, Minneapolis, where a small colony of pitcher plants grows after transplantation from another area.

IMPORTANCE — This species is not definitely known to attack man, or any other animal or plant so far as the author is aware. If they attack animals it is probably some kind common in swamps such as frogs or birds. If they regularly attacked mammals, or even birds, it seems likely that they would have been taken on humans from time to time.

GENUS *URANOTAENIA*

Uranotaenia sapphirina (Osten Sacken)

ADULTS — Tiny mosquitoes with lines of brilliant blue scales on the head, thorax, and wings. Second submarginal cell less than half as long as its stem (measured from the branching of R_{4+5}; fig. 19). Thoracic bristling much reduced; post spiraculars absent; only one postpronotal, spiracular, pre-alar, postnotal, upper sternopleural, and lower mesepimeral.

MALE TERMINALIA (fig. 32) — Basistyles short, globular, with setae-bearing basal lobes. Dististyle broad, of characteristic shape, claw subterminal. Ninth tergum broad, emarginate anteriorly, lobes bare.

PUPA — Described and figured by Darsie (1951).

LARVA (fig. 58) — Small; head longer than wide. Upper and lower head hairs single, stout, peg-like, not hair-like. Eighth segment with comb scales fused to a plate, not free. Air tube with pecten and associated large, multiple hair tuft. Anal segment completely ringed by saddle; ventral tuft posterior of saddle; saddle hair large, multiple.

EGG — The egg raft has been described but not figured by Dyar (1901); the egg itself is figured and described.

BIOLOGY — Practically nothing is known of the biology of this species notwithstanding its wide distribution and, in some cases, abundance. The adult females overwinter (Lawlor, 1935; Hinman, 1935; Zukel, 1949b); they were found in dark, moist places in caves, buildings, and hollow trees respectively. There appear to be several generations a year.

The feeding habits of the females have not been extensively studied; there has been some doubt as to whether or not they take blood at all (Ross, 1947). Rozeboom (1942) records their biting horses and man. Remington (1945) reviews the literature on the biting habits of the *Uranotaeniae* and presents evidence to show that *lowii* feeds readily on amphibians. It seems likely that *sapphirina* females do feed on blood but rarely bite mammals even though they may be capable of so doing. According to Mitchell (1907): "The females bit but once and laid one raft, averaging 41 eggs. . . . The boat hatches in a day and will not stand drying. . . . The larval stage lasts from nine to twelve days."

Larvae are most abundant in late summer and are usually found in semipermanent or permanent water, usually associated with duckweed. The larvae rest with their bodies almost parallel to the surface of the water, unlike most culicines, and may, at first glance, be mistaken for anophelines.

The adults of this species according to Carpenter *et al.* (1946) rest in damp places in culverts, hollow trees, and amongst vegetation near breeding places. King *et al.* (1944) found them around the bases of trees and stumps in swampy places, and Rozeboom (1942) in wet hoof-prints, creek beds, and on damp underbrush and logs in swampy places.

The females appear to be rather highly attracted to light traps. Pratt (1946) in Puerto Rico found them only in traps near breeding places which suggested a short flight range, "possibly not more than half a mile."

DISTRIBUTION — Eastern United States from New England south; also West Indies, Mexico, and Central America. Owen remarked that in Minnesota *sapphirina* could probably be found in all the timbered regions of the state (south of Warba and Swan River in Itasca Co.). All state records are from the eastern half and most from the southern quarter.

IMPORTANCE — Since this species rarely if ever bites man, it is of no known importance.

GENUS *CULISETA*

Key to *Culiseta* females

1. Dorsum of abdomen completely dark-scaled (wing scales broad; mesonotum entirely reddish-brown; small, dark species) ______________________________ *melanura* (p. 51

1. Dorsum of abdomen with pale as well as dark scales, usually with pale banding ___ 2

2. Pale bands on apices as well as bases of abdominal terga; pale scaling on abdominal terga brownish, not white; wing scales all dark; tarsi with narrow pale rings ______________________________ *minnesotae* (p. 52

2. Pale scales arranged in bands on the bases only of the terga; scales of abdominal bands usually white, if brownish the wing scales are pale and dark intermingled; if tarsi have pale rings, the abdominal bands are basal only and usually distinctly white_______ 3

3. Wing scales dark and light intermingled; abdominal bands usually with mixture of white and yellow scales, sometimes brownish; tarsi may have a sprinkling of pale scales but without bands_________*inornata* (p. 4

3. Wing scales all dark; abdominal bands distinctly white; with narrow, pale bands on tarsi __________________ *morsitans* (p. 52

Key to male terminalia of *Culiseta*

1. Lobes of the ninth tergum with short, dark, stout spines (fig. 64) ________ *inornata* (p. 47)

1. Lobes of the ninth tergum with elongate setae which are not excessively dark (fig. 65) ________ 2

2. Phallosome with dark, apparently folded portion at apex (fig. 66) with angular subapical shoulders ________ *minnesotae* (p. 52)

2. Phallosome without darker apex, rather evenly sclerotized (figs. 65, 67), without angular subapical shoulders ________ 3

3. Phallosome broadly oval, broadest just before apex (fig. 65); small __ *melanura* (p. 51)

3. Phallosome rather 8-shaped, the basal swelling at least as broad as the apical one (fig. 67); large ________ *morsitans* (p. 52)

Key to *Culiseta* larvae

1. Siphon with a row of median tufts (8-14) along the ventral side in addition to the basal tufts (fig. 69) ______ *melanura* (p. 51)

1. Siphon without such a row of tufts _____ 2

2. Outer pecten teeth produced into long hairs (fig. 60) ________ *inornata* (p. 47)

2. Outer pecten teeth not produced into long hairs (fig. 68) ________ 3

3. Upper head hairs usually with 7 or more branches; ventral brush usually with 18 or fewer tufts; postantennal tuft usually with 9 or more branches _____ *minnesotae* (p. 52)[8]

3. Upper head hairs usually with 5 or fewer branches; ventral brush usually with 20 or more tufts; postantennal tuft usually with 8 or fewer branches (fig. 68) ________ *morsitans* (p. 52)

Culiseta (Culiseta) inornata (Williston)

ADULT FEMALE — The only *Culiseta* in the state with intermingled dark and pale wing scales. Large; usually with a sprinkling of light scales on the proboscis medially. Mesonotum with coppery brown scales, sometimes with indefinite lines of lighter ones. Abdomen with light, basal bands on the terga, the medial scales usually yellow, the lateral ones white. There is often a sprinkling of light scales on the dark portions of the terga. Legs mostly covered with darker scales but quite variable, often with a sprinkling of pale ones. There are often light bands or spots at the apices of the femora and tibiae and rarely also on the two proximal segments of the hind tarsi. Wing scales dark, with a sprinkling of light ones, particularly anteriorly. Figured by Carpenter and La Casse (1955). Rees and Onishi (1951) give a detailed analysis of the genitalia.

ADULT MALE — The male is different from the female in that it has a lighter thorax, lighter wing scales with few or no pale ones, lighter scales on the legs with little or no speckling, and no pale bands on the bases of the abdominal terga. The dorsal surface of the abdomen is usually entirely dark except for the lateral margins and the eighth segment; sometimes there is a sprinkling of light scales on the abdomen. The dorsal surface of the eighth segment is usually pale scaled. The palps of the male differ from other *Culisetae* of Minnesota in that they are sparsely bristled. Terminalia (fig. 64) differ from all other *Culisetae* in that the lobes of the ninth tergum have stout, short spines instead of hairs. A detailed analysis of the terminalia is given by Rees and Onishi (1951).

PUPA — Described and figured by Darsie (1951).

LARVA — Unique among *Culisetae* in the state by virtue of the outer pecten spines which are produced into long hairs (fig. 60). Antennae shorter than head. Upper and lower head hairs multiple, of about equal length. Air tube with basal tuft. Anal segment encircled by dorsal saddle; anterior tufts of ventral brush passing through holes in saddle. The "stirrup-shaped piece" is figured by Breland (1952).

EGG — Raft and individual eggs figured by Mitchell (1907) and Howard *et al.* (1913b).

BIOLOGY — Hibernation is by the adult female in northern areas (Thompson, 1953). In the south there may be almost continuous breeding during the winter (Carpenter, 1941). The females may be fairly active even in the winter and often appear when snow is yet on the ground (Lugger, 1896; Hearle, 1926). Hibernating females have been taken in houses (Ross, 1947), caves and under cabins (Mail, 1934).

The females leave their hibernating quarters in the early spring and in Minnesota are among the earliest mosquitoes on the wing, generally appearing some time before the *Culexes* and *Anopheles*; this is usually in April but may be somewhat earlier or later. The females may attack humans readily in the spring (Ross, 1947) although as a rule they appear rather reluctant to bite humans at

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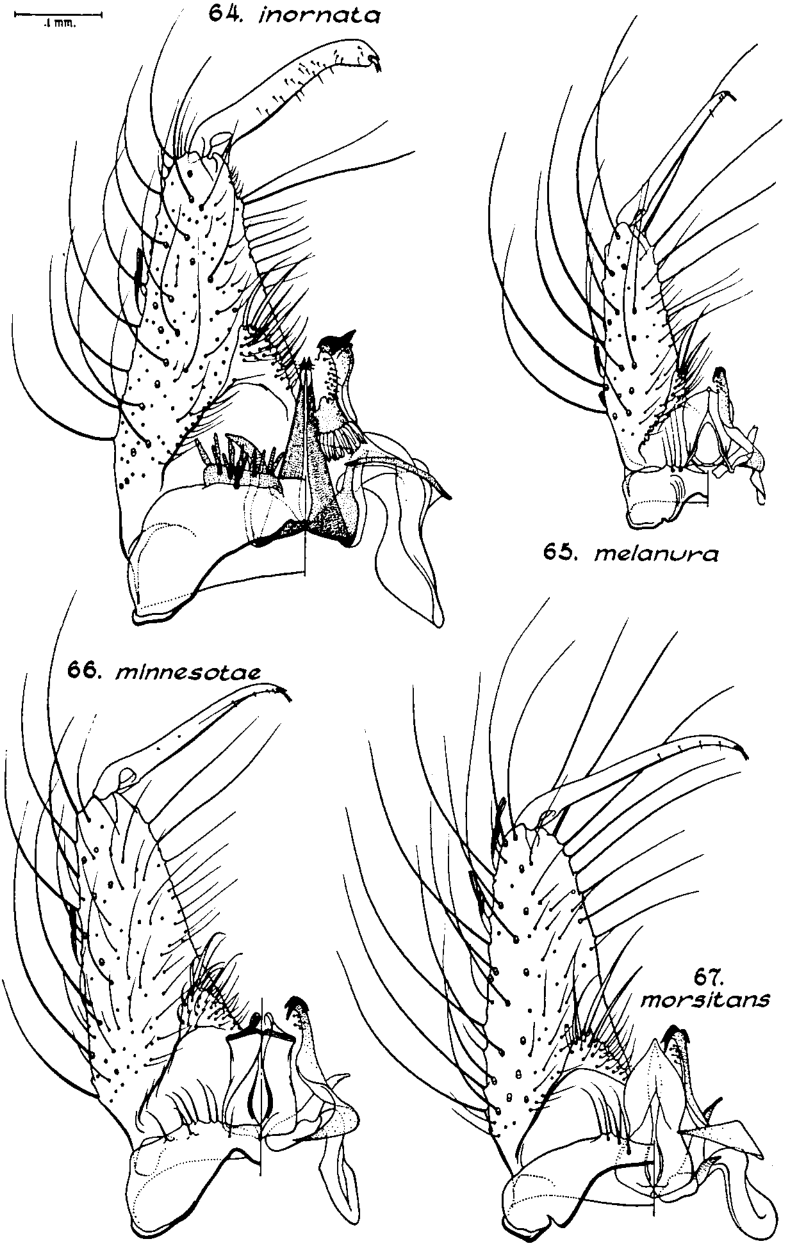
[8] This separation is taken from Price (1958).



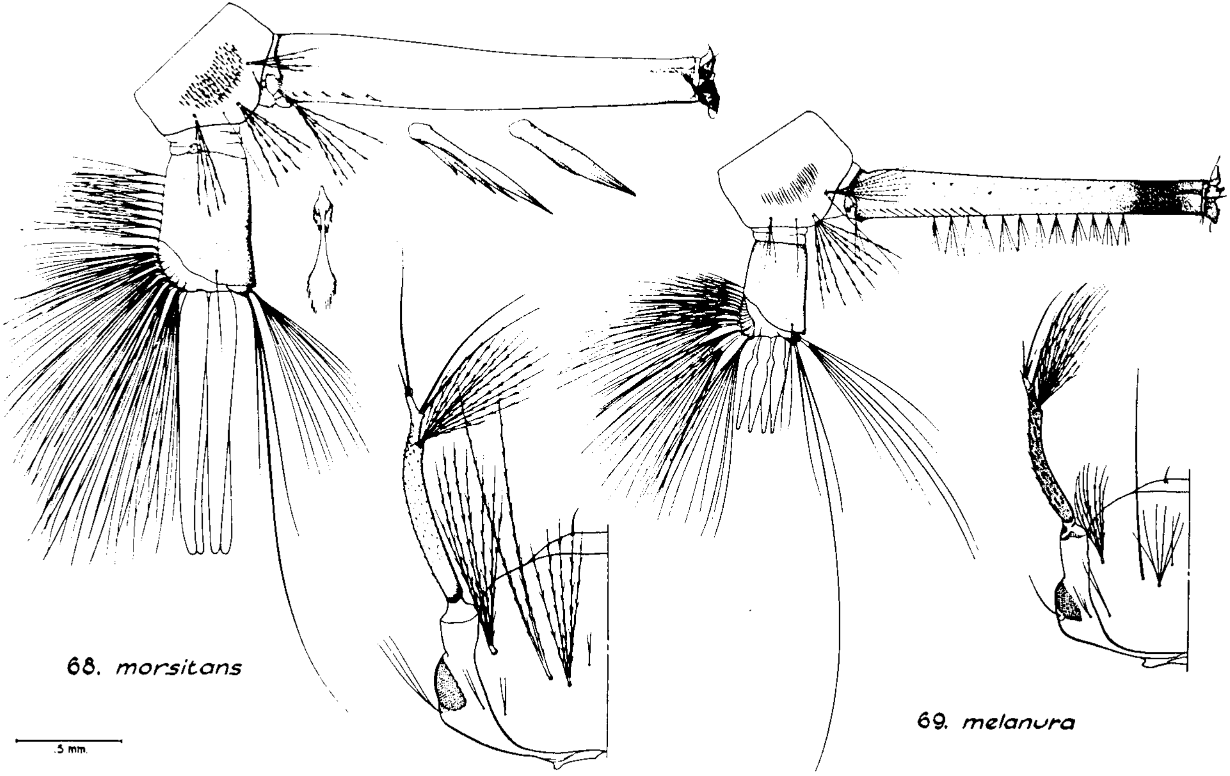
64. *inornata*

65. *melanura*

66. *minnesotae*

67. *morsitans*

PLATE 15 (figs. 64-67). Male terminalia of *Culiseta.*



68. *morsitans*

69. *melanura*

PLATE 16 (figs. 68, 69). Larvae of *Culiseta*.

other times. Domestic animals are said to be the preferred hosts of the females (Thibault, 1910; Reeves and Hammon, 1944; Yates, 1953). The females usually feed on blood but once before ovipositing (Owen, 1942) but may feed more than once (Mitchell, 1907). Adults have been taken feeding on flowers (Philip, 1943) but a blood meal seems to be necessary for developing viable eggs. The preoviposition period is about five days at room temperature according to Owen (1942) and the hibernating females are said to die as a rule immediately after ovipositing (Owen, 1937). Owen (1942) found that the preoviposition period may be longer for later egg batches than for earlier ones; he found an average of 8.9 days for the last raft as contrasted with 5.3 days for the first one. He also found that the first egg raft deposited by a female was likely to be the largest one; the first rafts laid averaged 207 eggs, the last ones 99. A group of 14 females took an average of 5.6 blood meals and laid an average of 5 rafts containing a total of 701 eggs on the average. Their average life was 96 days.

McLintock (1952) found that oviposition took place in the early evening and required 30 minutes to an hour. The incubation period is said to be 57 hours at 20 to 21° C. (McLintock) and 8 days at 11° C. If the eggs are first allowed to darken, they may be stored at 4-5° C. and will not begin to hatch for about 21 days; the undarkened eggs are said to be killed by this temperature but they have been taken in the field when the water is near the freezing point (Thompson, 1953). The eggs are somewhat resistant to drying (Buxton and Breland, 1952) and viable ones have been recovered from dry materials (Wilkins and Breland, 1949; Buxton and Breland). The embryology of this species has been described by Larsen (1952).

Owen (1942) found that 88.3% of about 9800 eggs hatched; 2.3% were undeveloped (many were abnormal) and 9.4% contained dead embryos. The length of larval development is, of course, variable but usually requires a week or more at 20 to 21° C. (McLintock); the pupal stage requires about 2 days at the same temperature. Males can be distinguished in the fourth larval instar (Rees and Onishi, 1951) and begin pupating a day or so before females (McLintock); the sexes of pupae can be differentiated on the basis of size, the males being smaller.

Culiseta inornata is exceptional in Minnesota in that larvae may be taken in abundance in the early spring while larvae of some species of *Aedes* are still in the water; at this time they are often taken in temporary water from melted snow. The larvae of other mosquitoes which hibernate in the adult stage (*Culiseta Anopheles, Culex, Uranotaenia*) are usually found in abundance only later in the summer. In the summer the larvae of *inornata* are usually found in various types of semipermanent or permanent water. Ross (1947) found them particularly in marshes in Illinois. The larvae are occasionally found in foul or scummy water; McLintock (1952) found them in water in which no dissolved oxygen could be demonstrated. Yates (1953) found the larvae particularly in alkaline or neutral water in the northwestern states.

Male adults begin emerging a day or so before females on the average. The terminalia of the male rotate in from 6 to 12 hours according to Rees and Onishi and a female may begin to mate a few minutes after she has emerged. Flight appears to be sufficient stimulus to induce mating (Owen, 1942); disturbances which agitate the adults usually produce mating. Copulation appears to take an extraordinarily long time in this species in contrast with other species which have been studied (*Aedes, Culex, Anopheles*) in which it requires only a few minutes. In *inornata* Rees and Onishi found that copulation required from 3.5 to 6 hours. Although some authors have noted shorter periods of mating for this species, there is no indication that insemination actually occurred in such cases. Rees and Onishi also discuss the process of copulation in great detail. There appear to be no reliable records of swarm formation and Owen (1937) found that mating took place in very small enclosures. The peculiar antennae of the males may have some relation to their mating habits. Males are said (Owen, 1942) to mate repeatedly while females usually do not.

McLintock found that unmated females were reluctant to feed although mated ones fed readily in the laboratory. Owen (1942) observed that females which were not allowed to feed on sucrose solution would begin taking blood in 2 to 3 days but those which were given such nutriment usually fed 5 or 6 days after eclosion. Feeding was maximal in the evening as is the case in the field.

The seasonal cycle of *inornata* has been partially investigated. In the south (Louisiana, Mitchell, 1907; Arkansas, Thibault, 1910; Carpenter, 1941), it is a winter mosquito while in more northerly areas (Illinois, Ross, 1947; Missouri, Harmston, 1952) it appears to be more common in the spring and fall with a more or less definite period of inactivity in the middle of the summer. Records in the University of Minnesota collection are mostly in April to June and September to October, suggesting a bimodal peak of abundance, however these times coincide with the periods of greatest activity of the females, *viz.*, entering and leaving hibernation quarters. In places where there appears to be a period of inactivity during the warmer portions of the year, there is some evidence for believing that estivation may occur in the egg stage (Wilkins and Breland, 1949). The author has found in Kansas, however, that the first adults taken in the fall are old females so it appears likely that adult females estivate. In the northwestern states (Yates, 1953) the numbers of adults appear to be rather uniform throughout the summer. In some areas there appear to be two generations a year, *e.g.* Ross (1947) says: "In Illinois the species apparently has an early spring and late summer generation with a fairly definite period of inactivity during the hottest part of the summer. The two-brooded condition is especially pronounced in southern Illinois, where the first wave of adults comes out in April and early May and the next in September and October." In other areas, particularly in the extreme north, there are said to be several generations a year (Hearle, 1926; Mail, 1934; Rempel, 1950).

The adults are said by Owen (1937) to migrate a mile or more from their breeding grounds. Their resting habits have not been extensively studied although adults have been taken in "resting stations" (Carpenter *et al.*, 1946) and in rodent burrows (Ryckman and Arakawa, 1952). Both sexes are readily taken in light traps.

The species has been colonized by Owen (1937, 1942) and McLintock (1952) and was found to do best at 20 to 21° C.

DISTRIBUTION — All over United States from southern Canada to Mexico. In Minnesota, Owen (1937) found it to be more common in prairie and hardwood forest regions but to the present author it appears to be generally distributed over the state. Thibault (1910) found that it seemed to prefer open fields to woods.

IMPORTANCE — Owen (1937) considered the species to be of major importance in Minnesota but in view of its usual reluctance to bite humans, the present author is inclined to consider it as not being particularly annoying. Hammon *et al.* (1942) found the species infected with the virus of western equine encephalomyelitis.

***Culiseta (Climacura) melanura* (Coquillett)**

This species has been taken in the state only by Sandve (1946); the identification was based on the terminalia of males which were taken in light traps. No Minnesota specimens have been examined by the author; the descriptions below are based on Connecticut material provided by Dr. R. C. Wallis.

FEMALE — The only Culiseta in the state without broad pale bands on the dorsum of the abdomen. Resembles a small *Culex* but can be separated from that genus also by the lack of pale banding on the abdomen; the spiracular bristles are often difficult to see. Wing scales dark; legs unbanded.

MALE TERMINALIA (fig. 65) — Basistyle with basal but without apical lobe. Ninth tergum with elongate setae. Rather similar to both *morsitans* and *minnesotae* but can be distinguished by the shape of the phallosome.

PUPA — Undescribed.

LARVA (fig. 69; specimen figured from Connecticut) — Antennae about as long as head, tuft situated near outer fourth; with a pair of long subapical setae. Head wider than long. Lower head hairs usually single, about twice as long as uppers which are multiple. With several shoulder hairs longer than the length of the head. Comb scales of eighth segment in single row. Air tube very long and thin, 8 or more times as long as wide at middle; pecten confined to basal third, pecten spines not hair-like; basal tuft small, inserted ventrally; with a row of a dozen or so multiple tufts inserted along the mid-ventral line of the air tube; also with a series of about 5 tiny, branched, lateral tufts. Anal segment longer than wide; saddle completely encircles segment, saddle hair usually single or double; anterior tufts of ventral brush often appear to pierce the saddle. Anal papillae about as long as dorsal saddle.

EGG RAFT — Described and figured by Chamberlain *et al.* (1955).

BIOLOGY — Very little is known of the biology of this species, practically all observations having been made by Smith (1904b), Wallis (1954a), and Chamberlain *et al.* (1955). Hibernation is probably by the adult female (Wallis) as is the case with most *Culisetae* although it has been believed for many years that the larvae hibernate. The observations of Wallis, however, are not conclusive in this regard since his "hibernating" females were gravid. As a rule gravid female mosquitoes are very susceptible to cold so that only unfed females are able to overwinter unless they show gonotrophic dissociation (i.e., blood is taken but the ovaries remain undeveloped).

An egg raft examined by Wallis produced about 100 larvae after about two days at room temperature. The larval stages required from 1 to 2 weeks and the pupal stage about 3 days. The adults in the laboratory would feed neither on humans or chickens, presumably because mating did not occur. Chamberlain *et al.* (1955) also found that mating did not occur in cages but females fed on chicks or rabbits.

Adults enter light traps readily (Carpenter *et al.*, 1946). The hosts of the female are unknown; Chamberlain *et al.* (1955) found that one female had fed on avian blood in the field. Apparently the females do not regularly attack humans. The larvae are usually found in permanent water as in swamps (Matheson, 1944); Masters (1943) found them in waters of a low specific gravity in Georgia. There are several generations a year according to Horsfall (1955).

DISTRIBUTION — Eastern United States from Canada to Gulf of Mexico. In Minnesota, known only from St. Croix State Park.

IMPORTANCE — Since this species is not known to attack humans it is not an important pest species. Chamberlain *et al.* (1951) have found the species naturally infected with eastern equine encephalomyelitis. This disease has occurred recently in Wisconsin (Hanson *et al.*, 1954) so *melanura* could conceivably be of importance as a vector in Minnesota.

Culiseta (Culicella) *minnesotae* Barr

FEMALE — Similar to *morsitans* except that the pale bands on the abdominal terga cover the apex of one segment and the base of the next. Several other differences which may prove useful are given by Barr (1957b).

MALE TERMINALIA — Very similar to *morsitans* except for the shape of the phallosome as shown in fig. 66.

PUPA — Described and figured by Price (1958).

LARVA — Described and figured by Price (1958) according to whom the most important differences from *morsitans* are as shown in Table 1.

EGG — Undescribed.

BIOLOGY — Larvae would be expected to occur in semi-permanent marshes. Hibernation appears to be by adult females. The species is attracted to light. Adults have been taken from April to June and September to October.

DISTRIBUTION — Known only from a few scattered localities in Minnesota (St. Louis, Clearwater, Hennepin, Ramsey, and Isanti Counties) and probably from the Pacific Northwest (see Barr 1957b).

IMPORTANCE — Has not been taken in hand catches and may not feed readily on man.

Table 1. Differential diagnosis of *Culiseta morsitans* and *C. minnesotae* larvae (Price, 1958)

	minnesotae		*morsitans*	
	usual	range	usual	range
Number of branches in upper head hairs	7-8	(6-11)	4-5	(3-7)
Number of branches in post-antennal tuft	9-12	(8-14)	6-8	(5-9)
Number of tufts in ventral brush	17-18	(16-19)	20	(19-22)

Culiseta (Culicella) *morsitans* (Theobald)

Although this species was first identified in Minnesota by Washburn (1905), there are no certain state records except in the present study.

FEMALE — *Culiseta* with dark wing scales, basal white bands on the terga, and pale, narrow tarsal rings. The author has not examined females of this species from Minnesota.

MALE — Similar to description of *minnesotae* above. Terminalia (fig. 67) differs from that of *minnesotae* by the shape of the phallosome.

PUPA — Described by Darsie (1951) and Price (1958).

FOURTH INSTAR LARVA (fig. 68; all from Itasca State Park) — Antennae about as long as head which is wider than long; tuft situated at about the outer fifth, strongly multiple, the branches reaching considerably beyond the tip of the antenna. Antenna with a long and a short seta as well as various other processes at the tip and with two long setae subapically. Antenna darkened basally and apically, light in the middle. Preclypeal spines separated by about 4 times the length of one of the spines. Upper and lower head hairs in a line with postantennal tuft. Uppers usually with 4 or 5 branches (21 and 39 of 71; range 3 to 7). Lower head hairs usually double (61 of 64; range 2-4). Upper head hairs reaching about to front of head; lowers reaching beyond base of antennal tuft. With the posterior shoulder hair and its 2 associated hairs (1-3) reaching beyond front of head. Lateral abdominals on I-II usually with 4 branches (27 of 39 and 29 of 40; range 3-5); single on III to VI (100% of 36, 45, and 28 on III to V, 13 of 14 on VI; range 1-2). With a great many comb scales in more or less triangular patch; comb scale rather spatula-shaped, narrow at base and wide apically. Siphon long and narrow, about 8 times as long as wide at middle. With pecten of about 13 or so spines confined to basal fifth of siphon; outer spines unevenly spaced. Siphonal tuft basal, usually with 4 or 5 branches (26 and 39 of 69; range 3-6); about twice as long as width of siphon at base. Anal segment ringed by saddle which is longer than wide; lateral hair single (100% of 41), not as long as the saddle; middle part of saddle with large spines dorsally. Dorsal brush with a strongly multiple tuft and a usually triple (38 of 40; range 1-4) hair on each side; the triple hair has one strong and two weak branches. Ventral brush usually with 20 or 21 tufts (19 and 12 of 37; range 19-22) of which 7 or 8 usually arise from the saddle (14 and 17 of 34; range 6-9). Anal papillae about twice as long as saddle, tapering to bluntly rounded tips.

THIRD INSTAR LARVA (2 specimens) — Similar but smaller with darker sclerotized areas. Upper head hairs with 2-3 branches, lowers double. Siphon stouter than in fourth instar; tuft with 3-4 branches. Saddle extending 1/3 to 1/2 down the sides of the anal segment; lateral hair slightly ventral of saddle. Ventral brush with about 20 tufts.

EGG — The eggs of this form are unknown in North America (Howard *et al.*, 1915) but Marshall (1938) has figured the egg of the European form; they are said to be laid singly, not in rafts.

BIOLOGY — What is known of the biology of this species is reviewed by Horsfall (1955). Most observations are from Europe and there would appear to be some doubt that the American and European forms are identical.

Marshall (1938) summarizes the life history of this form in England as follows: "Adults are found from April to August. The eggs are laid singly in dried-up hollows or above the water level of partly-filled ones in the manner of *Aedes* eggs. The eggs hatch in the fall and the larvae develop to the fourth instar by November. The fully grown larvae remain on the bottom during the winter and pupate the following spring." (See also Wesenberg-Lund, 1921).

This cycle, if true, is very peculiar since most *Culisetae* oviposit on a water surface, lay eggs in rafts, and hibernate as adult females. There has been no confirmation of the cycle in America.

In America there is said to be one generation a year (Howard *et al.*, 1915; Matheson, 1944). Howard *et al.* suggested that hibernation may take place in the egg stage. The feeding habits of the adults are not known but females have not often been taken feeding on man. Larvae have been taken in a number of types of habitats, mostly in semipermanent or permanent bodies of water in forested areas. Wesenberg-Lund (1921) describes how larvae of this species are able to obtain air from plants. The males are said to be readily attracted to light (Dyar, 1922a).

DISTRIBUTION — Northern parts of palaearctic and nearctic regions. In North America, northern United States and Canada from coast to coast; south to New Jersey, Kentucky (Blakeslee and Payne, 1953), Illinois, South Dakota, and Colorado; north to Alaska, Yukon Territory, and Labrador (Haufe, 1952). In Minnesota the author has certain records (males) only from Clearwater (Itasca State Park), Beltrami (Bemidji), Aitken (McGregor), and Carlton (Cloquet Forest Experimental Station) Counties.

IMPORTANCE — Probably none.

GENUS *ORTHOPODOMYIA*

Orthopodomyia signifera (Coquillett)

This species has only recently been taken in Minnesota by Price and Abrahamsen (1958). Minnesota specimens not seen by the author.

FEMALE — With lines of brilliant white scales on antennae (torus and flagellum), palps, proboscis, behind eyes, and on mesonotum and sides of thorax. Palpi about half as long as proboscis. Mesonotum brown, with two narrow, white, submedian lines and posterior half lines; also with white lines around the lateral edges of the mesonotum. Side of thorax with a white line of scales across the anterior and posterior pronotum. With another line across the propleuron, sternopleuron, and mesepimeron. Bristling of pleurae undistinguished; lacking spiraculars, post-spiraculars, and lower mesepimerals. Legs mostly dark-scaled but with white scaling on femora and tibiae; tarsi of front legs mostly dark-scaled but hind legs with broad, white rings covering the apex of one segment and the base of the next. Wings with intermingled dark and light scales. Abdominal terga dark-scaled, with narrow, white basal bands.

Male terminalia (plate 7, from Kansas specimens) — Rather similar to those of *Culiseta.* Claw of dististyle with frayed appearance at apex. Basistyle rather conical; with basal lobe bearing several stout spines; also with row of spines lateral of basal lobe. Phallosome with teeth on subapical shoulders. Ninth tergum without lobes but with a few long setae where the lobes should be.

Pupa — Described by Darsie (1951).

Larva (plate 7; illustrated from Kansas and Georgia material) — Small; found in tree-holes or artificial containers. Head slightly longer than wide, with pouches ventral of antennae. Antennae less than half as long as head, bulbous basally, narrow apically. Upper and lower head hairs and postantennal tuft multiple. Seventh and eighth segments usually with large saddles which are incomplete ventrally. Comb scales in overlapping double row. Siphon about 4 or so times as long as wide at middle; the ventral profile is more or less abruptly broken at the insertion of the tuft which is strongly multiple and much longer than the width of the siphon at the point of insertion. Pecten absent. Anal segment ringed by saddle; lateral hair single, shorter than length of saddle. Inner hair of dorsal tuft strongly multiple. Anal papillae about as long as dorsum of saddle.

Egg — Described and figured by Howard *et al.* (1917 and 1913b, respectively).

Biology — Reviewed by Jenkins and Carpenter (1946). Overwintering appears to be by larvae which are taken in tree-holes and artificial containers. The food of the adults is unknown and females are not known to take vertebrate blood.

Distribution — Eastern United States and West Indies; north to Massachusetts, New York, Minnesota, North Dakota; west to Nebraska, Kansas, and Arizona; south to Gulf Coast. In Minnesota, known only from Dakota and Scott Counties.

Importance — None.

GENUS *MANSONIA*

Mansonia (Coquillettidia) perturbans (Walker)

The European replacement of this species, *richiardii*, is considered by some authors to be identical (Hagmann, 1953).

Female — Large; proboscis with definite pale ring. Mesonotum dark brown with irregular lines of lighter golden scales. Wing scales very broad, dark and light intermixed (fig. 21). Abdomen dark above, terga sometimes with narrow white basal bands which are widened at the sides; more often only the white lateral patches are seen, the "bands" being interrupted medially. Tip of abdomen rounded, cerci not evident. Legs with dark and light scales; usually there is a white band just before the tip of the hind tibia; the first tarsal segment usually also has a median white ring; other tarsal segments dark with broad, white, basal rings (fig. 23). Many specimens taken by the author at Itasca State Park have pale, uniformly colored legs without banding of any kind. Figured by Carpenter and LaCasse (1955).

Male terminalia (fig. 31) — Readily recognized by the single, large, blunt spine borne on the mesal face of the basistyle. The dististyle also has a characteristic shape.

Pupa — The pupa is unique among Minnesota mosquitoes by virtue of its attenuated respiratory trumpets and its narrow, elongate, distally notched paddles; the float hair (1-I) is tiny and most of the other hairs are much reduced. Described and figured by Darsie (1951).

Fourth instar larva (fig. 59) — The larva can be recognized immediately by the air tube which is adapted for piercing plants. Unusually small when related to the size of the adult; the larva probably has a high specific gravity as compared with species which hang from the surface of the water. Head wider than long, slightly over a mm. wide. Antennae about 1½ or more times as long as head, abruptly narrowed beyond insertion of tuft near basal third; with a pair of spines near middle. Lower head hairs large, usually with 6 or 7 branches (14 of 15; range 6-8); upper small, with about 9-12 branches. Lateral abdominals usually all single. Eighth segment with average of about 17 comb scales (12-24) in irregularly single row; comb scale with long terminal spine. Siphon modified for piercing plants, more or less triangular, rather sharp at tip; about 1.5 times as long as wide at base; very dark at base and apex; pecten absent; tuft usually quadruple (18 of 22; range 2-5). Anal segment completely ringed by saddle which is about twice as long as wide; ventral brush with 2-3 tufts preceding the barred area of which 1 or 2 may pierce the saddle; all hairs in dorsal brush multiple; saddle hair usually with 4-5 branches (13 of 15; 3-6). Anal papillae usually somewhat longer than saddle. The larva differs in a number of respects from the European form as described by Wesenberg-Lund (1921).

THIRD INSTAR LARVA — Head about 3/4 mm. wide. Saddle of anal segment extending about 1/4 down the sides, with hair at edge; siphon longer in proportion to width than in fourth instar. With average of 9.3 comb scales (8-12).

EGG — The eggs are laid in rafts which are figured by Hagmann (1952); the individual egg is figured by Mitchell (1907).

BIOLOGY — Reviewed by Horsfall (1955). The overwintering stage in this species is the larva; Hagman (1953) found second, third, and fourth instar larvae in the winter in New Jersey; even in that latitude the larvae appeared to be active in the winter. The finding of larvae of this species is rather difficult since they are attached for the most part to the roots of aquatic plants and are thought usually to detach themselves only when the plant is disturbed. McNeel (1931) described a method of finding larvae by examining the debris from the bottom after plants have been pulled out. Hagmann (1953) found larvae most easily by examining plants at a time of the year (fall) when the water was near the freezing point; at this temperature the larvae did not detach themselves from the plants so quickly.

Recently Bidlingmayer (1954) has described a trap for sampling larval populations. The device is a cylinder longer than the depth of water to be sampled. The cylinder is pushed into the mud around the bases of aquatic plants and projects above the surface of the water. The plants within the cylinder are then pulled out and their roots washed thoroughly within the cylinder to remove all larvae. A funnel the same diameter as the cylinder is then pushed down into the cylinder so that it has its smaller opening beneath the surface of the water and pointing upwards. The larvae, presumably having been deprived of their sources of air, will eventually make their way up through the funnel to the surface of the water, and will not be able to go down through the opening again. The trap is usually examined the next day. It should be a valuable tool for evaluating breeding places of this species.

A number of host plants are known for the species but the most important ones are probably sedges and cattails. The author has taken larvae and pupal skins in cattail marshes in Itasca State Park; sedges were also abundant in these marshes and there was a light growth of duck weed. Headlee (1945) found that larvae were in water usually at least 10 inches deep and always at least 6 inches.

Larvae begin pupating in the early summer somewhat after most of the early *Aedes* have appeared. The pupal stage is said (Hagmann, 1953) to take about 5 days at 20 to 22° C., which is somewhat above average for mosquitoes. The pupal respiratory trumpets develop precociously in the larva so that they are ready for attachment as soon as the larva begins pupation. Although the larvae are able to reattach to another plant after being disturbed, the pupae apparently are not. Hagmann found that when pupae detached from a plant, the tips of the respiratory trumpets were usually broken off so that the pupa could not reattach to a plant although it could float at the surface and the adult could emerge normally. Examination of pupal skins recovered by the author showed that practically all had the tips broken off; this presumably happens normally just before emergence.

Pupae of Minnesota specimens appear to attach to rootlets in a manner different from that described by Wesenberg-Lund and Marshall; the respiratory trumpets usually straddle the rootlet so that one inserts on either side rather than both inserting at the same point as described by European authors. In Hagmann's study males appeared before females. Dorer *et al.* (1950) describe a method for the capture of pupae which hinges on the fact that the pupae are not easily disturbed; these authors pull out the host plants, wash their roots in water, and then wave the plants violently in the air to remove the excess mud. The pupae can then be easily seen.

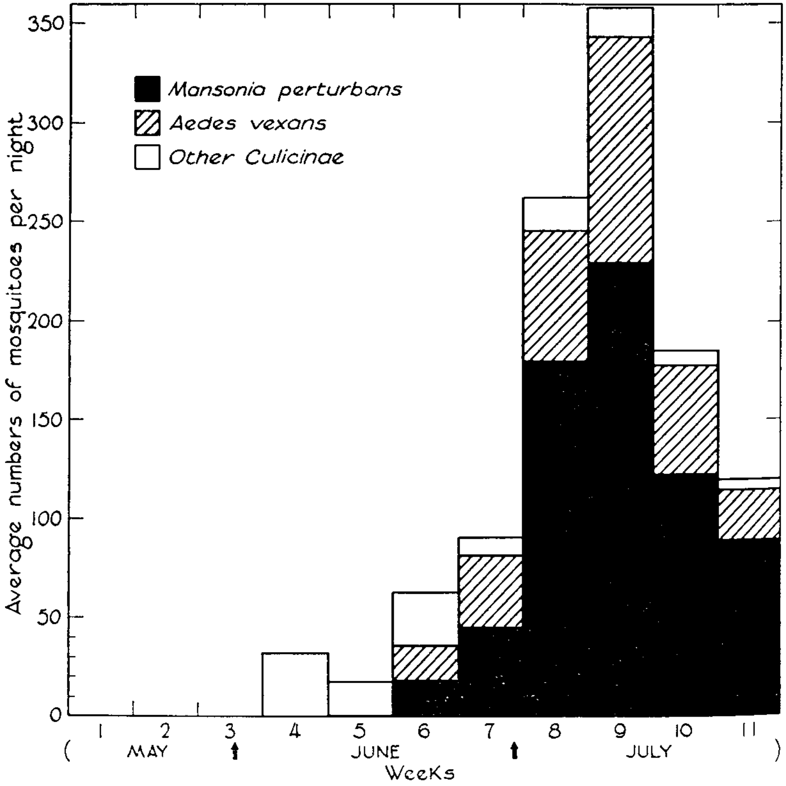
At Itasca State Park in 1954 numbers of pupal skins were first found on June 22 indicating a large emergence. The adults had first appeared in the light trap two days earlier and were still being taken in abundance on July 24 when the study was ended (fig. 70). The peak of abundance according to the light trap was in the first two weeks of July; in the second week there was an average of 228 per trap night. The peak of abundance in Virginia was found by Dorer *et al.* to be in the middle of June; Hagmann in New Jersey found it in the last week of June and the first week of July, and Sandve (1946) in Minnesota found it to be the middle of July.

There appears to be no information on mating of *perturbans* but such has been reported for the European form, *richiardii.* Shute (1930) records the males of this species as swarming late at night and again early in the morning.

There is no definite information on migration of this species although Dyar (1922a) says it will fly several miles. The feeding habits are also unknown but the species is avid in its feeding on humans. The abundance of females of this species is likely to be underestimated by hand catches because the females are reluctant to feed in the daytime except in heavily shaded places. Headlee (1945) has pointed out that the adults usually attack at dusk and the numbers fall off soon afterward. Dyar (1909) found they were most active at dusk from 7 to 9 p.m. and just before dawn from about 3 to 5 a.m. The reluctance of the females to attack in the daytime is very striking when compared with many other species. Hagmann (1952) found that females often oviposited inside hummocks of sedge.

The number of eggs in a raft is given by Hagmann (1952) as 131, and by Dyar and Currie (1904) as about 150. At Itasca State Park in June 1954 Mr. W. R. McKibben fed a group of females and attempted to induce them to oviposit in the laboratory but all died 5 days later without ovipositing. Upon dissection he found an average of 206.7 eggs per female (SD 33.2, SE 10.4); there were no relict eggs present. It is possible that some of these eggs would have been resorbed be-

70. Species Composition of Catch of a Light Trap Operated at Itasca State Park from May 14 to July 29, 1954



fore laying but such does not seem likely because of their advanced stage of development. The rafts are said (Dyar and Currie, 1904; Newkirk, 1955) to hatch in 4-5 days. Afterward, according to Howard *et al.* (1913a), "The newly hatched larvae make their way down through the water to the roots of these plants and there they attach themselves by inserting the apex of the peculiarly constructed breathing-tube. Here they remain anchored until full grown, obtaining air through the vascular tissues of the plant-roots."

Presumably there is a single generation a year but King *et al.* (1944) found that larvae could mature in the laboratory in 3 months and believed that, in Florida at least, there could be a partial second blood. It seems likely that in Minnesota there is but a single generation a year but the adults appear not to emerge all at once. Although there seems to be a peak emergence in early July, small numbers of adults appear to emerge for some time thereafter.

Distribution — Throughout the United States from Canada to Mexico and possibly in Europe. In Minnesota Howard (1916) stated that it was apparently widely distributed over the state and Owen (1937) found it uniformly distributed over the timbered portions of the state. Actually there are few Minnesota records except for the Twin Cities area and the northeastern quarter of the state. This paucity of records probably is due to the lack of light trapping or hand captures at dusk in many areas. The species is abundant at Itasca State Park and was commonly taken wherever the author spent a considerable amount of time collecting in the state. Although it appears to be more abundant in timbered regions, it is probably present over most of the state.

Importance — This mosquito is undoubtedly one of our most important species from the standpoint of annoyance. The only comforting fact is the reluctance of the females to feed in the daytime; in well shaded places, even this consolation disappears. The females are very aggressive and not easily discouraged. They are most ingenious in getting into houses and bite readily once they are inside. Larval populations tend to reach staggering proportions in favorable places; Hagmann (1953) estimates this as 3 to 4 million per acre. The species is undoubtedly of major importance particularly in towns in the northeastern part of the state which are closely associated with timbered regions. Howitt *et al.* (1949) have recovered the virus of eastern equine encephalomyelitis from wild-caught females in Georgia. The control of this mosquito is exceedingly difficult since larvae are not found at the top of the water and are therefore somewhat inaccessible to insecticides.

GENUS *PSOROPHORA*

Key to *Psorophora* adults

1. Hind legs shaggy, with black, erect scales toward the apices of the femur, tibia, and 4 basal tarsal segments; without white scales on last two hind tarsal segments; very large ------------------------ *ciliata* (p. 57)
1. Hind legs without erect scales, not noticeably shaggy; ultimate and penultimate tarsal segments of hind legs white scaled; medium-sized ------------------- *horrida* (p. 60)

Key to male terminalia of *Psorophora*

1. Dististyle bulbous in middle, with few or no setae, lacking subapical tooth; with more than one filament on claspette; apex of phallosome lightly sclerotized (fig. 72) ---- ----------------------- *horrida* (p. 60)
1. Dististyle not bulbous, with many setae and a subapical tooth; with single claspette filament; apex of phallosome heavily sclerotized (fig. 71) ---------------- *ciliata* (p. 57)

Key to *Psorophora* larvae

1. With only a few pecten teeth (about 3 to 5); antennae about as long as head; head rounded anteriorly; medium-sized --------- ------------------------ *horrida* (p. 60)
1. Many pecten teeth (upwards of 10), each terminating in a filament (fig. 62); antenna less than half as long as head; head truncate anteriorly; very large-------*ciliata* (p. 57)

Psorophora (Psorophora) ciliata (Fabricius)

Not previously recorded from Minnesota. There is a single male in the collection taken September 7, 1939, in a light trap at Wabasha, Minnesota, by R. H. Daggy and identified by Daggy and H. T. Peters. Several females were taken in St. Paul in 1953 and each summer thereafter.

Adults — Very large, largest species in the state. Proboscis with dark, erect scales proximally. Mesonotum with a broad line of golden scales medially, flanked on either side by a bare area; covered with white scales at the sides. Abdomen unbanded. Legs, particularly the hind pair, with dark, erect scales

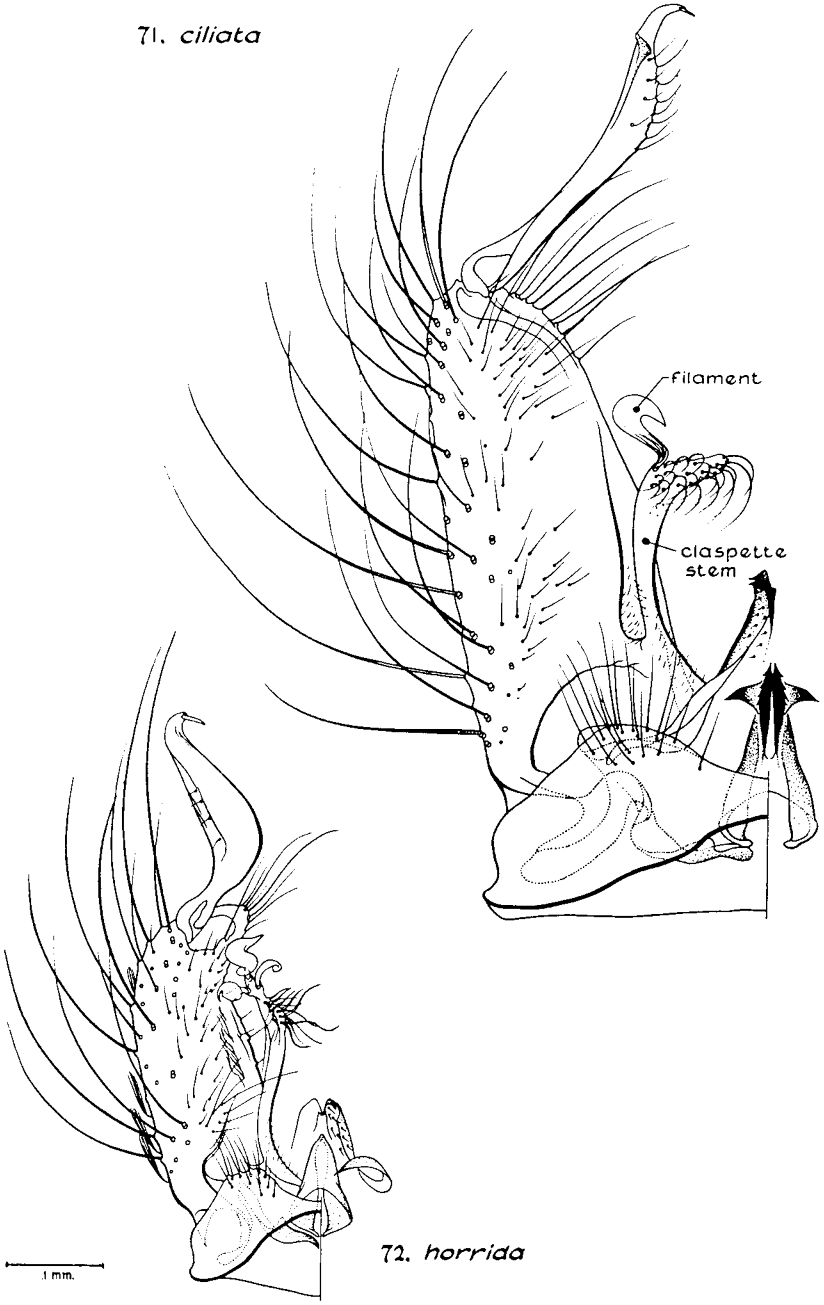


PLATE 17 (figs. 71, 72). Male terminalia of *Psorophora*.

distally on the segments. Figured by Carpenter and LaCasse (1955). A detailed description of the anatomy of the thorax is given by Snodgrass in Howard *et al.* (1913a).

MALE TERMINALIA (fig. 71) — Basistyle without basal or apical lobes. Claspettes with many long setae; filament inserted before apex, curved. Dististyle curved, somewhat angular on lateral surface; with many setae medially and a subapical tooth.

PUPA — Figured by Knight and Chamberlain (1948).

LARVA (fig. 62) — Head truncate anteriorly and with stout mouthparts. Antenna small, about half as long as head. Head hairs weak. No plate on eighth segment anterior of comb scales. Siphon not swollen; pecten with many spines, each terminating in a long filament. Anal segment ringed by the saddle, a number of tufts of the ventral brush passing through holes in the saddle.

EGG — Described and figured by Mitchell (1907), Howard *et al.* (1913b, 1917), and Horsfall *et al.* (1952).

BIOLOGY — Mitchell (1907) has described the biology of this species in Louisiana as follows: "*Psorophora ciliata* seems to feed almost always three times before laying, generally at intervals of three days. It usually deposits two batches of from fifteen to thirty eggs, but sometimes four batches; and there have been as many as sixty-three, and as few as five, eggs in a clutch. The first laying is always the smallest, which is not usually the case among mosquitoes. The species, as a rule, seems to feed between depositions but once. Ovulation occurs at intervals of from two to four days. It will take a meal two days after emerging and before mating, which latter act it readily performs in captivity. It mates but once. The adults were found from April to November 17, the length of life being about that of *P. howardii* (females 14-27 days, males 10-15 days), as is the larval stage (5-6 days). The pupal stage lasts from 49-54 hours in a temperature of about 60° F. (about 16° C.)."

The biology of this species has been more recently reviewed by Horsfall (1955). Hibernation is by the egg stage. In New Jersey the earliest adults according to Smith (1904b) come out in June which is rather late in the season. The adults are usually reported as being uncommon. The females are reported (Smith) to prefer to feed on horses rather than on humans; they have also been taken feeding on plants (Howard *et al.*, 1917). The adults are said to be diurnally active (Howard *et al.*) and males are at least weakly attracted to light.

Eggs are probably laid in small groups around the edges of temporary rainpools or in moist depressions; they have been recovered from dry leaves and surface soil by Buxton and Breland (1952). The females are said by Horsfall (1955) to lay 54.0 ± 2.4 eggs. Howard *et al.* and Schwardt (1939) say that the eggs do not hatch until the following year but this is unlikely. Schwardt found that although larvae developed in the eggs in five days, the eggs could not be induced to hatch; they collapsed when dried which probably indicates that they were killed. Casual laboratory observations by the writer indicate that the eggs are more resistant to desiccation than is generally the case with ground-pool *Aedes*. Horsfall (1955) says that eggs will not hatch unless first dried. Howard *et al.* also state that the eggs do not all hatch after a single wetting, a few hatching after each rain.

Larvae appear in breeding places shortly after a rain and develop quickly. The larvae are predaceous and feed particularly on other mosquito larvae; larvae taken in Minnesota were found only with those of *Aedes vexans*. They are also cannibalistic. The act of feeding has been described at some length by Howard *et al.* (1913a). Breland (1948) found that *Megarhinus* (= *Toxorhynchites*) larvae, which are also predaceous, would feed on fruit flies on the surface of water but larvae of *ciliata* would not. Ross (1947) found that large larvae would eat 3 to 4 mosquito larvae a day.

The larvae are usually found in breeding places which dry quickly after a rain and so are believed to be frequently killed by drying; in fact Howard *et al.* (1917) believe that a second rain in less than a week after hatching is usually necessary for larvae to complete their development.

DISTRIBUTION — Eastern North America from southeast Canada to Central America. In Minnesota this species has been taken only in Wabasha, Northfield, and in or near St. Paul. The 1953 outbreak of this species in St. Paul was probably due to the extended warm weather in the fall of 1952 and the mild winter of 1952-1953. The following winter (1953-1954) was also mild and the species was taken again in the summer of 1954. Two females were taken by T. A. Gochenour in Northfield in July, 1955. It seems likely that Minnesota is on the northern edge of the range of this species; it probably is able to survive only mild winters here, being wiped out during severe ones.

Importance — Although this species bites severely, its overall aspect is probably beneficial since the larvae consume such large numbers of larvae of other mosquitoes. It rarely occurs in such numbers as to be troublesome.

Psorophora (Janthinosoma) horrida (Dyar and Knab)

This mosquito was first reported from Minnesota by Riley and Chalgren (1938, 1939) as "*Psorophora posticata*", a synonym of *P. ferox.* All (of 5) recognizable specimens collected by these authors key to *horrida,* although they cannot be definitely separated from *longipalpis; ferox* is still unknown in the state. There have been no Minnesota records of *horrida* since those of Riley and Chalgren.

Female — Medium-sized. Proboscis dark scaled. Mesonotum with a broad, median stripe of dark brown scales, white scales at the sides. Abdominal terga covered with dark scales with purplish reflections, apical portions white scaled at the sides. Wing scales dark. Legs mostly with dark scales having purplish reflections; femora largely dark scaled, with white scales posteriorly and ventrally; white knee spots present; remainder of each leg dark except for last two segments of hind tarsi which are white.

Male terminalia (fig. 72, based on specimens from Mississippi) — The peculiar, bulbous dististyle will separate this species from all others known from Minnesota. Basistyle rather elongate, lacking basal and apical lobes, rather truncate at apex. Claspettes present, main filament tortuous, inserted at apex. Dististyle bulbous, lacking conspicuous setae, with distal claw. The terminalia are said to be identical with those of *P. ferox.*

Pupa — Undescribed.

Larva (Minnesota specimens not seen by the author; description from literature) — Head wider than long. Antennae about as long as or longer than head. Head hairs with about 2 to 3 branches. Eighth segment with about 6 to 8 long comb scales. Anal segment completely encircled by saddle, a number (14 or so) of tufts of the ventral brush passing through holes in the saddle. Air tube bulbous, with only a few (about 3 to 5) pecten spines; tuft small, not associated with pecten. The larva is said to be rather similar to those of *longipalpis, ferox,* and *varipes.*

Egg — Described and figured by Howard *et al.* (1913b, 1917) and Horsfall *et al.* (1952).

Biology — Practically all that is known of the biology is included in a paper by Roth (1945b). Overwintering is by the egg stage. The eggs are probably laid on moist soil around the edges of rainpools or in moist depressions; the process is described by Roth. Eggs will hatch the same season they are laid, particularly if allowed to dry first; Newkirk (1955) hatched eggs in a grass infusion. Larvae are found particularly in temporary rainpools; they have also been taken abundantly in bottomland pools (Ross, 1947). The larval stages probably require a week or less in the field. Females rest on low vegetation close to the ground and attack readily when disturbed; they will take up to 9 blood meals (Carpenter and LaCasse, 1955) and probably live about a month in nature. Newkirk (1955) got a maximum of 51 eggs from a single female.

Distribution — Eastern United States from Maryland to Florida and west to Texas and Kansas. The Minnesota records appear to be the most northern ones for this species; known only from Hennepin Co. in the state.

Importance — This species is an invader from the south and probably is not usually present in Minnesota. It could, under unusual conditions, become abundant and would then be an important species but is customarily rare.

GENUS *AEDES*

Key to *Aedes* females of Minnesota

1. Tarsal segments ringed with white ______ 2
1. Tarsal segments not ringed with white _ 8
2. White tarsal rings, especially on hind legs, involving apex of one segment and base of next (fig. 24) ______________________ 3
2. White tarsal rings on the bases of the segments only (figs. 25, 26) ____________ 6
3. Wing scales dark and light intermixed, very largely white-scaled; dorsum of abdomen with white median stripe, often entirely white ___________________________ 4
3. Wing scales dark except sometimes for patch at base of costa; dorsum of abdomen without white median stripe _______________ 5
4. Tarsal claws as in fig. 28 ___ *dorsalis* (p. 107)
4. Tarsal claws as in fig. 27 ___________________ *campestris* (p. 108)
5. Mesonotum with broad, dark brown, median stripe, yellow on the sides; prominent white patch of scales on base of costa; abdomen with complete, white, basal bands on the

terga, at least on the more anterior ones ------------------------- *atropalpus* (p. 93)

5. Mesonotum without dark median stripe, rather evenly reddish brown, paler at the sides; without patch of white scales on base of costa; dorsum of abdomen without complete basal bands, always interrupted medially ------------------ *canadensis* (p. 106)

6. Proboscis (usually[9]) with clearly defined white ring; wing scales dark and light intermingled; dorsum of abdomen with white median stripe, often entirely white; mesonotum with two broad, widely separated yellow stripes, with brown scaling between stripes and on sides ------ *nigromaculis* (p. 97)

6. Proboscis without clearly defined white ring; wing scales variable; dorsum of abdomen usually without white median stripe, rarely entirely white; mesonotum not as above -- 7

7. Tarsal rings very narrow (fig. 26); white tergal bands "B"-shaped; wing scales dark except for a few pale ones at base of wing; mesonotum reddish brown, without stripes of any kind ------------------- *vexans* (p. 88)

7. Tarsal rings broad, especially on the hind legs (fig. 25); pale bands on terga not "B"-shaped; wing scales often dark and light intermixed; mesonotum variable, often striped ------------------------------- *stimulans* group (p. 98)

8. Dorsum of abdomen with a white median line, entirely white, or at least with a scattering of pale scales down the median line; mesonotum dark brown centrally, whitish at the sides; wings light scaled except for C, R_1, R_{4+5}, and Cu ------------- *spencerii* (p. 113)

8. Dorsum of abdomen with basal white bands on the terga, either complete or interrupted, or entirely dark-scaled, never with median white stripe; mesonotum variable; wings dark scaled, except at base or on subcosta in some species -------------------------- 9

9. Sides of mesonotum and thorax covered with dense, broad, flat, brilliant white scales; central area of mesonotum with dark brown scales; dorsum of abdomen with white lateral triangles on the bases of the terga ---------------------------- *triseriatus* (p. 95)

9. Thorax without broad, flat, brilliant white scales, usually they are rather dingy, narrower, and curved; mesonotum not as above; often with complete basal bands on terga --------------------------------------- 10

10. Mesonotum with two broad, well separated stripes of white scales; median stripe and sides of mesonotum dark brown; postpronotum largely dark-scaled; dorsum of abdomen with white lateral triangles at bases of more posterior terga ---- *trivittatus* (p. 109)

10. Mesonotum variable, never with five stripes colored as above; postpronotum usually pale-scaled; abdominal bands usually complete ---------- *communis* group (p. 110)

Aedes males

Male *Aedes* can sometimes be identified by running them through the key to females; in those cases where the specimen cannot be thus identified it is usually necessary to dissect the terminalia. It is for this reason that keys to males are not ordinarily given.

In identifying male *Aedes* the specimen should first be run through the key to females; the worker will then have narrowed down the identity of the specimen. If dissection is then necessary, the terminalia should be mounted by the schedule given on page 18.

Key to male terminalia of *Aedes* of Minnesota

1. Dististyle forked at base and at apex, claw absent; dististyle inserted well before apex of basistyle; the latter produced into a prominent point (fig. 35) ---- *cinereus* (p. 87)

1. Dististyle never forked at base, inserted at or near apex of basistyle; the latter not produced into point at apex ---- 2

2. Claw of dististyle situated subapically; the latter flattened, obliquely truncate at apex; claspettes tipped with setae; filament absent (fig. 34) ---------- *vexans* (p. 88)

2. Claw of dististyle apical; dististyle cylindrical, not flattened, not truncate unless broken; claspette filament present ---- 3

3. Claspette filament with transverse striations; basal lobe small with one or two long, thin, light-colored, posteriorly-directed spines, the longer one of which is several times the length of the basal lobe; basal lobe without basal spine (fig. 73) ---------- *trichurus* (p. 120)

3. Claspette filament without transverse striations; if large, posteriorly-directed spines are present on basal lobe, they are short, dark, and stout (fig. 76) or there are several (fig. 91); basal spine (fig. 76) usually present) -- 4

4. One or two large, dark, curved, posteriorly-directed spines on posterior margin of basal lobe (figs. 75, 76, 77); claspette filament fenestrated -------------------------- 5

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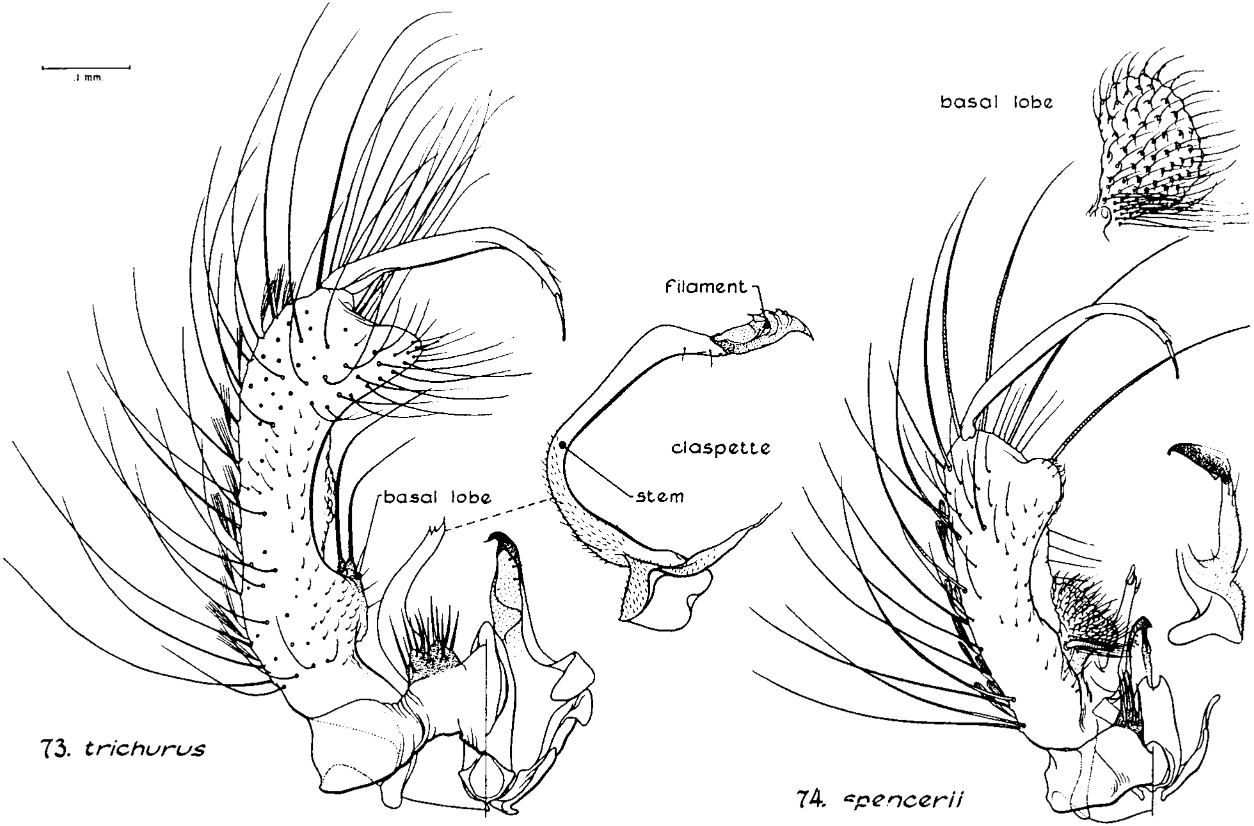
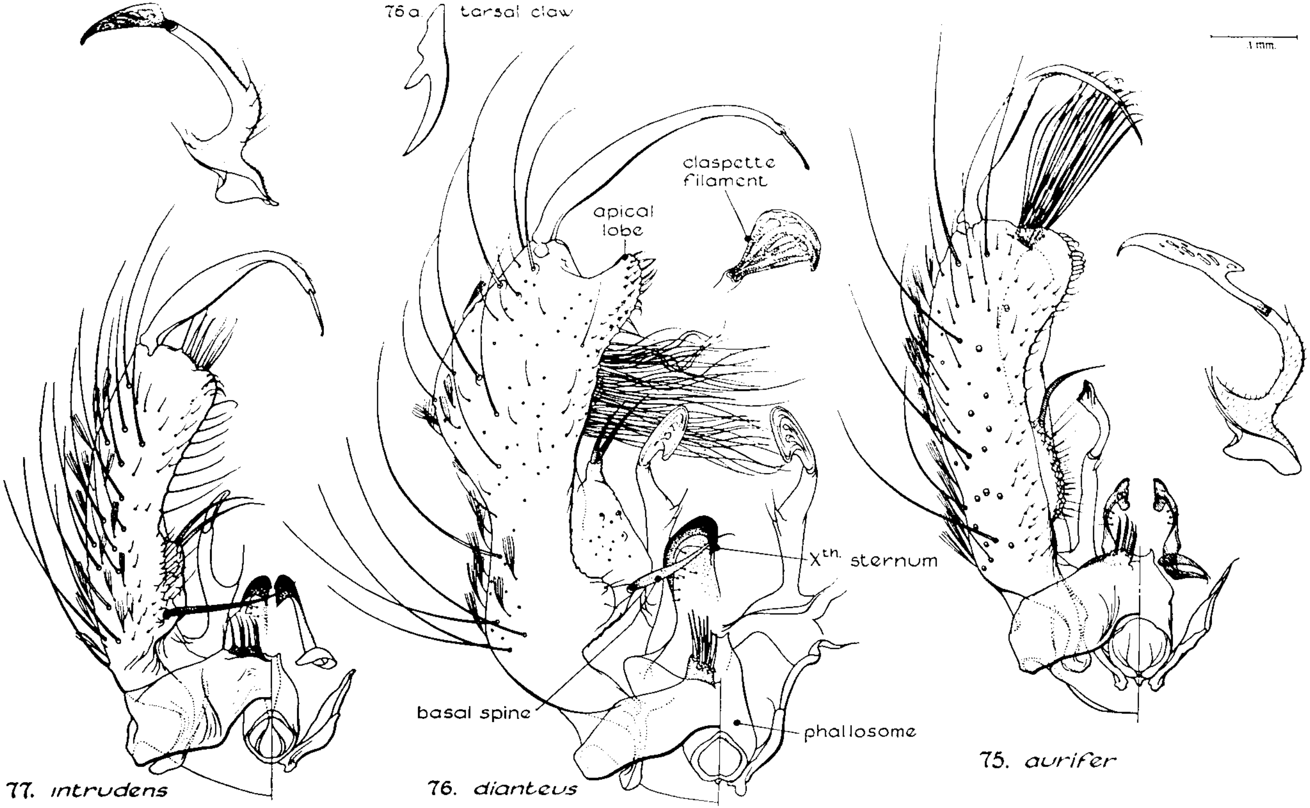
[9] According to Carpenter and LaCasse (1955).



73. *trichurus*

74. *spencerii*

PLATE 18 (figs. 73, 74). Male terminalia of *Aedes*.



77. *intrudens*

76. *dianteus*

75. *aurifer*

PLATE 19 (figs. 75, 76). Male terminalia of *Aedes*.

4. Basistyle without such posteriorly-directed spines on the posterior margin of the basal lobe or with three or more smaller, lighter ones (fig. 83); claspette filament not fenestrated ---------------------------------- 7

5. Basal spine absent; claspette filament with retrorse spine on outer side; a single, large, posteriorly-directed spine on basal lobe; apex of basistyle with prominent posteriorly-directed tuft (fig. 75) ------ *aurifer* (p. 121)

5. Basal spine present; claspette filament without retrorse spine on outer side; a pair of posteriorly-directed spines on each basal lobe; apex of basistyle with (fig. 77) or without (fig. 76) a posteriorly-directed tuft ------ 6

6. With very prominent, medially-directed tuft at base of apical lobe; claspette filament highly expanded medially, about as wide as long; without posteriorly-directed tuft on apex of basistyle (fig. 76) -- *dianteus* (p. 123)

6. Without prominent, medially-directed tuft at base of apical lobe; claspette filament not highly expanded medially, much longer than wide; with prominent posteriorly-directed tuft on dorso-medial face of apex of basistyle (fig. 77) ------------------ *intrudens* (p. 122)

7. Lobes of ninth tergum with conspicuous setae; apical lobe usually present; basal lobe usually well developed; claspette filament variable, usually expanded --------------- 8

7. Lobes of ninth tergum without conspicuous setae, with microscopic pubescence only, the lobes are often difficult to see at all; apical lobe absent; basal lobe indicated only by a setiferous area; claspette filament cylindrical, not flattened (fig. 36) ----- *atropalpus* (p. 93)

8. Basal spine absent ------------------------ 9

8. Basal spine present (as in fig. 87) although sometimes very light and difficult to see (fig. 82) ------------------------------- 12

9. Claspette filament noticeably expanded and flattened (figs. 78, 80); basal lobe a long, flattened, setiferous area on medial face of basistyle (figs. 78, 80) ------------------------------ *barri* (p. 101), *excrucians* (p. 100)

9. Claspette filament not expanded, not noticeably flattened; basal lobe not long, either raised and rather circular (fig. 81) or reduced or absent (figs. 84, 85) ---------- 10

10. Basal lobe large, raised, with flat surface facing posterio-ventrally; apical lobe with prominent patch of flattened setae (fig. 81) ---------------------- *canadensis* (p. 106)

10. Basal lobe a flattened setiferous area; apical lobe without such a patch of setae (figs. 84, 85) ---------------------------------- 11

11. Medial face of basistyle with prominent tuft at outer third; basal lobe absent; dististyle less than half as long as basistyle (fig. 85) ------------------------ *triseriatus* (p. 95)

11. Medial face of basistyle without prominent tuft at outer third; basal lobe small, represented by dense tuft of setae; dististyle at least half as long as basistyle (fig. 84) ---------------------- *nigromaculis* (p. 97)

12. Basal lobe with a single short, stout spine lateral of the basal spine; apical lobe small; basal lobe with flat surface facing medio-posteriorly (fig. 82) -------- *dorsalis* (p. 107)

12. Basal lobe with basal spine but without accessory spine as above; apical lobe usually large; basal lobe not shaped as above except in *campestris* (fig. 83) ---------------- 13

13. Basal lobe with about three stout spines on anterior (ventral) margin lateral of basal spine; the spines are similar to, but much wider than the setae of the basal lobe; apical lobe small; basal lobe with flat surface facing medio-ventro-posteriorly (fig. 83) ---------------------------- *campestris* (p. 108)

13. Basal lobe without such spines in addition to the basal spine; apical lobe usually large; basal lobe not as above --------------- 14

14. Claspette filament expanded only on outer half, angle of expansion near middle of filament; posterior margin of basal lobe sloping gently to the basistyle (fig. 88) ------------------------------ *stimulans* (p. 102)

14. Claspette filament expanded on basal as well as on outer half, angle of expansion closer to base than to middle; posterior margin of basal lobe usually not as above ------- 15

15. Claspette filament with small basal lobe on inner side (figs. 74, 89) ------------ 16

15. Claspette filament without such a lobe - 17

16. Basal lobe with deep incision on posterior margin, situated on medial face of basistyle; apical lobe rounded, without incision at apical junction with basistyle; claspette stem with several setae near base of filament (fig. 74) ----- *sticticus* (p. 111), *spencerii* (p. 113)

16. Basal lobe without deep incision on posterior margin, continuous with ventral face of basistyle; apical lobe conical, with incision at apical junction with basistyle; claspette stem without setae near filament (fig. 89) ------------------------------ *fitchii* (p. 102)

17. Claspette filament with retrorse spine and accessory denticles (fig. 86) ---------------------------------- *trivittatus* (p. 109)

17. Claspette filament usually without retrorse spine; if present (fig. 87), accessory denticles absent ---------------------------- 18

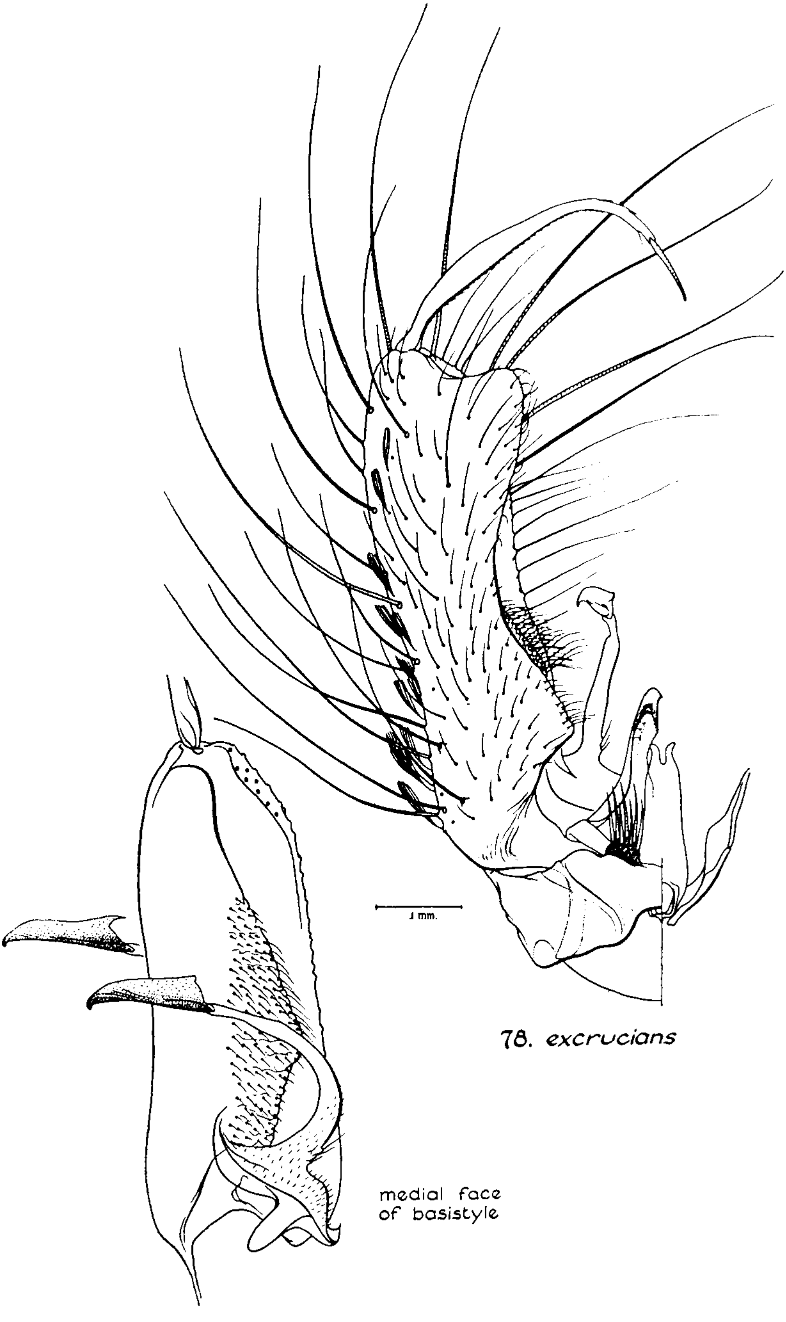
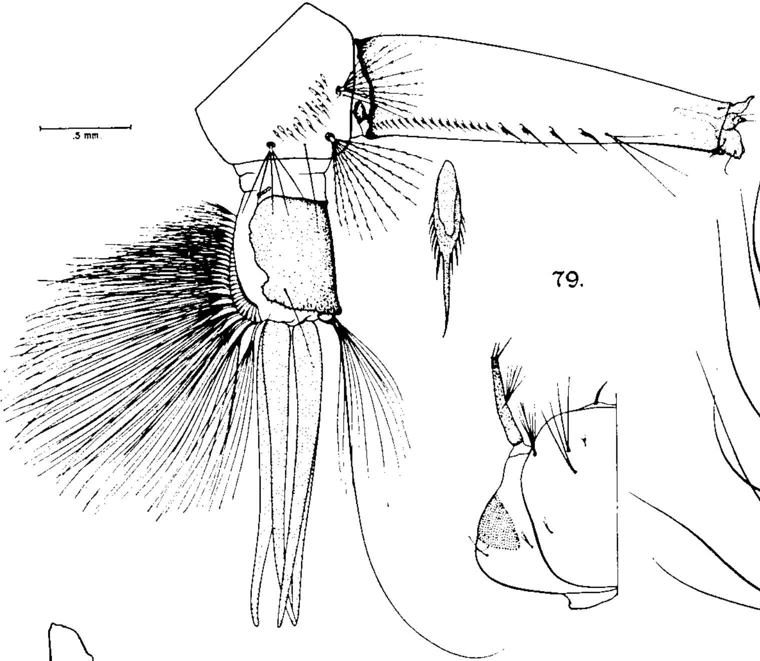


PLATE 20 (fig. 78). Male terminalia of *Aedes*.



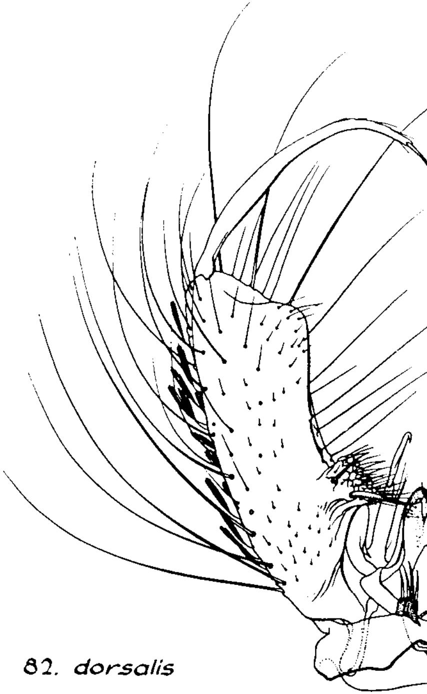
79.

79a.

80.

PLATE 21 (figs. 79, 80). Larva, female claw, and male terminalia of *Aedes barri.*

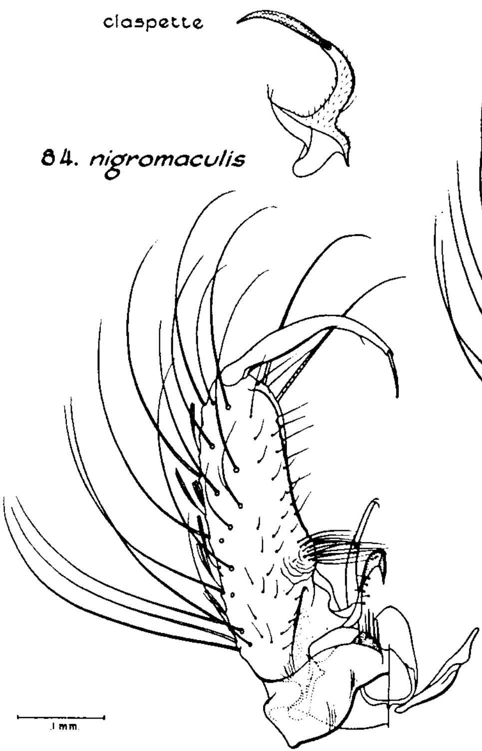
81. *canadensis*



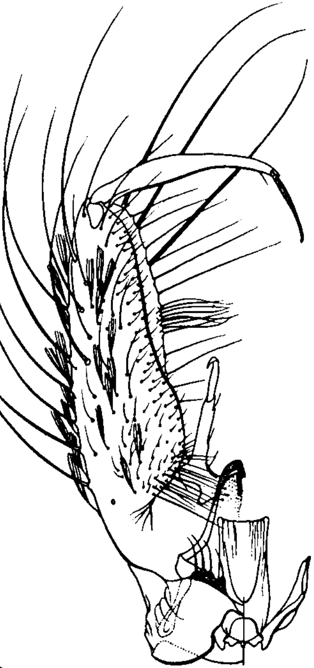
82. *dorsalis*

83. *campestris*

PLATE 22 (figs. 81-83). Male terminalia of *Aedes*.



84. *nigromaculis*

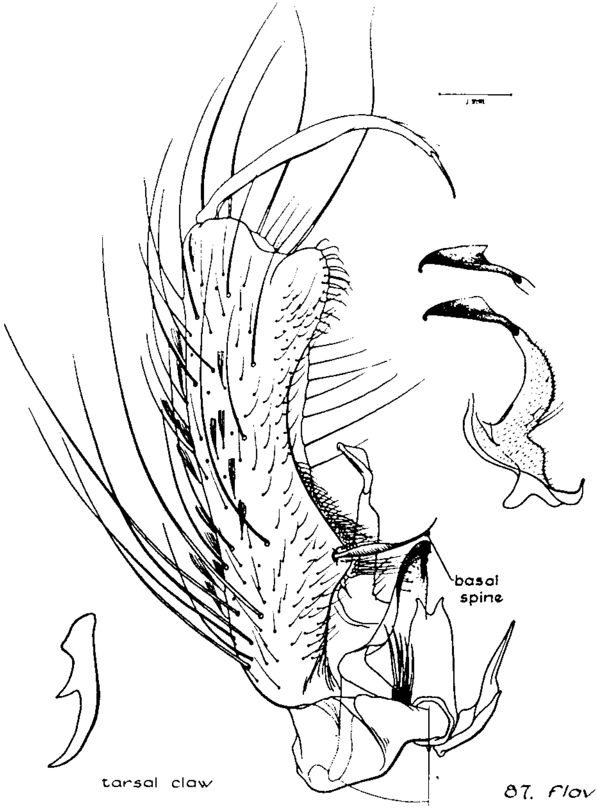


85. *triseriatus*

86. *trivittatus*

PLATE 23 (figs. 84-86). Male terminalia of *Aedes*.

PLATE 24 (figs. 87, 88). Male terminalia of *Aedes*.



87. flavescens

88. stimulans

89. *fitchii*

90. *riparius*

PLATE 25 (figs. 89, 90). Male terminalia of *Aedes*.

18\. Basal lobe with apex curved posteriorly and with prominent tuft directed medio-posteriorly (fig. 90) ------------ *riparius* (p. 105)

18\. Basal lobe with apex not curved posteriorly and with tuft not directed medio-posteriorly ------------ 19

19\. Posterior margin of dorsal portion of basal lobe with several light, posteriorly-directed spines; claspette filament with strong longitudinal ridges on its lateral surface, shaped as in fig. 91; apical lobe with small setae on the ventral face ------------ *communis* (p. 115), *pionips* (p. 117)

19\. Basal lobe without such posteriorly-directed spines; claspette filament without strong longitudinal ridges or if with light ridges (fig. 92) the ventral face of the apical lobe has no setae, only microscopic pubescence; claspette filament variable, usually not as in fig. 91 ------------ 20

20\. Anterior margin of basal lobe a smooth, gentle curve; claspette stem usually with prominent bulge on medial face; claspette filaments as in fig. 87 ---- *flavescens* (p. 101)

20\. Anterior margin of basal lobe not a smooth, gentle curve; claspette stem without prominent bulge on medial face; claspette filament not as in fig. 87 ------------ 21

21\. With tuft of long hairs at base of apical lobe; if these hairs are missing there is a compact group of large sockets in this location; claspette filament with longitudinal striae, shaped as in fig. 92 ------------ *implicatus* (p. 113)

21\. Without tuft at base of apical lobe; claspette filament without longitudinal striae, shaped as in fig. 93 or fig. 94 ------------ 22

22\. Basal lobe strongly produced medially, wider than long; claspette filament as in fig. 94 ------------ *abserratus* (p. 117)

22\. Basal lobe not strongly produced medially, as long as or longer than wide; claspette filament as in fig. 93 ---------- *punctor* (p. 118)

Aedes pupae

A system of chaetotaxy of mosquito pupae (Belkin, 1952) is as given in fig. 47. A key to the known pupae of North American *Aedes* is given by Darsie (1951) but this work must be consulted in the original for purposes of identification.

Aedes larvae

The following key to larvae is a tentative one since the author has not seen Minnesota larvae of some species (*campestris*) and has scanty material of some others (*riparius, flavescens, stimulans*) which, in some cases, is not definitely associated with adults. In addition to these difficulties, larvae are very variable and this variability has, in most cases, not been adequately described. Occasional larvae are abnormal and may be unidentifiable unless associated with normal ones. The characteristics used in identifying larvae are, for the most part, quantitative, not qualitative and such characters are difficult to use in the ordinary dichotomous key. The best key that the author has used is one that utilizes punch-cards (Barr, 1954b). With a key of this type quantitative characters are very useful.

A general discussion of the morphology of *Aedes* larvae will not be given except to comment on certain characters. The key is designed for fourth instar larvae and will not always identify third instars correctly. In general third instars have smaller heads and fewer branches in all hairs. The most reliable method of detecting third instars is to examine the anal saddle which is larger in fourth instars. Third instars usually have the saddle extending a third or less down the sides of the anal segment. The lateral hair is practically always near the ventral edge of the saddle in thirds. The only obvious exception is *atropalpus* (fig. 105) which has a short saddle in the fourth instar with the lateral hair placed below the saddle. Third instars are usually identifiable if it is remembered that the branching of the hairs is usually less than in fourth instars. There appear to be no important differences in the number of comb scales in third and fourth instar larvae as a rule.

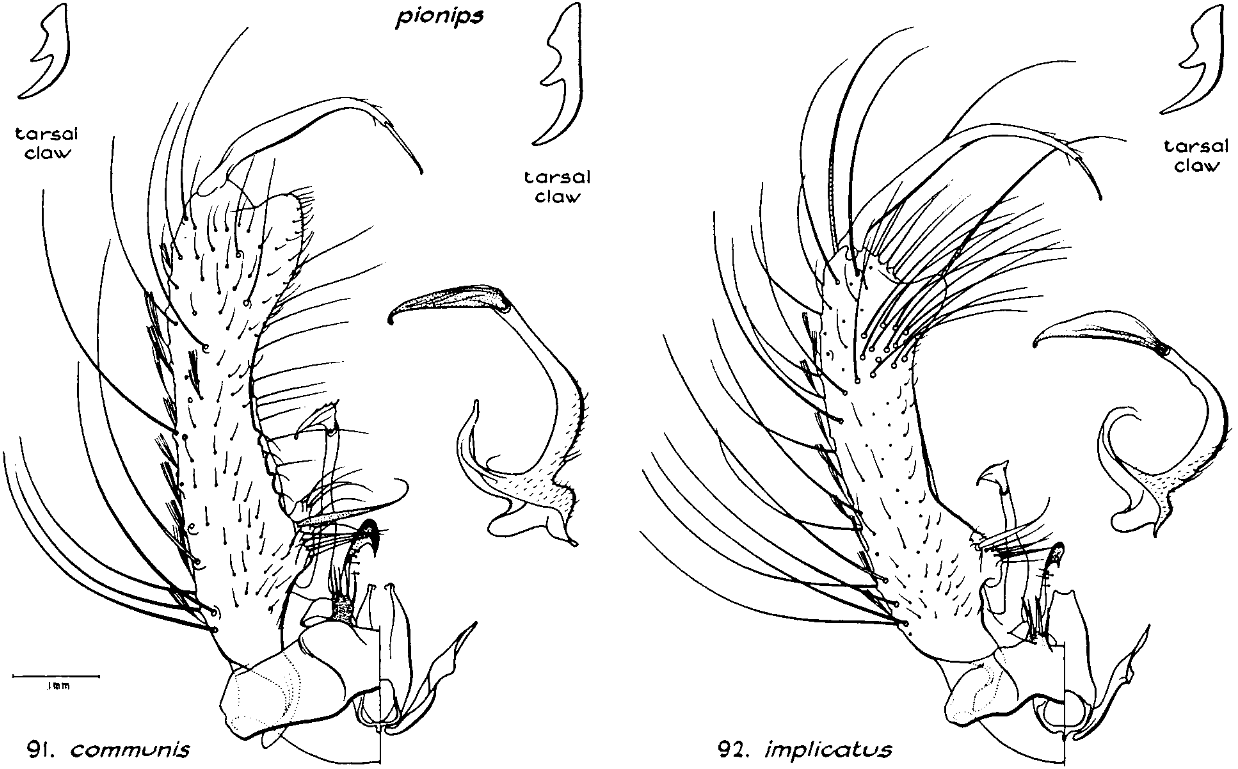
The hairs used are shown in fig. 55. The siphonal index, as used in this work, relates the total length of the siphon to its width in the middle. The length of the siphonal tuft is, in all cases, related to the width of the siphon at the point where the tuft is inserted.

Key to fourth instar *Aedes* larvae of Minnesota

1\. Siphon with 4 or 5 pairs of dorsal hair tufts; with 2 or 3 pairs of extra, lateral hair tufts; pecten with several detached teeth; siphonal tuft proximal of outer pecten teeth (fig. 63) ------------ *trichurus* (p. 120)

1\. Siphon without such dorsal or (usually) extra lateral hair tufts; pecten and siphonal tuft variable ------------ 2

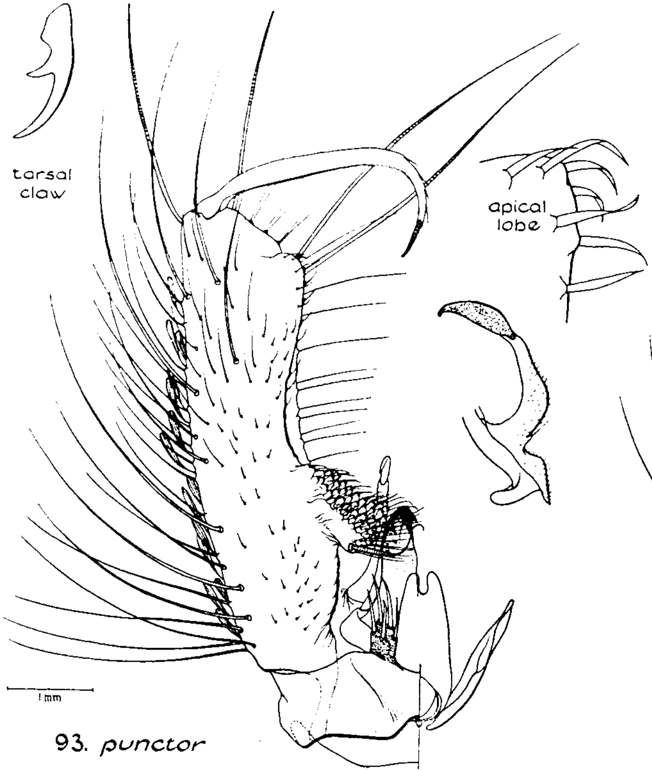
2\. Anal plate completely encircling anal segment, without tufts ventral of saddle, all are posterior of it; and usually with no or one



91. *communis*

92. *implicatus*

PLATE 26 (figs. 91, 92). **Male terminalia of** ***Aedes.***



93. *punctor*

94. *abserratus*

PLATE 27 (figs. 93, 94). **Male terminalia of *Aedes*.**

tuft preceding barred area; upper and lower head hairs usually single (sometimes double, occasionally one is triple) (figs. 95, 96, 97, 113) ------ 3

2. Anal plate not completely encircling the anal segment, the sides of the plate do not fuse on the midventral line of the segment, frequently with several tufts ventral of saddle and preceding barred area; head hairs variable ------ 6

3. Pecten with distal teeth (usually 2 to 4) strongly detached; pecten usually extends over 2/3 the length of the siphon; antennae about one-third the length of the head (fig. 97) ------ *nigromaculis* (p. 97)

3. Pecten with teeth usually regularly spaced, none detached (if as many as two teeth are detached the pecten is confined to the basal half of siphon and the hairs are very coarse); pecten confined to basal half of siphon; antennae closer to one half the length of the head than one third ------ 4

4. Average comb scale with very large terminal spine, lateral spinelets minute; siphonal tuft about as long as width of siphon at point of insertion; lateral hair of anal segment about as long as dorsal surface of anal plate; posterior shoulder hair and its 2 associated hairs stout, usually reaching to front of head ------ 5

4. Average comb scale with terminal spine not much larger than lateral spinelets; siphonal tuft not as long as width of siphon at point of insertion; lateral hair of anal segment distinctly shorter than dorsal surface of anal plate; posterior shoulder hair and its 2 associated hairs fine, not reaching to bases of head hairs (fig. 96) ------ *trivittatus* (p. 109)

5. Inner hair of dorsal tuft of anal segment single; with 7 or fewer comb scales (fig. 113) ------ *abserratus* (p. 117)

5. Inner hair of dorsal tuft of anal segment multiple (usually 4- to 7-branched); usually with 8 or more comb scales (fig. 95) ------ *punctor* (p. 118)

6. Head hairs in straight line with postantennal tuft (fig. 101); comb scale with strong central tooth; usually with all head hairs branched ------ 7

6. Head hairs not in straight line with postantennal tuft, the lowers are considerably anterior of as well as somewhat lateral of the uppers (fig. 102); comb scales variable; sometimes with 2 or more single head hairs ------ 9

7. All head hairs usually with 4 or more branches; antennae markedly shorter than head, usually about 2/3 as long; antennal tuft on basal half of antenna; usually with fewer than 15 comb scales; siphonal tuft about half as long as width of siphon at point of insertion; lateral hair of anal segment weak, usually branched (fig. 101) ------ *cinereus* (p. 87)

7. All head hairs usually with 3 or fewer branches; antennae about as long as or longer than head, always at least 6/7 as long as head; if antennae are shorter than head the antennal tuft is placed beyond the middle of the antenna and there are usually more than 15 comb scales (fig. 103); siphonal tuft about as long as or longer than width of siphon at point of insertion; lateral hair of anal segment only rarely branched ------ 8

8. Antennal tuft distinctly beyond middle of antenna; antenna about (6/7) as long as head; usually with more than 15 comb scales (fig. 103) ------ *aurifer* (p. 121)

8. Antennal tuft not distinctly beyond middle of antenna, at or near middle; antennae not about as long as head, either distinctly longer or shorter; usually with fewer than 15 comb scales ------ 9

9. Pecten with at least one strongly detached pecten spine (usually 2 or more on each side) ------ 10

9. Pecten with all spines rather evenly spaced (occasionally one is more or less detached from the rest) (fig. 106) ------ 23

10. Antennae about as long as or longer than head; lower head hair usually slightly anterior of a line connecting upper head hair and postantennal tuft; with fewer than 15 comb scales (fig. 104) ------ *dianteus* (p. 123)

10. Antennae much shorter than head; lower head hair not placed as above, usually well anterior of and only slightly lateral of upper head hair (as in fig. 110); frequently with more than 15 comb scales ------ 11

11. Siphonal tuft inserted a considerable distance proximal of distal end of pecten, also ventral of pecten; head roughly oval, not strongly narrowed in front of eyes; comb scales numerous, upwards of 30, without large terminal spine, placed in triangular patch; siphon stubby, usually less than 2½ times as long as wide at middle; lateral hair of anal segment inserted below anal plate; head hairs single (occasionally one or more is double) (fig. 105) ------ *atropalpus* (p. 93)

11. Siphonal tuft inserted distal of pecten (if the tuft is slightly proximal of the end of the pecten, the comb scales have a strong, central spine); head roughly triangular, strongly narrowed in front of eyes; usually with fewer than 30 comb scales; pattern of comb scales

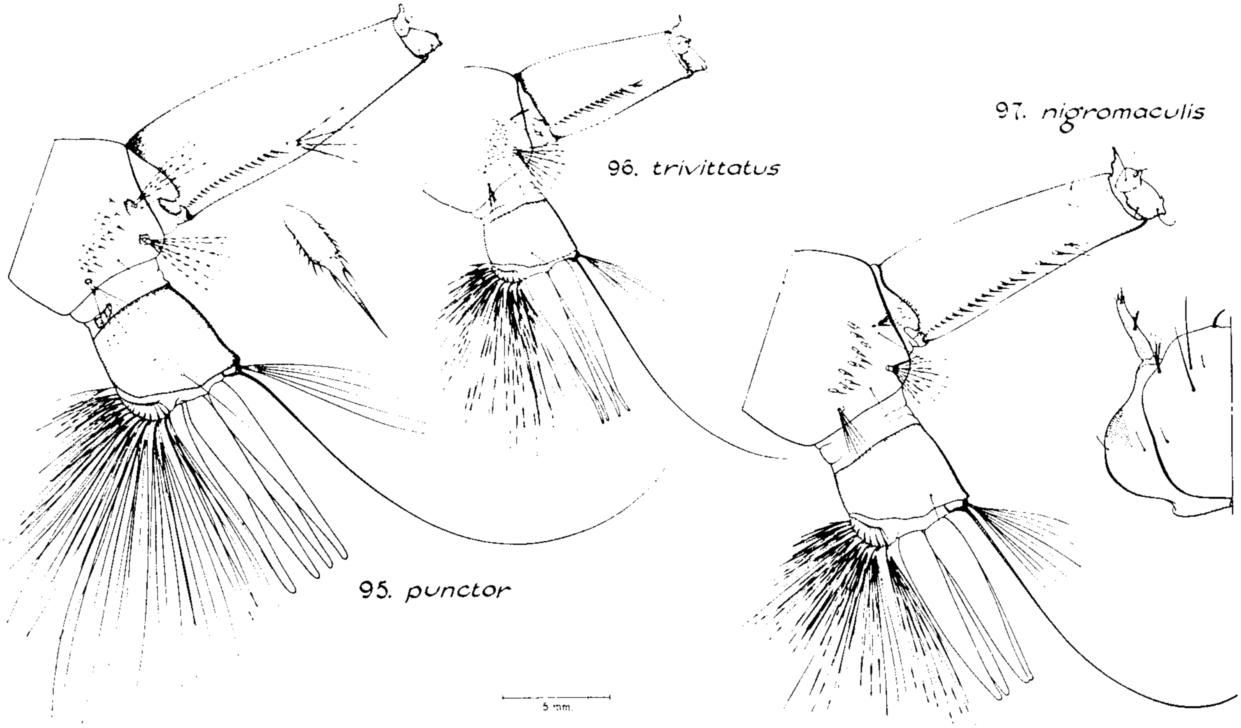


PLATE 28 (figs. 95-97). Larvae of *Aedes*.

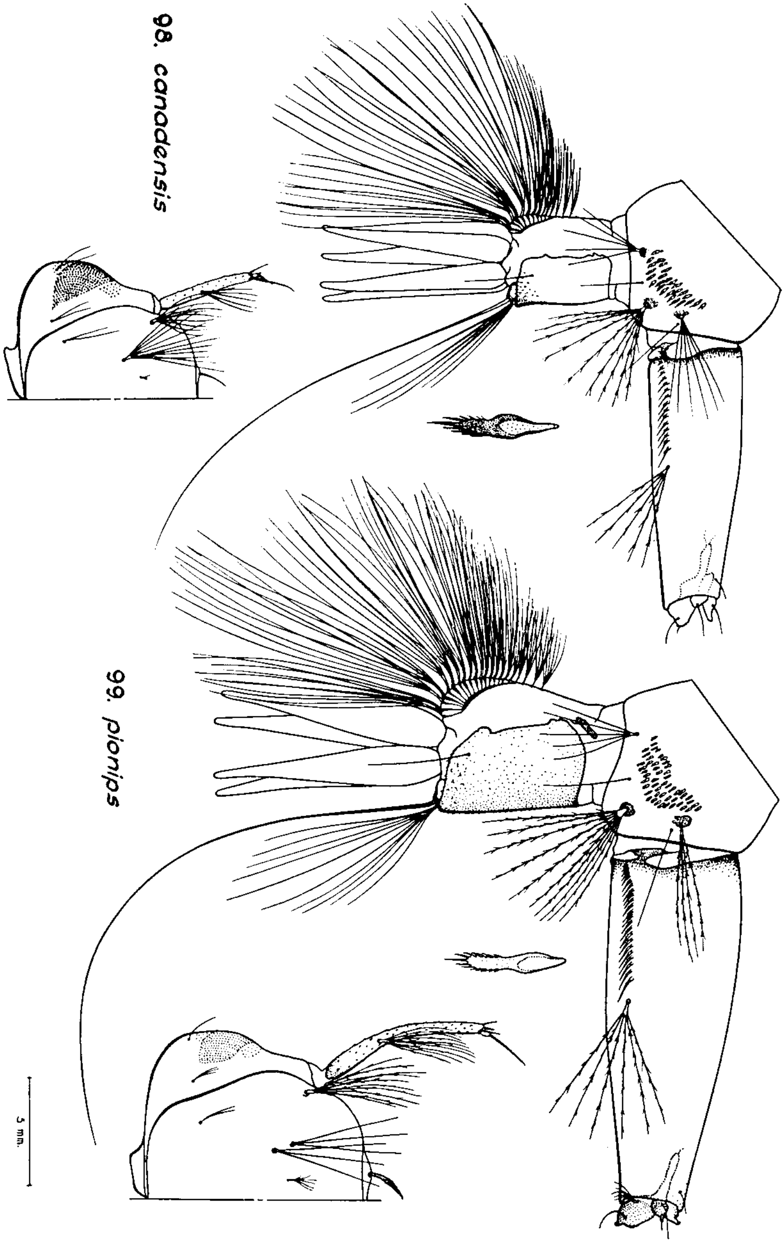
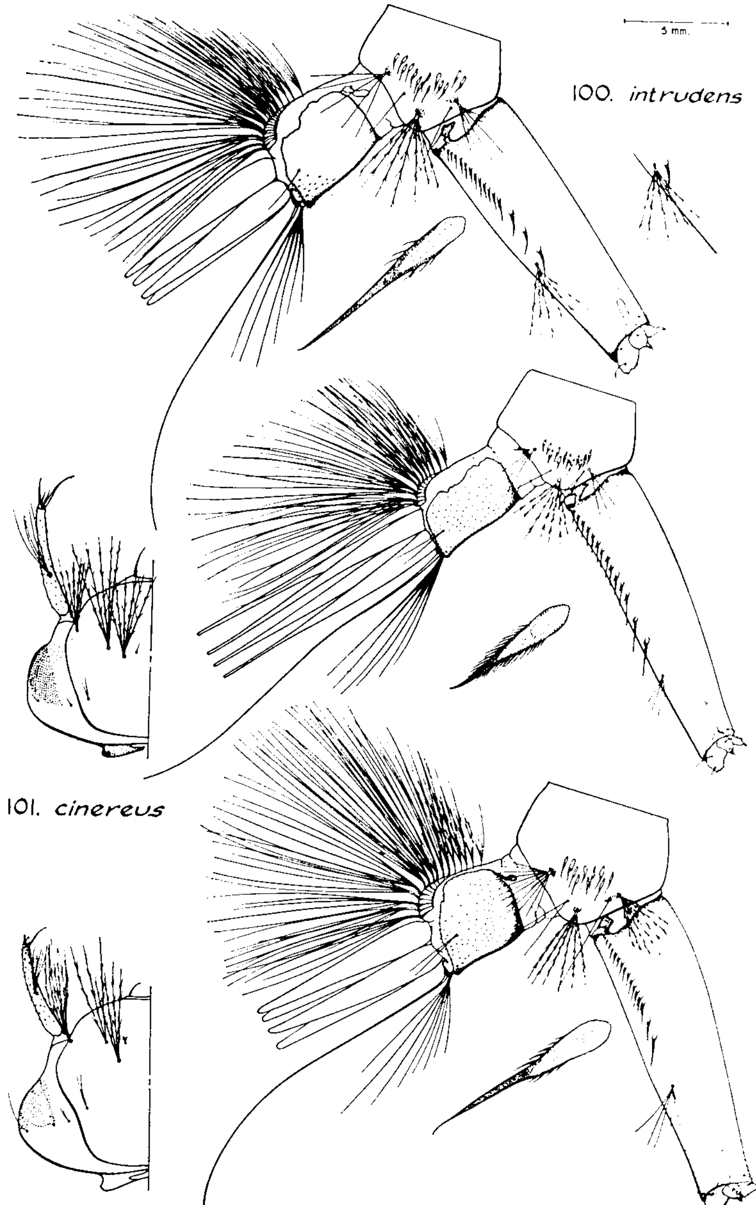


PLATE 29 (figs. 98, 99). Larvae of *Aedes*.

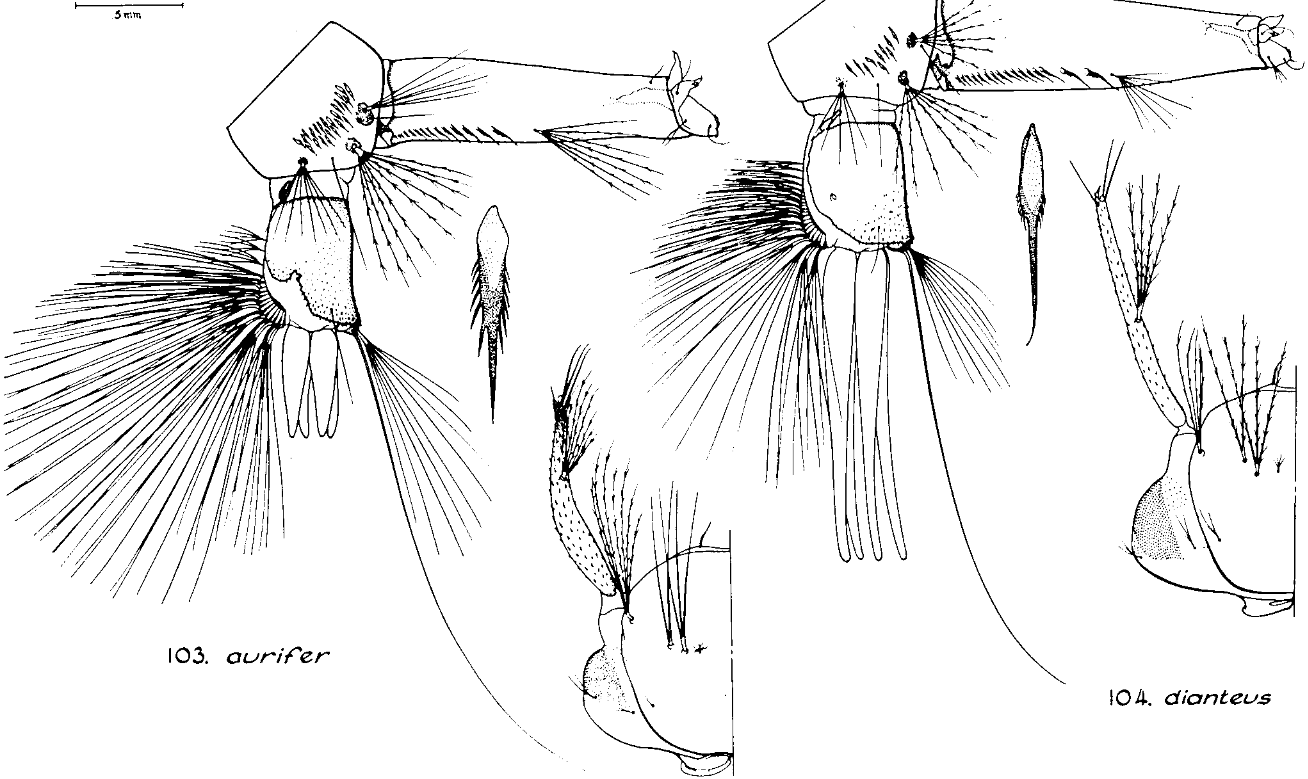


100. *intrudens*

101. *cinereus*

102. *vexans*

PLATE 30 (figs. 100-102). Larvae of *Aedes*.



103. *aurifer*

104. *dianteus*

PLATE 31 (figs. 103, 104). Larvae of *Aedes*.

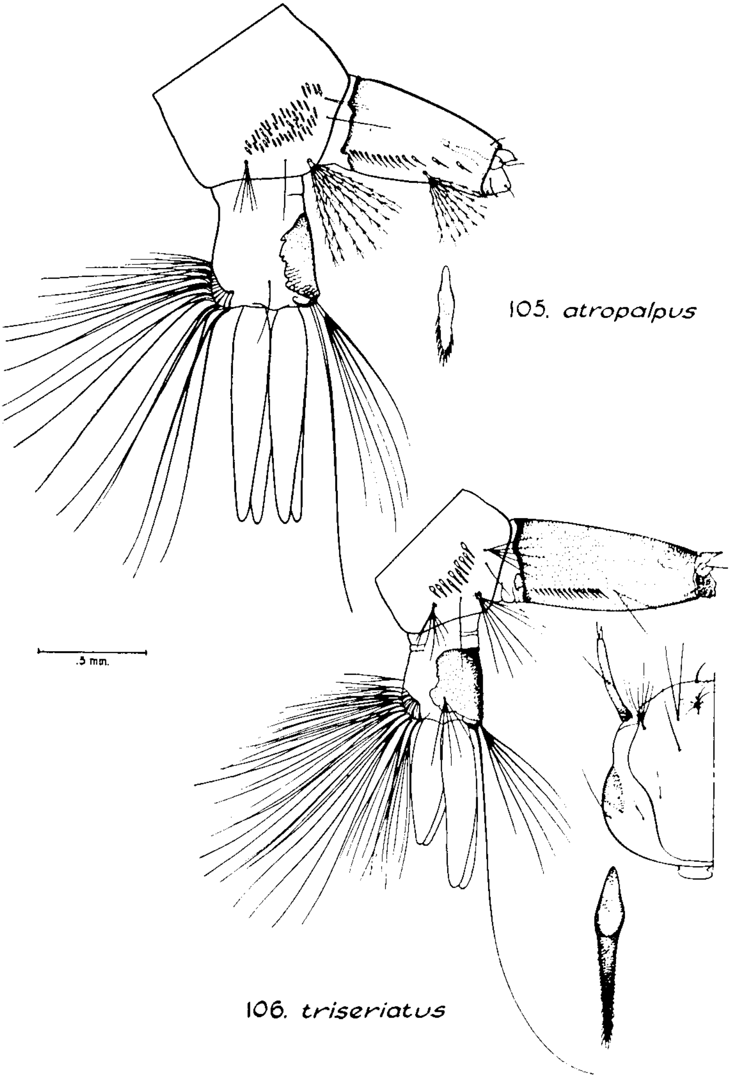


PLATE 32 (figs. 105, 106). Larvae of *Aedes.*

variable but often in single or irregularly double row; siphon usually 3 or more times as long as wide at middle; lateral hair of anal segment inserted on saddle in fourth instar; if most head hairs are single, the siphonal tuft is distinctly beyond the pecten ---------- 12

12. Comb scales 15 or more in triangular patch ---------- 13

12. Comb scales less than 15, often in single or irregularly double row ---------- 16

13. Siphonal tuft about twice as long as width of siphon at point of insertion; siphon about 5 or more times as long as wide at middle; usually with 20 or more comb scales (fig. 108) ---------- *excrucians* (p. 100)

13. Siphonal tuft never much longer than width of siphon at point of insertion, usually noticeably shorter; siphon usually less than 5 times as long as wide at middle, often much less; usually with fewer than 20 comb scales ---------- 14

14. Pecten not extending beyond middle of siphon ---------- 15

14. Pecten extending beyond middle of siphon ---------- 16

15. Siphonal tuft about as long as or longer than width of siphon at point of insertion; practically always with 20 or more comb scales; comb scales in triangular patch; air tube 4 or more times as long as wide; "mesothoracic dorsal principal" small; usually with average of 2 or fewer detached pecten teeth (fig. 107) ---------- *flavescens* (p. 101)

15. Siphonal tuft distinctly shorter than width of siphon at point of insertion (if the siphonal tuft is as long as the width of the siphon, the comb scales lack a large median spine or the mesothoracic dorsal principal is about as large as the head hairs); usually with less than 20 comb scales; comb scales usually not in triangular patch, usually in irregularly double row; siphon often less than 4 times as long as wide; usually with average of more than 2 distinctly detached pecten teeth ---------- 16

16. With 10 or fewer comb scales ---------- 17

16. With more than 10 comb scales ---------- 18

17. Siphonal tuft about as long as, or longer than width of siphon at point of insertion; air tube usually about 4 or more times as long as wide at middle; head hairs usually average 1.5 to 3.5 branches (fig. 110) ---------- *riparius* (p. 105)

17. Siphonal tuft distinctly shorter than width of siphon at point of insertion; air tube often less than 3.5 times as long as wide at middle; if air tube is 4 times as long as wide, the siphonal tuft is weak (has very fine branches); head hairs often average fewer than 1.5 (*spencerii*) or more than 3.5 branches ---------- 18

18. With 19 or more comb scales in triangular patch; comb scales without median spine or with spine not much larger than lateral spines ---------- 19

18. With 18 or fewer comb scales, usually in single or irregularly double row; comb scale with large median spine ---------- 20

19. Prothoracic hairs 1 and 5 branched; pecten extending beyond middle of siphon; lower head hairs usually single; mesothoracic dorsal principle well developed, as large as head hair (fig. 111) ---------- *campestris* (p. 108)

19. Prothoracic hairs 1 and 5 single; pecten usually confined to basal half of siphon; lower head hairs frequently branched; mesothoracic dorsal principle much smaller than head hairs (fig. 114) ---------- *sticticus* (p. 111)

20. Head hairs usually all single (rarely one or more is double); siphonal tuft shorter than width of siphon at point of insertion, usually with 3 to 5 branches (occasionally 6); comb scales average about 10 (5 to 13); antennae about one-third the length of the head (fig. 115) ---------- *spencerii* (p. 113)

20. Head hairs usually double or more highly branched, particularly the uppers (an occasional one is single); length of siphonal tuft variable, often with 6 or more branches; comb scales variable; antennae usually half the length of the head or longer ---------- 21

21. Lateral abdominals on I to V usually all single; siphonal tuft usually closely associated with, ventral of, and often proximal of last pecten tooth; siphonal tuft strong, about 1/2 to as long as width of siphon at point of insertion, with 5 or more branches; posterior shoulder hair strong, usually extending to or beyond head hairs (fig. 100) ---------- *intrudens* (p. 122)

21. Lateral abdominals on I to V mostly branched, usually all double or better; siphonal tuft placed distinctly beyond and often on a level with the last pecten tooth; siphonal tuft either weak and not over half as long as width of siphon at point of insertion or if the branches are strong and as long as the width of the siphon, there are only 2-4 branches; if the posterior shoulder hair extends as far as the head hairs the pecten extends about to the outer third of the siphon ---------- 22

22. Posterior shoulder hair weak, not reaching to head hairs; pecten usually confined to basal half of siphon; siphonal tuft weak, not over half as long as width of siphon at point

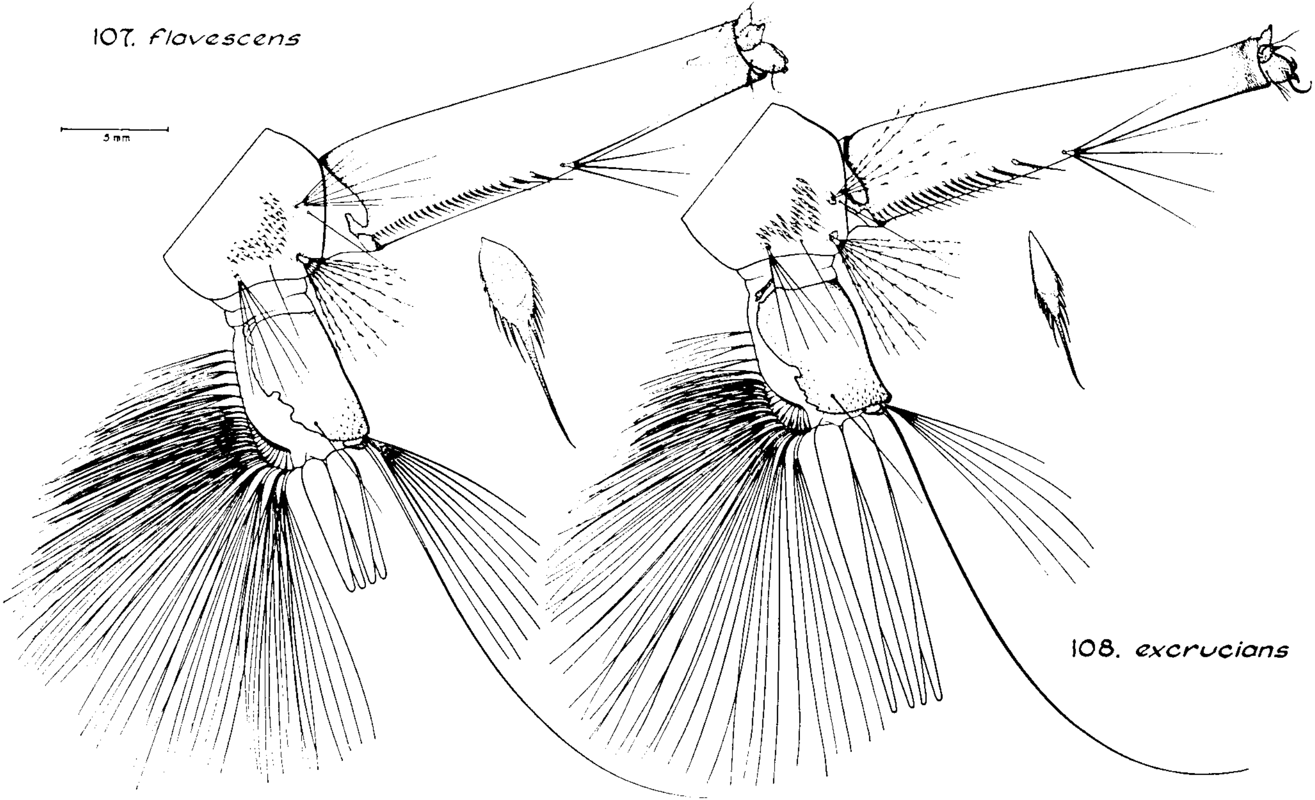


PLATE 33 (figs. 107, 108). Larvae of *Aedes*.

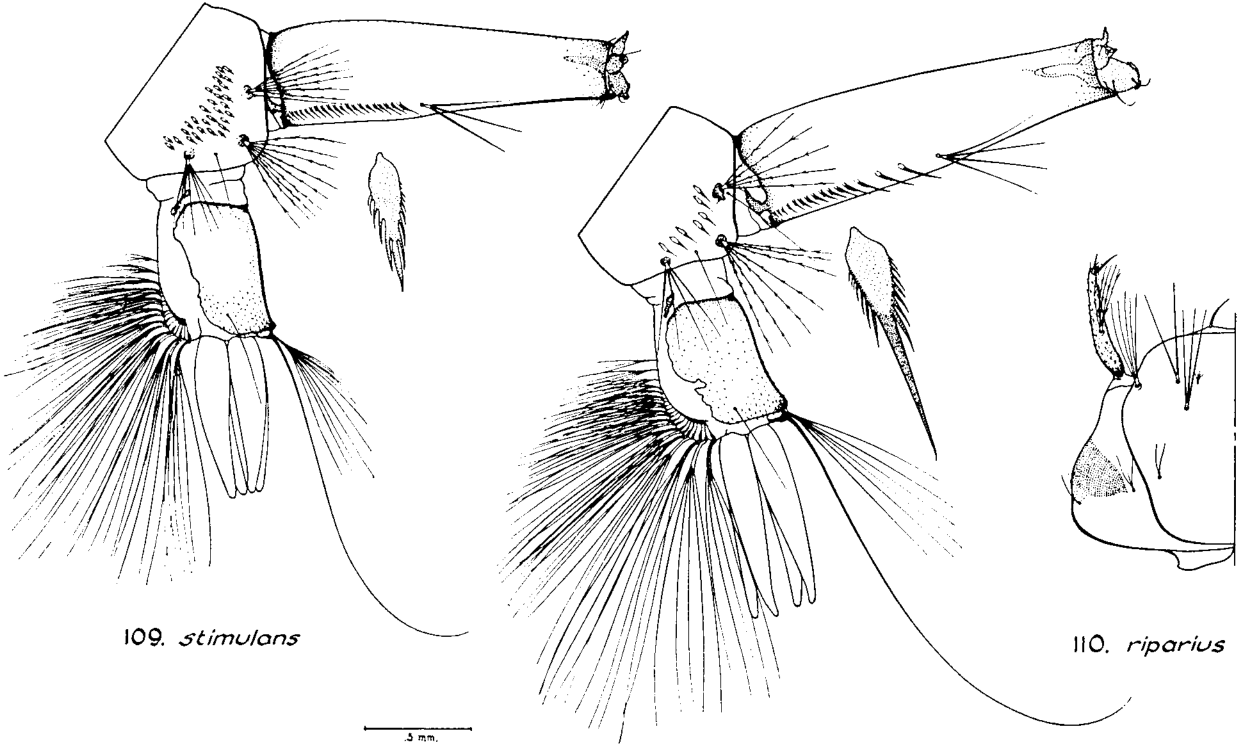


PLATE 34 (figs. 109, 110). Larvae of *Aedes*.

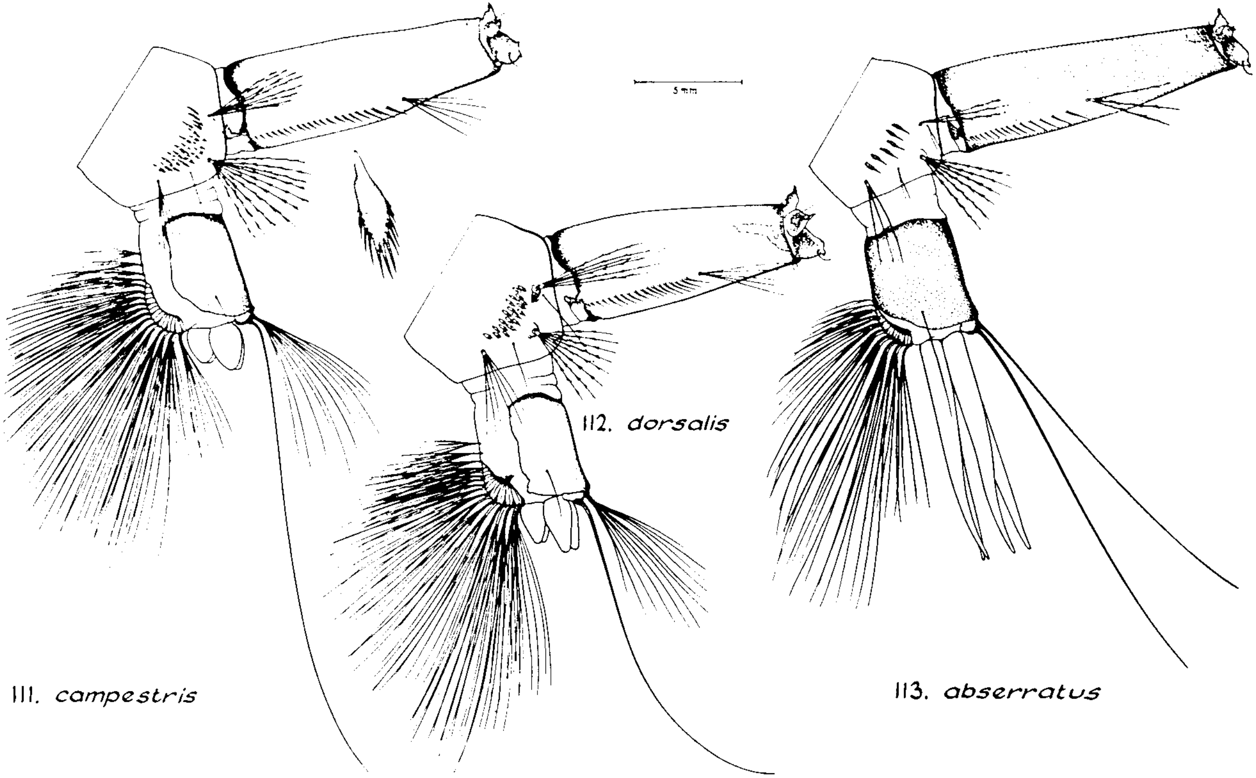
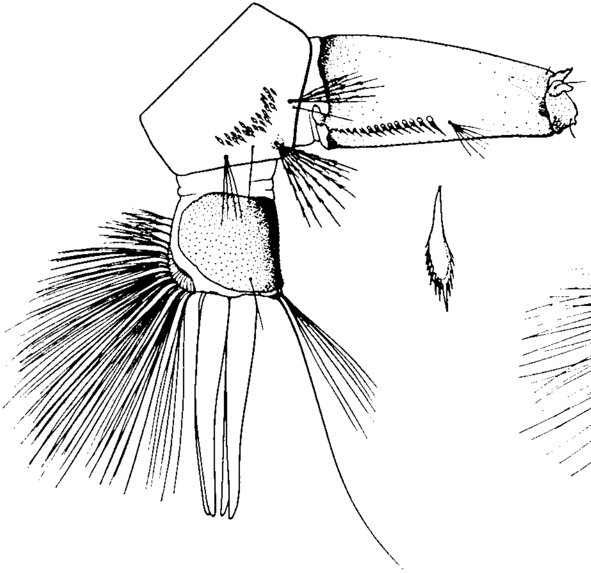
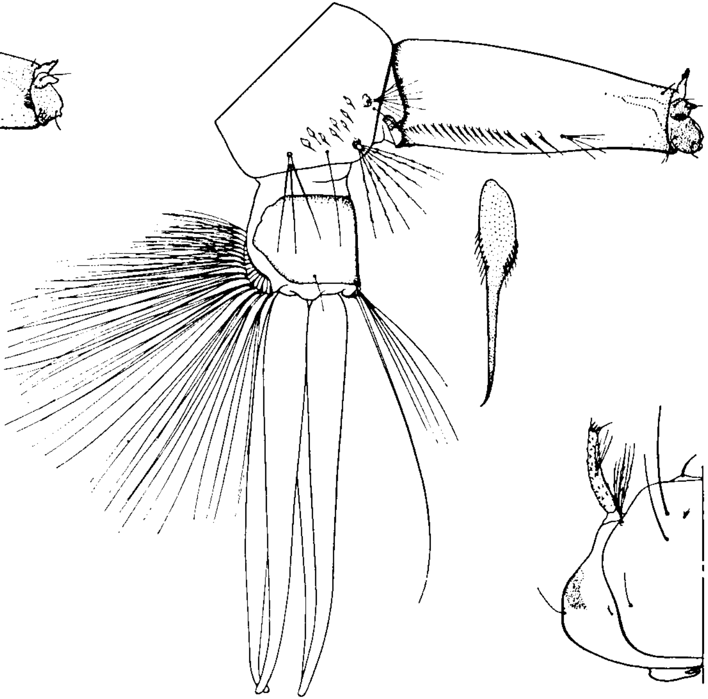


PLATE 35 (figs. 111-113). Larvae of *Aedes.*



114. *sticticus*



115. *spencerii*

PLATE 36 (figs. 114, 115). Larvae of *Aedes*.

of insertion, usually with 5 or more branches (fig. 102) ---------------- *vexans* (p. 88)

22. Posterior shoulder hair strong, reaching beyond head hairs; pecten extends to outer third of siphon; siphonal tuft strong, about as long as or longer than width of siphon at point of insertion, with 4 or fewer branches (fig. 79) ---------------- *barri* (p. 101)

23. Lateral hair of anal segment multiple; comb scales placed in single row although one or two may be slightly out of line; individual comb scales as in fig. 106, about 10 in number; head about as long as wide; antennae glabrous, without tiny spines; antennal "tuft" usually single; siphonal tuft usually single or double (usually from tree holes) ---------------- *triseriatus* (p. 95)

23. Lateral hair of anal segment usually single, rarely double; comb scales usually not in single row, usually in triangular patch; comb scale not shaped as above; usually with 20 or more scales (except *fitchii*); head distinctly wider than long; antennae with numerous small spines; antennal tuft usually multiple; siphonal tuft usually with more than 2 branches ---------------- 24

24. Mesothoracic dorsal principal (fig. 55) very long, usually reaching to head hairs; with dorso-lateral on III as long as width of abdomen; comb scales often with strong terminal spine; siphon usually about 5 or more times as long as wide at middle; siphonal tuft about twice the width of siphon at point of insertion; lateral hair of anal segment longer than dorsal surface of anal plate ---- *fitchii* (p. 102)

24. Mesothoracic dorsal principal weak, never reaching to head hairs; dorso-lateral on III never as long as width of abdomen; comb scales usually without strong central spine (except *flavescens*); siphon usually about 4 or fewer times as long as wide at middle; siphonal tuft usually about as long as or shorter than width of siphon at point of insertion, never twice as long; lateral hair of anal segment usually shorter than dorsal surface of anal plate, never noticeably longer ---------------- 25

25. With 50 or more comb scales ---------- 26

25. With fewer than 50 (usually fewer than 40) comb scales ---------------- 27

26. Head hairs usually all triple or more highly branched; all shoulder hairs (1-3) long, single, reaching to head hairs (fig. 99) ---------------- *pionips* (p. 117)

26. Head hairs usually single or double; anterior and middle shoulder hairs (2 and 3) weak, do not reach to head hairs ------------ 27

27. Pecten extends beyond middle of siphon (fig. 111) ---------- *campestris* (p. 108)

27. Pecten confined to basal half of siphon ---- 28

28. Head hairs all with three or more branches ---------------- 29

28. Not all of the head hairs with as many as 3 branches ---------------- 30

29. Prothoracic hair 5 single; upper head hairs usually with 5 or more branches; lower head hair usually with 4 or more branches (fig. 98) ---------------- *canadensis* (p. 106)

29. Prothoracic hair (5) branched; upper head hair usually with 4 or fewer branches, lower head hair usually with 3 or fewer branches ---------------- 30

30. Prothoracic hair (5) branched ---------- 31

31. Prothoracic hair (5) single ---------- 32

31. Prothoracic hair (1) single; all head hairs branched (fig. 107) ---- *flavescens* (p. 101)

31. Either with prothoracic hair (1) branched or with at least one single head hair ---- 32

32. Siphonal tuft noticeably shorter than width of siphon at point of insertion; with very small dorsolaterals on IV and V (often difficult to find); siphon usually less than 3 times as long as wide at middle (fig. 114) ---------------- *sticticus* (p. 111)

32. Either the siphonal tuft is about as long as or longer than the width of the siphon at the point of insertion or the dorsolaterals on IV and V are about as large as or larger than the head hairs; siphon frequently more than 3 times as long as wide at middle ---------- 33

33. Mesothoracic dorsal principle as large as the head hairs and usually branched; prothoracic hairs (1) and (5) branched; upper head hairs usually branched; dorso-laterals on IV and V usually branched (fig. 112) ---------------- *dorsalis* (p. 107)

33. Either the mesothoracic dorsal principle is smaller than the head hairs and single or prothoracic hairs (1) and (5) are single; upper head hairs frequently single; dorsolaterals on IV and V often single ---------- 34

34. Prothoracic hairs (1) and (5) branched; usually with more than 40 comb scales (fig. 116) ---------------- *communis* (p. 115)

34. Prothoracic hairs (1) and (5) single (occasionally 5 is branched); with fewer than 40 comb scales ---------------- 35

35. Siphon 3.5 or more times as long as wide at middle; upper head hairs branched; head about 1½ mm. wide (fig. 109) ---------------- *stimulans* (p. 102)

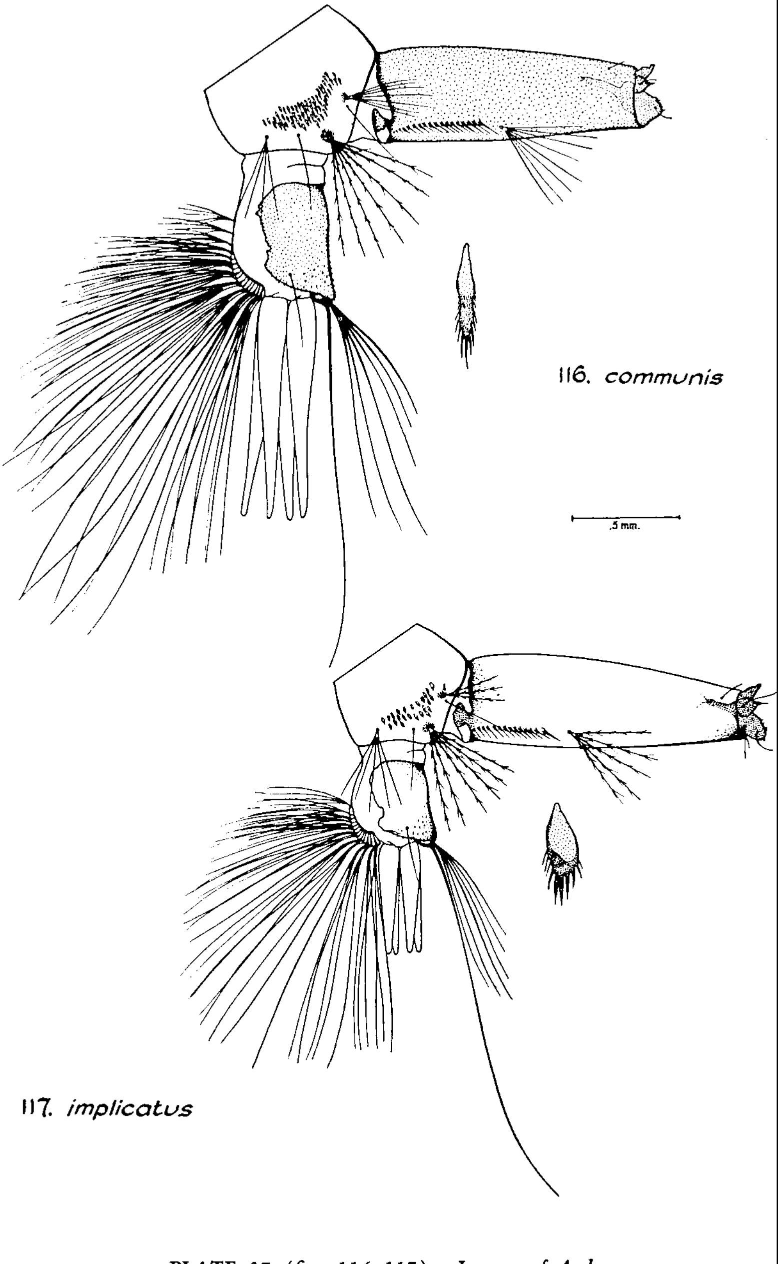


PLATE 37 (figs. 116, 117). **Larvae of *Aedes*.**

35. Siphon 3 or fewer times as long as wide at middle; upper head hairs usually single; head slightly over a mm. wide (fig. 117) ------------------------------ *implicatus* (p. 113)

Aedes (Aedes) cinereus (Meigen)

FEMALE — Small. Palps and proboscis dark-scaled. Mesonotum uniformly covered with reddish-brown scales, somewhat paler in the antescutellar area. Dorsum of abdomen largely, sometimes entirely dark-scaled; usually with a median patch of pale scales at the base of each tergum; sometimes the median patches extend all the way to the sides thus producing transverse bands. Sides of abdomen and venter entirely pale-scaled. Wing scales dark.

MALE — Palps short as in female, thus differing from all other male mosquitoes in Minnesota except *Wyeomyia*. Terminalia (fig. 35): dististyle forked at base and apex, without claw, inserted subapically on basistyle. Claspette stem forked, without filament. The shapes of the basistyle and dististyle are unique and can usually be seen on pinned specimens without dissection.

PUPA — Described and figured by Darsie (1951).

FOURTH INSTAR LARVA (fig. 101) — Head wider than long, about 1¼ mm. wide. Antennae about 2/3 as long as head, spinose. Lower head hair placed directly between upper head hair and post-antennal tuft; lowers usually 4-6 branched (33, 49, and 15% respectively of 85; range 3-7); uppers usually 5-8 branched (28, 43, 20 and 6% respectively of 94; range 4-9). Lateral abdominals single to triple on I and II, single on III to VI. Eighth segment usually with 10, 12, or 14 comb scales (19, 49, and 15% of 67; range 8-15), each with strong terminal spine and in irregularly double or single row. Siphon about 4.5 to 5 times as long as wide at middle; pecten usually with 2 to 3 detached teeth (48 and 44% of 108; range 2-4; a single specimen was without detached teeth on one side), extending to or somewhat beyond middle of siphon; pecten spines usually pale; tuft usually with 3-5 branches (17, 48, and 25% respectively of 60; range 2-7), not as long as width of siphon at point of insertion. Occasionally there is a tiny lateral tuft dorsal of the siphonal tuft. Anal segment with saddle extending about 3/4 down the sides; saddle longer than wide, lateral hair inserted on saddle, usually with 2 or 3 branches (42 and 45% of 60; range 1-4; single in about 10%), much less than half as long as saddle. Anal papillae 2 or more (usually several) times as long as saddle.

THIRD INSTAR LARVA — Head about .8 mm. wide; antennae almost as long as head; upper head hairs with 3 or 4 branches; lowers with 2 or 3 branches. Notes on the earlier instar larvae are given by Marshall (1938).

EGG — Undescribed.

BIOLOGY — Overwintering is by the egg stage. Larvae may be found rather early in the spring but the adults emerge rather late for *Aedes* mosquitoes, near the middle or end of May; they emerge after the *communis* group and at about the same time as *canadensis* and *vexans*. A number of authors including Dyar (1928) and Jenkins (1948) have noted the late emergence of this species.

Adults have been taken in Minnesota from the middle of April to the third week in September although the largest numbers probably emerge from mid-May to mid-June. Larvae have been collected in small numbers throughout the summer months in Minnesota and there is undoubtedly some emergence during all of that time; males and apparently fresh females have been taken in the fall. Howard *et al.* (1913a) and many subsequent workers have noted emergence during the summer months.

This species is said by many authors (*e.g.*, Bates, 1949; Frohne, 1954) to have a single generation a year and presumably the eggs must be exposed to cold before they will hatch. The writer has been able to hatch small percentages of eggs of this species within a week or ten days of the time that they were laid, they having been maintained at room temperature during this time; overwintering then is not necessary for the hatching of at least some of the eggs (see also Newkirk, 1955). A large proportion of the eggs did not hatch under such conditions and it is problematic whether most of the eggs needed exposure to cold in order to hatch or whether the proper conditions were not supplied for hatching.[10]

Marshall (1938) says that eggs of this species appear to hatch rather late in the year even if submerged, indicating a threshold temperature for hatching. Gjullin *et al.* (1941) found that reduction of dissolved oxygen was an important stimulus for hatching overwintered eggs of this species. Frohne (1954) expressed the opinion that the eggs become fully embryonated soon after laying but do not hatch until overwintered.

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[10] Unpublished observations by J. W. Kliemer indicate that eggs of this species do not need to be exposed to cold before they will hatch.

The larvae of this species are found in a wide variety of temporary and semipermanent ground pools in Minnesota and seemingly exhibit no decided preference although they are perhaps more common in semipermanent water. Frohne (1953) has taken the species from brackish water, in which situation the larvae had reduced anal papillae. The period of larval development is 8-10 days according to Wesenberg-Lund; in Minnesota it is much longer as a rule due to the low temperature of breeding places.

Males are said by Dyar (1922b) to swarm after sunset. The writer has invariably found that biting females have been inseminated; usually at least 2 of the 3 spermathecae contain spermatozoa. Females will lay eggs in the laboratory in 4 to 5 days. The eggs, at least in the laboratory, are laid on water or in moist places as found by Gjullin *et al.* (1941) and not in dry places (Wesenberg-Lund, 1921; Frohne, 1954). The average number of eggs laid is given by Hearle (1926) as being 120; Newkirk (1955) found a maximum of 106.

Many authors emphasize that the adults are found in wooded areas. A striking instance of this was seen by the author in 1952. Hand collections were made from July 8 to August 21 in an open situation in St. Paul (7 collections) and in a wooded area about 100 yards away (3 colls.). In the open situation 21% of 546 biting females were *cinereus* and 78% were *vexans;* in the wooded situation 71% of 205 were *cinereus* and 22% were *vexans.* Thus *vexans* was the commonest species in the open area and *cinereus* in the wooded one. The difference probably lies in higher humidity requirements for *cinereus* than for *vexans.* The fact that *cinereus* adults are usually more or less confined to wooded areas probably accounts for the general impression that the adults do not fly far. In August of 1953 the most abundant biting females present in several wooded areas near Virginia, Tower, and Ely were *cinereus* although in early June of the same year, species of the *communis* group, particularly *communis* itself, had been most abundant; the females taken in August were all badly rubbed indicating that they had been on the wing for some time. Twinn (1931) and other authors have noted the females to be exceptionally long-lived.

As previously stated, biting takes place particularly in wooded places. Although biting rates seem to be at their peak in the early evening, the females are rather active throughout the day, probably due to the reduced illumination and increased humidity in wooded areas. No credence can be given to the belief (Freeborn and Bohart, 1951) that adults prefer walking to flying or (Wesenberg-Lund, 1921; Freeborn and Bohart, 1951) that females have difficulty in piercing human skin. Adults are said (Wesenberg-Lund, 1921) to rest in grass during the day.

DISTRIBUTION — Northern part of palaearctic region; further south in wooded and mountainous areas. In Minnesota practically all records are from wooded areas, particularly in the northeastern 2/3 or so of the state. Howard (1916) recorded it as being one of the most abundant mosquitoes in northern Minnesota in the early spring.

IMPORTANCE — Often an important pest in wooded areas in summer.

***Aedes (Aedimorphus) vexans* (Meigen)**

FEMALE — The combination of narrow, white, tarsal bands and indented abdominal bands are diagnostic for this species. Proboscis dark-scaled, with a sprinkling of pale ones medially and ventrally. Palpi dark-scaled, a few pale ones at the tip. Mesonotum coppery brown, paler toward the antescutellar area; occasionally a few vague, paler markings on the disc. Abdomen with white "B"-shaped bands at the bases of the terga; there are often pale apical bands on the more posterior terga and occasionally scattered pale scales down the median line. Wings dark-scaled, with a few pale ones at the base. Tarsal segments with white, basal bands, narrow, even on the hind legs (fig. 26); white knee spots present. The female genitalia have been described by Gjullin (1937).

MALE — With practice males can usually be easily identified by the narrow tarsal rings. Terminalia (fig. 34): the shape of the dististyle, the subapical claw of the dististyle, the lack of claspette filaments, and the crown of spines on the claspette stem are characteristic of this species. The broad, flattened dististyle with a subapical claw is diagnostic and can usually be seen on pinned specimens without dissection.

PUPA — Described and figured by Darsie (1951).

FOURTH INSTAR LARVA (fig. 102) — Head wider than long, about 1¼ mm. wide. Antennae slightly over half as long as head. Upper head hairs usually with 3-5 branches (20, 56, and 20% respectively of 196; range 2-7); lower head hairs usually with 2 or 3 branches (60 and 31% of 207; range 1-4). Posterior shoulder hair weak, not reaching to head hairs. Lateral abdominals usually with

3-4 branches on I (37 and 48% of 67; range 3-6) and II (61 and 27% of 66; range 2-5), 2-3 branches on III (44 and 56% of 75), double on IV (82% of 67; range 1-4), and double or single on V (70 and 28% of 61; range 1-3) and VI (23 and 77%). Eighth segment usually with 10 or 12 comb scales (48 and 43% of 149; mean 10.9; range 8-16) in irregularly double or single row; average comb scale with terminal spine longer than rest of comb scale, usually pale. Siphon about 3½-4 times as long as wide at middle; pecten usually confined to basal half, usually with 1-3 detached teeth (18, 66, and 22% respectively of 206; range 1-4); tuft not as long as width of siphon at point of insertion, about on a level with and considerably beyond pecten, usually with 4-7 fine branches (13, 30, 36 and 17% of 131; range 3-8). Anal segment almost encircled by saddle, lateral hair about half as long as saddle, usually single or double (59 and 40% of 95; range 1-3). Anal papillae about 1½ or more times as long as saddle.

THIRD INSTAR LARVA — Head about .8 mm. wide, upper head hairs usually double, lowers single. Siphonal tuft usually with 4 or 5 branches. Saddle extends about 1/4 down the sides of the anal segment. Notes on earlier instar larvae are given by Marshall (1938).

EGG (fig. 9) — Described by Horsfall & Craig (1956).

BIOLOGY — Overwintering is by the egg stage. *A. vexans* adults usually appear in the spring in late May a short time after those of *canadensis* and *cinereus.* Adult records in Minnesota extend from the end of April to mid-October. The spring emergence of *vexans* is light when compared with the numbers which emerge in mid- or late summer. Although in southern areas this species may be an early spring one (Howard *et al.*, 1917), it is a summer species in Minnesota as in New Jersey (Smith, 1904b).

The species is variously said to have one or more than one generation per year. Mail (1934) was unable to hatch *vexans* eggs unless they were exposed to subzero temperatures. Arnold (1953) found that eggs of *vexans* which were 30 days old had developed only as far as those of *nigromaculis* which had developed for 70 hours; since the latter completed their development at about 120 hours, *vexans* embryos had completed only about half (58%) of their development in a period of a month (but see Jones and Arnold, 1952). These facts would support the concept of one generation a year. Mitchell (1907), on the other hand found eggs of this species to hatch in as little as 4 days. Gjullin *et al.* (1950) found that 56-82% of the eggs of *vexans* had completed their development by 10-12 days and that some eggs would hatch 3 to 5 days after being laid. Jones and Arnold (1952) found *vexans* eggs would hatch in 10 days (see also Newkirk, 1955). The writer has also gotten eggs of this species to hatch within a week of the time they were laid. Horsfall (1956a) and the author (Barr and Azawi, 1958) have developed techniques for hatching *vexans* eggs in the laboratory soon after laying. This is easily done if the eggs are exposed to air ("conditioned") for a few days before attempting to hatch them. There appears to be no doubt that *vexans* is a multivoltine species.

Larvae develop in a remarkable variety of temporary and semipermanent ground pools in Minnesota. From the literature this would appear to be usual for the species except in New Jersey where several authors (*e.g.*, Miller, 1930; Headlee, 1945) emphasize that larvae are usually found in permanent water. Gjullin *et al.* (1950) have described breeding places of this species in the Pacific Northwest where it is often associated with flood-waters. In such a location, the authors state, clearing of brush from breeding places has proved to be a valuable control measure. In Minnesota, on the other hand, the writer has most consistently found larvae in temporary water accumulations. The rather close correlation between peaks of rainfall and abundance of adults found by Riley and Chalgren (1938) supports the concept that breeding is primarily in temporary water accumulations; Darsie *et al.* (1953) found that the number of days with one or more inches of rainfall (from May to September) was positively related to the abundance of adults of this species in Delaware. The writer has the impression that larvae in the early spring are found predominantly in semipermanent water collections; later in the summer they are most often taken in small accumulations of water, either in rain pools or in ponds which are almost completely dry, particularly in hoofprints around such ponds.

There has been little attention devoted to the biology of *vexans* larvae. It is known that although they are usually taken in clear water, they may also be taken in heavily polluted water (Young, 1918; Matheson, 1929); the author has repeatedly taken larvae in large numbers in water heavily polluted with cow feces. The larvae are often taken in prodigous numbers; Twinn (1931) records 5,000 to 20,000 per square foot of surface area of water and Rees (1943) found 500 or more per pint of water. The writer has observed similar concentrations, particularly in the summer months in drying pools. The observations of Buxton and Hopkins (1927) and Headlee (1945) indicates that the larvae feed indiscriminately on plankton. Chidester (1916) tested the salinity tolerance of *vexans* larvae and found they were killed by 8% sea water. Mail (1934) found that first instar larvae were killed by a temperature of 37° C. but older larvae were not; this is a rather surprising finding in view of the fact that anopheline larvae become progressively more susceptible to high temperatures as they age (Barr, 1952).

There are many observations of the relation between temperature and the length of the aquatic stages of this species although all such studies are fragmentary. An idea of the relative lengths of the various stages is given by Hearle (1926) who found that the first instar required 4 days, the second 1 day, third 2 days, fourth 4 days, and the pupa 5½ days; the total developmental time was 15½ days and males emerged about one to two days before females. Mail (1934) found in the laboratory that larvae required 17.9 days at 22° C., 10.2 days at 27° C., and 4.7 at 32°; pupae required 5.3 days at 15-22° and 1.2 to 1.8 days at 27 to 37°. At 40° the pupal stage was lengthened to 2 days and the mortality rate was approximately 50%. Keener and Edmunds (1954) found that in the field, larvae developed for 9 to 12 days at average air temperatures of about 12-16° C. and 4.5 to 7 days at 20 to 25°. Under summer conditions in Minnesota Riley and Chalgren (1938) found that peaks of abundance of adults (as judged by light trap catches) tended to occur about two weeks after peaks of rainfall. Developmental times have also been given by a number of other authors (Mitchell, 1907; Parker, 1916; Hearle, 1926; Twinn, 1931) but they add little to the above. The minimum period for aquatic development observed by Mitchell (1907) was 5½ days and by Gjullin *et al.* (1950) 6 days (about 26° C.). Since Bick and Penn (1947) found that pupae could survive stranding, it might be expected that in warm weather the aquatic stages could be completed in water which remained for only 4-5 days.

According to Cantrell (1939) the pupae of the two sexes are not noticeably different in size; observations of the author, while not critical, are not in agreement with this point of view.

The ratio of the sexes of adults at the time of emergence is approximately 1:1 in the experience of Mail (1934). Mating probably occurs soon after emergence. The author has invariably found that biting females had been inseminated; usually the large and one of the smaller spermathecae contain spermatozoa; they are occasionally found only in the large spermatheca or in all three. Identical results were obtained by W. R. McKibben at Itasca State Park in 1954.

Mating swarms have been observed by Dyar (1919) and Hearle (1926). The species has never been colonized, probably because insemination does not occur in the laboratory. Buxton and Hopkins (1927) could not get eggs from reared females. Gjullin *et al.* (1950) observed mating with reared individuals but such females never laid viable eggs. The author has established many "cage colonies" of reared adults but mating never really occurred since all females dissected had empty spermathecae. Swarm formation was once observed in the field in a large grove of trees. The swarm was composed of several thousand individuals and was twenty or so feet high. The swarm was observed on a cloudy afternoon. Probably a colony of this species could be established if a large outdoor cage were used; at a later time a stenogamous strain might be selected.

The adults are most active under conditions of reduced illumination. Although females will bite in the daytime, particularly when disturbed, the peak of biting seems to occur just before dusk. Headlee (1931) found one peak from about dusk to 9 p.m. and another one between midnight and dawn. Often the females are also active on cloudy days, particularly when there is light precipitation (Rees, 1943).

Migration of this species has been rather extensively, if not effectively, studied. Rees (1943) distinguishes between two kinds of flights. One is a localized random movement about a breeding place and covers little distance. The other is a generalized migration over a long distance. Movements over a distance of a mile or so are well documented (Smith, 1904b), and there is good evidence that on occasion, migrations may take place up to 30 miles (Smith, 1904b; Headlee, 1918; Hearle, 1926; Headlee and Miller, 1927; Miller, 1931; Rees, 1935; Stage *et al.*, 1937; Clarke, 1943a, 1943b, 1943c; Rees, 1943). Rees (1943) found such flights always took place during the period of a full moon. Stage *et al.* (1937) found that the distance covered by such flights was influenced by the size of the brood. The evidence of Horsfall (1954) for major flights of 90 to 230 miles within 24 to 48 hours is hardly credible. Although Gjullin *et al.* (1950) found that females usually fly near the ground (less than 20 or

30 feet), Glick (1939) took occasional specimens at 1,000 to 5,000 feet.

A noteworthy characteristic of this species is the remarkable degree to which it is attracted to light (Hearle, 1926). This was particularly noticeable at Itasca State Park in 1954 when a much higher proportion of light trap catches (fig. 70) were *vexans* than was the case with hand catches; although females of the *communis* and *stimulans* groups were taken in large numbers in hand catches, relatively few were taken in light traps. Weiss (1913) remarked that *vexans* was positively phototropic at low light intensities (as at night) but negatively so at high intensities (as in the daytime). The writer is of the opinion that humidity is an important factor here but the variation of light attraction with humidity has not been studied, nor has the variability of light attraction of adults in different physiological states. The bulk of the females taken in light traps appear to be unfed but this might be expected on the basis of the ratio of unfed to fed females in nature. It is interesting to note that Riley and Chalgren (1938) found *vexans* to comprise over 90% of light trap catches but only 66% of hand catches.

The resting habits of this species are important if insecticides are to be used in controlling adults. Thibault (1910) found that adults rest in low vegetation, particularly grass. The writer has found adults of both sexes resting in long grasses and in shrubs in the daytime; on cloudy or moist days or in the evenings the females also rest in short grasses. The writer once observed a situation where there was a group of shrubs surrounded by a broad expanse of short grass. In the daytime adults could be readily collected in the shrubs but not on the lawn. As the evening approached the females moved out from the shrubs over the lawn. One could allow the approaching wave of females to reach him and then retreat and await the wave once again. The movement seemed to be more or less random and in rather short flights, the females often landing on the damp grass and then taking to wing again. The author's impression is that a high saturation deficiency is probably an important factor keeping females in resting places in the daytime; lowering of the saturation deficiency may be an important releasing mechanism for activity at dusk. When the females are observed in their daytime resting places it can be seen that they usually rest upside down on the undersides of leaves. If such places are to be sprayed, the spray should be directed upward from below. The writer also on one occasion found huge numbers of adults resting on the cool concrete foundation of buildings at the Mud Lake Wildlife Reserve; this was in the daytime but most of the adults were not in direct sunlight.

The longevity of mosquitoes is a very difficult thing to measure in a way that has meaning; it is certainly shorter under dry or warm conditions than under cold or humid conditions and thus varies from place to place and at different times. Hearle (1926) thought that adults normally live about 6 weeks. Stage *et al.* (1937) collected stained females as long as 104 to 113 days after release. Clarke (1943a,b,c) found an "average longevity" of 10.3 days for females and 5.3 for males by the capture-mark-release-recapture method. Rees (1943) noted that each brood of adults was annoying for about 10 days. In Minnesota breeding is likely to take place throughout the summer months so that broods are not well defined unless periods of rainfall and dryness are also well defined. Information on the longevity of females of this species under various conditions would, however, be useful in predicting the date of cessation of annoyance due to such a peak of abundance, particularly in dry summers when the peaks are relatively well-defined. The writer is of the opinion that the average length of life of females at warm temperatures is usually quite short, on the order of 1-2 weeks or less.

Adults of *vexans*, both male and female, have often been observed to feed on flowers, particularly on goldenrod (Knab, 1907; Hearle, 1926; Philip, 1943). The writer has often observed this, particularly in the early evening or on cloudy days There is no evidence that such food can supply the proper nutriment for the development of eggs. The feeding preferences of adult females are not known but mammals are probably preferred. Hearle (1926) found that females would first bite 3-7 days after becoming adult. Stage and Yates (1936) have shown that a female usually takes about 2 mm^3. of blood at each meal. Females as a rule feed only once before laying eggs, although some individuals do feed more than once (Mitchell, 1907). Virgin females will occasionally feed but in the experience of the author, are very reluctant to do so; such females will on occasion lay a few eggs although these are likely to be obviously abnormal and do not hatch. After once engorging the female will usually not feed again until after ovipositing, several days later. Hearle (1926) found that mermithids (Nematoda) prevent the development of eggs entirely.

The preoviposition period of *vexans* is not easy to measure and varies at least with temperature. Part of the difficulty in the measuring of this period is that females do not necessarily lay their eggs as soon as they are capable of so doing; they may retain them for several weeks, apparently because the proper conditions are not supplied to induce oviposition. High light intensities and a lack of a proper oviposition medium will delay oviposition in the experience of the author. Oviposition at temperatures of about 22° C. should occur about 4 to 7 days after taking a single blood meal (Mitchell, 1907; Mail, 1934; Gjullin *et al.*, 1950) or a week or two after emergence (Stage *et al.*, 1952); if more than one blood meal is taken before oviposition, eggs may be laid a very short time after the second one. Mr. W. R. McKibben found that with 22 females fed once on human blood, the preoviposition period was 10.1 ± .5[11] days, the uniformity of results indicating that females laid readily; this work was done in the field in a partially heated building so the average temperature was low, around 13° C.

So far as the author is aware, the oviposition of this species has not been observed in the field although many workers have observed it in the laboratory. Early workers observed females ovipositing on the surface of water and concluded that this was the normal oviposition site (Mitchell, 1907; Hearle, 1926); the author has witnessed this in the laboratory by illuminating the "colony" with red light which apparently has little or no "light effect" on the mosquitoes. At a later time, as the potentialities for dormancy of *Aedes* eggs became more fully understood, many workers thought that *vexans* eggs were laid in dry places which would subsequently become inundated (Bresslau, 1917; Matheson, 1929); there is, however, no evidence to indicate that *Aedes* eggs, or for that matter, eggs of any mosquito, can survive if not exposed to free water during at least the first part of their developmental period (24-48 hours in *aegypti*, Shannon and Putnam, 1934). The author is inclined to place faith in the results of Bodman and Gannon (1950) which support the idea that eggs are laid around the margins of breeding places, probably on moist soil. In the laboratory females appear reluctant to oviposit on the surface of water, on damp filter paper (the customary medium used in rearing *aegypti*), or on light, coarse sand; they will, however, oviposit readily on moist cotton. This probably indicates that the female is reluctant to oviposit on a flat surface but prefers to insert her eggs down into moist crevices as is the case with *nigromaculis* (*q.v.*). In the laboratory, eggs are invariably deposited on moist surfaces and will not hatch if dried in the first day or so. As a matter of fact, the author has experienced difficulty with drying eggs for storage as is customary for *aegypti*, even after the eggs have been exposed to water for several months. This is in accord with the results of Yates (1945) who found that *vexans* eggs, although normally long-lived in soil, were rapidly killed by removal from soil or by allowing the soil to become too dry; the water content of soil in which viable eggs were found was about 40% by weight and eggs ceased to hatch when the moisture dropped to 3%. Filsinger (1941) also found that sods which were excessively dried would not produce larvae.

There are a few other shreds of evidence concerning oviposition. Hearle (1926) was able to hatch numbers of larvae from clumps of grass but not from loose soil between such clumps. Miller (1930) found that although eggs were widely distributed in nature, they did not seem to be randomly distributed. Filsinger (1941) found that larvae could be hatched from soil which was frequently flooded but not from infrequently flooded soil; the eggs appeared to be in the first two inches of soil and were most abundant in soil from patches of tussock grass or smartweed but not short grass. He further found that if the surface of a sod were washed with water, most of the eggs were removed, showing that they could be "translocated" by water in nature. Bodman and Gannon (1950) were able to hatch more larvae from heavier soils than lighter ones. Eggs were found near streams only when there was evidence of overflow and they were found in the soil down to two inches. Eggs were not associated with shaded places in Filsinger's study although they were in Bodman and Gannon's.

Hearle (1926) found that eggs darken in about 3/4 hour after laying. The average number of eggs laid by *vexans* is variously given as 43 (Gjullin *et al.*, 1950) and 51.4 (Mail, 1934). Hearle (1926) dissected fed females and tabulated an average of 132 eggs in the ovaries; he states that about 130 were laid on the average. W. R. McKibben found that 22 females laid an average of 88.5 ± 42.7 (SE 9.1) in the early summer at Itasca State Park. This included a few normal eggs which were not laid but were present in the oviducts upon dissection. A few abnormal eggs were also laid but were not included since they did not contribute to the reproductive potential of

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[11] Standard deviation.

the species; the two females laying abnormal eggs (6 and 5 respectively) laid only 18 and 27 normal eggs which were the smallest lots laid by any of the females in the group. This finding suggests that the two females may not have completely engorged. The high number of eggs laid in this study may be due to the size of the females since they were of the early summer generation and rather large; they were fed on the 28th and 29th of June and probably had not fed previously. Upon dissection it was found that there were no large follicles in the ovaries (secondary follicles had not begun to develop) and all females had been inseminated. Some authors (Mitchell, 1907; Hearle, 1926) believe that only one batch of eggs is usually laid by a female which may be true under field conditions, but this is probably more a function of longevity of the female than of her reproductive ability; some females lay as many as four lots of eggs (Gjullin *et al.*, 1950).

Mail (1934) has shown that very fresh eggs may be killed by freezing although older ones tolerate this treatment. Water temperature also is certainly important in the hatching of eggs. The observations of Twinn (1931) indicate a threshold temperature for the hatching of eggs; Gjullin *et al.* (1950) cite this as being about 7-10° C. Hearle (1926) found that larvae started hatching in one minute at 38° C. but in several hours at about 10°; since equal numbers had hatched after 24 hours at 10 and 27° he concluded that temperature affects the rate of hatching but not the numbers which hatch. Filsinger (1941) noted that abnormally small eggs produced weak larvae.

The longevity of *vexans* eggs may be very prolonged under favorable conditions. Mitchell (1907) found that eggs continuously wet would hatch after a year. Gjullin and Yates (1946) found that eggs might be viable several years although hatching fell off markedly after the first one. Annand (1941) reports work showing that eggs may be viable as long as 7 years although less than 1% hatched after 5.

Desiccation of eggs has been discussed above but an additional point deserves comment. The susceptibility to drying of *vexans* eggs is truly amazing to one who is accustomed to rearing *aegypti*. When one remembers that *aegypti* eggs are usually found in artificial containers, often on glass or metal, and are subject to an absence of free water, this difference is not surprising; *Aedes* eggs which are laid in moist soil (as in most species occurring in temperate zones) are probably not normally exposed to such desiccating conditions.

Distribution — Palaearctic. In North America generally distributed over the United States from Mexico to Canada; there are records from all of the United States. In Minnesota it has been taken wherever mosquitoes have been collected although it appears to be most abundant in plains areas.

Importance — In terms of nuisance value this species is undoubtedly the most important in the state. The study of Riley and Chalgren (1938) shows that the problem of controlling mosquitoes in the Twin Cities Area is very largely a problem of controlling this one species. The author believes that this is probably true in most of the non-forested portions of the state. The species is also important in towns close to forested regions but not themselves forested (*e.g.*, Virginia) and may be abundant even in forested regions (*e.g.*, Itasca State Park).

Subgenus *Finlaya*

This subgenus can be characterized in the state only by the male terminalia; apical lobe absent; basal lobe weak indicated by a seriferous area; dististyle markedly less than half as long as basistyle, about 1/3 as long. These are the only *Aedes* in the state which have been colonized; biologically they differ from other subgenera in the state in that mating will take place in a small cage. Both species are multivoltine.

Aedes (Finlaya) atropalpus (Coquillett)

Female — Probiscis and palps dark-scaled. Mesonotum with dark brown scales forming a median stripe which becomes wider posteriorly; sides with yellowish scales, particularly anteriorly. Dorsum of abdomen largely covered wtih dark brown scales, bases of the terga with narrow white bands which widen laterally and may be interrupted medially. Wing scales dark except for a large, conspicuous, white patch on the base of the costa. Legs mostly dark-scaled; with prominent white knee spots; with white bands at the articulations of most tarsal joints except on the forelegs, the bands being on the apex of one segment and base of the next, especially on the hind legs; last tarsal segment of hind legs entirely pale-scaled.

Male — The male is easily identified by the key to females. Terminalia (fig. 36): apical lobe completely absent; basal lobe indicated only by a densely setiferous area; claspette filament cylindrical, not flattened; lobes of ninth tergum not very dark, without conspicuous spines or setae. The terminalia are rather similar to those of *triseriatus* and *nigromaculis*, both of which have large setae on the lobes of the ninth tergum; *triseriatus* also has a tuft on the basistyle.

PUPA — Described and figured by Darsie (1951) according to whom the emarginate paddles are unique.

LARVA (fig. 105) — Usually found only in rock holes. Fourth instar: head slightly longer than wide; about 1 mm. wide. Antennae less than half as long as head. Head hairs single (6.9% of 188 uppers double; 1.1% of 185 lowers double). Lateral abdominal hairs usually multiple on I to V, double or single on VI. Eighth segment with average of 42.3 comb scales (28 specimens; range 28-58; 82% with 30 to 50), in triangular patch; comb scales without strong terminal spine. Siphon about 1.5 to 2.5 times as long as wide at middle; pecten covers 3/4 or more of length of siphon, usually with 2 or 3 detached spines (45 and 39% of 161; range 1-7); tuft ventral of pecten and usually proximal of outer 2 to 4 pecten spines (rarely 1), not quite as long as width of siphon at point of insertion, usually with 6 to 10 branches (12, 14, 25, 24, and 13% respectively of 92; range 5-12). Anal segment with saddle extending about 1/3 down the sides; lateral hair inserted below saddle, about half as long as saddle, usually single or double. Anal papillae usually 2 or more times the length of the dorsal saddle.

Third instar with head about .7 mm. wide, with fewer comb scales (about 25 to 35); siphonal tuft with 4-5 branches.

EGG — Figured by Howard *et al.* (1913b).

BIOLOGY — Overwintering is by the egg stage. Larvae are, as a rule, found only in depressions or crevices in rocks which are usually associated with streams or waterfalls; the writer has taken larvae in great abundance at Gooseberry Falls in association with *Culex restuans*. There are a few records of larvae having been taken some distance from streams (Carpenter *et al.*, 1946); they have also been taken, although rarely, from septic tanks (Shields, 1938), from depressions in concrete (Stough *et al.*, 1949), and from tree holes and artificial containers (Hedeen, 1953). The larvae require about a week for development at 21-30° C. (Trembley, 1947); Haufe (1952) has pointed out the tendency for rock pools to heat up when exposed to sunlight, thus accelerating larval development. The larvae are thought (Hedeen, 1953) to feed indiscriminantly on diatoms, desmids, green algae, "worms", and crustaceans. They are said to spend a great deal of time browsing on the bottom and Hedeen has shown that they are negatively phototropic; younger larvae appear to be more susceptible to lack of oxygen than are older ones. Trembley (1947) found that males developed somewhat faster than females and (1945) that male pupae were smaller than female; larval mortality in one experiment was about 10-15% and pupal mortality 2-3% (1947).

According to Trembley the usual method of reproduction is autogenous; a laboratory colony maintained itself by this method for 26 generations without showing a loss of vigor. After emergence, mating took place, apparently at reduced light intensities, in small cages. Dyar (in Howard *et al.*, 1913a) found that mating would take place in a quart jar. Over 50% of the females will oviposit autogenously and this takes place in an average of about 3-4 days according to Trembley; females which do not lay autogenous eggs generally will not lay even after a blood meal. The females are said to be very reluctant to bite and only a small proportion of blood-fed females lay viable eggs. After engorging on blood the preoviposition period was somewhat longer, about 4-7 days as a rule.

Oviposition probably takes place in the dark (Trembley, 1947) and in nature probably on depressions in rocks at the surface of the water although it is said (Dyar, 1903b; Hedeen, 1953) that this is usual only in the fall, eggs being laid on the water surface in the summer. In the laboratory, oviposition will take place on the water surface or on moist filter paper. The eggs are said to be stuck tightly to the rock so that they will not be washed away by flooding but Buxton and Breland (1952) have bred larvae from soil and sand taken from dry rock holes. An average of about 80-90 eggs is laid by each female (Trembley, 1947). About half of the eggs hatch; "conditioning" did not materially raise the percentage of eggs which hatched. Trembley (1947) found that continuously-wet eggs would hatch in an average of 2.5 days; such eggs hatched somewhat irregularly but "conditioning" of eggs was difficult since they would hatch on moist filter paper. It should be noted, however, that Hedeen (1953) was not able to hatch some eggs until they had been dried several times. Trembley (1947) also found that younger females laid a higher proportion of fertile eggs than older ones; dried eggs remained viable for at least 2 months (1945).

Since eggs hatch so readily in the laboratory and since larvae are found in rock pools throughout the summer months, it is thought that there are several generations a year (see also Carpenter, 1941); Trembley (1947) found that a complete cycle required a little over two weeks at 21-30° C. At 22° C. larval development took about 10 days and pupal 1-3 (Trembley, 1955).

In the field, colonies may disappear with the advent of dry weather only to reappear when the rock hole is once again filled with water (Carpenter, 1941); Carpenter found larvae most commonly in the spring and fall, probably due to increased rainfall at these times. Trembley (1945) found that adults required a high humidity and were quickly killed by drying; adults even under the best conditions (1947) were very short-lived. Carpenter (1941) found both sexes of adults resting under rock ledges near breeding places in the daytime.

The females are known to feed on both mammals and birds and may be annoying in the field even though they are reluctant to feed in captivity.

DISTRIBUTION — North and Central America. In the United States, eastern, and from Canada to Mexico; as far west as Minnesota and Arizona. In Minnesota there are only a few records from scattered localities, most near Lake Superior.

IMPORTANCE — As Owen (1937) states, this species is much too localized to be of general importance although it may be annoying in such places. Adults are usually found only in the immediate vicinity of breeding places.

Aedes (Finlaya) triseriatus (Say)

FEMALE — Palps and proboscis dark-scaled. Mesonotum with median area clothed with brown scales, sides of mesonotum densely clothed with flat, white or silvery ones. Sides of thorax with patches of flat, white or silvery scales. Dorsum of abdomen dark-scaled with purplish reflections; usually with white, lateral triangles on the bases of the most posterior segments. Legs largely dark-scaled with purplish reflections; prominent white knee spots present.

MALE — May be identified by the key to females. Terminalia (fig. 85): apical lobe absent; basal lobe more or less indicated by a setiferous area; basistyle with more or less prominent tuft on medial face; lobes of ninth tergum with a few stout setae. Rather similar to *atropalpus* (*q.v.*) and *nigromaculis*, both of which lack the tuft on the basistyle; *nigromaculis* has a small basal lobe when viewed correctly and has a relatively longer dististyle.

PUPA — Described and figured by Darsie (1951).

LARVA — Usually taken from trees holes or wooden containers. Fourth instar (fig. 106; based mostly on Mississippi specimens): Head subquadrate, not noticeably wider than long, about 1¼ mm. wide. Antennae about 1/4 the length of the head, glabrous, "tuft" single (100% of 37). Upper head hairs with fewer branches than lowers; uppers single (100% of 52), lowers usually double or triple (66 and 32% of 56; range 2-4). Eighth segment usually with 8-12 comb scales (14, 12, 29, 16, and 12% respectively of 49; mean 10.0; range 4-14) of characteristic shape, in single or irregularly double row. Siphon about 2½ to 3 times as long as wide at middle; pecten confined to basal half, teeth evenly spaced; tuft near middle of siphon, about as long as width of siphon at point of insertion, usually single or double (22 and 72% of 54; range 1-3). Anal segment with saddle extending about 1/2 to 3/4 down the sides, lateral hair strong, about as long as saddle, usually with 4-7 branches (29, 35, 16, and 18% respectively of 45; range 3-8). Anal papillae about 1.5 or more times as long as saddle. The reduction in length of the antennae is customary in tree hole breeders according to Wesenberg-Lund (1921).

EGG — Figured by Howard *et al.* (1913b) and Horsfall and Craig (1956).

BIOLOGY — Overwintering is probably by the egg stage in Minnesota although larvae may overwinter in more southern areas (Love and Whelchel, 1955). Owen (1937) found larvae in Minnesota in early May; adult records extend from early May to late August. Baker (1935) presented evidence to show that dormant eggs needed reactivation by light before they would hatch but later work (Love and Whelchel) failed to confirm this. Dyar (1903a) also was unable to hatch eggs the year they were laid but Repass (1952) conditioned them in the manner customary for *aegypti* and was successful in hatching them; such eggs are viable for at least 6 weeks.

Larvae, as a rule, are taken in rot holes in trees or in stumps of trees, less often in collections of water among the roots of trees; lists of such trees are given by Jenkins and Carpenter (1946) and Lake (1954). Carpenter (1941) describes an apirator for removing water from tree holes; eggs may be collected in dry materials from such holes. Larvae also occur regularly in various types of wooden containers such as barrels, buckets, and troughs and rarely in glass or metal containers (Michener, 1947), tires (Ryckman, 1952), or in ground pools; Matheson (1944) gives a record from pitcher plants. Many authors stress the association between decaying vegetation and the presence of these larvae in such breeding places; Michener (1947) found larvae in artificial containers only when they were shaded. The waters in which these larvae were found had the highest specific gravity (1.00180) of any tested by Masters (1943); his collections were from tree holes. The larvae are said by Jenkins and Carpenter (1946) to be negatively phototropic; they also found that larvae feed on the usual diet (protozoans, rotifers, nematodes, crustaceans, and debris). The development of the aquatic stages takes about 2 weeks according to Love and Whelchel. Jenkins and Carpenter found that the pupal stage lasted about 3 days at about 27° C. and 3½ to 7 days in the field. Male pupae are somewhat smaller than females (Jenkins and Carpenter, 1946). The last-named authors found a sex-ratio of 2:1 in favor of males at emergence but this is probably incorrect since this ratio is about 1:1 in all well-studied mosquitoes.

Recent work by Love and Whelchel (1955) indicates that the species shows a remarkable sensitivity to light during a part of the year. Eggs were never affected by light. Larvae, on the other hand, developed and pupated normally in the summer but in the winter did not. Winter larvae lived for long periods of time without pupating although they would pupate when placed at warm temperatures and constant illumination. They did not pupate at all at normal winter light intensities; neither would they under constant illumination at cool temperatures. Only a combination of constant illumination and high temperatures produced pupation and this in all experiments took about 4 days. Summer larvae would pupate even in darkness. When summer females were kept in darkness some, but not all of their eggs gave rise to winter-type larvae.

It appears that nothing is known about mating in this species except that it will take place readily in the laboratory; continuous generations have been reared in captivity (Repass 1952, Love & Whelchel). Both sexes will feed on a sugar solution and females will begin to take blood as early as 2 days after emergence although most will not feed for 4 or more days. Newkirk (1955) found females would deposit up to 126 eggs in one batch. Oviposition probably takes place on the walls of the container just above the water level; this disposition of eggs has been noticed in the field (Smith, 1904b) and in the laboratory (Dyar, 1903a; Repass, 1952; Newkirk, 1955). There is no reason to believe that eggs can survive if laid in dry tree holes (as stated by Lake, 1954) since they probably must have access to water to mature; the shrivelled eggs noticed by Repass were probably due to too rapid or too intense drying. In the laboratory it appears best to provide wooden blocks for oviposition.

The adults are most commonly encountered in deciduous forests and in Minnesota are usually rather common in the summer although practically never abundant. It is said that adults are most active in the morning and evening although they will bite at any time of day when disturbed; the rarity of females of this species in light trap collections is remarkable although males are commonly taken; this and the fact that females are rarely taken in hand catches after dark have given rise to the belief that females are not active after dark. The adults are said by Jenkins and Carpenter to be positively phototropic. Biting females are rarely taken outside of wooded areas and are believed not to fly far although it is possible that they disperse freely within such areas; they are said to be particularly common in dry woods. Jenkins and Carpenter have observed adults resting on vegetation and in tree holes. Females feed freely on man and probably on other mammals and, to a lesser extent, on birds.

In view of the facts that fresh females may be taken all summer (Dyar, 1903a), there appears not to be an obligatory diapause in the egg stage (Repass, 1952), and Masters (1953b) found larvae in a tank the first season it was exposed to oviposition; it seems likely that there are several generations in a year. The life-cycle (probably from the hatching of eggs to laying of eggs) is said by Lake (1954) to take 22-28 days.

DISTRIBUTION—Eastern North America, from southern Canada to the Mexican border; as far west as Montana, Wyoming, Colorado, and Texas. In Minnesota known only from hardwood or mixed forest areas.

IMPORTANCE — Adults of this species in Minnesota are usually too rare to be of importance as a pest. Workers in Massachusetts (according to Jenkins and Carpenter) believe that this species may be important in the dissemination of eastern equine encephalitis.

Aedes (Ochlerotatus) nigromaculis (Ludlow)

This species has been placed in the subgenus *Taeniorhynchus* but most present-day workers include that subgenus in *Ochlerotatus*.

Female — The only *Aedes* in Minnesota with a definite white ring on the proboscis. Abdomen with white median line. Wing scales dark and light. Legs with broad, white rings at the bases of the tarsal segments. Female rather similar to *sollicitans* which has not been taken in Minnesota although it has in neighboring states. See Ross (1947) and Carpenter & LaCasse (1955) for the differentiation of these closely related species. The female terminalia have been described by Gjullin (1937).

Male — May be identified by the key to females. Terminalia (fig. 84): apical and basal lobes both weak, rather similar to *atropalpus* and *triseriatus* (*q.v.*).

Pupa — Undescribed.

Fourth instar larva (fig. 97; description and figure are of Kansas specimens) — Head wider than long, about 1¼ mm. wide. Antennae less than half as long as head, usually about 1/3. Antennal and postantennal tufts multiple. Upper and lower head hairs usually both single (100% of 58 lowers, 55 of 56 uppers; range 1-2). Posterior shoulder hair single, not extending to head hairs. Mesothoracic dorsal principle small. Lateral abdominals usually double on I-V (88, 87, 95, 91, and 67% respectively) single on VI (95%; range 2-3 on I-III, 1-2 on IV-VI). Comb scales usually in irregularly double row but variable. Most often with 10 comb scales (34 of 52; range 7-14); usually with even number of scales, 8, 10, or 12. Individual comb scale thorn-shaped, median spine about as long as rest of scale, lateral spines minute; scales often dark. Siphon usually about 2½ to slightly over 3 times as long as wide at middle. Pecten extending beyond middle of siphon, usually to outer fifth or so; usually with outer 2-4 teeth detached (50, 34, and 12% of 58 respectively; range 1-4). Siphonal tuft inserted beyond and about on a level with pecten; about 1/3 as long as width of siphon at point of insertion, usually with 3-7 branches (12, 30, 25, 19, and 12% respectively; range 3-8). Dorsal preapical spine large, usually about 1/2 as long as outer pecten tooth. Anal segment ringed by saddle; lateral hair less than half as long as dorsum of saddle, usually single. Anal papillae usually about twice as long (range 1.4-3.6) as dorsum of saddle. The first instar larva has been described by Bohart (1954).

Egg — Described by Jones and Arnold (1952).

Biology — Overwintering is by the egg stage. Eggs may hatch very quickly when immersed in water (Thurman *et al.*, 1951a); the threshold temperature for hatching is said (Husbands and Rosay, 1953) to be about 20-21° C.

Larvae are found in various types of temporary water, particularly in irrigation water. An excellent series of data correlating the length of development of the aquatic stages with temperature in the field is given by Thurman *et al.* (1951a, b) and Husbands and Rosay (1952); the length of time from flooding of a pasture to the emergence of adults ranges from somewhat less than 5 days at 30° C. (average air temperature) to about 16 days at about 10° C., at a temperature of about 18-19° the aquatic stages require about 8 days. These data should provide a firm basis for the prediction of the date of emergence of a brood of *nigromaculis* provided that the time of hatching and the average air temperature are known. The data of Keener and Edmunds (1954) appear to indicate a somewhat faster development for this species in Nebraska (the former work was done in California); it is possible that more northern populations are better adapted to development at lower temperatures than are southern ones. The relative amounts of time required for the different stages are also given by Thurman *et al.* (1951a, b). Husbands and Rosay (1952) found that overcrowding retards the development of larvae.

Thurman and Mortenson (1950b) found that adults may emerge from pupae when the latter have become stranded on moist soil for at least as long as 29 hours. Males tend to emerge before females (*ibid.*) and the sex ratio is approximately 1:1 at emergence (Thurman *et al.*, 1951b); actually a slight preponderance of females was noted. In the field, emergence is said usually to be completed in a 24 to 48 hour period (Thurman and Husbands, 1951).

Males are said by Dyar (1922a) to swarm over prominent objects after sunset but further evidence on this point is lacking. Virgin females lay non-viable eggs (Husbands and Rosay, 1952). The females are known to bite readily in daylight as is customary with prairie mosquitoes but adults appear to be more active in the late afternoon than in the morning or at midday (Thurman and Mortenson, 1950b). Factors attracting this species to feed have not been extensively studied although Reeves (1953) found that higher CO_2 concentrations were more attractive than lower ones. Husbands and Rosay (1953) found that the bulk of fed females had engorged on cows although many fed on other mammals or birds; these results of course may reflect the relative availabilities of different animals rather than a feeding preference. Mail (1934) found that adults would engorge in 30 seconds to a little over 2 minutes. Husbands and Rosay (1952) found that adult females usually did not feed until at least 24 hours after emergence.

Excellent data are given by Husbands and Rosay (1952) to show that there are peaks of egg laying about 3 to 5 days and 9 to 11 days after emergence in the field; this would indicate a preoviposition period of about 3 days for the first oviposition and about 6 days for the second one; the technique given is a valuable one and should be used on other mosquitoes which develop in rather distinct broods; the exact figures given, of course, will vary with temperature. The first preoviposition period is surprisingly short and indicates that mating takes place soon after emergence.

Oviposition of this species has been described in the field which is a rare observation among mosquitoes. Husbands and Rosay (1952) observed females inserting eggs in cracks and crevices in moist soil and concentrations of eggs were found in moist areas rather than in dry ones; it seems likely to the author that this is the normal method of oviposition for most, if not all, of our ground-pool *Aedes.* The eggs are rather susceptible to drying and collapse under such conditions; such collapsed eggs will not hatch. Husbands and Rosay (1952) found that up to 110 eggs could be laid by a female at one oviposition although previous studies indicated that up to 200 could be produced.

This species may have several generations in a year (Dyar, 1922a; Mail, 1934). A number of workers (Thurman and Mortenson, 1950b; Thurman *et al*., 1951a; Jones and Arnold, 1952; Arnold, 1953) have shown that eggs may begin hatching within 6 days, even when continuously wet (see also Barr & Azawi, 1958). The embryology of this species is currently being studied and preliminary observations have been given by Arnold (1953) and Franco and Arnold (1953). There are indications (Thurman and Mortenson, 1950b) that more than one flooding may be necessary to hatch all eggs. The entire time necessary for a complete cycle of this species to occur in warm weather may be as little as 13 days (Thurman *et al*., 1951a); at somewhat lower temperatures the cycle requires 15 days or longer.

Adults are most abundant during the summer months in most areas. Both sexes are readily taken in light traps and adults are known to rest in grass (Thurman and Mortenson, 1950b). Thurman and Mortenson (1950a) have described a "flag" method of estimating the abundance of adults in pastures; dark grey and red flags gave higher counts than green, light grey, or white flags so the adults presumably prefer darker colors. There is a belief that this species is migratory and Husbands and Rosay (1952) have taken marked specimens seven miles from the release point; Thurman and Husbands (1951) on similar evidence believe that the species will fly at least a mile in significant numbers. Under a particular set of conditions females appear to live about 3 weeks and males up to 17 days (Husbands and Rosay, 1952).

The story of this species in California is very interesting. It was unknown there until 1937 and was taken sparingly for a few years after that date (Thurman, 1950). Subsequently it has thrived in hot areas where irrigation is practiced and is said to be replacing *Aedes dorsalis* (? *Aedes melanimon*; see Barr, 1955) in such areas (Freeborn and Bohart, 1951); at the present time it is one of the major pests in such areas.

DISTRIBUTION — Western United States from southern Canada to Mexico; as far east as Illinois, Kentucky, and Texas. In Minnesota all collections are from the prairie regions in the western and southern parts of the state.

IMPORTANCE — In Minnesota this species has been said (Owen, 1937) to be rare although this may only be reflection of the lack of collecting in plains areas; the author has found *nigromaculis* to be common in summer light trap collections in such areas. The species may become more important in Minnesota if irrigation becomes more widely practiced; under such conditions it could be a major pest. Bohart and Murray (1950) have shown that the species has acquired a good deal of resistance to DDT.

Aedes stimulans group

Adults of this group are characterized by having broad, white bands at the bases of the tarsal segments especially on the hind legs but lacking a clear-cut white band on the proboscis. At least six species occur in the state: *barri, excrucians, fitchii, flavescens, riparius,* and *stimulans.* The identification of these species is not completely clear-cut in any stage.

There are many keys to the adult females (Mail, 1934; Matheson, 1944; Gjullin, 1946; Yamaguti and LaCasse, 1951; Rempel, 1953; Vockeroth, 1954b; Carpenter and LaCasse, 1955) but none of these has, in the experience of the author proved very reliable. It would seem that, at the present time, a good proportion of even fresh specimens is unidentifiable. The following key to adult females is modified from that of Vockeroth (1954b). It works poorly for the last four included species.

Key to Adult Females

1. Dorsum of abdomen clothed entirely with yellow scales, without banding; mesonotum golden, with well-defined, darker, median stripe; tarsal claw as in fig. 87 .... *flavescens* (p. 101)

1. Dorsum of abdomen with a great deal of dark scaling although pale scales (yellowish or whitish) are present on the terga; usually with distinct, pale, basal bands on the terga; mesonotum often unstriped, when striped usually not with above combination of colors; tarsal claw usually not as above 2

2. Claws of pro- and mesothoracic tarsi with long accessory tooth which is about parallel with the primary tooth, usually the primary tooth is rather angularly bent and the outer part is straight, not curved (fig. 29) .... *excrucians* (p. 100)

2. Tarsal claws not as above, the primary tooth is curved and the accessory tooth is shorter 3

3. Tarsal claws as in figs. 90 and 80 (accessory tooth very short) 4

3. Tarsal claws as in fig. 30 (accessory tooth longer) 5

4. Mesonotum almost unicolorous, usually without white markings; abdominal terga with many scattered, pale (yellowish) scales; claws as in fig. 90 .... *riparius* (p. 105)

4. Mesonotum usually with markings of white scales; abdominal terga with small numbers of scattered, pale (whitish) scales; claws as in fig. 79) .... *barri* (p. 101)

5. Mesonotum usually with gray sides, frequently with dark brown median line; torus of antenna with pale scales .... *fitchii* (p. 102)

5. Mesonotum usually with golden sides, without dark brown median line; torus of antenna usually without pale scales .... *stimulans* (p. 102)

The larvae of the *stimulans* group are notable for their wide heads, long air tubes and long setae, particularly those of the prothorax, the lateral abdominals, the siphonal, and the lateral hair of the anal segment. There are many keys to the larvae (Mail, 1934; Matheson, 1944; Rempel, 1950; Yamaguti & LaCasse, 1951; Carpenter & LaCasse, 1955) but again none is entirely satisfactory; this is due mostly to the variability of larval characters, abnormal specimens being common. *Ae. flavescens* is a particularly troublesome species; the short anal papillae and detached pecten teeth are often used as key characters but these are both very variable.

The egg and pupal stages are incompletely known.

The biologies of these species are also incompletely known; since they, for the most part, appear to be rather similar they will be considered together. *Aedes barri* is omitted from the following discussion since practically nothing is known of its biology.

All five species are northern in distribution, three being holarctic (*excrucians*, *flavescens*, and *riparius*) and two (*fitchii* and *stimulans*) primarily Canadian. Three are found in wooded regions (*excrucians*, *fitchii*, and *stimulans*) and two are said to be plains species (*flavescens* and *riparius*).

Overwintering is by the egg stage; Dyar (1904b) found that the eggs of one of these species (*stimulans?*) would not hatch until overwintered; Newkirk (1955) was not able to hatch the eggs of *stimulans* or *fitchii* unless their shells were removed with NaOCl. Wesenberg-Lund recorded the hatching of larvae of *excrucians* in December but none were able to overwinter. Larvae are found early in the year and mature slowly, due partly to low water temperatures and partly to the large size of the adults. Adults in Minnesota, at least of *fitchii* and *excrucians*, usually emerge later than those of the *communis* group and before or with the early summer species (*canadensis*, *cinereus*, *vexans*). *Ae. excrucians* consistently emerges a week or so before *fitchii* even though it is a somewhat larger species on the average; its larger size may, of course, be due to the lower average temperature at which it develops.

Larvae in Minnesota (particularly of *excrucians* and *fitchii*) are found primarily in semipermanent water, especially in marshes, although they may be taken in more temporary water; in the latter situation the larvae are often killed by drying. The writer has taken larvae of all five species at the same time in a marshy snow pool in St. Paul. Both *excru-*

cians and *flavescens* have been taken from brackish water (Frohne, 1953) in which situation the anal papillae are much reduced. *Ae. flavescens* has been extensively recorded also from alkaline waters, again with reduced papillae; it seems likely that *riparius* would occur in similar places and Mail (1934) notes that *fitchii* is able to tolerate such alkalinity (pH 8.3) although it is usually found in neutral water. In Minnesota larvae (particularly *excrucians* and *fitchii*) usually are found in slightly acidic waters. The breeding places of *excrucians* and *fitchii* are said (Jenkins, 1948) to be open rather than shaded; this is probably general for the group with the possible exception of *stimulans.*

Haufe (1953) and Haufe & Burgess (1956) have presented data on the rate of growth as influenced by temperature for *excrucians* and *flavescens.* Hocking *et al.* (1950) found that the pupal stage required an average of 5.1 days in *excrucians,* 6.1 in *flavescens,* and 3 in *riparius;* these figures are rather high and probably reflect low water temperatures. Smith (1904b) gives the pupal period of *excrucians* as 4 to 5 days.

Swarm formations have been described for *fitchii* (Knab, 1908), *flavescens* (Hearle, 1929) and *excrucians* (latest observations by Frohne and Frohne, 1954) and are said to occur in *stimulans* (Dyar, 1922a) and probably in *riparius* (Dyar, 1923b).

Females of this group (particularly of the woodland species) are likely to be found throughout the summer months although fresh females are usually encountered for only a short period of time. These facts suggest that there is a single generation a year and that the adults are long-lived. The females probably feed for the most part on mammals but Natvig (1948) has taken *excrucians* on birds.

There are no observations on oviposition of these forms; probably it is similar to that of *nigromaculis* which appears to be typical of *Aedes* developing in ground pools. Hocking *et al.* (1950) found that five dissected females of *excrucians* had 130, 203, 213, 254, and about 300 developing eggs; these figures are much larger than is customary in *Aedes* mosquitoes. Mr. W. R. McKibben took a number of females which appeared to be mostly *excrucians* and *fitchii* and fed them once on human blood (Itasca State Park, 1954); 21 females laid eggs. The preoviposition period was 7.6 ± 2.8 days (SEm = 0.5) at about 13° C., the uniformity of results (range 6-9 days) suggesting that there was no appreciable delay in oviposition. Females oviposited on moist cotton as was the case with *Aedes vexans.* The average number of normal eggs laid (including those retained in the ovaries) was 70.7 ± 21.0 (SEm 3.8). Small numbers of abnormal eggs were laid, practically all by females laying the smallest numbers of normal eggs (as in *vexans*). A notable fact was that 7 of the 31 females showed new follicles developing in the ovaries (none of the 22 *vexans* showed this). All females dissected had spermatozoa in the spermathecae.

Adults of *stimulans* are said to fly a mile or two (Twinn, 1931; Owen, 1937) although they are not particularly migratory.

***Aedes (Ochlerotatus) excrucians* (Walker)**

FEMALE — Large. Mesonotum usually reddish-brown with patches or lines of yellowish scales, but very variable. Lower mesepimeral bristles usually absent, rarely one or two present. Tarsal segments, particularly of the hind legs, with broad, basal, pale bands (fig. 25). Females can practically always be identified by the peculiar tarsal claws of the fore and mid legs (fig. 29). The female genitalia have been described by Gjullin (1937) under the name *aloponotum.*

MALE TERMINALIA (fig. 78) — Apical and basal lobes present, the latter inconspicuous in ventral view but in lateral view is seen to be very long; basal spine absent. Claspette filament flattened and highly expanded; outer surface angularly rounded or with a small retrorse spine. The shape of the basal lobe is outstanding and is similar to *stimulans* and *flavescens,* both of which have a basal spine. The terminalia of *barri* are very close to those of *excrucians.*

PUPA — Described and figured by Darsie (1951).

FOURTH INSTAR LARVA (fig. 108) — Head wider than long; about 1⅔ mm. wide. Antenna about half as long as head. Lower head hairs usually double (4% of 70 single, 86% double, 10% triple); uppers usually double (77% of 69, 22% triple, 1% quadruple). Mesothoracic dorsal principal small. Lateral abdominals usually single or double. Eighth segment with average of 26.2 comb scales (38 specimens; range 15-34; 95% had 20 or more) in triangular patch (occasionally in irregularly double row); comb scale with terminal spine about as long as rest of comb scale or shorter. Siphon about 5 or 6 times as long as wide at middle; pecten confined to basal half with outer spines, usually 1 to 3, detached (in

66 specimens 24% had 1 detached; 64%, 2; 11%, 3; a single specimen was without detached spines on one side); tuft about 2 or more times as long as width of siphon at point of insertion, placed distinctly beyond the pecten in all cases and usually with 4 or 5 branches (52 and 36% of 50 specimens; range 3-7). Anal segment with saddle extending about 3/4 down the sides; lateral hair almost as long as dorsal saddle, often stout, and usually single. Anal papillae 1½ or more times as long as dorsal saddle, reduced in brackish water specimens (Frohne, 1953).

THIRD INSTAR LARVA — Head between 1 and 1¼ mm. wide; lower head hairs single, uppers usually single, about 9% double or triple. Eighth segment with average of 25.9 comb scales (12 specimens; range 13-31). Siphonal tuft usually double (14 of 19; range 2-4). Anal segment with saddle extending about 1/3 down the sides; lateral hair at edge of saddle.

EGG — Fig. 8 is probably an egg of *excrucians.*

DISTRIBUTION — Holarctic. In North America in northern forested regions from coast to coast; as far south as Washington, Colorado, Illinois, and New Jersey; north to timber line, Alaska, Yukon. In Minnesota found in timbered regions; all records from northeastern 2/3 of state.

IMPORTANCE — May be an important pest in timbered areas of the state, especially in the early summer.

Aedes (Ochlerotatus) *barri* Rueger

FEMALE — Medium to large. With scattered pale scales on proboscis and palpi. Tori of antennae with pale scaling. Mesonotum coppery with white lines or spots; occasionally the sides of the mesonotum are white and there is a well-defined darker median stripe. Post-coxal scale patch present. Scaling of sternopleuron not extending to anterior edge of that sclerite. Lower mesepimeral bristles absent; lower 1/5 or so of mesepimeron without scaling. Legs with scattered pale scales, banded as in other members of the *stimulans* group; pale knee spots present. Tarsal claws as in fig. 79. Wings with intermingled dark and light scaling. Abdomen with basal white bands on the terga; usually with few or no scattered pale scales on the abdomen.

The female is often inseparable from *fitchii, stimulans,* and *riparius* in the experience of the author.

MALE TERMINALIA (fig. 80) — Very similar to those of *excrucians;* I am unable to separate the two.

PUPA — Described and figured by Rueger (1958).

LARVA (fig. 79) — Head wider than long, about 1.5 mm. wide. Antennae about half as long as head. Upper and lower head hairs usually double (74% of 27 uppers, 26% triple; 86% of 28 lowers, 7% single, 7% triple). Posterior shoulder hair reaching to lower head hairs. Mesothoracic dorsal principal small. Lateral abdominals usually double; on I 17 of 21 (range 1-3), on II 22 of 22, on III 22 of 24 (range 1-2), on IV 17 of 23 (range 1-2), on V 15 of 23 (1-2), and on VI 8 of 13 (1-2). Eighth segment most often with 14 or 16 comb scales (6 and 9 of 26 respectively; mean 15.0; range 12-18) in irregular double row or triangular patch; comb scale with strong terminal spine. Siphon usually 3½ to 4½ times as long as broad at middle; pecten extending beyond middle, often to outer third, usually with 3 or 4 detached teeth (12 and 13 of 28; range 2-4); tuft strong, about as long as or somewhat longer than width of siphon at point of insertion, usually with 2 or 3 branches (10 and 16 of 27; range 2-4), placed in outer third of siphon, usually ventral of, sometimes proximal of, and usually closely associated with last pecten tooth. Anal segment with saddle extending about 5/6 down the sides, often with ventral notch at posterior third; lateral hair rather strong, over half the length of the saddle (often 3/4), usually single. Anal papillae 2 or more times the length of the saddle.

THIRD INSTAR LARVA (2 specimens) — Head slightly over a mm. wide; head hairs single; lateral abdominals single or double on I and II, single on III to VI; with 16-18 comb scales and 3-5 detached pecten spines; siphonal tuft double; saddle on upper third or half of anal segment, lateral hair at edge.

EGG — Undescribed.

DISTRIBUTION — This newly described species is known only from Minnesota. The writer has taken it only at Itasca State Park.

IMPORTANCE — Probably none; rare thus far.

Aedes (Ochlerotatus) *flavescens* (Müller)

FEMALE — Torus of antenna with pale scales. Mesonotum golden-brown, usually with darker median stripe. Tarsi with broad, basal, pale bands, particularly on the hind legs. Tarsal claws as in fig. 87. Dorsum of abdomen usually completely covered with pale scales, sometimes with a sprinkling of darker ones. Pale scales of abdomen usually yellowish rather than white. The female genitalia have been described by Gjullin (1937)

Male terminalia — Similar to *excrucians* except that the basal lobe has a spine and the claspette filament is as in fig. 87.

Pupa — Undescribed.

Fourth instar larva (fig. 107; only 2 specimens, neither definitely associated with adults) — Head wider than long, about 1⅔ mm. wide. Antennae about half as long as head. Lower head hairs triple, uppers triple or quadruple. Mesothoracic dorsal principal small. Lateral abdominals double or triple on I, II, and VI, double on III to V. Eighth segment with 21-38 comb scales (average 24.5; 20-35 according to literature) in triangular patch; average comb scale with terminal spine longer than rest of scale. Siphon about 4 times as long as wide at middle; pecten confined to basal half, with 1 detached spine in the specimens at hand (detached spines may or may not be present according to Marshall, 1938); tuft about as long as or somewhat longer than width of siphon at point of insertion, with 4-5 branches, placed beyond pecten. Anal segment with dorsal saddle extending about 3/4 down the sides, sometimes with ventral notch at posterior third; lateral hair rather stout, almost as long as saddle, usually single. Anal papillae often rather short, particularly in specimens from brackish or strongly alkaline water. The early instars have been characterized by Marshall (1938).

Egg — Figured by Marshall (1938).

Distribution — Holarctic. In North America in northern plains regions from Pacific coast east to Ontario; as far south as north California, Utah, Iowa, Illinois, and Michigan; north to Alaska, Hudson's Bay. In Minnesota in plains areas of western part of state, less common in south. The adult of the European form is said to lack the mesonotal stripe of the American form and may thus represent a different species.

Importance — Probably of some importance as a pest in summer months in plains areas.

Aedes (Ochlerotatus) stimulans (Walker)

Female — The author has no reared females of this species and is somewhat uncertain of its appearance. The torus of the antenna appears usually to lack pale scales. The mesonotum appears to be rather similar to that of *excrucians*. Legs with broad, basal, pale bands. Tarsal claw as in fig. 30. Females at the present time cannot be reliably differentiated from *fitchii*; the number of lower mesepimeral bristles is, in the experience of the author, useless in this separation.

Male terminalia (fig. 88) — Similar to *excrucians* but has spine on basal lobe; the shape of the claspette filament is unique to our fauna.

Pupa — Described and figured by Darsie (1951).

Fourth instar larva (not definitely associated with adults; fig. 109) — Head wider than long, about 1½ mm. wide. Antennae not quite half as long as head. Upper head hairs usually double (22 or 24; range 1-2); lower head hairs usually single (24 of 26; range 1-2). Posterior shoulder hair usually not reaching to head hairs. Mesothoracic dorsal principal small. Lateral abdominals usually single or double. Dorso-laterals rather weak. Eighth segment usually with 28-32 comb scales (average 30.8 in 13 specimens; range 28-36), in a triangular patch; comb scale with terminal spine not much larger than lateral spines. Siphon about 3½ to 4 times as long as wide; pecten on basal half, with regularly spaced teeth (occasionally one is detached); tuft about 3/4 to 1½ times as long as width of air tube at point of insertion, usually with 3 or 4 branches (12 and 8 of 21; range 2-4). Anal segment with saddle extending about 1/2 down the sides, saddle hair about 2/3 as long as saddle, usually single. Anal papillae about 1-1½ times as long as saddle.

Egg — Described and figured by Horsfall & Craig (1956).

Distribution — Northern forested regions from coast to coast; south to California, Utah, Illinois, and New Jersey; north to Alaska, Yukon Territory, Nova Scotia. There is a single record from Mississippi. In Minnesota in timbered regions; never found commonly by the present author.

Importance — May be important as a pest in timbered regions of state.

Aedes (Ochlerotatus) fitchii (Felt and Young)

Female — Usually smaller than other members of the *stimulans* group. Torus of antenna with pale scales. Mesonotum often with gray sides and wide, brown stripe; females with these markings are easily identified but a large proportion of the females have a mesonotal pattern similar to that of *stimulans;* such females cannot be reliably identified. Wing scales dark and light intermingled. The pale, abdominal bands on the terga are usually semi-circular, being widest in the middle; often there is a sprinkling of pale scales over the abdomen which may be concentrated in the mid-line forming a pale stripe down the abdomen. I have seen one female, apparently of this species, which had the entire dorsum of the abdomen white. Female genitalia described by Gjullin (1937). Tarsal claw as in fig. 30.

MALE TERMINALIA — Claspette filament with small basal lobe; basal lobe of basistyle as in fig. 89.

PUPA — Described and figured by Darsie (1951).

FOURTH INSTAR LARVA (fig. 55) — Head wider than long, about 1½ mm. wide. Antennae about half as long as head. Upper head hairs usually triple (71% of 109; 13% double, 16% quadruple; range 2-5); lower head hairs usually double (78% of 109; 19% triple; range 1-3). Posterior shoulder hair reaching beyond head hairs, usually triple. Mesothoracic dorsal principal longer than head, usually single (this character is unique to our fauna). With dorso-lateral on III of the same size as the lateral abdominals. Lateral abdominals usually double on I-VI. Eighth segment with 10-36 comb scales (*vide infra*) in irregularly double row or triangular patch; comb scale usually with strong terminal spine, sometimes reduced. Siphon about 5 times as long as wide; pecten confined to basal half, with regularly spaced teeth (occasionally one is more or less detached); tuft usually more than twice as long as width of siphon at point of insertion, usually with 4 or 5 branches (43 and 38% of 98; 10% triple, 7% with 6 branches; range 3-7). Anal segment with saddle extending about 2/3 down the sides, lateral hair stout, usually about 1½ times the length of the dorsal saddle. Anal papillae usually 2 or more times the length of the dorsal saddle.

The comb scales of this species are uncommonly variable in both number and shape. Collections of larvae were made from four breeding places in north St. Paul on April 29, 1955. The numbers of comb scales on each side of the eighth segment were counted and tabulated for each specimen. The result of pooling these four collections is shown in the black portion of fig. 119. From this histogram it should be noticed that there is a tendency for the larvae to have an even number of comb scales, a tendency which has been found in the larvae of a number of species. Because of this tendency, the original numbers of comb scales are not plotted; the figures are grouped by two (10 and 11, 12 and 13, etc.) for plotting. The histograms of the original collections (figs. 118a-d, 119) show a tendency for a bimodal distribution, *i.e.*, larvae tend to have either 12-14 or 24-28 comb scales but in some collections (167; fig. 118a) the former predominate, in some (165; fig. 118d) the latter, and in some (166, 168; figs. 118b, 118c) the two forms are approximately equally distributed. The collection containing mostly individuals with few comb scales (167) was the earliest of the four as judged by the size of the larvae, the association of other species, and the history of the pond; the collection containing predominantly many-scaled individuals was the latest and the two collections with intermediate numbers of comb scales were also intermediate in time.

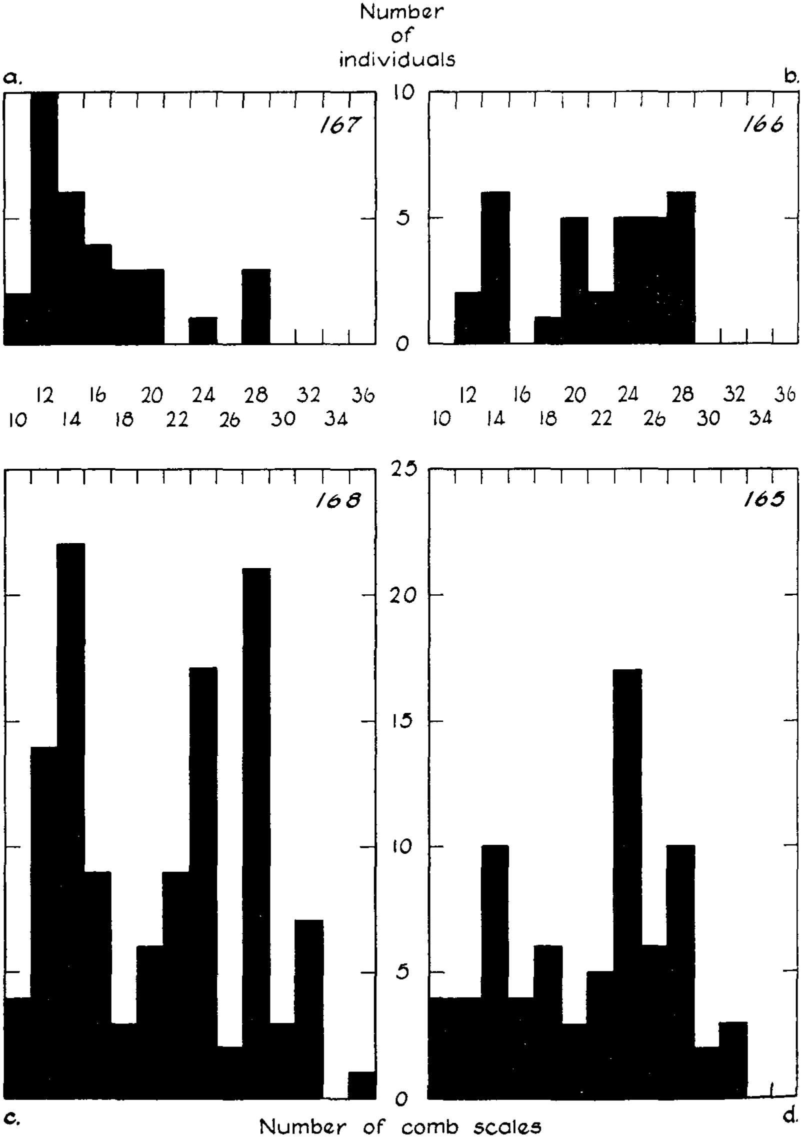
The breeding place where collection 166 was made was visited a week later (collection 171). Thirty-two larvae collected April 30 had an average of 21.7 ± 1.0 (SEm) comb scales; in the same breeding place on May 7, 113 larvae had an average of 25.4 ± .3 comb scales. In the former collection 28% had fewer than 20 comb scales, in the latter only 4%. These paired collections also show that individuals with fewer comb scales tend to occur earlier than individuals with more comb scales.

The tabulations for the four collections previously mentioned were pooled and plotted in fig. 119 which shows a distinctly bimodal curve. It will be noticed that the most frequent low numbers were 12, 14, and 16 and the most frequent high numbers were 24, 28, and 32, exactly double the low numbers. For this reason the most likely explanation of the variability observed seems to be that under certain conditions there is a doubling in the number of comb scales and this doubling appears more frequently in late than in early individuals. No other characters have been found which correlate with the number of comb scales so it seems unlikely that two different species are involved. This type of variability has, however, not been found in other species.

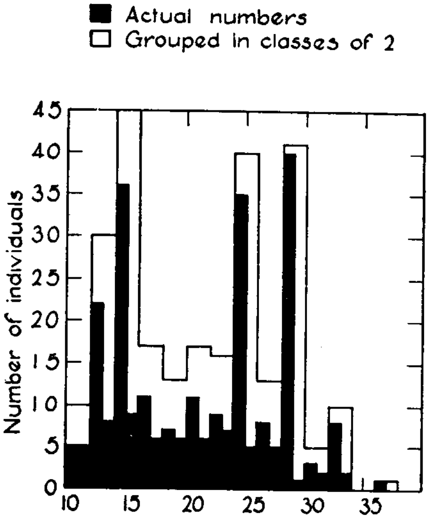
If one assumes that the upper half of the curve (from 21 to 36 comb scales) actually represents a doubling of the lower half (10 to 20 scales) and plots the former grouped by fours and the latter grouped by twos, one gets the histograms shown in fig. 120.

The histogram for the larger numbers of scales is similar to but not the same as the

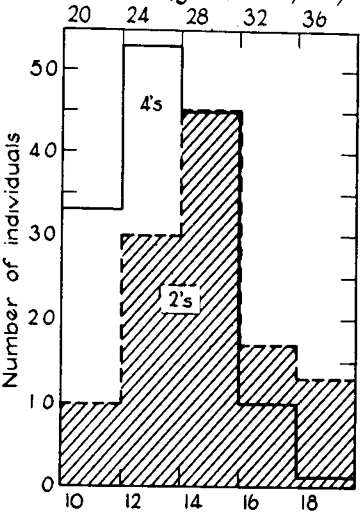
118. Frequency distributions of numbers of comb scales in four collections of *fitchii* larvae



119. Frequency distribution of numbers of comb scales in 4 collections of *fitchii* larvae



120. Frequency distribution of numbers of *fitchii* larvae having 10-19 comb scales (grouped by 2's) and 20-39 comb scales (grouped by 4's)



one for the smaller numbers. From this it appears that doubling is more likely to take place in individuals with 10-15 scales than in those with 16-20, if the doubling hypothesis is true.

Third instar larva — Head about 1 mm. wide. Upper head hairs usually double, lowers single. Siphonal tuft double or triple. Anal saddle extending about 1/3 down the sides with lateral hair near edge. The first instar larva has been described by Bohart (1954).

Egg — Undescribed.

Distribution — Northern forested region from coast to coast; south to California, Illinois, New York; north to Alaska, Yukon Territory, Hudson's Bay, Labrador.

Importance — May be of some importance as a pest in timbered regions, particularly in the early summer.

Aedes (Ochlerotatus) riparius Dyar and Knab

Female — Not definitely recognized by the author; probably best separated from *flavescens* by the reddish brown rather than yellowish mesonotum, lack of stripe on mesonotum, and presence of banding on abdomen; the best separation from the rest of the *stimulans* group is probably on the character of the tarsal claws (fig. 90; from Vockeroth, 1954b).

Male terminalia (fig. 90) — The peculiar, pointed basal lobe with its medio-posteriorly directed setae is diagnostic of this species.

Pupa — Described and figured by Darsie (1955).

Fourth instar larva (fig. 110) — Head wider than long, about 1.5 mm. wide. Antennae about half as long as head. Head hairs usually coarse; uppers usually with 2 or 3 branches (2-4), lowers usually double (2-3). Mesothoracic dorsal principal small. Lateral abdominals usually single or double. Eighth segment with 6-8 comb scales (4, 8, and 2 of 14 respectively) usually in single or irregularly double row; scales usually very dark with central spine longer than rest of comb scale. Air tube about 4 times as long as wide at middle; pecten confined to basal half, with 2 or 3 detached spines (12 and 2 of 14); tuft beyond pecten, about as long as or somewhat longer than width of siphon at point of insertion, usually with 4 branches (11 of 14; range 3-5). Anal segment with saddle extending about 3/4 or more down the sides; lateral hair about 2/3 as long as saddle, usually single and rather stout; saddle often with ventral notch at posterior third. Anal papillae slightly longer than dorsal saddle.

Third instar larva (3 specimens)—Head about 1 mm. wide; head hairs single; with 7 or 8 comb scales (3 and 3 of 6); siphonal tuft with 2 or 3 branches; saddle extending about 1/3 down the sides with lateral hair at edge.

Egg — Undescribed.

Distribution — Similar to *flavescens* but probably does not occur as far north. Holarctic; in North America in northern plains regions from Alberta to Ontario; south to Wisconsin, North Dakota, and Colorado.

Importance — None, rare in state.

Aedes dorsalis group

Aedes (Ochlerotatus) canadensis (Theobald)

Female — Proboscis and palps dark-scaled. Mesonotum almost unicolorous (dark reddish or yellowish brown) but may have pale markings at the sides and posteriorly. Abdominal terga almost entirely dark-scaled, never with complete, white, basal bands; lateral, white triangular patches can usually be seen at the bases of terga VI to VIII when viewed from above; viewed from the side, these patches can also be seen on the more anterior terga. Wing scales dark. Legs mostly dark-scaled; small pale knee-spots present; tarsal segments, particularly on the hind legs, with pale bands covering the apex of one segment and the base of the next; last tarsal segment of hind legs entirely white.

Male — May be identified by key to females. Terminalia (fig. 81): basistyle about 4 times as long as wide; apical lobe not projecting prominently, rather flattened, with a dense patch of flattened, leaf-like setae; basal lobe prominent, rather triangular, papillose, with many short setae, no spines. Claspette filament about half as long as stem, cylindrical, bent near base. Lobes of ninth tergum prominent, with several large setae. The appearance of the apical lobe is unique.

Pupa — Described and figured by Darsie (1951).

Fourth instar larva (fig. 98— Head wider than long, about 1¼ mm. wide. Antennae over half as long as head (about .6). Upper head hairs usually with 5-8 branches (32.7, 34.6, 20.2, and 6.7% of 104; range 4-9), lowers usually with 3-5 branches (21.7, 50.0, and 23.6% of 106; range 2-6). Posterior shoulder hair reaching to or beyond head hairs. Mesothoracic dorsal principal small. Lateral abdominals usually double on I (13 of 15; range 1-3), II (16 of 17; range 2-3), III (19 of 19), IV (19 of 19), V (17 of 19; range 1-2), single on VI (14 of 14). Eighth segment usually with 20 to 36 comb scales (mean 27.8; 44 specimens; range 19-53) in triangular patch; comb scale with apical spinule equal to lateral spines or with central one somewhat larger. Siphon about 3 times as long as wide at middle, pecten with evenly spaced teeth (occasionally one is more or less detached), not extending to middle of siphon; tuft about 1 to 1½ times as long as width of air tube at point of insertion, usually with 4-6 branches (20, 37, and 31% of 95; range 3-8). Anal segment with saddle extending about 1/2 down the sides; lateral hair about 2/3 as long as saddle, usually single. Anal papillae about 2 or more times as long as saddle.

Egg — Figured by Mitchell (1907) and Horsfall and Craig (1956).

Biology — Little is known of the biology of this species. Overwintering is by the egg stage. In Minnesota the spring emergence occurs somewhat after the early species and about the same time as or somewhat before *cinereus* and *vexans,* around the middle of May. Although this is often said to be a spring species, fresh females and often larvae may be taken throughout the summer months. The author has taken larvae abundantly at Basswood Lake (Lake Co.) in late August. Egg development in this species appears to be similar to that in *cinereus* in that at least some eggs can hatch without exposure to cold (Smith, 1904; Mitchell, 1907; Newkirk, 1955). Barr and Azawi (1958) found that most eggs would not hatch the year they were laid. Eggs have been taken from mud at the bottom of breeding places by Smith (1904). The same author found that larvae were taken in breeding places in or near woods and that the larvae could survive being frozen in ice. The pupal stage was about normal in length (2-7 days). Masters (1943) found larvae in waters with a medium specific gravity.

According to Dyar (1922a) males of this species swarm. Females feed on cold as well as warm blooded animals (Carpenter, 1941). Mitchell (1907) found that females laid 30 to 75 eggs 4 to 7 days after feeding; Newkirk (1955) found they would lay up to 139 in one batch. Larval development requires about 7 days and pupal 2 days (Mitchell). Flight in this species is thought to be short since females are found rather locally, in wooded places (Headlee, 1931).

DISTRIBUTION — North America; Canada south to Gulf Coast; west to British Columbia, Washington, Nebraska, and Texas. In Minnesota found in wooded regions, primarily in northeastern 2/3 of state.

IMPORTANCE — May be of some importance as a pest in wooded areas, particularly in the spring.

Aedes (Ochlerotatus) *dorsalis* (Meigen)

FEMALE — Palps mostly dark-scaled but usually with a sprinkling of pale ones. Proboscis dark-scaled, with a sprinkling of pale scales, particularly medially and ventrally but without a definite white ring. Mesonotum white- and brown-scaled; pattern very variable but usually with a median brown stripe which does not extend entirely to the antescutellar area; sides of mesonotum usually brown-scaled also. Sides of thorax with extensive white scaling. Dorsum of abdomen largely white-scaled; as a rule the only dark scaling is a pair of patches on either side of the median line, particularly on the more anterior segments. Wings with extensive dark and light scaling; intermixed on C and Sc. R_2, R_3, and M mostly pale-scaled, R_{4+5} and Cu mostly dark-scaled. Legs with dark and light scaling, tarsi with pale bands covering apex of one segment and base of next, particularly on mid- and hind tarsi (fig. 24). The adults are similar to a pair of adults from China in the University collection and also to a series of *campestris* from Alaska identified by H. G. Dyar. The best separation of *dorsalis* and *campestris* females appears to be on the basis of the tarsal claws as pointed out by Rempel (1953; figs. 27, 28; fig. 28 is redrawn from Vockeroth, 1954b).

MALE TERMINALIA (fig. 82) — Rather similar in overall appearance to *canadensis* from which it can be differentiated by the shape of the claspette filaments, the presence of a small spine lateral of the basal spine, and the absence of a dense patch of spatulate setae on the apical lobe. Very similar to *campestris* which, however, lacks the short, stout, dark, spine lateral of the basal spine but has 3 stout setae in this area which are much larger than the other setae of the basal lobe.

PUPA — Undescribed.

FOURTH INSTAR LARVA (fig. 112; description and figure based on material taken from brackish water in Kansas) — Head wider than long, slightly over a mm. wide. Antennae less than half as long as head. Head hairs rather fine, single (100% of 50 lowers, 91% of 47 uppers; range 1-2). Mesothoracic dorsal principle well developed, rather long, usually double, less often single (67% of 85 double, 24% single, range 1-3). Lateral abdominals usually double on I-VI (83% of 41, 70% of 40, 74% of 46, 76% of 46, 83% of 47, and 100% of 17; range 2-4 on I-IV, 1-3 on V). Eighth segment most often with 20, 24, or 26 comb scales (average 25.6; range 18-36; a single specimen had about 56 or more). Individual comb scale fringed with many, long subequal spines; without distinctly larger median spine. Siphon about 2 to 2¾ times as long as wide at middle. Pecten confined to basal half of siphon. Spines of pecten usually evenly spaced; occasionally one is detached on one side and rarely on both. Siphonal tuft inserted beyond and usually somewhat ventral of the pecten; branches of tuft somewhat shorter than to almost as long as width of siphon at point of insertion; usually with 4 to 7 branches (24, 47, 16, and 8% of 62; range 3-8). Dorsal preapical spine less than half as long as apical pecten tooth. Anal segment with saddle extending about 1/3 down the sides of the anal segment; lateral hair single, much shorter than the saddle. Anal papillae at most about 1/2 the length of the saddle in the specimens at hand which are from brackish water; the dorsal pair is usually considerably longer than the ventral pair.

THIRD INSTAR LARVA (4 specimens) — Head slightly less than a mm. wide. Mesothoracic dorsal principle well developed, usually single. Lateral abdominals double. With as many comb scales as the fourth instar (20-26 in the specimens at hand). Siphonal tuft with 3-4 branches. Anal segment with dark brown saddle extending about 1/4 down the sides; lateral hair slightly ventral of saddle.

Notes on the earlier stages are given by Marshall (1938) and Bohart (1954) has described the first instar.

EGG — Figured by Marshall (1938), described by Rees and Nielsen (1947).

BIOLOGY — The biology of this species has been recently summarized by Rees and Nielsen (1947); except when otherwise indicated all information is from this work. Some parts of the literature on *dorsalis* undoubtedly refer to *melanimon* (see Barr, 1955).

Overwintering is by the egg stage. The spring emergence, according to Hocking *et al.* (1950) takes place a little after that of *excrucians*; in Minnesota emergence should occur at about the same time as that of the early summer *Aedes*, about the middle of May. The species is more of a summer one than an early spring one. Hatching of the eggs is said (Gjullin *et al.*, 1941) to be stimulated by a reduction in dissolved oxygen.

Larvae are found predominantly in water heavily charged with salts, especially brackish water or alkaline pools, although they also are found in fresh water; the anal papillae, of course, are much shorter in larvae from the former type of situation than from the latter. Larvae have been taken in water which contained up to 12% salts by weight, although they are killed by higher concentrations; Mail (1934) took larvae at alkalinities up to pH 9.6. Breeding places are usually in open, sunlit locations and are usually temporary or semipermanent. The optimum temperature for the aquatic stages is said to be about 24-27° C. and development of the aquatic stages (hatching to emergence) takes from 5½ to 7 days at this temperature. Keener and Edmunds (1954) found, however, that the larval stages alone required 5 to 8 days at about 20-25° C. and 9-12 days at about 12-16° C. Larvae are said to be killed by a temperature of about 38° C. It is said that each of the larval stages requires about the same length of time (24 to 30 hours) at the optimum temperature; if larval development is retarded due to low temperatures, etc., the fourth larval instar is especially prolonged. Development of this species appears to be somewhat slower than with *Aedes nigromaculis* or *vexans* (Keener and Edmunds, 1954; Thurman and Mortenson, 1950b).

As noted above, the length of the pupal stage is about normal for mosquitoes. Pupae are said to be more resistant to high temperatures than are larvae. Adults may emerge even from stranded and drying pupae. Adult males on the average emerge sooner than females and the emergence of an entire brood may take place over a short period of time, as little as 18 hours or so.

Mating usually takes place within 24-48 hours after the emergence of a brood and swarm formations have been described (Dyar, 1922a; Rees and Nielsen, 1947). Adults appear to rest primarily in vegetation. Adult females appear to prefer to feed on mammals and take a blood meal in about 2 minutes on the average. The blood is digested in about 48 hours at warm temperatures and eggs are laid about 60-72 hours after feeding. The females have been observed to probe the ground with their ovipositors and lay their eggs in moist depressions (Rees and Nielsen, 1947; Thurman and Mortenson, 1950b). It is said that an average of 133 eggs is laid (range 30-153).

Major migrations of this species have been followed for 22 miles (Rees and Nielsen, 1947); other data on this point are given by Smith [G. F.], (1952) and Husbands and Rosay (1952): Rees (1945) recorded seven migrations of this species, all of which occurred during a full moon. Rees and Nielsen (1947) found that migrations occurred only when the relative humidity was 50% or higher. The adults are most active at dusk although females will bite readily during the day, even in sunlight. Adults are most active at temperatures between 10 and 35° C. and at high humidities (at least up to 80% relative). Males appear to be more highly attracted to light than females. Females in the field usually live less than 3 months and males less than 3 weeks.

It is said that a period of partial drying is necessary for the hatching of the eggs (Rees and Nielsen, 1947) although eggs are readily killed by complete drying (Hayes, 1950; Thurman and Mortenson, 1950b). Eggs may begin hatching as early as 5 days after being laid (Mail, 1934) and are capable of remaining viable in soil for years. The threshold for hatching is said to be about 6° C. Thurman and Mortenson (1950b) found that there was a staggering in the hatching of the eggs. It is believed that there may be several generations per year; Mail (1934) figures about 17 days for a generation dependent, of course, on temperature.

DISTRIBUTION — Northern Europe, Asia, and America. In North America in interior plains and coastal regions from Pacific to Atlantic; as far south as Mexico, Louisiana, Mississippi, Kentucky, and Delaware; north to Hudson's Bay. In Minnesota in plains areas extending into hardwood forest in southwestern 2/3 of state.

IMPORTANCE — Although this species is not generally found in abundance in Minnesota it is said to be the dominant mosquito of the western plains of the United States. It is probably an important pest at times in the western part of the state. The species may be involved in the epidemiology of the arthropod-borne encephalitides (Hammon and Reeves, 1945; Thompson *et al.*, 1951).

Aedes (Ochlerotatus) campestris Dyar and Knab

FEMALE — The female is very similar to that of *dorsalis* and records based on this stage are unreliable. As stated by Rempel (1953) the tarsal claws (figs. 27, 28) of the fore and midlegs of the female differ in the two species;

this appears to be the most reliable difference yet found for separating females. In the experience of the author there are no reliable differences in the scaling of the wings.

MALE (fig. 83) — Although the terminalia are very similar in *dorsalis* and *campestris,* the armament of the basal lobes is quite different; instead of the long and short spines possessed by *dorsalis, campestris* has a series of about three spines lateral of the long (basal) spine. The basal spine is not at all prominent in *campestris* as a rule and may be overlooked entirely. The three or so associated spines are smaller than the basal spine but larger than the other setae of the basal lobe as can be seen by an examination of their sockets. The subtlety of these differences has caused great confusion in descriptions of the terminalia of *campestris.*

PUPA — Undescribed.

LARVA (Minnesota specimens not seen by the author; description from Utah and Nevada specimens; fig. 111) — Head wider than long, about 1 mm. wide. Antennae about 1/2 as long as head. Head hairs not in line with post-antennal tuft. Upper head hairs usually double or triple (2-4), lowers usually single, occasionally double. Posterior shoulder hair (1) reaching to head hairs, usually double (1-2); associated hairs (2 and 3) shorter, not reaching head hairs. Prothoracic hair 5 usually triple, occasionally double; hair 7 usually triple (3-4). Mesothoracic dorsal principal about as large as head hairs, usually triple (3-4). Lateral abdominals double or triple on I-II; usually double (2-3) on I-VI (occasionally single on VI). Dorsolaterals small on I-VI, long on VII; usually double on VII. Eighth segment most commonly with 24 comb scales (20-27) in triangular patch; individual comb scale with median spine not much, if any, larger than the lateral spines. Siphon about 3 times as long as wide at middle; pecten usually extends beyond middle of siphon at least on one side and usually with 1 detached pecten tooth (0-3); an occasional specimen lacks detached pecten teeth on both sides. Siphonal tuft inserted beyond pecten; about as long as or somewhat shorter than width of siphon at point of insertion; with about 5 branches. Dorsal preapical spine small, less than half as long as last pecten spine. Anal saddle extends about 2/3 to 5/6 down the sides of the anal segment; lateral hair short, less than half as long as saddle. Anal papillae very small, usually less than 1/4 the length of the saddle; lower papillae shorter than upper ones. Richards (1956) has recently published a comparison of this species with related forms.

EGG — Undescribed.

BIOLOGY — The biology of this species is incompletely known but is, in all probability, essentially the same as in *dorsalis.* Overwintering is by the egg stage. Emergence in the spring is probably somewhat earlier than *dorsalis* since *campestris* has a more northerly distribution. Larvae are often taken in alkaline pools. The pupal period is about 2-7 days (avg. 4.8) according to Hocking *et al.* (1950) but this probably reflects low water temperatures. Swarming has been observed (Dyar, 1922a) and adults rest in grass (McLintock, 1944); Philip (1943) noted adults feeding on flowers. The females probably feed for the most part on mammals and will attack at any time of the day (Howard *et al.,* 1917) although they probably feed most readily under conditions of reduced illumination (Hocking *et al.,* 1950); two dissected females contained 104 and 166 developing eggs. Adults can fly as far as 10 miles (Rees, 1943). The experiments of Mail (1934) show that eggs are rather susceptible to drying and will not hatch after collapsing; about 25% of a batch of eggs hatched after storage in water at 0-10° C. in a refrigerator for 20 months; a few dry eggs hatched under similar conditions. As far as is known there is a single generation a year although Rempel (1953) records a second brood, if not a second generation.

DISTRIBUTION — North America, in northern prairie regions; eastern Washington and British Columbia east to Ontario and Michigan; south to Utah; north to Alaska, Yukon Territory, Hudson's Bay. In Minnesota a few records from the northwestern part of the state and the Twin Cities.

IMPORTANCE — Too rare in the state to be of much importance.

Aedes scapularis group

Aedes (Ochlerotatus) *trivittatus* (Coquillett)

FEMALE — Palps and proboscis dark-scaled. Mesonotum with two rather broad, widely separated line of white scales; median stripe and sides of mesonotum dark brown. Postpronotum largely dark-scaled. Dorsum of abdomen with white lateral triangles at the bases, particularly of the more posterior terga. Wings dark-scaled. Legs mostly dark-scaled, with lines of white scales on inner margin of tibia and basitarsus.

MALE — Can be identified by key to females. Terminalia (fig. 86): basistyle unusually short and wide; apical lobe rather low and continuous with basal lobe which is of distinctive shape. Claspette filament with retrorse spine and accessory denticles.

PUPA — Described and figured by Darsie (1951).

FOURTH INSTAR LARVA (fig. 96; based on material from Douglas Co., Kansas).— Head wider than long, about 1 mm. wide. Antennae about 1/2 as long as head or somewhat shorter. Upper and lower head hairs single (100% of 44 and 44 respectively). Prothoracic shoulder hair single, not reaching to upper head hairs. Mesothoracic dorsal principal small, usually double. Lateral abdominals double on I-II (95 and 97% respectively of 41 and 40; range 2-3), single on III-VI (100% of 43, 44, 41, and 22 respectively). Eighth segment most commonly with 20 or 24 comb scales (10 and 12 of 31; range 15-24), usually in triangular patch but may be in irregularly double row when smaller numbers of comb scales are present. Comb scale with median spine which is about twice as thick and a little longer than lateral spines. Siphon about 2 to 2½ times as long as wide at middle; pecten of evenly spaced teeth, extending to or a little beyond the middle of the siphon. Siphonal tuft inserted beyond pecten, about 1/3 to 2/3 as long as width of siphon at point of insertion: usually with 5-7 branches (19, 42, and 32% of 31; range 5-8). Dorsal preapical spine less than half as long as apical pecten tooth. Anal segment ringed by saddle which is usually wider than long; lateral hair not as long as saddle, usually single. Ventral brush posterior of saddle. Anal papillae usually over twice as long as the saddle, the two pairs being of about the same length. There was remarkably little variation in the specimens examined due probably to their being for the most part from a single female.

EGG — Described and figured by Horsfall & Craig (1956).

BIOLOGY — Reviewed by Abdel-Malek (1948); unless otherwise stated, all information is from this source. Horsfall (1955) reviews additional material.

Overwintering is by the egg stage. The spring emergence of adults is said to be rather late, about the same time as *vexans* according to Ross (1947); the species is thus a summer one rather than a spring one; most Minnesota records of adults are in July and August. Indications are that there are several generations each year (Howard *et al.*, 1917). Abdel-Malek (1948) has presented data to show that auxins may be important in stimulating the hatching of eggs of this species but his results are rather erratic; Newkirk (1955) was unable to confirm them. It is true, however, that grass extracts induce hatching of the eggs of this species (Barr and Azawi, 1958). Larvae are found primarily in temporary rain pools. In the field observations of Abdel-Malek the first 3 larval instars required about one day each but the fourths took 3-4 days and the pupa a single day; thus the entire aquatic life required a minimum of about 8 days at about 18-20° C. In the laboratory at about 27° C. this development took about 6 days. In the field larvae were taken in slightly alkaline water; Mail (1934) took larvae at pH 8.5-9.

Males emerged on the average before females and adults tended to rest for an hour or two after emergence before leaving the breeding place. It appears that nothing is known of mating in this species but Abdel-Malek thought it probably occurred soon after emergence. Females began feeding on blood about 3-4 days after emergence. At about 27-29° C. the preoviposition period was 3-5 days and females oviposited on wet cotton; they laid 55-100 eggs (125 according to Newkirk, 1955). There was a suggestion that Hydrachnid mites reduced the numbers of eggs laid.

The females appear to be non-migratory and rest in vegetation. Females will bite by day although most bite at dusk; most attacked the arms rather than other parts of the body. Males disappeared after about 5 days but some females lived 5-6 weeks in the field.

DISTRIBUTION — Eastern North America: southern Canada south to South Carolina and Louisiana, west to Montana, Colorado, and New Mexico; Dyar (1922a) gives Central American records also. In Minnesota in plains and deciduous forest regions.

IMPORTANCE — The species is regularly but not abundantly found in Minnesota and is thus of little importance. As stated by Owen (1937) it has been found all over the state except in the coniferous forests.

Aedes communis group

This is Edwards' (1932) group G of the subgenus *Ochletotatus* and aside from the species in the key below includes *spencerii*. *Aedes trichurus* has been included for convenience. The identification of females of this group is frequently difficult if not impossible at the present time. See also the keys by Beckel (1954a) and Vockeroth (1954b).

Tentative key to the females of the *Aedes communis* group

1. Mesonotum with clearly defined stripes or distinctly bicolorous 3

1. Mesonotum unicolorous, golden, without clearly defined stripes although two vaguely darker lines may be seen medially (due mostly to narrowness of scales in this area); the scales may be somewhat paler at the edges of the mesonotum but the mesonotum is not distinctly bicolorous 2

2. Scales of sternopleuron extending to the anterior edge of that sclerite; post-coxal scale patch present .... *abserratus* (p. 117)

2. Scales of sternopleuron not extending to the anterior edge of that sclerite; post-coxal scale patch absent .... *intrudens* (p. 122)

3. Scales of sternopleuron not extending to the anterior edge of that sclerite 4

3. Scales of sternopleuron extending to anterior edge of that sclerite 7

4. Mesonotum tricolorous, with two dark brown stripes surrounded by coppery scales and white or gray at the sides (tarsal claw as in fig. 92) .... *implicatus* (p. 113)

4. Mesonotum biclorous, not marked as above 5

5. Abdomen entirely dark-scaled dorsally; mesonotum with dark median stripe widening posteriorly[12] .... *aurifer* (p. 121)

5. Abdomen with at least white, lateral triangles on the bases of the terga; frequently with the median stripe narrowly divided to form two stripes 6

6. Most of the tergal bands interrupted medially; mesonotum golden to whitish with darker median stripe which is usually interrupted medially by a line of dark scales (tarsal claw as in fig. 76) .... *dianteus* (p. 123)

6. Tergal bands not interrupted medially; mesonotal markings not as above; usually with well-separated darker lines 7

7. Post-coxal scale patch present 8

7. Post-coxal scale patch absent 10

8. Costa with large patch of white scales at base; mesonotum with much white scaling at sides, usually with vaguely defined darker area medially (the white scales at the sides of the mesonotum are curled more than in other species) .... *trichurus* (p. 120)

8. Base of costa with few or no pale scales; mesonotum with well defined dark median stripe or stripes; mesonotum frequently with yellow rather than white scaling 9

9. Base of costa usually entirely dark-scaled; usually with single dark brown or coppery median stripe or mesonotum; bristles of scutellum usually yellow; tarsal claw as in fig. 93) .... *punctor* (p. 118)

9. Base of costa with small patch of pale scales; mesonotal stripe usually divided medially by pale scales; bristles of mesonotum usually black; tarsal claw as in fig. 94 .... *pionips* (p. 117)

10. With large patch of pale scales at base of costa; mesonotum with two dark brown, well separated stripes; scales of postpronotum the same color as those on the sides of the mesonotum; tarsal claws as in fig. 94 .... *communis* (p. 115)

10. With few or no pale scales at base of costa; mesonotum usually not as above, variable, with two stripes or one broad stripe, the stripes are reddish to dark brown; scales of the postpronotum usually much darker than those on the sides of the mesonotum, generally of the same color as the mesonotal stripes .... *sticticus* (p. 111)

Aedes (Ochlerotatus) sticticus (Meigen)

The status of *sticticus* is not yet settled; most of the literature on this species in the United States refers to it as *lateralis, aldrichi,* or *hirsuteron.* The European form is known as *sticticus.* The tendency at the present time is to consider all of these forms under the name *sticticus* but it is not certain that the American form is the same as the European form. Some authors also recognize eastern (*sticticus* or *hirsuteron*) and western (*aldrichi* or *lateralis*) forms in North America. Critical comparison of the eastern American, western American, and European forms is badly needed. Dyar (1928) says the eastern form has a single line on the mesonotum and the western form a double line, but there do not appear to be differences in the larvae or males.

FEMALE — Palps and proboscis dark-scaled. Mesonotum with central area coppery, sides yellowish, occasionally whitish; anterio-lateral corners dark-scaled. Dorsum of abdomen with white, basal bands on the terga, narrowest medially; remainder of dorsum dark-scaled. Wings dark-scaled. Legs mostly dark-scaled and unbanded but tibiae and basitarsi with much white scaling.

MALE TERMINALIA (as in fig. 71) Basistyle about 5 times as long as wide at middle; "apical lobe" situated subapically, rounded

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[12] This separation is probably unsound; the writer has not seen females of *aurifer*.

(of rather characteristic shape), with prominent, short, recurved, rather flattened setae; basal lobe not attached to basistyle apically (semi-detached), tuberculate, with many short setae, those near basal spine all pointing in the same direction as the basal spine, forming a vaguely defined, but dense tuft; basal spine dark, rather large and prominent, curved apically. Lobes of ninth tergum with large and small stout spines, about 3 of them on each lobe. Claspette filament not evenly rounded on outer margin, with prominent projection at base of inner margin. The terminalia appear to be identical with those of *spencerii* (*q.v.*).

Pupa — Described and figured by Darsie (1951).

Fourth instar larva (fig. 114) — Head wider than long, about 1¼ mm. wide. Antennae slightly less than half as long as head. Upper head hairs usually with 1-3 branches (4, 17, and 10 of 32; range 1-4), lowers usually with 1-2 branches (15 and 16 of 32; range 1-3). Prothoracic hairs 1 and 5 single (100% of 31 of each). Mesothoracic dorsal principal small. Lateral abdominals usually double on I-V (25 of 30 and 28 of 31 on I and II, range 2-3; 18 of 31 on III, 12 triple, range 2-4; 29 of 30 on IV, range 2-3; 23 of 29 on V, range 1-2), single on VI (13 of 14, range 1-2). Eighth segment most often with 20 or 24 comb scales (4 and 7 of 15; range 19-25), usually in triangular patch; comb scale usually with rather prominent terminal spine. Siphon about 2-3 times as long as wide at middle; pecten of evenly spaced spines usually confined to basal half of siphon, occasionally with outer spine detached; tuft with 4-7 branches (4, 8, 12, and 6 of 30 respectively), branches about half as long as width of siphon at point of insertion. Anal segment almost encircled by saddle; lateral hair shorter than saddle, usually single. Anal papillae about 1½ to 3 times as long as saddle. First instar described by Bohart (1954).

Egg — Described by Howard *et al.* (1917), Hearle (1926), Gjullin *et al.* (1950), and Horsfall and Craig (1956).

Biology — The biology of this species has been reviewed by Gjullin *et al.* (1950); unless otherwise stated the information below is from that source. Supplemental notes are given by Hearle (1926) and Horsfall (1955). In all important respects the biology of this species appears to be similar to that of *vexans*.

Overwintering is by the egg stage. Larvae are found particularly in flood water pools. The aquatic stage requires about 10 days to three weeks in the field, less at higher temperatures (Hearle, 1926; Twinn, 1926; Gjullin *et al.*, 1950). Larvae are usually found in neutral waters. Males emerge before females on the average (Hearle, 1926).

The initial emergence of adults in the spring is said to be rather late; Howard *et al.* (1917) said this species emerged at about the same time as *canadensis.* Most adult collections in Minnesota have been in June and July so this is one of the summer species. Swarming of males has been observed (Dyar, 1922a; Hearle, 1926) but Gjullin *et al.* (1950) were able to get viable eggs from females which mated in cages of about one cubic yard. According to Hearle females mate soon after emergence; both sexes feed on plants and females usually do not take a blood meal for several days after emergence. Most activity is said to occur at dusk although females will feed in the daytime (Hearle, 1926; Twinn, 1931). Females feed readily on livestock, particularly on horses and cattle, and man (Hearle, 1926; Twinn, 1931). According to Twinn (1931) females require about a minute and a half to feed on the average; females took about twice their weight in blood or about 4 mm^3. The preoviposition period is rather long according to Hearle.

In dissecting ovaries of females Hearle found an average of 68 developing eggs (range 46 to 92); Gjullin *et al.* found that females laid about 52 on the average. Oviposition has not been studied in this species but Gjullin *et al.* found that the clearing of brush was a useful control measure for this species due possibly to its effect on the ovipositing female. The latter authors found that 61% to 75% of the eggs completed their development in 10 to 12 days and that such eggs would hatch as soon as they were fully developed (see also Newkirk, 1955). Thus it seems likely that there may be several generations in a year. A reduction in oxygen concentration is said to be the chief factor governing the hatching of eggs in nature. Eggs hatched in large numbers after 2 to 3 years but survival rapidly fell off after this. Eggs were killed by drying of soil containing them.

Adults generally rest in underbrush or grass (Twinn, 1926). The adults are said to be migratory and Hearle recorded migration in numbers up to 15 miles; other workers (Twinn, 1926, 1931; Michener, 1947; Stage *et al.*, 1952) also testify to the migratory behavior of this species. Twinn (1931) says females probably migrate a few hours after emergence. According to Hearle, females may live from 4 to 6 weeks in the field.

Distribution — Holarctic; in North America the Atlantic to the Pacific; southern Canada south to Florida, Texas, Utah, and Oregon. In Minnesota, as Owen (1937) pointed out, more common in wooded regions but extends into prairie.

Importance — Sandve (1946) found this species to be the most common one present at the St. Croix State Park in late June and July, 1946. The author examined collections from this area in the summer of 1954 and found them all to be of this species. In August of the same year it was also the most important pest at Itasca State Park. This species is undoubtedly a major pest in wooded areas which occur along rivers where there is a possibility of floodwater pools.

Aedes (Ochlerotatus) spencerii (Theobald)

Female — The only dark-legged *Aedes* in Minnesota with a stripe of white scales down the center of the dorsum of the abdomen; sometimes the entire dorsum is clothed with white scales. Proboscis dark-scaled. Palps dark-scaled with a sprinkling of pale ones. Mesonotum with dark brown scales, scales whitish at the sides of the mesonotum. Postpronotum usually dark-scaled. Dorsum of abdomen with extensive white scaling; with median white line, white basal bands, usually with small apical bands also; more posterior terga usually entirely white-scaled; occasionally the entire dorsum is white-scaled. Wings dark and light scaled, outer part of costa, R_1, R_{4+5}, and Cu largely dark-scaled; base of C, base of R_s, R_2, R_3, and M largely pale-scaled. Legs without pale bands.

Male (fig. 74) — The male of *spencerii* is very similar to that of *sticticus* (*q.v.*) and I am unable to separate the two with certainty. In the material at hand both species have a basal lobe on the claspette filaments contrary to the statements of Ross (1947) and Rempel (1953). The difference in the lateral aspects of the apical lobes described by Ross for the two species are too vague to be of use.

Pupa — Undescribed.

Fourth instar larva (fig. 115) — Head wider than long, slightly over a mm. wide. Antennae less than half as long as head, often about 1/3. Head hairs usually all single (100% of 73 uppers; 97% of 74 lowers, 3% double). Lateral abdominals usually single or double, often multiple on I. Eighth segment most commonly with 8 or 10 comb scales (18 and 44% of 45; average 9.5; range 5-13, usually in irregularly single or double row; comb scale with strong terminal spine. Siphon about 3 times as long as wide at middle, pecten on basal half or extending somewhat beyond the middle, usually with 1-3 detached teeth (25, 47, and 18% respectively of 76; range 1-5); a single specimen lacked detached teeth on one side but was obviously abnormal since the pecten was much reduced); tuft beyond pecten, not as long as width of siphon at point of insertion, usually not much more than half as long, usually with 3-5 branches (37, 38, and 15% respectively of 60; range 2-6). Anal segment with saddle extending about 5/6 down the sides, about as wide as or wider than long; saddle hair weak, about half as long as saddle or shorter, usually single. Anal papillae several times as long as saddle.

Egg — Undescribed.

Biology — Little is known of the biology of this species. In Minnesota it appears to be the earliest *Aedes* on the wing although it is followed shortly by *intrudens* and *implicatus*. There is thought to be a single generation a year; Owen (1937) was not able to hatch eggs the year they were laid even after alternate drying and flooding. Larvae in Minnesota are usually taken in snow water pools overlying frozen ground. There is undoubtedly a high death-rate of larvae each year occasioned by drying. The swarming of males has been described by Knab (1908). The species is said to be strictly diurnal in feeding (Owen, 1937) and swarming (Knab) although females are often taken biting at dusk. Howard *et al.* (1913a) said that females are attracted to prominent objects on the prairie; Mail (1931) lists this species as being an important livestock pest. Both sexes rest in grass and feed on plants (Knab, 1908). Males are thought to live for a couple of weeks or less (Knab) but females sometimes live for several months (Owen, 1937; McLintock, 1944). Shemanchuck *et al.* (1953) discuss the tagging of this species with P_{32}.

Distribution — Northern prairies of North America; Manitoba and Minnesota west to British Columbia, Montana, and Wyoming. In Minnesota practically all collections are from prairie areas.

Importance — Usually not common but could be abundant at times in the early spring, especially in prairie regions.

Aedes (Ochlerotatus) implicatus Vockeroth

This is the *Aedes impiger* of many authors. Vockeroth recently (1954a) found that the type of *impiger* was of the species known as *nearcticus;* he therefore transferred the name to that species and renamed the present one *implicatus.*

Female — Small. Proboscis and palps dark-scaled. Mesonotum tricolorous; disc with coppery brown scales and with two widely separated lines of dark brown scales; sides pale-scaled, grayish to white; dark brown posterior half lines also present. Sides of thorax with extensive white scaling; scaling of sternopleuron not extending to anterior border of that sclerite. Dorsum of abdomen with white, rather wide, basal bands on the terga; the remaining parts dark-scaled. Wings mostly dark-scaled, usually with prominent patch of white scales at base of costa. Legs extensively dark-scaled, without pale bands on tarsi; prominent white knee spots present. Tarsal claw as in fig. 92 (from Vockeroth, 1954b).

Aedes implicatus females are most likely to be confused with those of *trichurus, dianteus,* and the small form of *communis. Aedes trichurus* is a much larger species which does not have two dark lines on the mesonotum, has the scaling of the sternopleuron extending to the anterior margin of that sclerite, and lacks pale knee spots; the character which is most distinctive of *trichurus* is the narrow, curved scaling on the sides of the mesonotum; in *implicatus* these scales are broader and appear very different. *Aedes dianteus* has one or two dark stripes on the mesonotum which are not surrounded by a coppery patch of scales as in *implicatus; dianteus* also lacks pale knee spots and usually has the pale scaling of the abdomen reduced (see also the discussion of the small form of *communis,* p. 238). Gjullin (1937) has described the female terminalia. Beckel (1954a) discusses the classification of denuded specimens.

Male terminalia (fig. 92) — Basistyle with prominent, narrow, apical lobe which is without small setae on its ventral face (compare with *communis*), with prominent tuft at base. Basal lobe with spine and posteriorly-directed setae as in *communis.* Claspette filament rather long, lightly sclerotized, without the prominent longitudinal striae of *communis.* Lobes of ninth tergum prominent.

Pupa (figs. 45-47) — Undescribed.

Fourth instar larva (fig. 117) — Head wider than long, slightly over a mm. wide. Antennae not quite half as long as head. Head hairs usually single (55 of 59 uppers, range 1-2; 62 of 62 lowers). Posterior shoulder hair reaching almost to upper head hairs, usually single. Mesothoracic dorsal principal usually much less stout than head hair, single. Lateral abdominals usually double on I (16 of 21; range 2-4), II (19 of 19), III (16 of 19; range 2-3), IV (21 of 22; range 1-2), single or double on V (6 and 17 of 23), single on VI (22 or 23; range 1-2). Eighth segment most commonly with 24 comb scales (16 of 42; average 24.4; range 20-29), in triangular patch; comb scale usually without prominent terminal spine. Siphon about 3½-4 times as long as wide at middle; pecten of evenly spaced teeth (occasionally one is detached), usually confined to the basal third of siphon; tuft about as long as width of air tube at point of insertion, usually with 4 or 5 branches (20 and 25 of 60; range 3-6). Anal segment with saddle extending about 3/4 - 5/6 down the sides, often with ventral notch at posterior third; lateral hair inserted on saddle, about 2/3 as long as saddle, usually single. Anal papillae usually about 1½-3 times as long as saddle. Brackish water specimens, according to Frohne (1953), have papillae averaging .6 as long as the saddle (.3-1.3) and are usually shorter than in *communis* when the two are associated.

Third instar larvae of *stimulans* may key to this species but may be distinguished by the reduced anal saddle; the lateral hair is placed at the very edge of the saddle.

Egg — Undescribed.

Biology — Practically nothing is known of the biology of this species. Overwintering is by the egg stage. The spring emergence in Minnesota is very early, usually after that of *spencerii* and probably *intrudens* but before *trichurus* and probably *communis.* Most Minnesota collections were made in May. Larvae were rather ubiquitous at Virginia, Minnesota, in 1953 although perhaps more common in melted snow water overlying frozen ground; numbers were also taken in semi-permanent water. Although the water of breeding places is quite cold, this species never attains a very large size; the developmental time at such temperatures is, of course, very long. The species has been taken in brackish water (Frohne, 1953).

The swarming of males of this species has been described by Dyar (1919) under the name *lazarensis.* According to Curtis (1953) females are crepuscular, not nocturnal. Females feed readily on humans and, according to Twinn (1931), on livestock. Adults are found primarily in wooded areas and appear to be rather short-lived. They are usually not abundant although they may be common in wooded areas in the early spring. Eggs collected by the author were quickly killed by drying.

DISTRIBUTION — Canadian forested region from Atlantic to Pacific south to New York, Michigan, Minnesota, Montana, Colorado, and Washington; north to Alaska, Yukon Territory. In Minnesota there are only scattered records, all in the northern forested region.

IMPORTANCE — Probably none; usually not abundant, even in wooded areas.

Aedes (Ochlerotatus) communis (DeGeer)

Some of Owen's (1937) records of this species apply to *punctor* and *dianteus.*

FEMALE — Usually rather large. Proboscis and palps dark-scaled. Mesonotum with yellowish to golden scales; with a line of dark brown scales on either side of the midline, separated by a line of yellowish ones; two similar posterior half lines lateral of the median ones. Sides of thorax with much white scaling; white scales of sternopleuron extending to anterior edge of that sclerite. Abdominal terga usually with broad, white, basal bands, narrowest in the middle; occasionally reduced. Wing scales dark except for a few pale ones on the base of the wing, particularly on the costa; occasionally these may be absent. Legs dark-scaled except for underside of femur; definite white knee spots present. Tarsal claws as in fig. 91 (from Vockeroth, 1954b).

Aedes communis typically has two dark, narrowly separated mesonotal stripes and thus differs from other *communis* group species in Minnesota (except *pionips*). *Aedes intrudens* tends to have two obscure stripes when viewed dorsally which appear to be due to the narrowness of the scales in this region allowing the dark integuement to show through; the stripes of *communis,* on the other hand, are due for the most part to the darkness of the scales constituting them; *intrudens* also has reduced sternopleural scaling and lacks the pale scales on the base of the wing. A few females are indistinguishable from *punctor* although the great majority are separable by the mesonotal striping, the pale scales on the base of the wing, and lack of post-coxal scale patch; the author has seen no *communis* which definitely have a wide single stripe on the mesonotum as in *punctor. Aedes dianteus* may practically always be separated from *communis* by its reduced sternopleural scaling, dark knees, and reduced pale abdominal scaling. *Aedes pionips* is very similar to *communis* but has a post-coxal scale patch.

Hocking *et al.* (1950) found that if a ratio of the lengths of the proboscis and wing of this species were plotted against frequency of occurrence, a bimodal curve resulted. Hocking later (1952) found that the form which had the smaller ratio (and incidentally was smaller in size) was able to lay eggs without blood and could not be induced to take blood. Vockeroth (1954b) suggested that *communis* may always be non-biting. In Minnesota practically all specimens taken are quite large and bite viciously. This large form is undoubtedly the form to which most of the literature on *communis* actually applies; if the small, autogenous form turns out to be specifically distinct, it is the form which should be renamed if the question cannot be settled by examination of types.

At Virginia, Minnesota, the author took two small females in hand catches which were referred to *implicatus* since the mesonotum was white with two dark brown lines; the coppery patch surrounding the lines was, however, not present. Numerous *communis* females were taken at the same time but all were much larger and had the mesonotum yellow (with two dark brown lines). Further study of these two aberrant females showed that they differed from *implicatus* in having the scaling of the sternopleuron extending to the anterior edge of that sclerite. Two similar males were taken in 1954 at Itasca State Park which were also identified as *implicatus* but the terminalia were identical with those of *communis.* No intergrades have been found between these specimens and *communis.* It would appear, therefore that at least two different species are included under the name *communis* in Minnesota and in some parts of Canada. It is not known whether or not the small form in Minnesota is autogenous but the females were taken in hand catches, presumably indicating that they were attempting to bite, which the autogenous form is reported not to do. The smaller females could be rather easily confused with *dianteus* which may also have whitish scaling on the mesonotum. Beckel (1954a) discusses classification of denuded specimens of the small, autogenous form.

MALE TERMINALIA (fig. 91) — The terminalia are very similar to those of *implicatus* except the ventral (actual, not morphological) face of the apical lobe has a few small setae. The longitudinal striae of the claspette filament are also less prominent in *implicatus* and *implicatus* has a tuft of bristles ventrally at the base of the apical lobe. The terminalia appear to be identical with those of *pionips* (*q.v.*).

PUPA — Described and figured by Darsie (1951).

FOURTH INSTAR LARVA (fig. 116) — Head wider than long, about 1.2 mm. wide. Antennae slightly over half as long as head. Head hairs usually all single (88% of 49 uppers, range 1-3; 98% of 51 lowers, range 1-2). Posterior shoulder hair reaching to head hairs. Lateral abdominals usually single or double. Eighth segment with average of 60.6 comb scales (17 specimens; range 50-71) in triangular patch; comb scales without strong terminal spine. Siphon about 2½-3 times as long as wide at middle; pecten confined to basal half, with regularly spaced teeth; tuft about as long as width of siphon at point of insertion, with 5-9 branches (6, 19, 6, 6, and 4 of 41). Anal segment with saddle extending about 3/4 down the sides; lateral hair slightly over half as long as saddle, usually single. Brackish water specimens are said (Frohne, 1953) to have gills averaging 1.3 (.3 - 1.5) times as long as the saddle but usually longer than *implicatus* when the two are associated. Notes on the early instars are given by Marshall (1938) and Bohart (1954).

EGG — Undescribed.

BIOLOGY — Most observations on this species appear to refer to the large form. Overwintering is by the egg stage. The spring emergence is rather early, after that of *intrudens* but before that of *trichurus*. Most Minnesota collections were made in May and early June. Wesenberg-Lund (1921) found occasional larvae in mid-summer in Denmark although they were common only in the early spring; he records a fall generation also in a few instances.

The larvae are usually taken in very cold water so that aquatic development is usually extended and adults are usually very large. Jachowski and Schultz (1948) found that the aquatic stages took almost a month; the pupal stage required 3 to 5 days. Haufe (1953) and Haufe and Burgess (1956) have presented data on the relation between temperature and growth rate. Larvae are usually taken in acidic water (Mail, 1934; Natvig, 1948; Jenkins and Knight, 1950; Haufe 1952); since most coniferous forest pools contain acidic water this may be a reflection of the availability of breeding places rather than a preference for acidic water. Larvae have been taken from brackish water (Natvig, 1948; Frohne, 1953). Males tend to emerge before females (Wesenberg - Lund, 1921; Jachowski and Schultz; Hocking *et al.*, 1950; Curtis, 1953). In work done in Minnesota all *communis* adults appeared to emerge in a rather short period of time but Curtis (1953) found this period to be rather prolonged. Wesenberg-Lund (1921) found that although hatching of larvae may take place at different times in different breeding places, the time of emergence of adults was rather uniform.

Mating probably occurs soon after emergence; mating swarms have been observed by Wesenberg-Lund (1921), Dyar (1922a), Owen (1937), Jenkins and Knight (1952), and Frohne (1954). The dispersal of forest mosquitoes has not been well studied but Jenkins and Hasset (1951) found practically all marked specimens within a quarter of a mile of the release point in one study. Adults are found practically only in wooded areas. The author encountered huge populations of females of this species in coniferous forests at Tower, Minnesota, on June 4, 1953. The time was in the afternoon of a very warm day just before a thunderstorm. Although large swarms of females attacked in the wooded areas at all of three different sites, one could get relief by moving 10-15 feet out of the woods into sunlight; at this distance biting was negligible. Wesenberg-Lund (1921) found that females began feeding about 2 weeks after emergence in cold weather; the feeding period lasted about 2-3 weeks.

Adults appear to be most active around dusk and dawn (Haufe, 1952) and biting is usually very heavy near or after dark (Dyar, 1922a, 1928; Natvig, 1948) although Curtis (1953) says the species is diurnal. Factors influencing the attraction of females have been studied by Brown (1951); heat, humidity, dark colors, and CO_2 appear to be especially important. The females readily feed on man and livestock (Natvig, 1948). Jenkins and Knight (1950) took adults feedings on plant juices.

As mentioned above, Hocking (1952, 1954) has found that the small form can lay eggs without engorging on blood (autogeny) and, as a matter of fact, never seems to feed on blood (see also Beckel, 1954b). According to Hocking these females are able to develop eggs using materials presumably already in the body at the time of emergence; the time required is about 450 degree-days (Fahrenheit) above 0°C. or about 18 days after emergence at Churchill, Manitoba. In developing these eggs the females are said to autolyze their flight muscles and are thus incapable of flight at the time of oviposition and presumably thereafter. Beckel (1954b) has also studied a small, autogenous form of *communis* but finds that there is not an autolysis of flight muscles in this form; it is problematic whether or not the forms the two authors are using are the same.

In the autogenous form an average of 65 (maximum 93) eggs is laid (Hocking, 1954); Jenkins (1948) found that a female (form?) laid 67 eggs. The oviposition of this species has been discussed by Wesenberg-Lund (1921); it is on this evidence that many authors say that mosquitoes lay their eggs in dry places. There is no evidence supporting the belief that mosquito eggs can survive when laid in dry places; it would appear that the eggs of most northern *Aedes* cannot survive desiccation even when fully developed. There seems to be a single generation a year. Adults are said to rest in coniferous trees (Jenkins and Knight, 1950) and to live for 2 months or more (Howard *et al.*, 1917; Dyar, 1928; Owen, 1937).

DISTRIBUTION — Holarctic; in North America from Atlantic to Rockies, south to California, northern United States; north to Alaska, Yukon Valley, Hudson's Bay. In Minnesota in forested areas of the northeastern half of the state, particularly in coniferous forest.

IMPORTANCE — As Dyar (1928) and Owen (1937) have pointed out, this is one of the most abundant of the forest mosquitoes. It is an important pest particularly in coniferous forest areas in the early spring.

Aedes (Ochlerotatus) pionips Dyar

This species has not been previously recorded from the state. Four larvae were taken at Itasca State Park in the spring of 1954 which appear to be this species. Adults have not been taken but this is not surprising since they would be readily confused with related species.

FEMALE — Dr. Alan Stone supplied three Canadian specimens identified by Dyar. The mesonotum is light yellow with two narrowly separated brown lines. These females could be confused with *punctor* or *communis.* They can be separated from the latter by the presence of the post-coxal scale patch. They have a wider separation of the mesonotal dark lines than is usually seen in *punctor* and also have a few pale scales at the base of the costa. Scaling of sternopleuron extending to the anterior edge of that segment. Tarsal claws as in fig. 91 (from Vockeroth, 1954b). For further details see Vockeroth (1952, 1954b).

MALE TERMINALIA — The author has dissected four of Dyar's specimens from Canada and Alaska supplied by Dr. Stone and finds the terminalia inseparable from *communis.* All four specimens have longitudinal ridges on the claspette filaments as in *communis.* Since other authors have not found these ridges in *pionips,* there is some doubt as to the identification of the specimens.

PUPA — Described and figured by Darsie (1955).

FOURTH INSTAR LARVA (fig. 99; 4 specimens not associated with adults) — Head wider than long, about 1.5 mm. wide. Antennae over half as long as head. Upper and lower head hairs with 3-4 branches, not in line with postantennal tuft. Posterior shoulder hairs long, all reaching to head hairs. Mesothoracic dorsal principal well developed, long (usually reaching to head) but not stout as in *fitchii.* Lateral abdominals usually all double, dorsolaterals long on IV-VII. Eighth segment with large numbers of comb scales, over 50, in triangular patch; comb scales very pale in the specimens at hand, very difficult to count. Siphon about 3 times as long as wide at middle, pecten with evenly spaced teeth, confined to basal third or half of siphon; tuft slightly longer than width of air tube at point of insertion, with 6-8 branches. Anal segment with saddle extending about 2/3 down the sides, sometimes with ventral notch at posterior third; lateral hair about 1/2 to 2/3 as long as saddle, usually single. Anal papillae about 1½ or more times as long as saddle.

EGG — Undescribed.

BIOLOGY — Practically nothing is known of the biology of this species.

DISTRIBUTION — Nearctic; south to Idaho, Colorado, North Dakota, Minnesota; north to Alaska, Yukon, Northwest Territories. In Minnesota known only from Clearwater Co.

IMPORTANCE — Probably none in state, rare.

Aedes (Ochlerotatus) abserratus (Felt and Young)

This is the species commonly known as *implacabilis* (Walker) which, according to Vockeroth (1954a), is a synonym of *punctor.* First recorded from Minnesota by Knight (1951) on the basis of a reared specimen from Ely. The author has confirmed this record.

FEMALE — One of the dark-legged *Aedes* with an unlined mesonotum. Knight (1951) indicates that this species is very difficult to separate from the unlined form ("tundra variety") of *punctor* (*q.v.*) but that it can be done on the basis of the mesonotal scaling. Vockeroth (1954b) considers that *punctor* has a lined mesonotum and *abserratus* does not, so that the separation is easy; there is, however, some doubt in his mind as to whether there may also be an unlined form of *punctor*. (At the present time this writer considers all unlined females to be *abserratus*, since all of the reared *punctor* he has seen are lined.)

The female lacks distinct lines or stripes on the mesonotum and can be differentiated from other *communis* group mosquitoes on this basis. The only other one with a similar mesonotum is *intrudens* which lacks the postcoxal scale patch and has reduced sternopleural scaling.

Male terminalia (fig. 94) — The male terminalia of this species are easily recognized by the peculiar shape of the basal lobe as figured by Knight (1951). The terminalia shown in Carpenter and LaCasse (1955) do not apply to this species as defined by Knight.

Pupa — Described and figured by Darsie (1951).

Fourth instar larva (fig. 113; all from Itasca State Park) — Head wider than long, about 1¼ mm. wide. Antennae about 1/2 as long as head, spined. With all hairs very coarse. Head hairs usually all single (39 of 43 uppers, 39 of 42 lowers; range 1-2). Posterior shoulder hair usually branched and extending to base of head hairs. Lateral abdominals usually all single (100% of 35, 38, 33, and 23 on III to VI) occasionally branched on I and II (4 of 32 and 1 of 28). Eighth segment usually with 5 to 7 comb scales (14, 56, and 12 of 84; range 4-8), usually in irregularly, single row; comb scale with very large terminal spine and practically no lateral spinelets. Siphon about 2½ to 3 times as long as wide at middle with pecten confined to basal half; the teeth are usually evenly spaced but frequently one or two are weakly detached. Siphonal tuft distal of pecten, stout, not quite as long as width of siphon at point of insertion, with 3 branches (30 of 36; range 2-4). Anal segment completely encircled by saddle which is almost as wide as long; ventral brush with none or a single tuft preceding the barred area but posterior of saddle; saddle hair about as long as saddle, coarse, single (100% of 41). Dorsal brush with 2 single hairs on each side (100% of 105). Anal papillae about 2 to 3 times as long as saddle.

Third instar larva — Head 1 mm. wide. Posterior shoulder hair single. Siphonal tuft with 2-3 branches. Saddle dark brown, extending about 1/2 down the sides of the anal segment; lateral hair near ventral edge of saddle.

Egg — Undescribed.

Biology — Practically nothing is known about this species since it is usually uncommon and difficult to identify. Biologically it is probably similar to *punctor*. Overwintering is by the egg stage. Larvae develop in the early spring and there is one generation a year. Adults are found in forested areas. Howard *et al.* (1917) say that females (*Ae. centrotus*) may live 2 to 3 months. Dyar (1928) says that the species is a derivative of *punctor* and occupies the eastern part of the latter's range. The swarming of males has not been observed but undoubtedly occurs.

Distribution — Incompletely known; Knight (1951) gives records from the extreme north of the United States, from Minnesota to the Atlantic coast and in Labrador and Ontario. In Minnesota known only from forested areas (Little Falls, Itasca St. Park, Duluth, Ely).

Importance — May be of some importance as a pest in wooded areas in the spring.

***Aedes (Ochlerotatus) punctor* (Kirby)**

Owen's (1937) identification of *punctor* in the University of Minnesota collection included some females of *communis* and *diantaeus* but most are reliable.

Female — Palps and proboscis dark-scaled. Mesonotum with single median stripe or none; the striped form ("typical" variety of Knight, 1951) has the mesonotum covered with yellow or golden scales and with a darker, broad, median stripe of coppery or dark brown scales; occasionally there is a line of yellow scales down the median stripe thus making two broad, narrowly separated stripes. The unstriped form (tundra variety of Knight) has the mesonotum covered with coppery scales; occasionally there are two vague, somewhat darker stripes on the mesonotum of this form. This unstriped form is not definitely recognized by me. Sides of thorax extensively white-scaled; scaling of sternopleuron extends to anterior margin of that sclerite. Dorsum of abdomen largely dark-scaled, white markings variable; usually on the bases of the terga there are rather narrow white bands which may be interrupted medially on the more anterior terga; occasionally the bands are rather wide, often they are reduced so as to be interrupted on most segments and occasionally they are practically absent. Wings usually entirely dark-scaled; rarely there may be a few pale scales at the base of the costa. Legs unbanded. Tarsal claw as in fig. 93 (from Vockeroth, 1954b).

As previously stated Knight (1951) recognized a lined or "typical" variety and an unlined or tundra variety. Vockeroth (1954b) recognizes only the typical form but there is some doubt in his mind as to whether an unlined form of *punctor* actually occurs. All adults reared from identified larvae by the author have produced lined adults. There are thus no definite records of the unlined form of *punctor* from Minnesota.

The lined form may be confused with *communis, dianteus,* and *pionips* and a few specimens cannot be separated with certainty. The separation from *dianteus* is usually easy since the latter has reduced scaling on the sternopleuron, usually has reduced white markings on the dorsum of the abdomen, and lacks pale knee spots and the post-coxal scale patch. Usually *communis* can be separated from *punctor* since it has two dark lines on the mesonotum separated by a narrow line of pale scaling where *punctor* usually has a single, wide dark stripe. There are, however, some females which cannot be separated with certainty; in such cases *communis* usually has much more white scaling on the base of the wing than does *punctor* and lacks the post-coxal scale patch. *Aedes pionips* usually has two mesonotal lines and some pale scaling on the base of the costa.

The unlined (tundra) form of *punctor* can be confused with both *abserratus* and *intrudens*; as previously stated the author cannot separate *punctor* from the former. *Aedes intrudens* is usually easily identified by its reduced sternopleural scaling, smaller size, and lack of a post-coxal scale patch. The classification of denuded specimens is discussed by Beckel (1954a).

MALE TERMINALIA (fig. 93) — Basistyle about 6 times as long as wide at middle; apical lobe rather prominent, mesal face with slightly flattened, recurved setae; basal lobe prominent, tuberculate, with many short setae and basal spine. Dististyle about half as long as basistyle, with prominent claw. Claspette filaments flattened, expanded medially, dark, "falcate." Lobes of ninth tergum each with 5-7 short, stout spines.

PUPA — Described and figured by Darsie (1951).

FOURTH INSTAR LARVA (fig. 95) — Head wider than long, about 1⅓ mm. wide. Antennae about 1/2 as long as head, spined. Head hairs usually all single (12 of 43 double; occasionally all are double), usually very coarse. Posterior shoulder hair coarse, usually branched and extending to upper head hairs. Lateral abdominals single or double on I and II and single on III to VI. Eighth segment most commonly with 14 comb scales (47% of 92; average 12.9; range 7-16); comb scales usually in irregularly double row (sometimes single) or triangular patch, each with strong terminal spine, rather dark. Siphon about 3 to 3½ times as long as wide at middle, with pecten confined to basal half or third, all teeth rather evenly spaced (occasionally one or more is more or less detached); siphonal tuft distal of pecten, about as long as or slightly shorter than width of air tube at point of insertion, with 3 to 5 branches, coarse. Anal segment completely encircled by saddle which is usually longer than wide but variable; ventral brush usually with 1-3 tufts preceding the barred area but posterior of saddle; saddle hair usually about as long as saddle, single, coarse, dorsal inner tuft multiple, usually with 5-7 branches (4-7). Anal papillae about 2-3 times as long as saddle.

The larva is rather similar to that of *abserratus* (*q.v.*). Knight (1951) found that the "typical" variety had the lateral abdominal hairs of IV to VI always single but in the tundra variety only 48 - 70% of these hairs were single; the former also had 97 to 100% of the lateral abdominal hairs on II single but this hair was always double or triple in the tundra variety. The anal papillae of brackish water specimens are usually over 1.2 times as long as the saddle (.5 - 1.5) according to Frohne (1953). Marshall (1938) discusses early instar larvae. There are a number of quantitative differences between the presently described form and the European form as described by Wesenberg-Lund (1921) and Marshall.

EGG — Undescribed.

BIOLOGY — Overwintering is by the egg stage. The spring emergence of adults appears to be rather early, after that of *intrudens* and probably *communis* but before *cinereus* and *canadensis*. Most Minnesota records are in May and June.

Larvae in Minnesota are usually taken in muskeg bogs, particularly in mixed vegetation although also to a considerable extent in coniferous muskeg. Such breeding places usually contain acidic water; most authors

(Mail, 1934; Natvig, 1948; Jenkins and Knight, 1950; Haufe, 1952) emphasize the acidic nature of breeding places of this species but this may be related to the availability of water in its habitat rather than to a preference for acidic water. In some areas the species invades brackish water (Jenkins, 1948; Frohne, 1953). The temperature of the breeding places is usually very low so most individuals become rather large. The time required for development at these temperatures is, of course, rather long; Jenkins (1948), Jachowski and Schultz (1948), and Twinn *et al.* (1948) found that the aquatic stages took from 2 weeks to over a month to mature. The last-mentioned authors found that the pupal stage required about 3-5 days. Males tend to emerge before females according to Jachowski and Schultz (1948) and Hocking *et al.* (1950).

Mating probably takes place soon after emergence; male swarms of this species have been noted by several authors (Twinn *et al.*, 1948; Jenkins and Knight, 1952). Frohne and Frohne (1952) give notes on a large number of swarms observed throughout the summer; they found swarms just before dusk but not in the morning. They also found that in Alaska activity was greatest at about 15°C., that emergence occurred from June to August, and that adults rested in vegetation.

Biting takes place for the most part in the late afternoon according to Jenkins (1948); Haufe (1952) found peaks of biting near dusk and dawn. Curtis (1953) found *punctor* to be more active after dark than was *communis.* Wind may reduce biting due to females of this species (Jenkins, 1948). Females feed readily on humans and, according to Mail (1934), livestock. The preoviposition period is about 5 to 6 days (Jenkins, 1948). The numbers of developing eggs which are found in the ovaries is about 48 (3-131) according to Jenkins (1948) and 170 according to Hocking *et al.* (1950); the total number of eggs laid and remaining in the ovaries in 4 females was 27, 53, 56, and 143 according to Jenkins. Marshall (1938) says that eggs are laid above the water level of hollows, etc., and that such eggs may begin hatching in the fall. There appears to be but a single generation a year in Minnesota.

Adults are found primarily in wooded regions (Hearle, 1926; Mail, 1934) and will bite by day. Some females are said to live all summer (Dyar, 1922a; Hearle, 1926).

DISTRIBUTION — Holarctic; in North America in the Canadian region from Atlantic to Rockies, south to New York, Michigan, Minnesota, and Colorado; north to Yukon Valley and Yukon Territory (Dyar, 1928); in Minnesota in forests of northeastern half of state.

IMPORTANCE — This species is likely to be a major pest in forested regions in the late spring and early summer, particularly in mixed forests; the author has not found this species in as large abundance in coniferous forests as in mixed types.

Aedes (Ochlerotatus) trichurus (Dyar)

FEMALE — Large. Palps and proboscis dark-scaled. Mesonotum usually with central area of dark scales, white on the sides and antescutellar area; without any kind of well defined striping; there are usually a few scattered pale brownish scales along the sides of the anterior part of the darker median area. Sides of thorax extensively white-scaled; scaling of sternopleuron extending to anterior margin of that sclerite. Post-coxal scale patch present. Dorsum of abdomen with white basal bands on the terga, remainder dark-scaled. Wings dark-scaled with rather prominent patch of white scales at base of costa. Legs mostly dark-scaled, without pale bands; white knee spots absent. May be confused with *implicatus* (*q.v.*).

MALE TERMINALIA (fig. 73) — Basistyle elongate, about 6 or 7 times as long as wide. Apical lobe fairly prominent; basal lobe small, with one or two very long, posteriorly-directed, curved setae on its posterior aspect. With prominent tuft dorsal of basal lobe. Claspette stem rather long, strongly curved ventrally, filament very short, about 1/5 as long as stem; filament of peculiar shape, with a number of curved, transverse, concentric folds. Ninth tergal lobes wider than long, dark, separated by a third lobe about the size of the other two; lateral lobes bearing several strong setae, middle lobe bare. Eighth tergum with prominent medial lobe bearing many long setae.

PUPA — Described and figured by Darsie (1951).

LARVA — Unique in North America in at least the second to fourth instars by virtue of a series of accessory lateral and dorsal hair tufts on the air tube (fig. 63). Fourth instar with head wider than long, about 1.75 mm. wide. Antennae about half as long as head, spined. Lower head hairs usually single, occasionally branched; uppers usually 2-3 branched. Lateral abdominals on III to VI usually single or double. Eighth segment with about 12-18 comb scales, each with strong terminal spine, usually in irregularly double row. Siphon usually 3 to 3½ times as long as wide at middle; pecten usually extending over 3/4 the length of the siphon, with about 4-7 detached spines; siphonal tuft about as long as width of siphon at point of insertion, usually 5-6 branched, placed ventral of pecten and proximal of the outer 4-6 pecten teeth. Siphon with 2-3 pairs of small, extra, 2-4 branched, lateral tufts and with about 6-11 dorsal, 2-4 branched tufts which are about 3/4 as long as the width of the siphon at middle. Anal segment with dorsal saddle not quite encircling the segment; lateral hair on saddle, usually single (occasionally branched); anal papillae usually about twice as long as dorsal surface of saddle.

Third instar with head about 1.25 mm. wide; saddle of anal segment usually confined to upper third of segment; head hairs usually single (occasionally one or more is 2-3 branched) and other hairs with fewer branches than in the fourth instar. Second instar with head about .75 mm. wide, otherwise rather similar to third instar except hairs less highly branched.

Egg — Described by Dyar (1904a).

Biology — Practically nothing is known of the biology of this species. Overwintering is by the egg stage. The spring emergence is after that of *implicatus* and the earlier *communis* group mosquitoes but before that of *canadensis*, etc. The larvae are found for the most part in semi-permanent marshes and larval development is usually rather long; the adults are quite large. Dyar (1923a) has described the swarming of males of this species. Females are rather aggressive and feed freely on humans. Eggs collected by the author were readily killed by drying. Dyar (1904a, under the name *punctor*) found that eggs would hatch only after being exposed to low temperatures.

Distribution — Southern Canada and northern United States from Atlantic to Rockies but not found in far north (Dyar, 1928). In Minnesota in forested areas of northeastern half of state.

Importance — May be an important pest in wooded areas in the spring.

Aedes (Ochlerotatus) aurifer (Coquillett)

Reported from state by Dyar (1922a) and by Owen (1937). Dr. Roger Price of the University of Minnesota collected larvae near Park Rapids, Minnesota, on May 19, 1956.

Female — The female is said to have a mesonotal stripe as in *dianteus* and the lined form of *punctor*. The tergal bands are said to be reduced or absent as in *dianteus* and the lower mesepimeral bristles are said to be lacking. See descriptions by Dyar (1928), Matheson (1944), Carpenter and LaCasse (1955).

Male terminalia (fig. 75) — The male terminalia are unique. Basistyle with prominent tuft at apex; basal lobe without basal spine, with prominent, dark, posteriorly - directed spine; claspette with prominent, medial, seta-bearing tubercle; claspette filament with prominent retrorse spine.

Pupa — Described and figured by Darsie (1951).

Fourth instar larva (fig. 103; based on 3 specimens from Massachusetts supplied by Dr. H. Pratt) — Head wider than long, about 1.3 mm. wide. Antennae over 3/4 as long as head, darkened at tip, curved medially at outer third. Antennal tuft large, multiple, extending beyond apex of antenna, inserted distinctly beyond middle of antenna. Upper and lower head hairs inserted about in a line with the post-antennal tuft which is large, multiple and extends beyond the insertion of the antennal tuft. Upper head hairs triple, lowers double or triple. Posterior shoulder hair single, extends to front of head. Mesothoracic dorsal principal small. Lateral abdominals triple on I, double or triple on II, double on III-VI. Eighth segment with 18 to upwards of 32 comb scales in irregular double row or triangular patch. Individual comb scale with prominent median spine which is usually not as long as rest of comb scale; lateral spines well developed although much smaller than median one. Middle pentad hair longer than saddle of anal segment. Siphon about 3½ to 4 times as long as wide at middle; pecten confined to basal half, with outer spine more or less detached. Siphonal tuft inserted beyond pecten, with 7-8 branches, almost twice as long as width of siphon at point of insertion. Dorsal preapical spine about half as long as outer pecten spine. Saddle of anal segment almost completely encircling the segment; saddle almost twice as long as wide, with deep apico-ventral notch; lateral hair about 1/2 to 3/4 as long as saddle. Dorsal brush a well developed tuft and a long, single hair. Ventral brush with about 2 to 3 tufts preceding the barred area. Anal papillae absent in the specimens at hand; said to be about as long as the saddle.

Egg — Undescribed.

Biology — Practically nothing is known of the biology of this species. Overwintering is by the egg stage. Larvae are said to occur in the early spring, especially in bogs (Dyar, 1922a, 1928). Adults are usually found in wooded areas and are said to be long-lived (Smith, 1904). Adults are said usually to be uncommon and there appears to be a single generation a year (Newkirk, 1955). Females will lay up to 84 eggs in a clutch (Newkirk).

Distribution — Southern Canada south to New Jersey, west to Minnesota and Manitoba. Owen (1937) gives a few records from the eastern part of the state.

Importance — Too rare to be of importance in the state.

Aedes (Ochlerotatus) intrudens Dyar

Most early North American records of this species are under the name "*impiger*"; Minnesota records of *impiger* prior to those of Owen (1937) probably refer for the most part to the present species. Of the 38 specimens in the University collection identified by Owen, only one, a male is recognizable as *intrudens*; the bulk of Owen's records of this species pertain to *punctor*.

Female — Palps and proboscis dark-scaled. Mesonotum almost unicolorus as a rule, scaling yellowish to golden, occasionally somewhat reddish; usually there are two narrow darker lines on the mesonotum, the darker color being due not so much to the color of the scales on the lines as to the color of the integument which shows through by virtue of the narrowness of the scales. Sides of thorax extensively white-scaled; scaling of sternopleuron not extending to the anterior border of that sclerite. Dorsum of abdomen brown-scaled with rather wide, white, basal bands on the terga. Wings dark-scaled, occasionally with a few pale scales at the base of the wing. Legs extensively dark-scaled, without light bands on the tarsi; white knee spots present. According to Vockeroth (1954b) *intrudens* is the only dark-legged species lacking a post-coxal patch and having a uniform brown mesonotum.

Can be confused especially with *punctor* but also with *communis* and *dianteus* (*q.v.*). Can usually be differentiated from *communis* (*q.v.*) by scaling of sternopleuron and the less distinct stripes of mesonotum; *communis* also usually has the base of the costa much more extensively white-scaled than *intrudens*. Can usually be separated from *punctor* by the sternopleural scaling and smaller size and lack of post-coxal scale patch; *abserratus* has a much redder mesonotum than *intrudens*.

Male terminalia (fig. 77) — Basistyle about 6 times as long as wide at middle, apical lobe fairly prominent with rather long recurved setae on mesal face, prominent tuft of setae on dorsal face at apex of basistyle; basal lobe large, with two dark, stout, curved, posteriorly-directed spines; basal spine present. Claspette filament longer than wide, expanded near base, without sharp projection, with clear areas; stem with seta set off on lobe. Ninth tergal lobes each with about 4-6 short, stout spines.

Pupa — Described and figured by Darsie (1951).

Fourth instar larva (fig. 100; not definitely associated with adults) — Head wider than long, about 1.3 mm. wide. Antennae about 2/3 the length of the head. Lower head hair placed somewhat anterior of a line connecting the upper head hair and postantennal tuft; upper head hairs with 2-4 branches (4, 15, and 2 respectively of 21), lowers usually with 2 or 3 branches (12 and 6 of 19; range 1-3). Lateral abdominals on I-VI all single in the specimens at hand. Eighth segment usually with 14 comb scales (12 of 23; average 13.9; range 11-18), usually in irregularly double row; comb scale with stout terminal spine which is about as long as the remainder of the scale, lateral spinelets minute. Siphon about 3-3½ times as long as wide at middle; pecten extends beyond middle of siphon, usually with outer 2 or 3 teeth detached (range 2-4); tuft 1/2-1 times as long as width of siphon at point of insertion, ventral of, often proximal of, and usually closely associated with last pecten spine, usually with 5-7 branches (6, 6, and 7 respectively of 20; range 5-8). Anal segment with saddle extending about 3/4 down the sides, often with ventral notch at posterior third; lateral hair about half as long as saddle, usually single. Anal papillae about twice as long as saddle.

Egg — Undescribed.

Biology — Nothing specific is known of the biology of this species. Overwintering is by the egg stage. Larvae in Minnesota are usually found in muskeg in or near coniferous or mixed forests. Adults appear to be preceded only by those of *spencerii* in the spring. At Itasca State Park in 1954 *spencerii* was first taken biting on May 19 and never became abundant. *Aedes intrudens* was first taken

May 21 and was the dominant mosquito until *punctor* and *abserratus* females appeared in numbers in the first week of June, although from the time of appearance of *intrudens,* small numbers of *implicatus* and *trichurus* were regularly taken. In the last week in May there were extremely large populations of *intrudens* which bit very aggressivly near the cabin where the author was staying; the cabin was situated in a clearing in the woods. It was impossible to remain outside in the evening at this time and even in the daytime biting was heavy. Adults entered the cabin freely although it was fairly well screened; on a couple of evenings over a hundred *intrudens* were captured indoors. Surprisingly enough this large population lasted only a few days in spite of the rather cool and humid weather; the author's impression was that the average length of life of the females was less than a week even though some adults were still present in July. Approximately the same overall picture was seen at Itasca State Park in 1957. There appears to be but one generation a year.

Distribution — Northern forested regions from Atlantic to Pacific and in Europe. In Minnesota in the forests of the northeastern half of the state. Possibly more abundant in mixed than in coniferous forest.

Importance — As stated above this is an abundant and annoying pest in wooded areas in the early spring but appears to be rather short-lived on the average.

Aedes (Ochlerotatus) dianteus (Howard, Dyar, and Knab)

Practically all of Owen's adult records of this species pertain either to *punctor* or *communis.* Dr. M. E. Smith (1952) has recently described a closely related species, *pseudodianteus* (now known as *decticus*), which has not been found in the state although it was diligently sought.

Female — Palps and proboscis dark-scaled. Mesonotum with yellowish to golden scales; usually with two narrowly separated dark brown stripes, often with a single broad one, rarely with the two stripes broadly separated as in *communis.* Sides of thorax with much white scaling; scales of sternopleuron not extending to the anterior margin of that sclerite. Post-coxal scale patch absent. Dorsum of abdomen extensively dark-scaled; usually white scales are seen only in lateral triangles at the bases of the more posterior segments; occasionally there may be a few complete basal bands, particularly on the more posterior segments. Wing scales dark. Legs dark-scaled except for underside of femora; usually there are not definite white knee spots. Tarsal claws as in fig. 76 (from Vockeroth, 1954b).

Can usually be separated from *communis* and *punctor* by scaling of sternopleuron, by reduction of white scaling on abdomen, and by lack of definite white knee spots. The lack of pale scaling at the base of the wing is also useful in differentiating this species from *communis. Aedes punctor* also has a post-coxal scale patch. *Aedes intrudens* never has one well defined mesonotal stripe and has more pale markings on the dorsum of the abdomen.

Male terminalia (fig. 76) — The male terminalia are quite distinctive and can be recognized at a glance, even in undissected specimens. The very large, medially-directed tuft of the basistyle is the most prominent feature. Basistyle with prominent concavity laterally. Basal lobe with a pair of dark, posteriorly-directed spines and a basal spine. Claspette filaments of characteristic shape, highly expanded, fenestrated.

Pupa — Described and figured by M. E. Smith (1952).

Fourth instar larva (fig. 104) — Head wider than long; about 1.5 mm. wide. Antennae very long, usually longer than head; tuft near middle; antennae not abruptly narrowed beyond the tuft. Lower head hairs usually with 2 or 3 branches (50% each in 52 specimens), uppers usually triple (82% of 55; range 2-4); lower head hair somewhat anterior of a line connecting the upper head hair and the postantennal tuft. Lateral abdominals single on I-VI, occasionally double on I and II. Eighth segment usually with 8 to 10 comb scales (84% of 56 specimens; range 6-14; average 9.8), each with strong terminal spine, in irregularly double (occasionally single) row. Siphon about 3-3½ times as long as wide at middle; pecten confined to basal half of air tube, usually with 2-3 detached spines (range 1-4); tuft distal of pecten, usually with 7-9 (5-10) branches, about as long as or somewhat shorter than width of siphon at point of insertion. Anal segment almost encircled by saddle which is about as wide as or wider than long, sometimes with a large perforation; saddle hair usually single (often with 2-3 branches), short, no more than half the length of the saddle. Anal papillae usually at least 2-3 times the length of the saddle. Minnesota specimens show a number of quantitative differences from the European form as described by Marshall (1938).

Third instar with head about 1 mm. wide; head hairs usually double; siphonal tuft about 5-branched; saddle of anal segment dark, extends about a quarter of the way down the sides of the segment; saddle hair at edge of saddle.

Egg — Undescribed.

Biology — Practically nothing is known with certainty. Has been taken only sparingly in Minnesota, mostly in late May. Overwinters in egg stage. Larvae are found in forest pools. The mating behavior has been described by Dyar (1922a) and Owen (1937) and is said to be peculiar in that there is no swarming of males; mating can be seen when the females come to feed and takes place around the host. Adults are seen only in wooded areas. There appears to be but one generation a year.

Distribution — Canadian forested region from New Hampshire and Ontario west to British Columbia, south to Wyoming in the Rockies; also known from Europe. In Minnesota there are a few records from the forested region of the northeastern half of the state.

Importance — Too uncommon to be of importance as a rule.

GENUS *CULEX*

Key to *Culex* females of Minnesota (modified from Ross, 1947)

1. Proboscis and hind tarsi with white bands; mesonotum with white lines ------------------------------------ *tarsalis* (p. 134)
1. Proboscis and hind tarsi entirely dark; mesonotum may have pale dots but without white lines on central portion ---------------- 2
2. Dorsum of abdomen with pale, apical bands or apical, lateral spots on some of the terga, without pale basal bands --- *territans* (p. 134)
2. Dorsum of abdomen with pale basal bands but without apical ones ---------------- 3
3. Wing scales on R_2 and R_3 much broader than those on R_s; occiput with broad scales along margin of eyes and on sides ------------------------------------ *erraticus* (p. 128)
3. Wing scales on R_2 and R_3 not noticeably broader than those on R_s; occiput without such broad scales -------------------- 4
4. Abdominal terga with dingy basal bands of yellowish or brownish scales, the bands usually irregular and narrow ------ *salinarius* (p. 133)
4. Abdominal terga with bright and conspicuous basal bands of white scales, the central bands wide ------------------------ 5
5. Mesonotum usually with a pair of central pale spots[12] -------------- *restuans* (p. 132)
5. Mesonotum without pale spots ------------------------------------ *pipiens* (p. 131)

Key to male terminalia of *Culex* of Minnesota

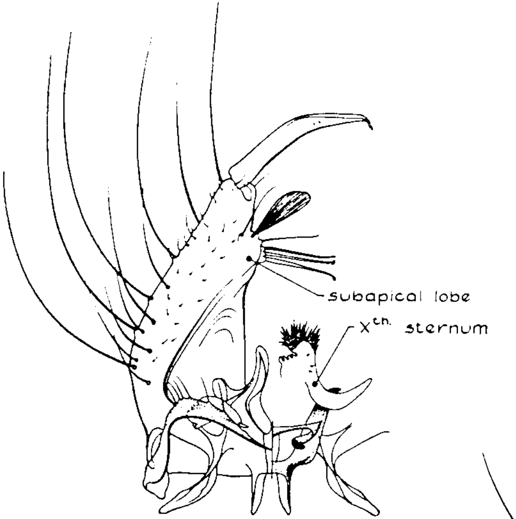
1. Ninth tergal lobes large, oval, oblique, set off from rest of ninth tergum; basistyle bulbous, subapical lobe with forked anterior lobe bearing two large spines and a posterior lobe bearing a large leaflet and several spines (fig. 123) ---------------------- *erraticus* (p. 128)
1. Ninth tergal lobes of normal size, rounded posteriorly, directed posteriorly; basistyle not bulbous, more or less linear, subapical lobe not noticeably divided into anterior and posterior lobes -------------------------- 2
2. Subapical lobe of basistyle without conspicuous leaflet (figs. 122, 124) ------------ 3
2. Subapical lobe of basistyle with conspicuous leaflet (figs. 121, 125, 126) ------------ 4
3. Ninth tergal lobes about as long as wide; a conspicuous H-shaped structure present (fig. 122) ------------------ *territans* (p. 134)
3. Ninth tergal lobes much wider than long, rather inconspicuous, lacking a conspicuous H-shaped structure but with a series of dark, pointed phallosomal plates (fig. 124) ------------------------------ *tarsalis* (p. 134)
4. Phallosomal armature very simple, with only a pair of posteriorly-directed arms; only the spines of the 10th sternum are heavily sclerotized (fig. 121) ---------- *restuans* (p. 132)
4. Phallosome with a series of complicate plates; with a number of heavily sclerotize parts (figs. 125, 126) ---------------- 5
5. Phallosome with a pair of blunt, postero laterally directed, ventral arms and a pai of pointed, curved, dorsal arms which ar more or less laterally directed at the tip (fig. 125) -------------- *pipiens* (p. 131
5. Phallosomal plates not as above, with a num ber of dark, more or less laterally-directe points (fig. 126) -------- *salinarius* (p. 133

Key to *Culex* larvae of Minnesota

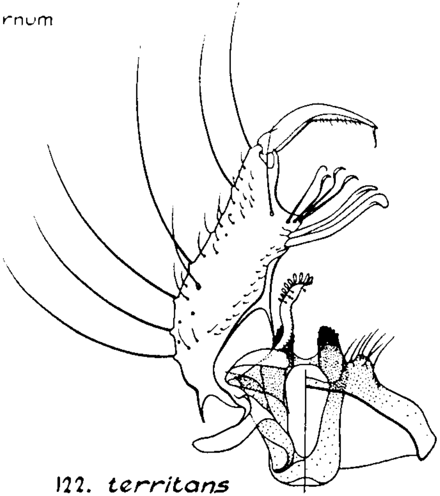
1. Antennal tuft placed before or near th middle of the antenna, never distinctly be yond; air tube with a series of single hai

---

[12] This is a poor separation but there appears to be no other.



121. *restuans*



122. *territans*

123. *erraticus*

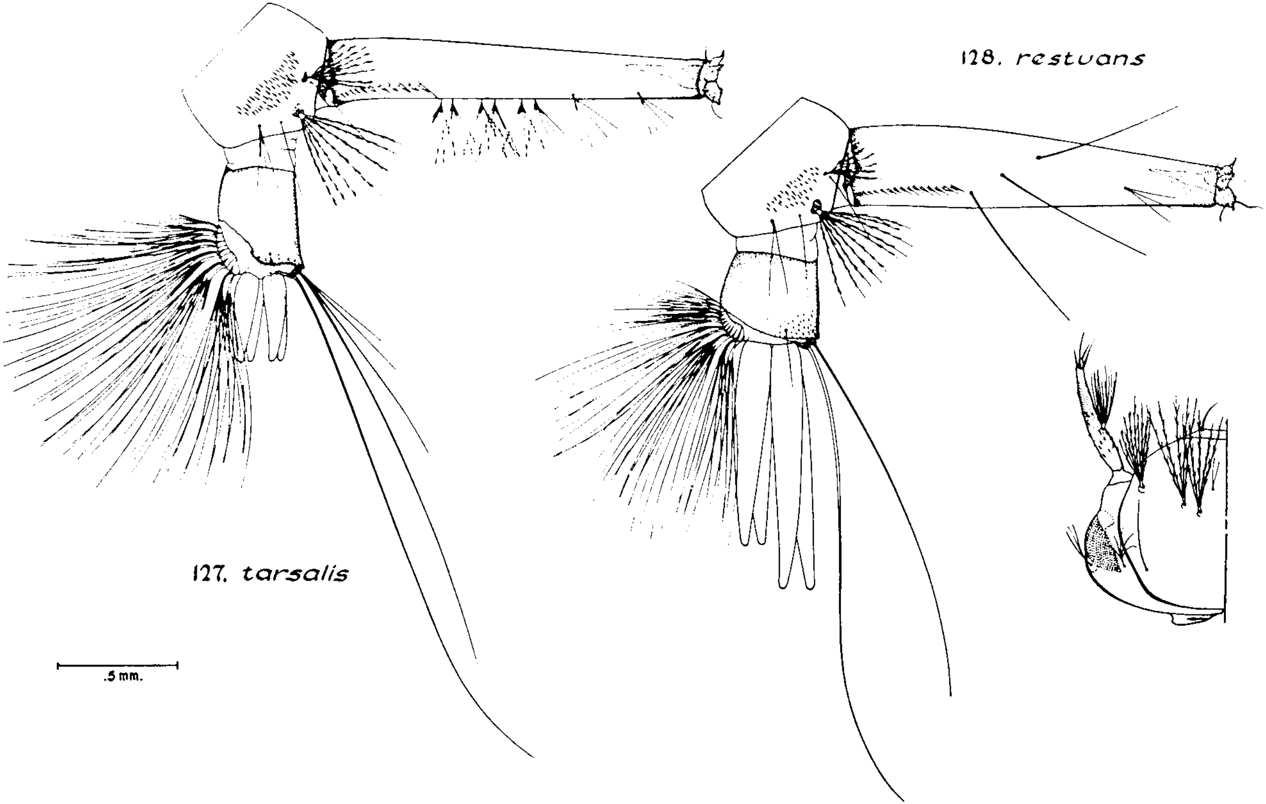
PLATE 38 (figs. 121-123). Male terminalia of *Culex*.

124. *tarsalis*

125. *pipiens*

126. *salinarius*

PLATE 39 (figs. 124-126). Male terminalia of *Culex.*



127. *tarsalis*

128. *restuans*

PLATE 40 (figs. 127, 128). Larvae of *Culex*.

as well as one smaller pair of tufts; dorsal brush of two long, single hairs on each side; dorsolaterals of IV and V single (fig. 128) ---------------------- *restuans* (p. 132)

1\. Antennal tuft placed distinctly beyond middle of antenna; air tube with a series of tufts, no single hairs as a rule; dorsal brush of a single hair and a branched one on each side; dorsolaterals of IV and V usually all branched ---------------------------------- 2

2\. Upper and lower head hairs markedly dissimilar in number of branches, uppers weak, with about 5 or more branches, lowers usually single, at least twice as long as uppers; thorax, abdomen, and anal segment markedly pilose; eighth segment with less than 30 comb scales, each with strong central spine; branched hair of dorsal brush with only 2 branches (fig. 129) ----------------- *erraticus* (p. 128)

2\. Upper and lower head hairs not markedly dissimilar in number of branches; usually without noticeable pile except on sides of thorax in *territans;* eighth segment with more than 30 comb scales, average comb scale never with long terminal spine; branched hair of dorsal brush usually with 4 or more branches--- 3

3\. Head hairs single or double; usually with one or two tufts before the barred area; usually with noticeable pile on sides of thorax (fig. 130) ----------------- *territans* (p. 134)

3\. Head hairs with 3 or more branches, particularly the uppers; without tufts preceding the barred area; without conspicuous pile ------------------------------------ 4

4\. Anterior 3 or 4 pairs of siphonal tufts set close to midventral line, most of these tufts with 6 or more branches; lateral abdominals mostly triple on III-VI; saddle hair double or better (fig. 127) --------*tarsalis* (p. 134)

4\. Anterior 3 or 4 pairs of siphonal tufts set well up from the midventral line, these tufts usually with 4 or fewer branches; lateral abdominals mostly double on III-VI; saddle hair frequently single --------------------- 5

5\. Siphon less than 7 times as long as wide at middle, usually only 5-6; dorsolaterals mostly double on IV-VI; anterior tufts of siphon well developed, usually very straight; saddle hair usually single (fig. 132) ------------ ----------------------- *pipiens* (p. 131)

5\. Siphon more than 7 times as long as wide at middle, usually over 8; dorsolaterals mostly with 3-5 branches on IV-VI; anterior tufts of siphon weak, usually not straight; saddle hair usually double (fig. 131) ------------ ---------------------- *salinarius* (p. 133)

***Culex (Melanoconion) erraticus* (Dyar and Knab)**

This species has not been previously recorded from the state. In the University Collection there are about 45 adults in two series taken in light traps at Wabasha; the first series was taken by H. T. Peters and R. H. Daggy in 1939 and the second by Peters in 1941. All were taken from July 1 to September 13.

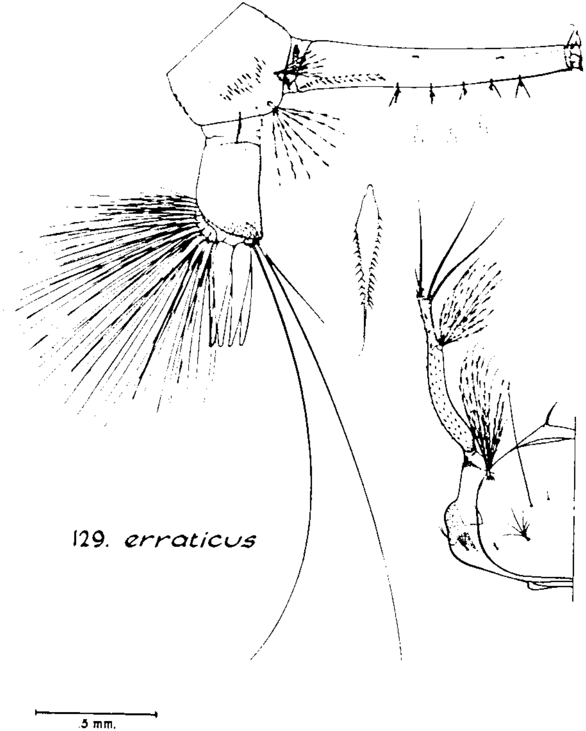
FEMALE — Small. Proboscis and palps dark-scaled. Occiput with a line of broad, appressed scales bordering the eyes. Mesonotum without prominent markings. Dorsum of abdomen dark brown, usually with basal, white bands on the terga. Wing scales dark; scales of R_2 and R_3 much shorter and wider than scales of R_5. Legs dark-scaled.

The key character for this subgenus is the character of the scaling of the wings and head but this character is difficult to see. Females of this species are characteristically very small and dark brown with bright, white markings on the abdomen. The species is easily separated from others in the state on this overall appearance; others are larger and a lighter brown.

MALE TERMINALIA — The oval ninth tergal lobes are diagnostic in this area. Basistyle globular; subapical lobe with armament as in fig. 123.

PUPA — Described and figured by Foote (1954).

FOURTH INSTAR LARVA (material from Georgia; fig. 129) — Head wider than long, about 1 mm. wide. Antennae about as long as or longer than head. Upper head hairs weak, usually with 5 or more branches. Lower head hairs usually single, 2 or more times as long as uppers. Head hairs not in line with post-antennal tuft. Thorax and abdomen markedly pilose. Lateral abdominals usually stout and with 2-3 branches on I and II, weaker and triple or better on III-VI. Large dorsolaterals on III-VII with about 5 branches. Eighth segment with about 18-20 pale comb scales, usually in double row; each comb scale with prominent central spine. Siphon about 8 or more times as long as wide at middle, with short pecten at base; with about 4 or 5 pairs of large tufts close to the mid-ventral line and 1 or 2 pairs of smaller dorso-lateral tufts: ventral tufts usually 2 or more times as long as width of siphon at point of insertion, with about 5-7 branches; dorso-lateral tufts smaller and with fewer branches. Anal segment completely encircled by saddle which is much


129. *erraticus*


130. *territans*

PLATE 41 (figs. 129, 130). Larvae of *Culex*.

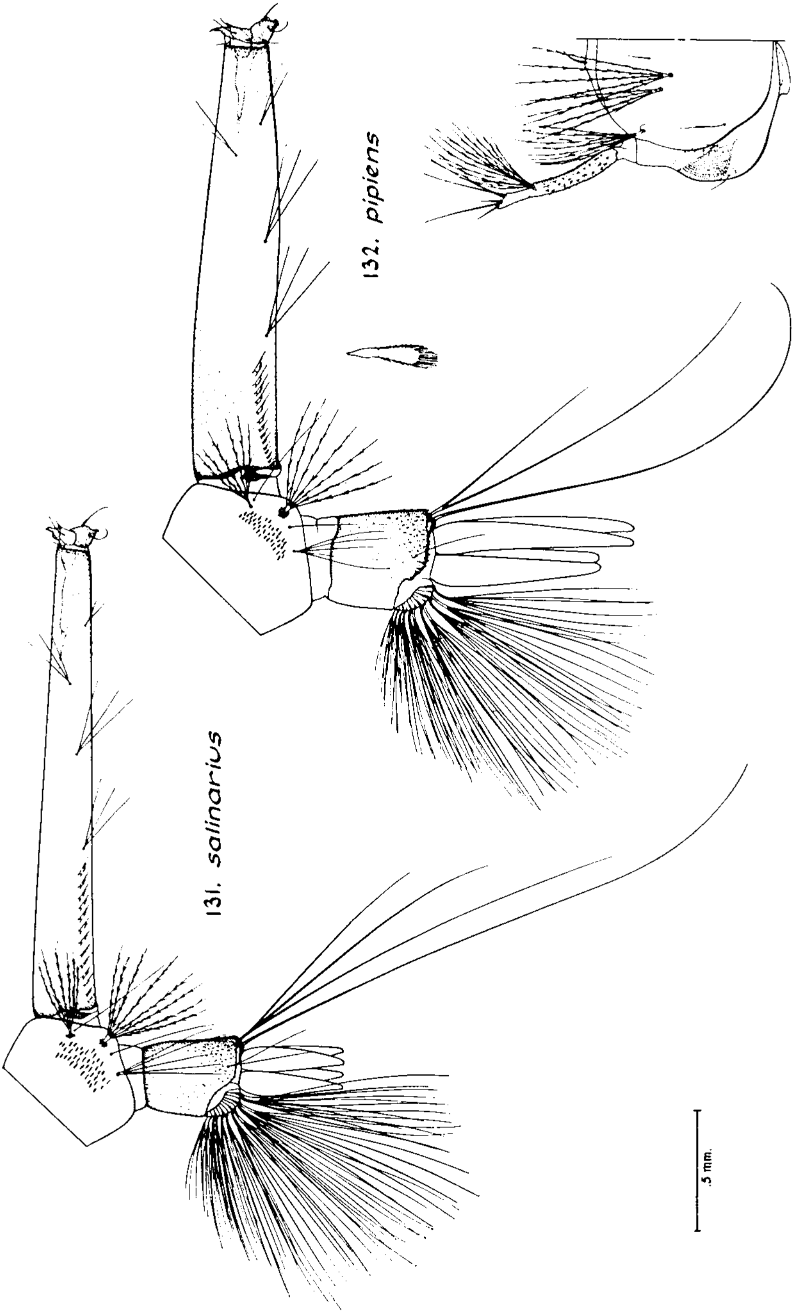


PLATE 42 (figs. 131, 132). Larvae of *Culex.*

longer than wide and markedly pilose (not spinose) especially in the posterior part; ventral brush with no tufts preceding the barred area; dorsal brush consisting of a long, single hair and a double hair (with one short branch) on each side; saddle hair small, inconspicuous. Anal papillae shorter than the saddle in the specimens at hand.

Egg — Figured by Howard *et al.* (1913b).

Biology — Practically nothing is known of the biology of this species. Overwintering is probably by the adult female (Zukel, 1949a). The female lays eggs in rafts which are said (Dyar, 1922a) to be firmly attached to leaves of aquatic plants; Newkirk (1955) found a maximum of 93 eggs in a raft. Larvae are usually taken in permanent water (Dyar, 1922a). There seem to be several generations a year. The females are known to bite man (Ross, 1947) but probably prefer avian hosts (King, *et al.*, 1939, 1944); biting takes place for the most part at night (King *et al.*).

Distribution — New World; United States to Brazil; West Indies. In eastern United States north to Minnesota, Illinois, New York; west to Nebraska, Texas. In Minnesota known only from Wabasha.

Importance — Too rare to be of importance.

Culex (Culex) pipiens pipiens Linnaeus

At the present time *Culex pipiens* is considered to be divided into northern (typical) and southern (*quinquefasciatus*) subspecies; intergrades are known from intermediate areas (Sundararaman, 1949; Barr, 1957). Various strains have been reported from northern regions which are autogenous and have been called "*Culex molestus*"; it now appears that these are strains of *pipiens* (possibly urban biotypes) and should not be recognized nomenclatorially. For an extended discussion of this complex see Mattingly *et al.* (1951).

Female — The female can be separated from *Culexes* other than *restuans* (*q.v.*) by characters given in the key; the separation from *restuans* in the adult female is never certain in areas where both are known to occur.

Male terminalia — Pear-shaped; subapical lobe of basistyle with a leaf-like appendage, as in fig. 125. Phallosome with straight, diagonal, dorsal arms and curved, laterally-directed, ventral arms. Tenth sternum with cluster of dark, pointed spines. Ninth tergal lobes low and inconspicuous.

Pupa - - Described and figured by Darsie (1951).

Fourth instar larva (fig. 132) - - Head wider than long, about 1.2 mm. wide. Antennae about 2/3 as long as head, tuft beyond middle. Head hairs of similar size, multiple (uppers usually with 4-6 branches, lowers usually with 4-5 branches); lower head hair slightly anterior of a line connecting the upper head hair and post antennal tuft. Thorax and abdomen not noticeably pilose. Lateral abdominals usually triple on I and II, double on III-VI; dorsolaterals usually double on III-VI, triple on VII. Eighth segment with about 35-50 comb scales in triangular patch; comb scales without strong terminal spine. Siphon usually about 5-6 times as long as wide at middle, with short pecten at base; anterior 2 pairs of tufts away from mid-ventral line, strong, with rather straight branches, about 1-1½ times as long as width of siphon at point of insertion, usually 3-4 branched; posterior 2 pairs of tufts weaker, usually double (2-4). Anal segment about as long as wide, spinose dorso-posteriorly; ventral brush without tufts preceding barred area; dorsal brush with a long, single hair and a 3-4 branched one (with one long branch) on each side; saddle hair usually single, about 1/2-1 times as long as saddle. Anal papillae usually 2 or more times as long as saddle, but sometimes shorter.

Egg - - The raft has been figured by many authors including Howard *et al.* (1913b); Christophers (1945) gives a wealth of detail on the structure of the raft of this form.

Biology - - The literature on the biology of this species is voluminous and has been summarized by Horsfall (1955). Overwintering is by the adult female; there have been many winter collections of this species from caves along the Mississippi River (Owen, 1937). Larvae are said by Owen to be found particularly in artificial containers, but the author has found them most extensively in clear, unpolluted ground pools around the Twin Cities. The aquatic stages require about 1½ weeks at warm temperatures (egg 2 days, larva 7 days, pupa 2 days). Male pupae are smaller than female and emerge sooner, on the average.

Mating swarms have been described by many authors. The author has seen small mating swarms in St. Paul which formed just before dusk and were active until they could no longer be seen because of darkness. One swarm formed over the corner of a garage and was only a couple of feet in height, being made up of from 2 to about 30 males. This swarm would dance about 7 or 8 feet from the ground and would then work up to a height of 20 feet or so before descending again. Mating was not observed. A significant point was that the nearest known breeding place was about a quarter of a mile away so there appeared to be ample opportunity for mixing of males from different breeding places.

The author has attempted on several occasions to colonize local strains from immature stages but reared females invariably proved to be uninseminated upon dissection. A few such females engorged on the author and practically all of these laid egg rafts which were more or less normal in appearance, but which never hatched. Females will bite humans but usually appear to be reluctant to do so; avian hosts are probably preferred. Where biting is severe, breeding places should be sought within a hundred yards or so since the females appear to disperse but little. There are probably several generations a year.

F. G. Wallace (1943) reported having collected a local strain which developed its eggs autogenously and which would mate readily in cages. Thus the strain "*molestus*" is known to occur in Minnesota. An interesting point is that the strain was colonized from females taken from caves in the winter; the females were said to be active at the time of collection (Wallace, personal communication). The strains known as "*molestus*" are usually considered to be non-hibernatory but there is some doubt that this is always the case.

DISTRIBUTION — Largely throughout the temperate areas of the world with its subspecies *quinquefasciatus* being found in tropical and subtropical areas; in Minnesota details are scanty due to the difficulty in separating this species from *restuans;* practically all certain records are from the vicinity of the Twin Cities. Collections in the northern parts of the state have yielded only *restuans.*

IMPORTANCE — Although *pipiens* females will feed on humans they are not annoying as a rule since they appear reluctant to do so. Females are often taken in houses particularly in damp, cold basements in the winter. Where large populations occur due to breeding in artificial containers the species can be a major pest although under such conditions it is rather easily controlled. The strains known as "*molestus*" often feed much more readily on humans than do the typical strains and may be very annoying. In such cases breeding areas should be sought in the immediate vicinity, particularly in cisterns, cesspools, etc.

***Culex (Culex) restuans* Theobald**

This is the *territans* of Owens and many other authors.

FEMALE — The female typically has a series of patches of pale scales on the mesonotum which has not been observed in *pipiens;* this is the only known difference. There is, however, evidence that *restuans* often lacks these patches (Howard, 1916; Michener, 1947). At any rate the pale patches are easily removed by rubbing; females lacking these pale spots cannot be identified by the author.

MALE TERMINALIA (fig. 121) — Easily recognized by lack of heavily sclerotized phallosomal armament.

FOURTH INSTAR LARVA (fig. 128) — Head wider than long, slightly over a mm. wide. Antennae about half as long as head, tuft placed near or before, not beyond, middle. Upper and lower head hairs of about the same length, multiple (usually with 4-6 branches), in line with postantennal tuft. Lateral abdominals usually double on I and II, single on III-VI; with long, single, dorsolaterals on IV and V and often on III. Eighth segment with about 34-40 comb scales in triangular patch; comb scales without prominent terminal spine. Siphon about 4-5 times as long as wide at middle, with short pecten at base; with about 5-7 long single hairs and a pair of smaller, double or more highly branched tufts. Anal segment encircled by saddle which is usually not as long as wide, with prominent patch of spines on upper posterior corner on each side; ventral brush without tufts preceding the barred area; dorsal brush of two long, single hairs on each side; saddle hair single, shorter than saddle. Anal papillae usually 2 or more times as long as saddle.

EGG — Raft figured by Howard *et al.* (1913b).

BIOLOGY — The biology of this species is probably rather similar to that of typical *pipiens.* Females are known to overwinter but there is little data on this point in Minnesota. Most Minnesota collections of adults are in June and July although the author has taken larvae breeding abundantly until late in the fall. The period required for the aquatic stages appears to be about the same as for *pipiens;* Mitchell (1907) says the eggs hatch in 1-3 days. Larvae have been reported from a variety of places but the author has taken them primarily from clean ground pools; they will breed in artificial containers especially in barrels (Howard, 1916). Swarming is probably required for mating (Michener, 1947).

Females probably feed by preference on avian hosts although they will attack man (Howard, 1916; Owen, 1937; McLintock, 1944); this is the only *Culex* the author has taken feeding on man in the state although others undoubtedly will do so. Mitchell (1907) found that females would bite 12 hours after emergence and generally laid eggs in 4-10 days; she also reported that some females would feed a second time and lay a second raft. Girault (1908) found that females laid about 267 eggs on the average. Adults are said to rest in damp vegetation (Michener, 1947). There are probably several generations a year; Carpenter (1941) found adults most common in the spring and the fall, fewer individuals being found in the summer. The species does not seem to be particularly migratory. There is a suggestion in the notes of the author that females are most commonly found in wooded areas. Adults will enter houses readily; Dyar (1922a) says that this species is the common house mosquito in northern areas.

Distribution — Eastern North America from Canada to Mexico; west to Saskatchewan, Montana, Utah, Texas; also in California. In Minnesota records are scanty due to confusion with *pipiens* but appear to be generally distributed over the state, especially in wooded areas. Only *restuans* and *territans* appear to be abundant in northern forested areas.

Importance — Although *restuans* usually does not feed readily on humans it may become annoying when abundant, particularly in wooded areas; McLintock (1944) lists it as the third-ranking species of importance in the Winnipeg area.

Culex (Culex) *salinarius* Coquillett

Female — Females can be confused with *pipiens* and *restuans*; the best character seems to be the abdominal bands which are small and yellowish rather than white in fresh adults.

Male terminalia — Phallosomal armature very dark as in *tarsalis* but shaped as in fig. 126.

Pupa — Described and figured by Darsie (1951).

Fourth instar larva (fig. 131) — Head wider than long, about 1¼ mm. wide. Antennae about 0.8 as long as head, with tuft beyond middle. Head hairs of about equal size; uppers with 3-5 branches, lowers 3-4; lower head hair slightly anterior of a line connecting upper head hair and postantennal tuft. Thorax and abdomen not noticeably pilose. Lateral abdominals usually triple on I and II, double on III-VI. Dorso-laterals usually with 2-4 branches on III, with 3-5 branches on V-VII. Eighth segment with about 35-60 comb scales in triangular patch; comb scale without prominent terminal spine. Siphon about 9 or more times as long as wide at middle, with short pecten at base; anterior 2-3 pairs of tufts usually well raised from the mid-ventral line, usually about as long as or somewhat longer than width of air tube at point of insertion, usually triple; more posterior 2 pairs of tufts shorter, usually 2-3 branched. Anal segment completely encircled by saddle which is somewhat longer than wide and with few dorso-posterior spines; ventral brush with no tufts preceding the barred area; dorsal tuft consisting of a long, single and a 3-4 branched (one long branch) hair on each side; saddle hair about 1/2-1 times as long as saddle, double or single. Anal papillae usually no longer than saddle.

Egg — Raft figured by Howard *et al.* (1913b).

Biology — Most of the pertinent literature on this species is given by Wallis and Spielman (1953). Females overwinter and will bite humans; the host preferences have not been studied. Females are said (Headlee, 1931) to bite especially at dusk and between midnight and morning and will feed more than once. Mitchell (1907) found the preoviposition period to be 2-10 days; females laid about 50-55 eggs in a raft which hatched in 2-4 days; Newkirk (1955) found up to 104 eggs in a raft. Larvae are reported to occur in a variety of places but have been taken by the author only in ground pools; they have been reported from brackish as well as fresh water. The larval stages require about 1½-2 weeks (Wallis and Spielman) and the pupal stage about 2-3 days at warm temperatures (Mitchell). The swarming of males has been described (Smith, 1904) but Wallis and Spielman found no evidence for this in the laboratory; mating was observed to take place in cages. Females will bite as soon as 12 hours after emergence and before mating (Mitchell, 1907) but it is likely that mating normally takes place soon after emergence. Females are said to rest in houses (Carpenter *et al.*, 1946). The species has been colonized by Wallis and Spielman.

Distribution — Eastern United States, Massachusetts to Gulf coast, west to Minnesota, Kansas, Utah, New Mexico. In Minnesota there are only scattered records of this species possibly due to the difficulty of separating it from *pipiens* and *restuans*.

Importance — Not usually abundant in Minnesota and probably of no importance.

Culex (Culex)
tarsalis Coquillett

Female — Only *Culex* in the state with white band on proboscis, white lines on mesonotum, and white bands and other markings on legs.

Male terminalia — Phallosomal armature dark as in *salinarius* but shaped as in fig. 124.

Pupa — Undescribed.

Fourth instar larva (fig. 127) — Head wider than long, about 1⅓ mm. wide. Antennae about as long as head, tuft beyond middle. Head hairs of about equal size, multiple (lowers usually with 4-5 branches, uppers with 5-6); lower head hair anterior of a line joining upper head hair and postantennal tuft. Thorax and abdomen not noticeably pilose. Lateral abdominals usually triple on I-VI; with large, usually 3-4 branched dorso-laterals on III-VII. Eighth segment with about 50-70 or more comb scales in triangular patch; comb scales without strong terminal spine. Siphon about 7-8 times as long as wide at middle, with short pecten at base; with anterior 3-4 pairs of ventral tufts set very close to mid-ventral line, each tuft with about 6-7 branches, usually 1-1½ or more times as long as width of air tube at point of insertion; posterior 2-3 tufts sometimes more lateral than anterior ones, weaker, with about 3-5 branches; siphon may be narrowest before apex. Anal segment completely encircled by saddle which is usually somewhat longer than wide; ventral brush without tufts preceding the barred area; dorsal brush of a long, single, and a 3-5 branched (with 1 long branch) hair on each side; saddle hair about half as long as anal segment, usually double (2-3). Anal papillae usually not much longer than saddle.

Egg — Described by Lungstrom (1954).

Biology — Jenkins (1950) partially summarized the information bearing on this species. Overwintering is by the adult female. Little is known of this particular phase of the species; Keener (1952) found females overwintering in food storage cellars and Mortenson (1953) has found them in natural resting places such as hollow logs and tree stumps. It may be possible for the virus of western equine encephalitis to overwinter in females (Jenkins, 1950). Most Minnesota records are from late May to the end of August.

Females appear to prefer avian hosts (Reeves and Hamman, 1944) although they will attack mammals, especially cattle (Horsfall, 1955; see also Lungstrom, 1954); females appear to be most active during the night (Carpenter *et al.*, 1946; Lungstrom, 1954). CO_2 may be a significant factor in the attraction of females (Reeves, 1951).

The oviposition behavior of this species has been described by Lungstrom (1954). Eggs are laid in rafts which average about 230 eggs of which over 90% usually hatch in fertile rafts (Hubert *et al.*, 1954; see also Lungstrom, 1954); the incubation period is about 2-3 days at warm temperatures (Husbands and Rosay, 1952; Hubert *et al.*, 1954; Keener and Edmunds, 1954; see also Lungstrom, 1954). Larvae are most often found in clear ground pools in Minnesota. The larvae mature in about 5-8 days at warm temperatures (Husbands and Rosay, 1952; Keener and Edmunds, 1954); Lungstrom (1954) gives 2, 2, 3, 3, and 2 days respectively for the four larval and the pupal stages at about 23° C.

Swarming probably takes place in nature and has been observed in the laboratory although strains have been developed which will mate in small cages (Hubert *et al.*). Females will feed as early as the third day after emergence and there is laboratory evidence for believing that females may not often take a second blood meal (Hubert *et al.*) although it is known that females can live as long as 4 months (Husbands and Rosay, 1952). Females will enter houses readily and there may be several generations in a year. Lungstrom (1954) found that the number of adults was greatest in late summer and declined in warm weather.

Distribution — United States from Canada to Mexico, especially west of the Mississippi (Jenkins, 1950). In Minnesota there are abundant records from all parts except the coniferous forest although it is probably most abundant in plains areas.

Importance — This species is thought to be the most important vector of western equine encephalitis and probably St. Louis encephalitis in the United States (Jenkins, 1950). The former disease has been of importance in Minnesota for several years (Eklund, 1946; Burroughs and Burroughs, 1954). Fortunately the species appears not to feed often on man; it is rather abundant in plains areas of the state in favorable years.

Culex (Neoculex)
territans Walker

This is the *apicalis* of Owens and many other authors (see Bohart, 1948).

Female — A small *Culex* with dark proboscis, wings, and legs and pale apical bands on the abdominal terga.

Male — May be identified by key to females. Terminalia (fig. 122). Subapical lobe of basistyle without leaf-like appendage; phallosome with an H-shaped structure; tenth sternum with blunt setae.

Pupa — Described and figured by Darsie (1951).

Fourth instar larva (fig. 130) — Head wider than long, slightly over a mm. wide. Antennae about as long as head, tuft beyond middle. Head hairs single or double, uppers frequently shorter than lowers, not in line with postantennal tuft. Dorsum of thorax with short pile, especially at sides; abdomen not noticeably pilose. Lateral abdominals usually triple on I-II, usually double on III-VI. Large dorsolaterals on III-VII with about 4-6 branches. Eighth segment with about 40 or so comb scales in triangular patch, comb scale without strong terminal spine. Siphon about 8 or more times as long as wide at middle, narrowest before apex; with short pecten at base; with about 4-5 pairs of long tufts near mid-ventral line and one or more pairs of smaller, more lateral tufts; ventral tufts with about 4-6 branches, usually 2 or more times as long as width of siphon at point of insertion; smaller tufts with about 4-5 branches, about as long as width of siphon. Anal segment completely encircled by saddle which is longer than wide; with spines on postero-dorsal surface; ventral brush usually with a pair of tufts preceding the barred area; dorsal brush with a long stout hair and a 3-4 branched hair (one branch very long) on either side; saddle hair about half as long as saddle, usually double (2-3). Anal papillae usually about twice as long as saddle.

Third instar larva — Saddle extending about 1/4 down the sides, lateral hair at edge.

Egg — Raft figured by Howard *et al.* (1913b).

Biology — Overwintering is by the adult female. In Minnesota adults are most commonly taken from late June to August. The females are not known to attack warm-blooded animals but have been observed feeding on amphibians (Shannon, 1915; Matheson, 1944; Büttiker, 1948) and snakes (Dyar, 1928). Adults are said (Michener, 1947) to rest in vegetation or shelters near breeding places (Carpenter *et al.*, 1946) but are not often taken in houses (Carpenter *et al.*). Oviposition has been described by Knab (1904) according to whom the eggs are laid on the banks of breeding places rather than on water; oviposition is said to take place in the daytime. The number of eggs laid is about 105-132 according to Howard *et al.* (1913a), 130 according to Hearle (1926), and 240 according to Mitchell (1907). The incubation period is about 2 days and larvae require about 13 days (Mitchell). In Minnesota larvae are usually taken in relatively permanent, clear ponds or marshes, usually in duckweed. The pupal stage requires about 2-3 days (Mitchell). Diurnal swarms of males have been described by Frohne and Frohne (1954). Ross (1947) indicates that breeding may fall off in midsummer in Illinois but Minnesota collections do not show this.

Distribution — Holarctic; generally distributed over the United States and Canada. Minnesota records are scattered over the entire state.

Importance — None.

MOSQUITOES OF NEIGHBORING REGIONS

The following species have been recorded from states or provinces (Canada) surrounding Minnesota but as yet are not known to occur in the state. The author cannot vouch for the accuracy of these records; the most doubtful ones are indicated by question marks. (From Post and Munro, 1949; Ross, 1947; Dickinson, 1944; Irwin, 1941; PHS, 1951; Dyar, 1928)

Anopheles crucians — Ia., Ill.

Toxorhynchites rutilus septentrionalis — Ill.

Culiseta alaskaensis — Manit.

impatiens — Ia., Wisc., Mich., Ont., Manit.

incidens — No. Dak.?, Mich.?

parodites — Wisc. (= *morsitans*?)

Orthopodomyia alba — Ia., Ill.

Psorophora confinnis — S.Dak., Ia., Ill.

cyanescens — Ill.

discolor — Ia., Ill.

ferox — S.Dak., Ia., Ill., Wisc., Mich.

howardii — Ill.

longipalpis — S.Dak.

signipennis — N.Dak., S.Dak., Ia.

varipes — Ia., Ill.

Aedes aboriginis — Mich.?
aegypti — Ill.
cataphylla — Manit.
decticus (= *pseudodianteus* Smith, 1952) — Mich.
dupreei — Ia., Ill.
fulvus pallens — Ill.
grossbecki — Ill.
hexodontus — Manit.
idahoensis — N.Dak.
impiger (= *nearcticus auct.*) — Manit., Ont.
mitchellae — Ill.
nigripes — Manit.
pullatus — Mich.?
sollicitans — N.Dak., Ill.
thibaulti — Ill.

Culex pipiens quinquefasciatus — Ia., Ill.
peccator — Ill., Mich.

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