Key to the *Culex* Species (Diptera: Culicidae) of New Jersey and the Northeastern U.S.A.

Written and Illustrated by
Dr. Diana Carle, PhD
2019

TABLE OF CONTENTS

Introduction

Vector Importance

Six distinct species of *Culex* mosquitoes occur within NJ: *Culex erraticus, Culex pipiens, Culex restuans, Culex salinarius, Culex tarsalis,* and *Culex territans*. These account for all *Culex* species within the northeastern USA. These species possess unique life histories resulting in novel combinations of host preferences, vector competences, distributions, and habitat requirements (Table 1), making accurate identification vital. In addition, *Culex quinquefasciatus* has been recorded as far north as Delaware and Maryland. However, it is difficult to distinguish from *Cx. pipiens* morphologically and keys often treat both species as a complex. The range of *Cx. quinquefasciatus* may expand over time due to climate change, making knowledge of its biogeography relevant.

The genus *Culex* is notorious for certain species that vector West Nile virus (WNV) (Molaei *et al*. 2016, Hamer et al 2009), but some *Culex* species can also vector St. Louis encephalitis (SLE), Western equine encephalitis (WEE), and Cache Valley virus (CVV) (Ayers *et al*. 2018, Hammon & Reeves 1943, Sardelis 2001). Of these viruses, only WNV and SLE are known to occur in NJ. *Culex* species have also been linked to the transmission of dog heartworm (Shaoming 2013) and avian malaria (Nayar 2008). In addition, multiple researchers have implicated five of the six *Culex* species which occur in NJ to play some role in the transmission cycle of Eastern Equine Encephalitis (EEE) in different regions based upon blood meal analysis and host preferences.

Though human cases of EEE are generally rare and less prevalent than cases of WNV, EEE is the deadliest of mosquito borne viruses in NJ, killing approximately 1/3 of individuals who present with symptoms, and leaving most of the surviving 2/3 of patients with mild to severe permanent neurological damage (CDC 2019). Enzootic EEE is maintained in the northeastern USA primarily through *Culiseta melanura* amplifying the virus in bird populations that usually inhabit freshwater swamps (Moncayo *et al*. 2000, Magnarelli 1977, Molaei *et al*. 2006, Burkett-Cadena *et al*. 2015). Even though *Cs. melanura* is extremely efficient at amplifying EEE within the bird population, it is not considered a primary bridge vector because it seldom feeds on mammals (Edman *et al*. 1972, Nasci and Edman 1981, Molaei and Andreadis 2006, Estep *et al*. 2011). Instead, authors have implicated *Aedes vexans* (Chamberlain *et al.* 1956, Vaidyanathan *et al.* 1997), *Aedes sollicitans,* *Coquillettidia perturbans*, and *Cx. salinarius* (Crans and Schulze 1986) as possible bridge vectors in the northeastern USA. More support for the possible role of *Culex* species in EEE transmission comes from New York in the years spanning 1993 to 2012, when EEE was identified in *Cx. salinarius*, and the *Cx. pipiens/restuans* group (Oliver *et al*. 2018). EEE was also identified in *Cx. pipiens* during a 1996 epizootic outbreak in southeastern Connecticut (Andreadis *et al*. 1996). Even though *Cx. territans* feeds primarily on amphibians, its ability to opportunistically feed on various other vertebrate hosts combined with data of field-collected specimens infected with EEE suggest a possible role in the epizootic cycle (Morris *et al*. 1971).

Culex erraticus has received considerable attention as a possible vector in the zootic transmission of EEE, especially when *Cs. melanura* populations are low or absent as is often the case in the southeastern USA (Cohen *et al*. 2009, Bingham *et al*. 2016). *Cx. erraticus* will opportunistically feed on a variety of hosts (Robertson *et al*. 1993). This species can be a persistent aggressive biter, especially in woodland habitats (King *et al*. 1960) and when it is abundant in more developed areas (Ross 1947). *Cx. erraticus* is also known to fly from 1.4 to 2.2 kilometers **(**Morris *et al*. 1991). Cupp *et al*. (2003) found *Cx. erraticus* in central Alabama infected with EEE from mid-June to September, and with a minimum infection rate of 3.2. Hassan *et al*. (2003) noted patterns of high *Cx. erraticus* and low *Cs. melanura* populations in combination with circulating EEE in swamps of Mississippi and Alabama. Cup *et al*. (2004) further hypothesized that extreme changes to the environment caused by development and deforestation have led to *Cx. erraticus* gradually replacing *Cs. melanura* in these disturbed habitats. *Cx. erraticus* does however appear to be a less efficient EEE vector than *Cs. melanura* due to a 6-day extrinsic incubation period for the former which is twice that of *Cs. melanura* (Scott and Burrage 1984). *Cs. melanura* also feeds almost exclusively on avian hosts, while *Cx. erraticus* is more of a generalist feeder (Oliveira *et al*. 2011). However, Bingham *et al*. (2016) noted that because of *Cx. erraticus'* opportunistic feeding behavior it may function in EEE transmission as both an enzootic amplification vector and bridge vector.

Without vector competence studies there are more questions than answers as to the exact role that *Culex* species may play in the EEE transmission cycle. However, because multiple *Culex* species vector viruses like WNV and SLE, and because these species may also be involved in EEE transmission, training in species level identification is paramount. Because each *Culex* species occupies a different ecological niche and utilizes different larval habitats, accurate species identification is critical to making the most effective control decisions that optimally conserve both human and environmental health.

Culex Species	Host Preferences	NJ Pathogens	American Distribution	Northeast Distribution	NJ Status	Larval Habitats
Cx. erraticus	Birds (especially large wading birds) mammals, reptiles, amphibians	May be involved in EEE cycle, found in field infected with SLE	Eastern USA south of Great Lakes, also in Central and South America	CT, NJ, NY, PA	Fairly Common	Mainly freshwater swamps & bogs, especially in woodlands
Cx. pipiens	Mostly songbirds, but also mammals	WNV, SLE, & may be involved in EEE cycle	Northern USA & parts of Canada	CT, MA, ME, NH, NJ, NY, PA, RI, VT	Common	Thrive in polluted water, & around homes in containers like old tires, buckets, bird baths, etc…
Cx. restuans	Mostly songbirds, but also mammals	WNV, may be involved in EEE cycle	Eastern USA & select western states, also southern Canada	CT, MA, ME, NH, NJ, NY, PA, RI, VT	Common	Varied - clean to polluted water, freshwater swamps & bogs, peridometic to woodlands
Cx. salinarius	Birds, mammals	WNV, may be involved in EEE & SLE cycle	Eastern 2/3 of USA and select western states	CT, MA, ME, NJ, NJ, NY, PA, RI, VT	Common	Varied, fresh or brackish water, salt marsh impoundments especially
Cx. tarsalis	Mostly birds, but also mammals	WNV, SLE, CVV	Throughout USA and southern Canada, but more common in west	NJ, PA	Rare	Varied - clean to polluted water, fresh to saline water, peridometic to woodland
Cx. territans	Almost exclusively frogs, but will also feed on lizards, birds, and mammals	Found in field infected with EEE, and may have some role in virus cycle	Throughout the USA excluding the SW, and throughout Canada	CT, MA, ME, NJ, NJ, NY, PA, RI, VT	Common	Mainly freshwater swamps & bogs, especially in woodlands

Table1. Abbreviated life history table of NJ & northeastern *Culex* species (Andreadis *et al.* 2005, Bajwa 2018, Burkett-Cadena 2013, Crans 2004, Darise & Ward 2016, Morris *et al.* 1971, Oliver *et al*. 2018). Note that with new research the information in this chart is subject to change.

Morphological Notes

Culex adults are often referred to as "little brown mosquitoes" which is unfortunate because these mosquitoes possess a diversity of characters at the species level that can be utilized by trained personnel to readily and accurately identify species. Larval identification and surveillance are also vital to vector control programs because the most effective forms of mosquito control are those targeted at the larval stage. *Culex* larvae possess a variety of excellent characters that facilitate accurate species determinations, which in turn help inform the most control decisions.

Adults: Troubleshooting Common Generic ID Mistakes

When identifying the genus *Culex* mosquito workers can have difficulty distinguishing whether the abdomen is "blunt" or "pointed" and may misidentify the specimen as an *Aedes* or a *Psorophora*. Instead, students should visualize this character as abdominal segment VIII much wider than long in *Culex*, which creates a more blunted appearance of the abdomen in dorsal view. Remember that segment VIII is the last segment of the adult abdomen and is usually reduced and much smaller than the proceeding segments. *Culex* adults also possess relatively narrow wing scales which separate them from the other similar, "little brown mosquito" *Cq. perturbans*. Lastly, the identification of *Culex* from *Culiseta* will be incorrect if mosquito workers confuse the metathoracic spiracle (located on the last thoracic segment), with the prothoracic spiracle (located on the first thoracic segment just behind the head). *Culiseta* has prespiracular setae located anterior to the spiracle on the **prothoracic** segment, whereas *Culex* has no such setae.

The loss of scales in mosquito adults is often a problem and can impair the ability of taxonomists to make reliable species identifications. The main problem in this genus is distinguishing *Cx. pipiens* from *Cx. restuans* because the characters are based upon differences in scale patterns which can easily be sloughed off by the fan of a trap or a large moth flapping around a collection container. For this reason, mosquito control programs will often report these two species as "*pipiens-restuan*s mix" in their identifications to accommodate the problem of damaged specimens.

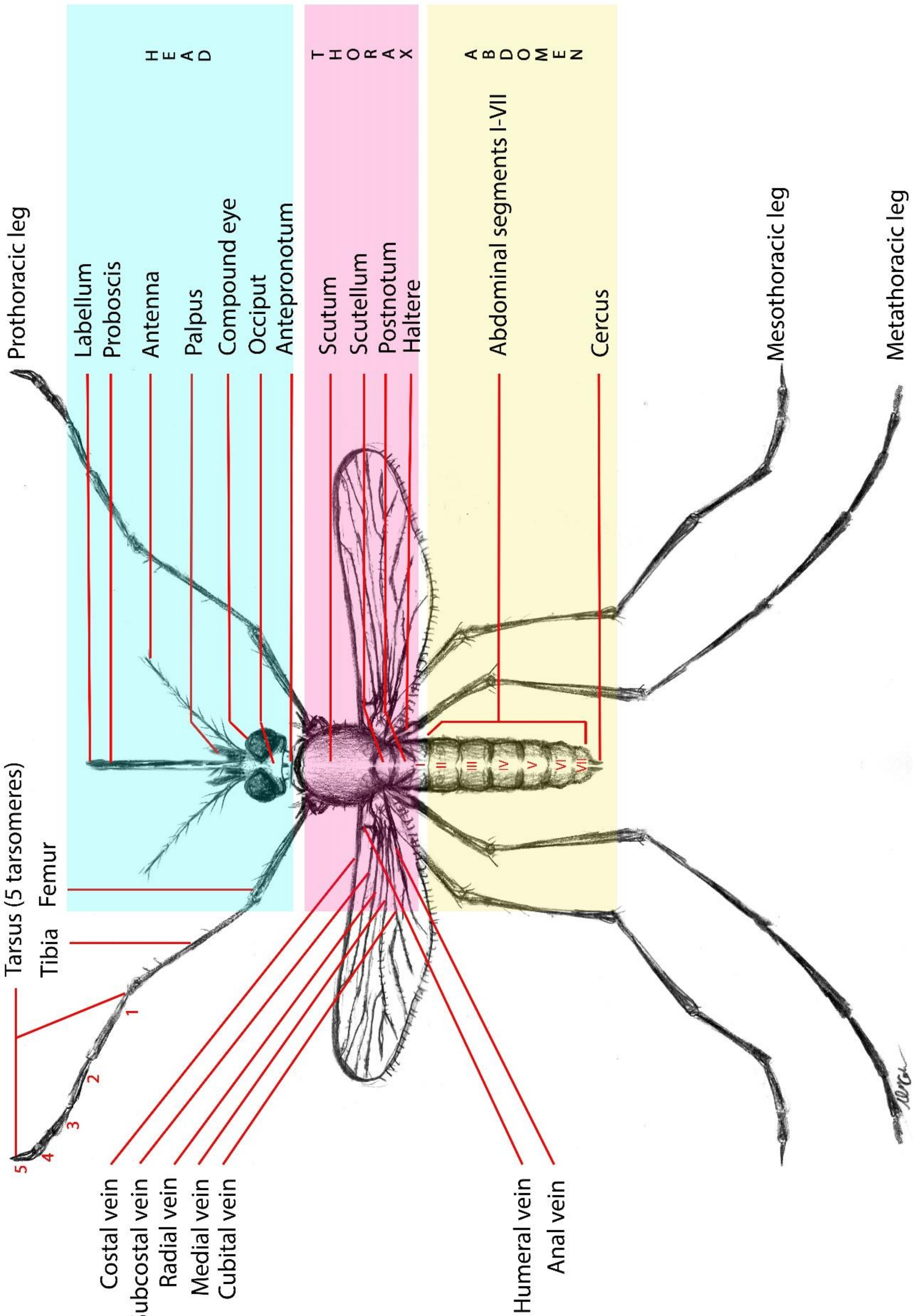
Larvae: Troubleshooting Common Generic ID Mistakes

There tend to be far fewer stumbling blocks in distinguishing *Culex* larvae from the other mosquito genera present in NJ. However, the reduced basal siphonal tuft of *Cs. melanura* combined with its extralong and slender siphon, can lead to misidentification of this species as *Culex*. If someone makes this mistake they will be left with an oddity that doesn't quite fit anywhere in the *Culex* key, if you find yourself in this position, look again for a very reduced basal siphonal tuft.

In identification keys that use the term "pairs" of siphonal setae, readers often think they should be looking for "pairs" of setae on the same side of the siphon. Instead, in this case, "pairs" refers to a bilaterally symmetrical "pair" of setae found on each side of the siphon. The fact that mosquitoes have matching setal hairs on each side of the siphon can be useful in identifying specimens where a few setae have fallen off because it allows mosquito workers to compare and utilize setae from either side. That is, because siphonal hairs occur in pairs in the same place on either side of the siphon, if a seta is missing on one side, but present on the other side in the corresponding location, it can be counted as 1 of the siphonal setal "pairs" being present. In most generic keys *Culex* is usually separated from *Psorophora* and *Aedes* based upon the number of siphonal setae. Therefore, when a key states that *Culex* has three or more pairs of siphonal setae, it does not mean six or more setae on each side of the siphon, but instead means three or more single or branched setae on each side of the siphon.

A more general morphological error made in reading larval keys is not recognizing that these keys are made for 4^{th} (final) instar mosquito larvae when characters are fully developed. Earlier larval instars do not have all of the essential characters needed for accurate identification. If you have collected only earlier instar larvae you will need to rear them to the final instar to allow accurate identifications. Mosquitoes will undergo molting to the next larval instar more quickly under warmer conditions with plenty of food. To expedite larval growth and the identification process, place live larvae in a covered container with some airflow, in a warm place, and feed the larvae plenty of crushed rabbit chow. Another pitfall in larval identification is collecting larvae that have begun transformation to the pupal stage. Larvae collected between the molt from larva to pupa have lost some of the larval characters and begin assuming a more sclerotized pupal appearance, though they still have the basic larval head, thorax, and abdomen. Collecting larvae like this usually only occurs if you happen to time your collections in concert with the emergence of a massive brood, as seen in early spring univoltine species which have a large synchronous emergence. If pupae begin emerging into adults inside of your sample jar as you collect, this is a fairly good indication that many of your collected larvae may be in a chimeric state between 4^{th} instar molt and pupa, and may not all be identifiable. Awareness of some of these common pitfalls can make the work of identification a much smoother and productive experience.

Culex Adult Anatomy



Key to *Culex* Adults

1. Scutum without middorsal setae (Fig. 1a); occiput with broad scales along postocular border (Fig. 1b) ……..……………………..……...…. ***Cx. erraticus***

1’. Scutum with middorsal setae (Fig 1c); occiput with narrow scales along postocular border (Fig. 1d) …………………………..…………………..…….... 2

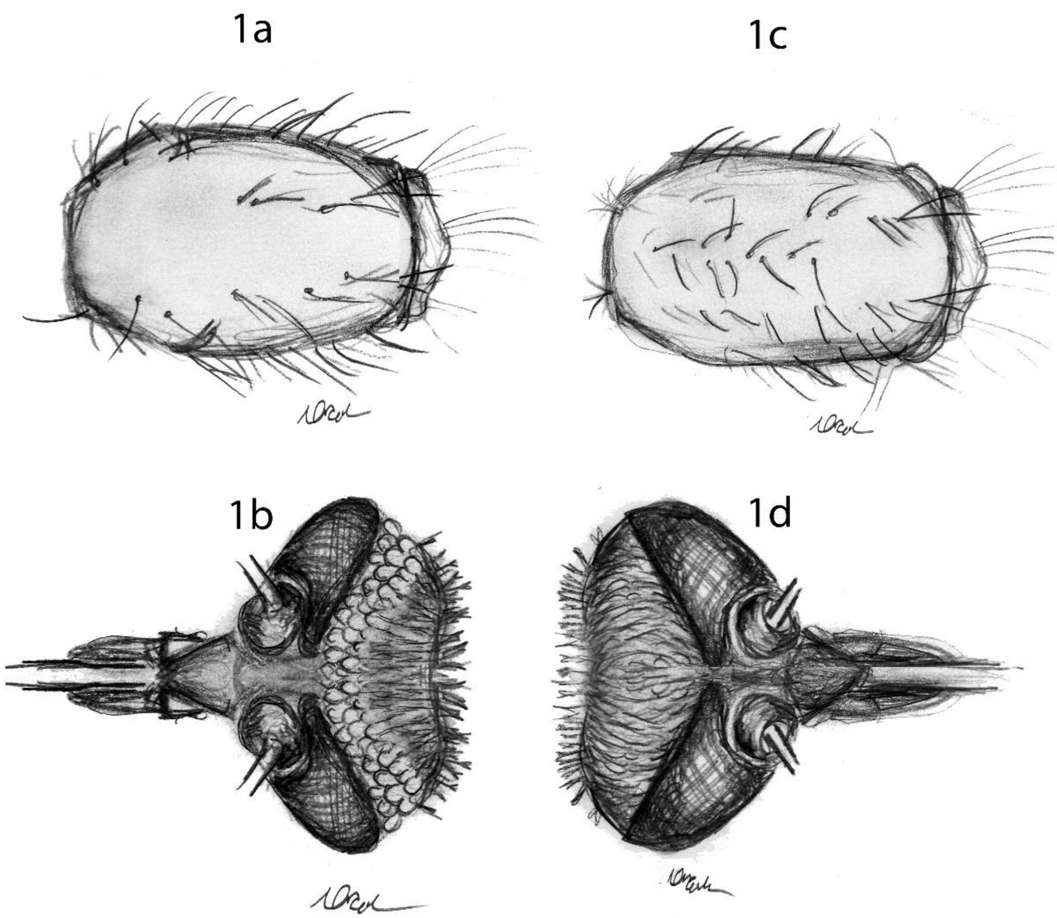


Figure 1.
a. Dorsal view of thorax, *Cx. erraticus*
b. Dorsal view of head, *Cx. erraticus*
c. Dorsal view of thorax, *Cx. pipiens*
d. Dorsal view of head, *Cx. pipiens*

2(1’). Abdominal terga with apical bands of pale scales (Fig. 2a) …… ***Cx. territans***

2’. Abdominal terga with basal bands of pale scales (Fig. 2b) ………..………. 3

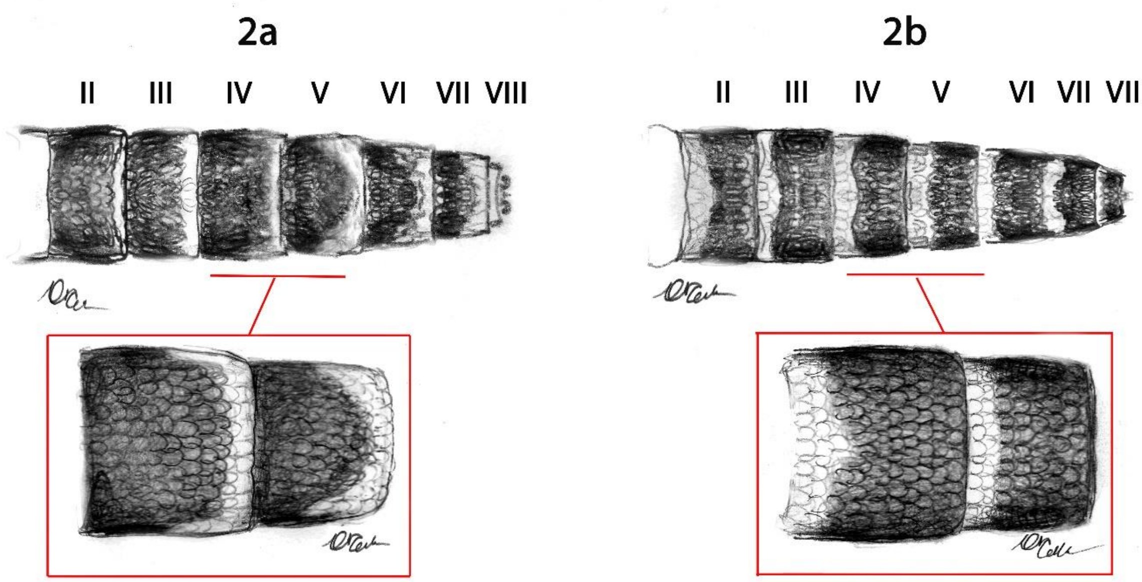


Figure 2.
a. Dorsal view of abdomen, *Cx. territans*
b. Dorsal view of abdomen, *Cx. restuans*

3(2’). Hind tarsomeres with basal and apical bands of pale scales (Fig. 3a); proboscis with band of pale scales (Fig. 3b) ……….……………….………… ***Cx. tarsalis***

3’. Hind tarsomeres without basal and apical pale bands of scales (Fig. 3c); proboscis without band of pale scales (Fig. 3d) ……………………….……….4

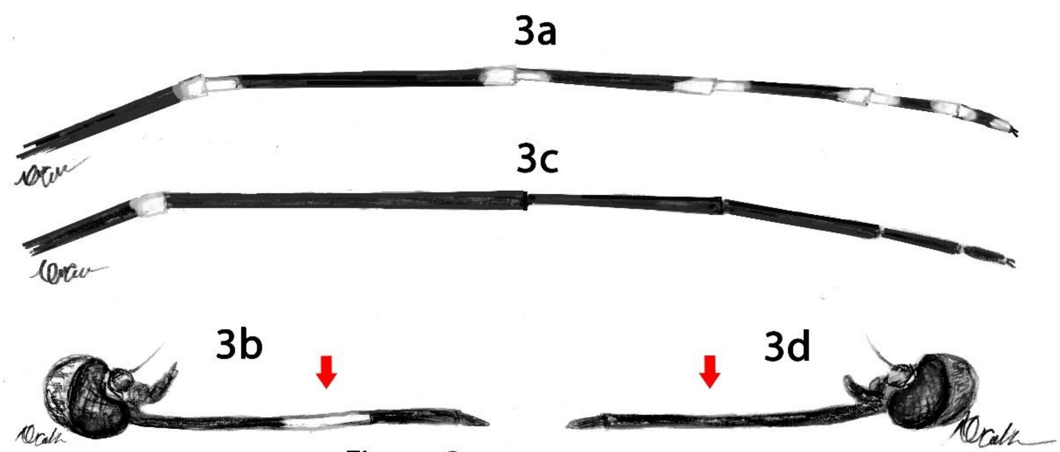


Figure 3.
a. Hindleg, *Cx. tarsalis*
b. Lateral view of head, *Cx. tarsalis*
c. Hindleg, *Cx. restuans*
d. Lateral view of head, *Cx. restuans*

4(3’). Scutellum bearing short dark scales (Fig. 4a); abdominal terga with narrow basal bands of pale scales, sometimes reduced or absent; abdominal tergum VII with mostly pale-yellow scales (Fig.4b) ……….………...…. ***Cx. salinarius***

4’. Scutellum bearing long pale scales (Fig 4c); abdominal terga with broad basal bands of pale scales; abdominal tergum VII with mostly dark scales (Fig. 4d) ……………………………………………….………………… 5

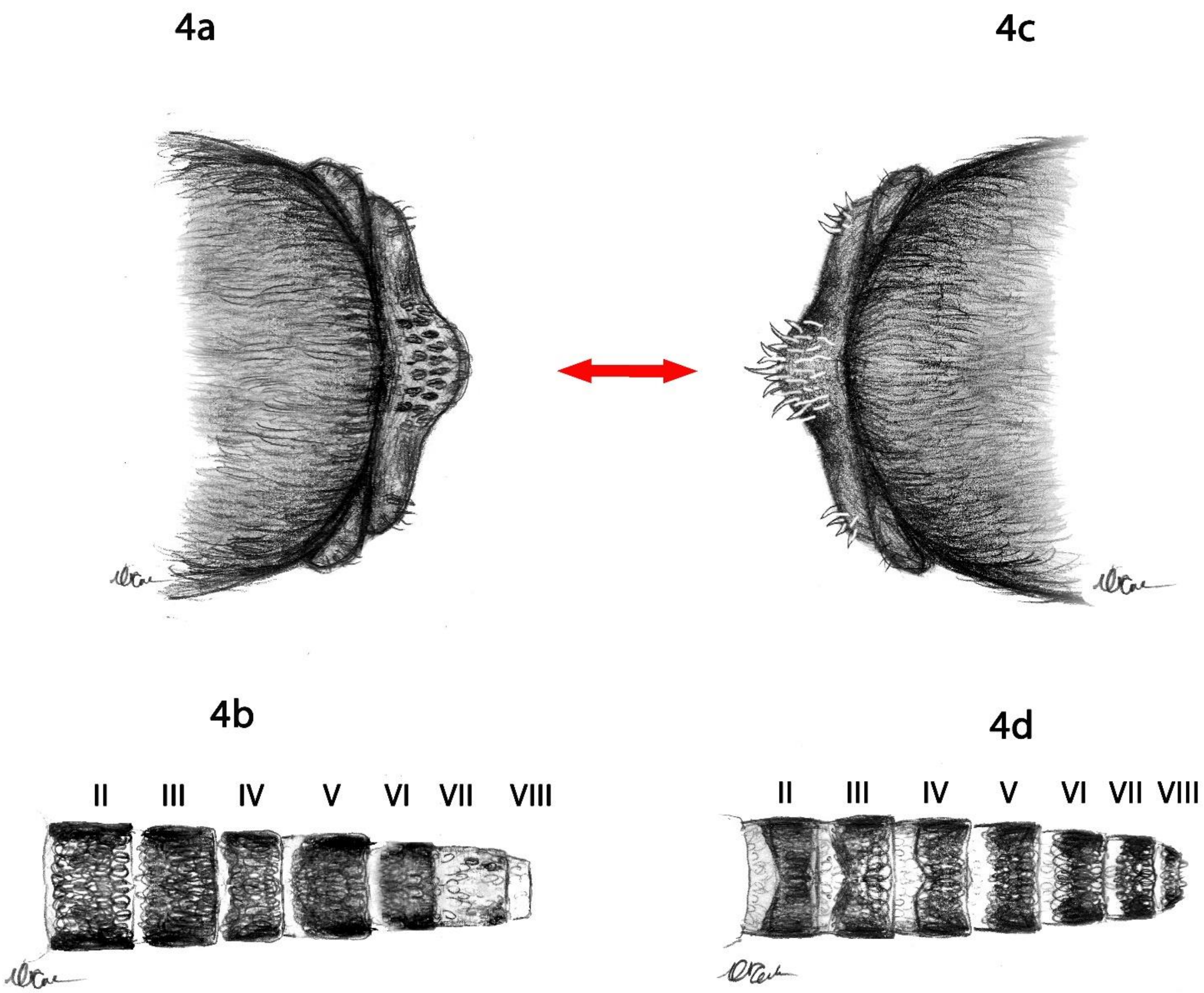


Figure 4.
a. Dorsal view of scutellum, *Cx. salinarius*
b. Dorsal view of abdomen, *Cx. salinarius*
c. Dorsal view of scutellum, *Cx. restuans*
d. Dorsal view of abdomen, *Cx. restuans*

5(4’). Abdominal terga dorsally with basal posteriorly rounded pale bands of scales strongly constricted sublaterally (Fig. 5a); scutum without spots of pale scales (Fig. 5b) …………………………………………….….…... ***Cx. pipiens***

5’. Abdominal terga dorsally with basal relatively straight bands of pale scales with slight sublateral constrictions (Fig. 5c); scutum with or without spots of pale scales (Fig. d) ……………….…………….………..………… ***Cx. restuans***

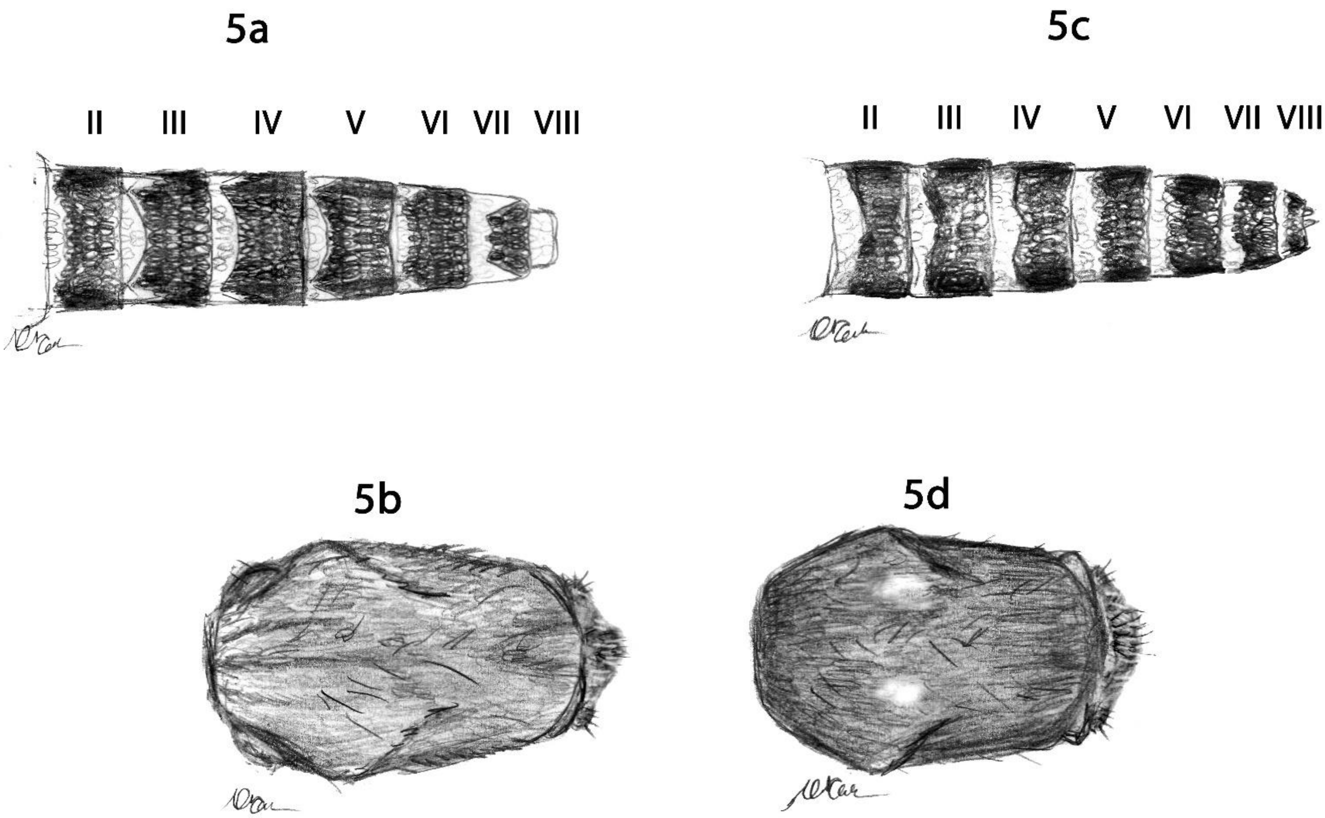
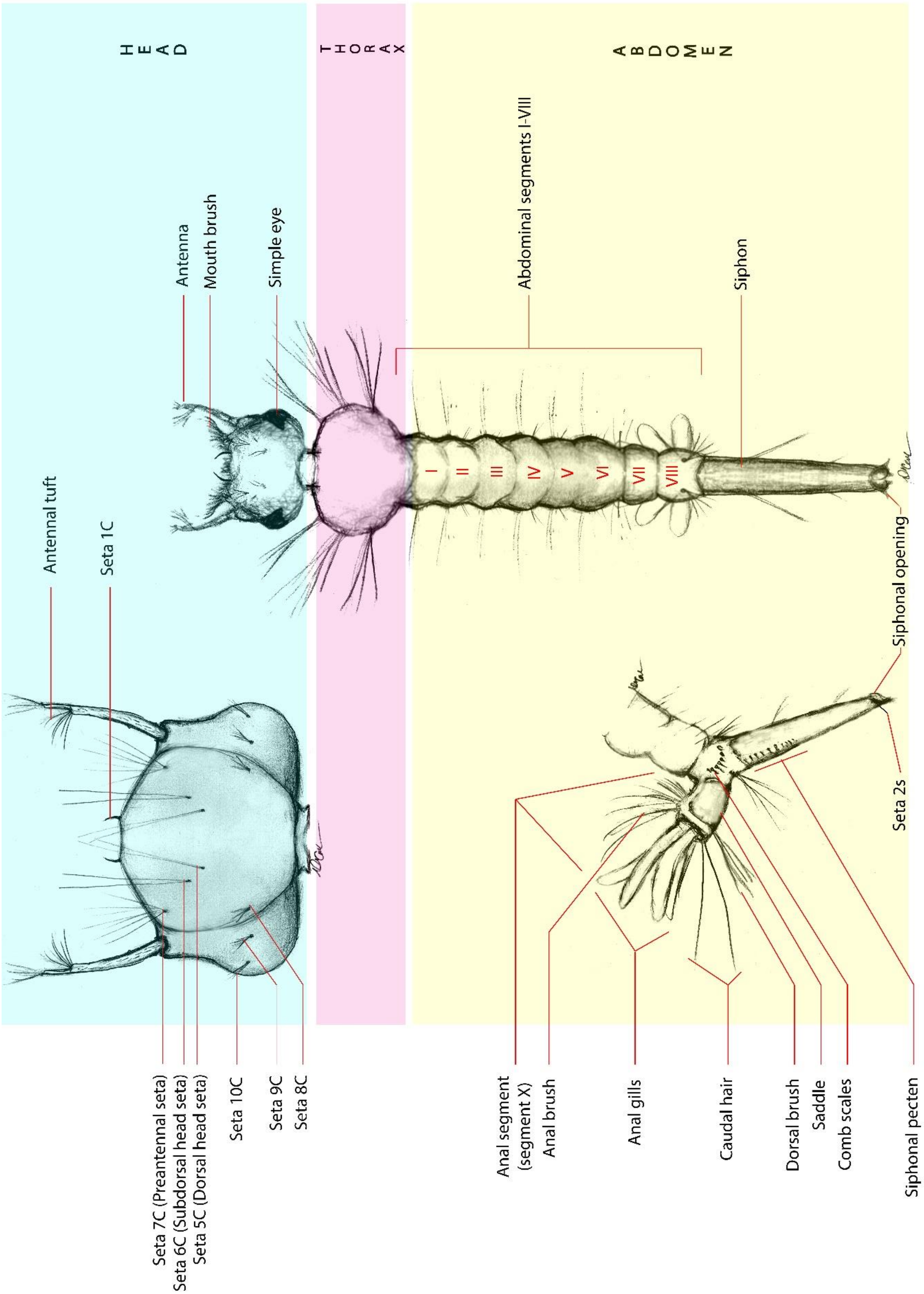


Figure 5.
a. Dorsal view of abdomen, *Cx. pipiens*
b. Dorsal view of thorax, *Cx. pipiens*
c. Dorsal view of abdomen, *Cx. restuans*
d. Dorsal view of thorax, *Cx. restuans*

Culex Larval Anatomy



Key to 4th Instar *Culex* Larvae

1. Subdorsal head setae (6C) single or double (Fig. 1a) ……………………..…. 2

1’. Subdorsal head setae (6C) with three to six branches (Fig. 1b) ……...….… 3

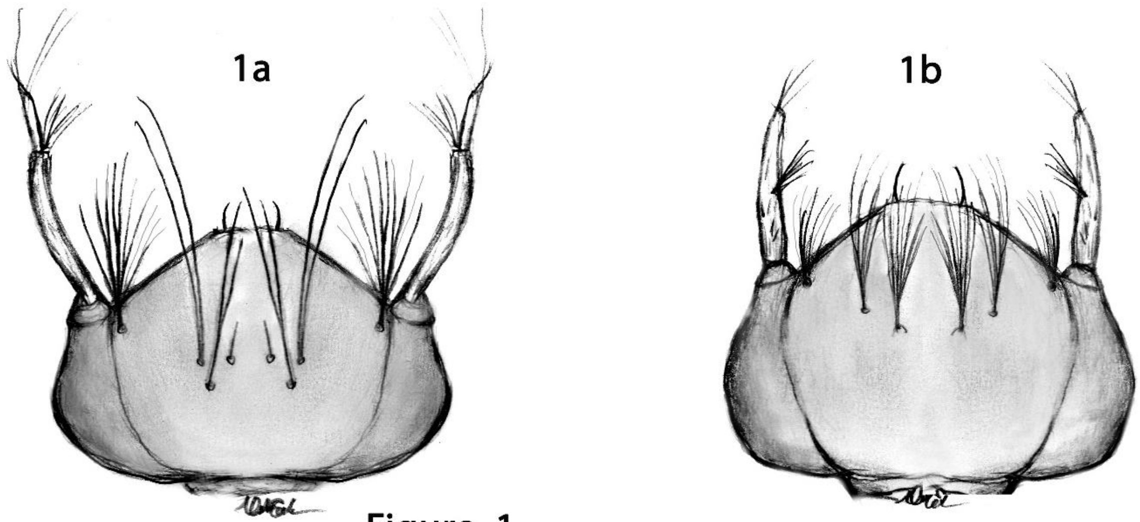


Figure 1.
a. Dorsal view of head, *Cx. territans*
b. Dorsal view of head, C*x. restuans*

2(1). Subdorsal siphonal setae present (Fig. 2a); comb scales arranged in single irregular row (Fig. 2b), with large median spine (Fig. 2c); seta 2s distinctly curved (Fig. 2d); siphonal pecten spines bearing ten or more lateral teeth (Fig. 2e) ……..……………….……….………...…… ***Cx. erracticus***

2’. Subdorsal siphonal setae absent (Fig. 2f); comb scales arranged in patch (Fig. 2g), without large median spine (Fig. 2h); seta 2s distinctly straight (Fig. 2i); siphonal pecten spines bearing 3-4 lateral teeth; (Fig. 2j) …. ***Cx. territans***

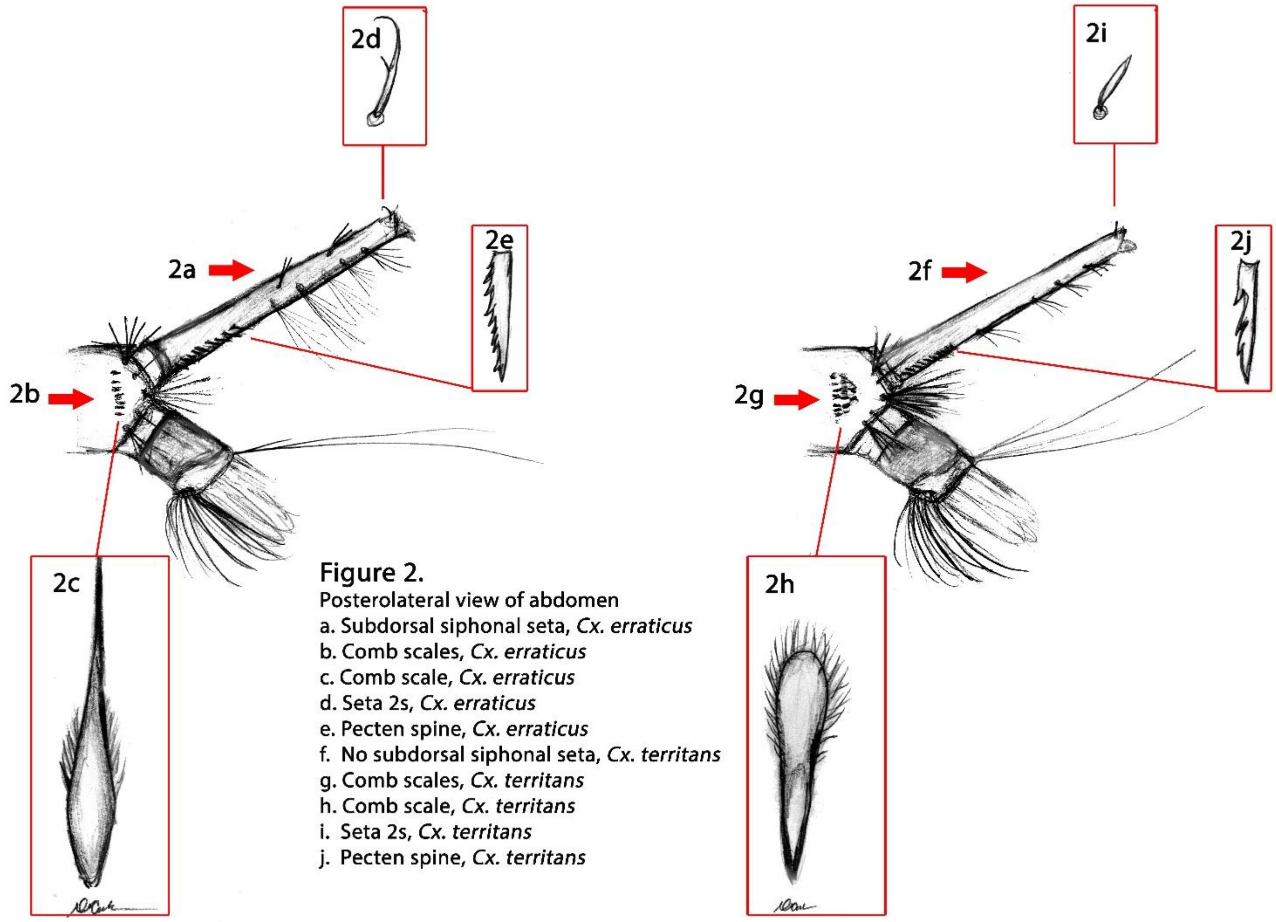


Figure 2.
Posterolateral view of abdomen
a. Subdorsal siphonal seta, *Cx. erraticus*
b. Comb scales, *Cx. erraticus*
c. Comb scale, *Cx. erraticus*
d. Seta 2s, *Cx. erraticus*
e. Pecten spine, *Cx. erraticus*
f. No subdorsal siphonal seta, *Cx. territans*
g. Comb scales, *Cx. territans*
h. Comb scale, *Cx. territans*
i. Seta 2s, *Cx. territans*
j. Pecten spine, *Cx. territans*

3(1'). Antennae not constricted at antennal tuft located near mid length (Fig. 1a); siphonal setae irregularly arranged, comprised of three long setae and short 2-3 branched subapical lateral setae (Fig. 3a) ………………...... ***Cx. restuans***

3'. Antennae constricted at antennal tuft located near 2/3 length (Fig. 1b); siphonal setae linearly arranged, sometimes with one or two branched hairs laterally out of line (Fig. 3b) ………………………………….……..…….. 4

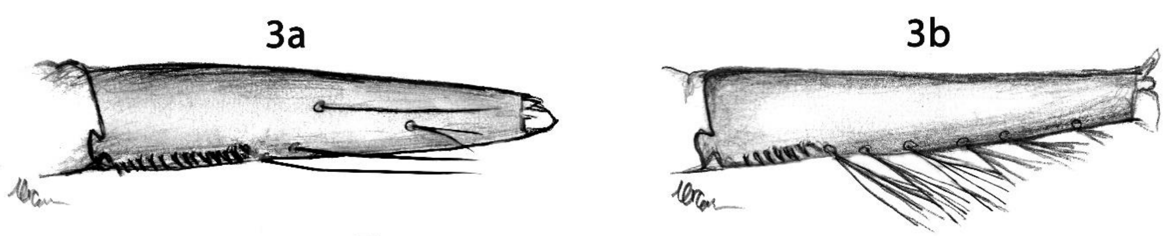


Figure 3.
a. Lateral view of siphon, *Cx. restuans*
b. Lateral view of siphon, *Cx. tarsalis*

4(3’). Siphonal setae arranged in straight subventral line, each five to nine branched (Fig. 4a) ……………….……………..……...………...…. ***Cx. tarsalis***

4’. Siphonal setae not arranged in straight subventral line, one or two inserted laterally (Fig. 4b) ……………………………………………….…….…………. 5

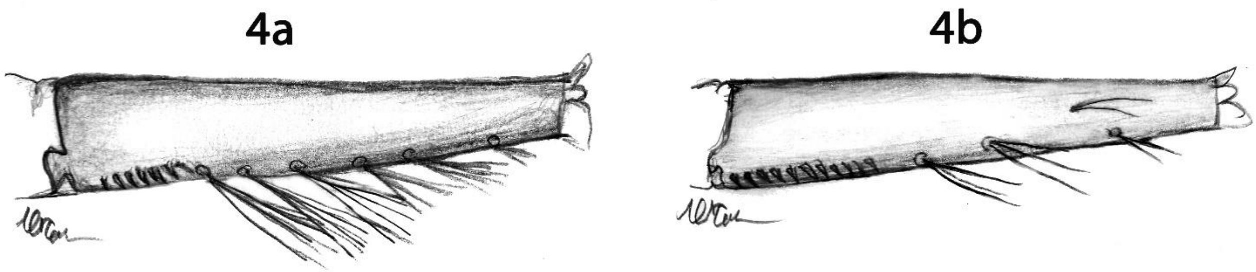


Figure 4.
a. Lateral view of siphon, *Cx. tarsalis*
b. Lateral view of siphon, *Cx. pipiens*

5(4’). Siphon length 5 times or less width at widest point; dorsal head setae (5C) typically with 5-6 branches (Fig. 5a) …………….…….………...…. ***Cx. pipiens***

5’. Siphon length 6-9 times width at widest point; dorsal head setae (5C) typically with 3-4 branches (Fig. 5b) ……………………...……………. ***Cx. salinarius***

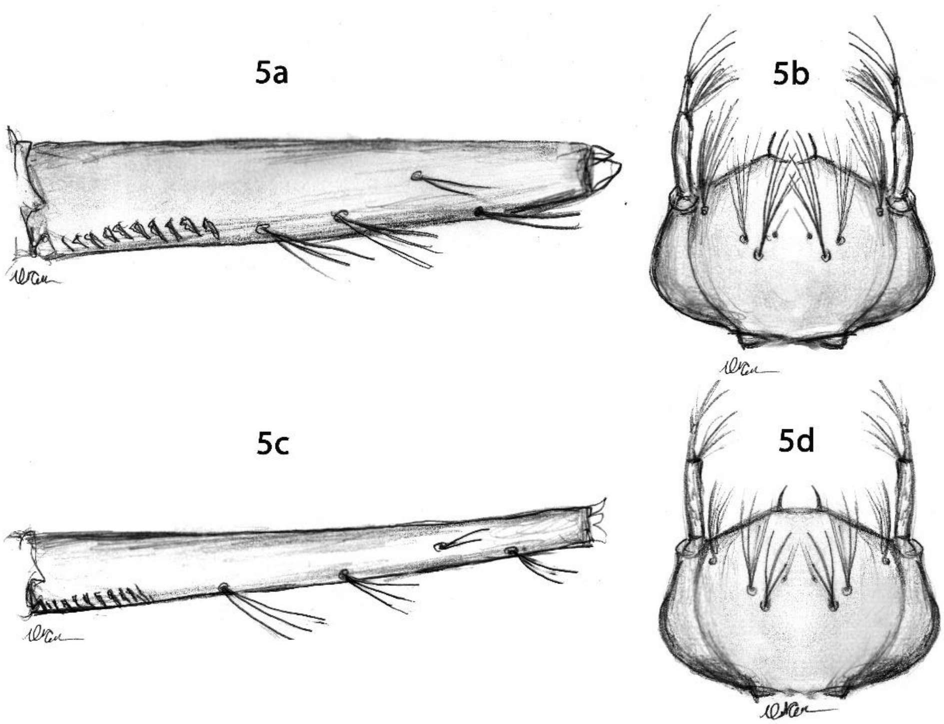


Figure 5.
a. Lateral view of siphon, *Cx. pipiens*
b. Dorsal view of head, *Cx. pipiens*
c. Lateral view of siphon, *Cx. salinarius*
d. Dorsal view of head, *Cx. salinarius*

Literature Cited

Andreadis T.G., Thomas M.C., Shepard J.J. 2005 An Identification Guide to the Mosquitoes of Conneticut. *The Connecticut Agricultural Experiment Station Bulletin* No. 966.

Andreadis T.G., Anderson J.F., Tirrell-Peck S.J. 1998. Multiple isolations of eastern equine encephalitis and highlands J viruses from mosquitoes (Diptera: Culicidae) during a 1996 epizootic in southeastern Connecticut. *J Med Entomol*. 35:296–302.

Ayers V.B., Huang Y.S., Lyons A.C., Park S.L., Higgs S., Dunlop J.I., Kohl A, Alto B.W., Unlu I, Blitvich B.J., & Vanlandingham D.L. 2018. Culex tarsalis is a competent vector species for Cache Valley virus. *Parasites & Vectors volume 11*, Article number: 519

Bajwa W.I. 2018. A Taxonomic Checklist and Relative Abundance of the Mosquitoes of New York City. *Journal of the American Mosquito Control Association*: June 2018, Vol. 34, No. 2, pp. 138-142.

Bingham, A. M., Burkett-Cadena, N. D., Hassan, H. K., & Unnasch, T. R. 2016. Vector Competence and Capacity of Culex erraticus (Diptera: Culicidae) for Eastern Equine Encephalitis Virus in the Southeastern United States. *Journal of medical entomology*, 53(2), 473–476.

Burkett-Cadena N. D. 2013. *Mosquitoes of the Southeastern United States*. The University of Alabama Press. Tuscaloosa, Alabama.

Burkett-Cadena N. D. Bingham A. M. Hunt B. Morse G. Unnasch T. R. 2015. Ecology of Culiseta melanura and other mosquitoes (Diptera: Culicidae) from Walton county, Florida during winter period 2013–2014. *J. Med. Entomol.* 54: 1074 – 1082.

CDC Technical Fact Sheet: Eastern Equine Encephalitis. Retrieved January 2019 from: https://www.cdc.gov/easternequineencephalitis/tech/factsheet.html

Chamberlain R. W. Kissling R. E. Stamm D. D. Sudia W. D. 1956. Transmission of eastern equine encephalitis to horses by *Aedes sollicitans* mosquitoes. *Am. J. Trop. Med. Hyg.* 5: 802 – 808.

Cohen S.B., Lewoczko K., Huddleston D.B., Moody E., Mukherjee S., Dunn J.R., Jones T.F. Wilson R., Moncayo A.C. 2009. Host Feeding Patterns of Potential Vectors of Eastern Equine Encephalitis Virus at an Epizootic Focus in Tennessee *Am. J. Trop. Med. Hyg*., 81(3)

Crans W. J. Schulze. T. L. 1986. Evidence incriminating Coquillettidia perturbans (Diptera: Culicidae) as an epizootic vector of eastern equine encephailitis. I. Isolation of EEE virus from C. perturbans during an epizootic among horses in New Jersey. *Bull. Soc. Vector Ecol*. 11: 178 – 184.

Crans W. J. 2004. A classification system for mosquito life cycles: life cycle types for mosquitoes of the northeastern United States. *Journal of Vector Ecology*. (1):1-10.

Cupp, E. W., Klingler, K., Hassan, H. K., Viguers, L. M., & Unnasch, T. R. 2003. Transmission of eastern equine encephalomyelitis virus in central Alabama. *The American journal of tropical medicine and hygiene*, 68(4), 495–500.

Cupp E.W., Tennessen K.J., Oldland W.K., Hassan H.K., Hill G.E., Katholi C.R., Unnasch T.R., 2004. Mosquito and arbovirus activity during 1997–2002 in a wetland in northeastern Mississippi. *J Med Entomol* 41: 495–501.

Edman J. D. Webber L. A. Kale H. W. 1972. Host-feeding patterns of Florida mosquitoes. II. *Culiseta*. *J. Med. Entomol.* 9: 429 – 434

Estep L. K. McClure C.J.W. Burkett-Cadena N. Hassan H. K. Hicks T. L. Unnasch T. R. Hill G. E. 2011. A multi-year study of mosquito feeding patterns on avian hosts in a southeastern focus of eastern equine encephalitis virus. *Am. J. Trop. Med. Hyg*. 84: 718 – 726.

Hamer G.L., Kitron U.D., Goldberg T.L., Brawn J.D., Loss S.R., Ruiz M.O., 2009. Host selection by *Culex pipiens* mosquitoes and west nile virus amplification. *Am J Trop Med Hyg.* 80:268–78.

Hammon W. McD., Reeves W.C. (1943) Laboratory Transmission of St. Louis Encephalitis Virus by Three Genera of Mosquitoes. *Journal of Experimental Medicine* (4) 241-253;

Hassan H.K., Cupp E.W., Hill G.E., Katholi C.R., Klingler K., Unnasch T.R., 2003. Avian host preference by vectors of eastern equine encephalomyelitis virus. *Am J Trop Med Hyg* 69: 641–647.

King W.V., Bradley G.H., Smith C.N., McDuffie W.C. 1960. A Handbook of the Mosquitoes of the Southeastern United States. Washington, DC: *U.S. Department of Agriculture, Agricultural Research Service Handbook;* pp. 173–188.

Magnarelli L. A. 1977. Host feeding patterns of Connecticut mosquitoes (Diptera: Culicidae). *Am. J. Trop. Med. Hyg*. 26: 547 – 552.

Molaei G. Andreadis T. G. 2006. Identification of avian- and mammalian-derived bloodmeals in Aedes vexans and Culiseta melanura (Diptera: Culicidae) and its implication for West Nile Virus Transmission in Connecticut, U.S.A. *J. Med. Entomol*. 43: 1088 – 1093

Molaei G. Oliver J. Andreadis T. G. Armstrong P. M. Howard J. J. 2006. Molecular identification of blood-meal sources in Culiseta melanura and Culiseta morsitans from an endemic focus of Eastern Equine Encephalitis virus in New York. *Am. J. Trop. Med. Hyg*. 75: 1140 – 1147.

Molaei G., Andreadis T.G., Armstrong P.M., Anderson J.F., Vossbrinck C.R. 2006 Host feeding patterns of Culex mosquitoes and west nile virus transmission, northeastern United States. *Emerg Infect Dis.* 12:468–74.

Moncayo A. C. Edman J. D. Finn. J. T. 2000. Application of geographic information technology in determining risk of eastern equine encephalomyelitis virus transmission. *J. Am. Mosq. Control Assoc*. 16: 28 – 35

Morris C.D., Larson V.L., Lounibos L.P. 1991. Measuring mosquito dispersal for control programs. *J Am Mosq Control Assoc.* 7:608–615.

Morris C.D., Whitney E., Bast T.F., Deibel R. 1973. An outbreak of eastern equine encephalomyelitis in upstate New York during 1971. *Am J Trop Med Hyg.* 22:561–6.

Nayar J.K. (2008) Avian Malaria, Bird Malaria. In: Capinera J.L. (eds) Encyclopedia of Entomology. Springer, Dordrecht

Nasci R. S. Edman. J. D. 1981. Blood-feeding patterns of Culiseta melanura (Diptera: Culicidae) and associated sylvan mosquitoes in southeastern Massachusetts eastern equine encephalitis enzootic foci. J. Med. Entomol. 18: 493 – 500.

Oliveira A., Katholi C. R., Burkett-Cadena N. D., Hassan H. K., Kristensen S., Unnasch. T. R. 2011. Temporal analysis of feeding patterns of Culex erraticus in Central Alabama. Vector Borne Zoon. Dis. 11: 413 – 421

Oliver, J., Lukacik, G., Kokas, J., Campbell, S. R., Kramer, L. D., Sherwood, J. A., & Howard, J. J. 2018. Twenty years of surveillance for Eastern equine encephalitis virus in mosquitoes in New York State from 1993 to 2012. Parasites & vectors, 11(1), 362

Robertson L.C., Prior S., Apperson C.S., Irby W.S. 1993. Bionomics of Anopheles quadrimaculatus and Culex erraticus (Diptera: Culicidae) in the Falls Lake basin, North Carolina: seasonal changes in abundance and gonotrophic status, and host-feeding patterns. *J Med Entomol*. 30:689–698

Ross H.H. 1947. The mosquitoes of Illinois (Diptera, Culicidae) *Ill Nat Hist Surv Bull*. 24:1–96.

Sardelis, M. R., Turell, M. J., Dohm, D. J., & O'Guinn, M. L. 2001. Vector Competence of Selected North American Culex and Coquillettidia Mosquitoes for West Nile Virus. *Emerging Infectious Diseases*, 7(6), 1018-1022.

Scott T. W., Burrage. T. G. 1984. Rapid infection of salivary glands in Culiseta melanura with eastern equine encephalomyelitis virus: An electron microscopy study. *Am. J. Trop. Med. Hyg*. 33: 961 – 964

Shaoming H., Smith D.J., Molaei G., Andreadis T.G., Larsen S.E., Lucchesi E.F. 2013. Prevalence of *Dirofilaria immitis* (Spirurida: Onchocercidae) Infection in *Aedes*, *Culex*, and *Culiseta* Mosquitoes from North San Joaquin Valley, CA, *Journal of Medical Entomology*, Volume 50, Issue 6, 1

Shepard J.J, Andreadis T.G., Thomas M.C., & Molaei G. 2016. Host associations of mosquitoes at eastern equine encephalitis virus foci in Connecticut, USA. *Parasites & Vectors volume* 9, Article number: 474

Vaidyanathan R. Edman J. D. Cooper L. A. Scott. T. W. 1997. Vector competence of mosquitoes (Diptera:Culicidae) from Massachusetts for a sympatric isolate of eastern equine encephalomyelitis virus . *J. Med. Entomol*. 34: 346 – 352.