

Annotated List of the Mosquitoes (Diptera: Culicidae) of the Great Smoky Mountains National Park

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May, 2010

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Prior to 2004, there were no published records of mosquito species from the Great Smoky Mountains National Park (GSMNP). As part of the All Taxa Biodiversity Inventory (ATBI), a project of Discover Life in America to document all species inside the Park boundaries, mosquitoes were collected, identified, and reported in the ATBI database. Reeves *et al.* (2004) published species records of the GSMNP museum specimens and individuals collected during 1999 – 2003. The list provided here was compiled from records published by Reeves *et al.* (2004) and from identification of material collected by Connelly and others during mosquito surveys conducted from 2006 – 2009, and from material in the GSMNP museum.

The list includes classification to genus, subgenus, and species, species author and year, notes on distribution, eggs, larvae and pupae, adults, medical importance, presence/abundance in the Park, and additional notes where appropriate. Classification follows that of the Walter Reed Biosystematics Unit (2010). Distribution includes that of the United States using maps published by Darsie and Ward (2005), and the zoogeographical region provided by Darsie and Ward (2005) which defines the area where the species are found *outside* of the North America, north of Mexico. Those defined as “indigenous” are restricted to North America, north of Mexico.

Concerning the classification of the genus *Aedes*, in 2000, Reinert published a reclassification of the genus where the subgenus *Ochlerotatus* was raised to generic level. Then in 2004, Reinert *et al.* published “Phylogeny and classification of Aedini (Diptera: Culicidae) based on morphological characters of all life stages,” which explored higher level relationships within the tribe Aedini and proposed raising the number of genera from 12 to 46. Reinert *et al.* (2004) anticipate that additional changes in genus names are likely after other species in the group are more carefully analyzed. The naming system proposed by Reinert and others was used in the report on mosquitoes collected in the GSMNP by Reeves *et al.* (2004).

In 2004, Savage and Strickman stated that they believed the use of *Aedes* and *Ochlerotatus* should be restored to their traditional usage of the time period 1906-2000. Then in 2005 (in response to the changes proposed by Reinert *et al.* 2004), Savage warned that future studies of Aedini using “different sets of morphological characters or/and molecular data will produce different fragments” that will “lead to a disruption of communication among those interested in mosquito-borne diseases, the destruction of the information system associated with a stable classification, and difficulties in literature search and database management.” While the controversy is ongoing, and the choice of names is up to individual authors, for this report, the classification follows that of the Walter Reed Biosystematics Unit (2010) by using the naming system in place prior to 2000.

The number of species reported by genus are as follows:

Aedes – 11

Anopheles- 3

Coquillettidia- 1

Culex- 6

Culiseta- 1

Orthopodomyia- 1

Psorophora- 1

Toxorhynchites- 1

In the lists and descriptions that follow, mosquitoes are listed alphabetically by genus and no phylogenetic relationship is implied or inferred by the order of appearance.

Table 1 (p. 33) provides a list of mosquito species from the GSMNP with their abundance and a short description of their aquatic habitat. The terminology for abundance follows that of the Discover Life in America and posted at:

<http://www.dlia.org/atbi/species/Plantae/key.shtml> and is included in Appendix I.

Table 2 (p. 35) provides a list of mosquito species from the GSMNP and the medical importance for humans (if known).

Genus *Aedes*

Subgenus *Aedimorphus*

vexans (Meigen 1830)

Subgenus *Aedes*

cinereus Meigen 1818

Subgenus *Finlaya*

japonicus (Theobald 1901)

Subgenus *Ochlerotatus*

atropalpus (Coquillett 1902)

canadensis (Theobald 1901)

infirmatus Dyar & Knab 1906

sticticus (Meigen 1838)

Subgenus *Protomacleaya*

hendersoni Cockerell 1918

triseriatus (Say 1823)

Subgenus *Stegomyia*

aegypti (Linnaeus 1762)

albopictus (Skuse 1895)

Genus *Anopheles*

Subgenus *Anopheles*

perplexens Ludlow 1907

punctipennis (Say 1823)

quadrimaculatus Say 1824

Genus *Coquillettidia*

Subgenus *Coquillettidia*

perturbans (Walker 1856)

Genus *Culex*

Subgenus *Culex*

nigripalpus Theobald 1901

pipiens Linnaeus 1758

restuans Theobald 1901

salinarius Coquillett 1904

Subgenus *Melanoconion*

erraticus (Dyar & Knab 1906)

Subgenus *Neoculex*

territans Walker 1856

Genus *Culiseta*

Subgenus *Culiseta*

inornata (Williston 1893)

Genus *Orthopodomyia*

signifera (Coquillett 1896)

Genus *Psorophora*

Subgenus *Grabhamia*

columbiae (Dyar & Knab 1906)

Genus *Toxorhynchites*

Subgenus *Lynchiella*

rutilus septentrionalis (Dyar & Knab 1906)

Genus: *Aedes*

Sub-genus: *Stegomyia*

Species: *aegypti*

Author: (Linnaeus 1762)

Distribution: Darsie and Ward (2005): Cosmotropical; Southeastern United States. *Aedes aegypti* was a common container-inhabiting species in the Southeastern United States until the late 1900s. It has disappeared from most of the United States, but is still common in the Florida Keys and New Orleans, LA. It has been reported from Tennessee and North Carolina collections, although these two states are in the “extreme range” according to Darsie and Ward (2005).

Egg: Eggs are laid singly just above the water line or on the water surface; the eggs require a period of ageing for at least several days before they will hatch; eggs can remain viable for many months.

Larva and pupa: Clean water in containers, especially man-made, but have been found in tree-holes; flower vases, tires, cans, pet dishes, and other water-holding containers near residences.

Adult: Females take their blood meals during the daylight hours. They are skittish feeders and prefer to feed on humans. The adults frequently are found inside dwellings resting in dark closets, behind cabinets, under tables, behind doors. Their flight range is limited to a few hundred feet.

Medical Importance: Vector of Yellow Fever and Dengue.

Presence: Very Rare.

Reeves *et al.* (2004) reported collecting one *Ae. aegypti* larva from a rain gutter in Swain County, Oconaluftee, North Carolina, and stated that it was likely an accidental reintroduction from a visitor to the Park. Collections by Connelly and others from 2006 – 2009 did not produce any additional specimens of *Ae. aegypti* despite collecting in habitats preferred by this species. Additionally, Jason Love (GSMNP – Tremont) assisted Connelly with mosquito egg monitoring throughout the year and while monitoring for eggs is a technique commonly used for container mosquitoes, the egg collections did not contain any *Ae. aegypti*.

Genus: *Aedes*

Sub-genus: *Stegomyia*

Species: *albopictus*

Author: (Skuse 1895)

Distribution: Darsie and Ward (2005): Cosmopolitan; Southeastern United States. This exotic, invasive species was first reported in the United States in 1985 (Sprenger and Wuithiranyagool 1986). *Aedes albopictus* was present in every Tennessee County by 1998 (Moore 1998). By 1999, *Ae. albopictus* was established in all North Carolina and Tennessee counties (Moore 1999). GSMNP: North Carolina, Tennessee.

Egg: Laid on the sides of containers just above the waterline; drying out period required before they will hatch.

Larva and pupa: Manufactured containers including tires, bottles, cans, flower pots, vases, pet dishes and others; close to residences and places of business where containers are left outside. Other habitats include rock pools, leaf axils, and bamboo stumps.

Adult: Feed most aggressively during daylight hours; will feed at dusk and dawn; they do not fly far from their larval habitats.

Medical Importance: Vector of Dengue virus.

Presence: Frequent.

In the GSMNP, Connelly collected *Ae. albopictus* eggs and adults from the Cades Cove Ranger Station and surrounding area, and eggs from Tremont and Purchase Knob. It is present in areas associated with high levels of human activity; areas with containers that hold water (trash receptacles, cans and bottles, flower vases). This species is exotic and invasive.

Genus: *Aedes*

Sub-genus: *Ochlerotatus*

Species: *atropalpus*

Author: (Coquillett 1902)

Distribution: Darsie and Ward (2005): Indigenous; Eastern United States to Central/South Georgia and Alabama. Seldom abundant due to specific aquatic habitat requirements, but occur throughout the Northeastern US. *Aedes atropalpus* was reported from Swain County, NC in 1966 and in Knox County, TN in 1934 in non-rockpool habitats (Nawrocki and Craig 1989). GSMNP: North Carolina, Tennessee.

Egg: Floodwater eggs that are laid singly above the waterline and attached firmly to rocks.

Larva and pupa: Rockholes filled with rain-water or along mountain streams; larvae are slow to develop. There are reports of collections from non-rockpool habitats including containers and an abandoned septic tank (Nawrocki and Craig 1989).

Adult: Several generations per year; persistent biters; seldom abundant, but can be pestiferous locally. *Aedes atropalpus* is autogenous (can lay the first batch of eggs without having had a blood meal).

Presence: Frequent.

Genus: *Aedes*

Sub-genus: *Ochlerotatus*

Species: *canadensis canadensis*

Author: (Theobald 1901)

Distribution: Darsie and Ward (2005): Mexico; Eastern (excluding South Florida), Central United States, Canada. GSMNP: North Carolina, Tennessee.

Egg: Floodwater eggs that hatch when the soil is flooded by rain. Overwinter in egg stage.

Larva and pupa: Temporary or semi permanent pools in shaded areas of woodlands; occasionally in small stream pools and ditches adjacent to woodlands.

Adult: Generally emerge during the months of Spring. Persistent biters; will aggressively seek blood meals during the daylight hours in shaded areas. Typically survive through late summer.

Presence: Frequent.

May be abundant in Spring.

Genus: *Aedes*

Sub-genus: *Aedes*

Species: *cinereus*

Author: Meigen 1818

Distribution: Darsie and Ward (2005): Palearctic; Eastern (excluding Florida), Central, Northwest United States, Canada. Rarely encountered by humans in the Southern states. GSMNP: North Carolina, Tennessee.

Egg: Overwinter in the egg stage; uni-voltine. Typically hatch during Spring months.

Larva and pupa: Woodland pools; temporary rain-filled pools in sunny areas; occasionally in marshes.

Adult: Can be a persistent biter; does not fly far from larval habitat.

Presence: Rare.

Genus: *Aedes*

Sub-genus: *Protomacleaya*

Species: *hendersoni*

Author: Cockerell 1918

Distribution: Darsie and Ward (2005): Indigenous; Eastern (excluding peninsular Florida), Central, Northwest. GSMNP: North Carolina, Tennessee.

Egg: Eggs are laid singly in tree-holes holding water, and although this species is sympatric with *Ae. triseriatus*, *Ae. hendersoni* is more arboreal in choosing tree-holes for oviposition (Scholl and DeFoliart 1977).

Larva and pupa: The aquatic stages of *Ae. hendersoni* occur in water-holding tree holes.

Adult: Known to feed on red, gray and fox squirrels.

Presence: Occasional.

Aedes hendersoni is geographically sympatric with *Aedes triseriatus*, and it can be difficult to distinguish the two species based on morphology alone. Experimentally *Ae. hendersoni* is not able to transmit the LaCrosse virus, whereas *Ae. triseriatus* is an important vector of the virus.

Genus: *Aedes*

Sub-genus: *Ochlerotatus*

Species: *infirmatus*

Author: Dyar & Knab 1906

Distribution: Darsie and Ward (2005): Mexico; Southeastern United States.
GSMNP: Tennessee.

Egg: Satiny black floodwater eggs that can withstand desiccation.

Larva and pupa: Temporary rain-filled pools; early Spring to late Fall.

Adult: Feed during daylight around wooded areas. Will feed on large mammals.

Presence: Occasional.

Genus: *Aedes*

Sub-genus: *Finlaya*

Species: *japonicus*

Author: (Theobald 1901)

Distribution: Darsie and Ward (2005): Palearctic. The first report of *Aedes japonicus* in Tennessee was in 2003 from Knox County. *Ae. japonicus* was first reported in collections from North Carolina in 2005. At the time of Reeves *et al.* (2006) survey, they did not report finding this species, but speculated that it would be in the Park eventually. GSMNP: North Carolina, Tennessee.

Egg: Eggs laid singly and require a short drying out period prior to hatching.

Larva and Pupa: Typical water sources utilized by *Aedes japonicus* include containers (both manufactured and natural), rock holes, and roadside puddles.

Adult: Will feed on a variety of avian and mammalian hosts.

Presence: Common.

Aedes japonicus was collected regularly from the GSMNP by Connelly in 2006, 2007, and 2008 in North Carolina (Purchase Knob) and in Tennessee. This species is considered exotic and invasive. The medical importance in the United States is currently unknown, but it has been shown in laboratory studies to be a competent vector of eastern equine encephalitis virus, LaCrosse virus, St. Louis encephalitis virus, and West Nile virus.

Genus: *Aedes*

Sub-genus: *Ochlerotatus*

Species: *sticticus*

Author: (Meigen 1838)

Distribution: Darsie and Ward (2005): Palearctic, Mexico . Eastern (excluding South Florida), Central, Northwest United States, Canada. GSMNP: North Carolina, Tennessee.

Egg: May remain viable in the absence of flooding for many months.

Larva and pupa: Woodland areas with floodwater pools in river valleys; open country; rain-filled pools with decaying vegetable matter.

Adult: Typically emerge in early - late Spring months; can be serious pests of humans during summer months; feed during daylight hours and early evening close to their larval habitats. May migrate several miles if blood hosts are unavailable close to larval habitats.

Presence: Occasional.

Genus: *Aedes*

Sub-genus: *Protomacleaya*

Species: *triseriatus*

Author: (Say 1823)

Distribution: Darsie and Ward (2005): Mexico, Eastern United States. GSMNP: North Carolina, Tennessee.

Egg: Eggs are laid on the side of the walls of deciduous tree-holes just above the water line; will hatch when water level rises to cover the eggs and when temperatures are favorable. Occasionally found in man-made containers including water troughs and wooden barrels.

Larva and pupa: Larvae and pupae develop inside the water in the tree-hole and can be found year around in most Southern states.

Adult: Crepuscular; most active during early morning and early evening.

Medical Importance: Vector of LaCrosse virus.

Presence: Frequent.

Genus: *Aedes*

Sub-genus: *Aedimorphus*

Species: *vexans*

Author: (Meigen 1830)

Distribution: Darsie and Ward (2005): Worldwide; United States and Canada.
GSMNP: North Carolina, Tennessee.

Egg: Overwinter in egg stage.

Larva and pupa: Temporary rain-filled pools, floodwater pools, irrigation seepage.
Hatch from eggs periodically after wetting and drying cycles over the summer months.

Adult: Adults are most common May – October, but can be found throughout the year in some areas of its southern distribution. Abundant and persistent biters; will fly long distances from their larval habitat (up to 10 miles). Will feed in shady areas during the day and most often during the dusk and evening hours.

Presence: Common.

Genus: *Anopheles*

Sub-genus: *Anopheles*

Species: *perplexens*

Author: Ludlow 1907

Distribution: Darsie and Ward (2005): Indigenous; Eastern (spotty). GSMNP: North Carolina.

Egg: Eggs are laid singly on the water surface. Jensen *et al.* (1995) found evidence that *An. perplexens* eggs may survive in the soil during dry periods; this is uncommon in Anophelines. The egg stage can be used to distinguish *Anopheles perplexens* from *Anopheles punctipennis*; the two species are morphologically very similar in the adult stage.

Larva and pupa: Intermittently flooded swamps, water-filled tires, containers; springs and outlet streams associated with limestone outcroppings, millpond.

Adults: Feed after dark, but will feed during daylight hours if hosts enter the resting sites of the adult female (densely wooded areas, under bridges and rock ledges).

Presence: Infrequent.

Notes: *Anopheles perplexens* can easily be confused with *Anopheles punctipennis* when using the adult stage to identify the species. Bellamy (1956) reported that eggs of the two species are “distinctly different” and subsequent authors report using the egg stage to confirm the species identity (Jensen *et al.* 1985; personal communication - Bruce Harrison, North Carolina Department of Natural Resources). Reeves *et al.* (2004) reported finding one adult and one larva of this species in North Carolina, and stated that this finding is evidence of a range expansion for this species; however, there was no indication that these authors examined the eggs, and there is no reference listed for the morphological keys used for any of the mosquito identification. This record is suspect at this time and the occurrence and distribution of this species needs to be investigated further and include examination of the eggs. Connelly collected several adult specimens in Tennessee (2006, 2007, 2008) that appear to be *An. perplexens*, however, has not been successful in collecting eggs from the females.

Genus: *Anopheles*

Sub-genus: *Anopheles*

Species: *punctipennis*

Author: (Say 1823)

Distribution: Darsie and Ward (2005): Mexico; Eastern (excluding South Florida), Central, Northwest United States. GSMNP: North Carolina.

Egg: Laid singly on water surface; cannot withstand desiccation.

Larva and pupa: Ponds, temporary pools, springs, pools in intermittent streams, borrow pits, roadside puddles, wheel ruts in muddy roads, hog wallows, eddies along the margins of flowing streams, rainwater barrels and other containers. Prefer cool, clear water, especially from hill streams.

Adult: Blood feed primarily at dusk. Adults rest in dark, shady areas during the day, usually in hollow trees, culverts, rock ledges. Prefer to feed on mammals. Abundant early spring to late fall; less abundant in mid-summer. Overwinter as adults in buildings, cellars, hollow trees, and other similar sheltered areas.

Medical Importance: Vector of malaria.

Presence: Frequent.

Genus: *Anopheles*

Sub-genus: *Anopheles*

Species: *quadrimaculatus sensu lato**

Author: Say 1824

Distribution: Darsie and Ward (2005): Mexico; Eastern United States. GSMNP: North Carolina, Tennessee

Egg: Laid singly on the surface of permanent waters of lakes, rivers, and swamps, primarily in the protected still waters along the edges and banks. Eggs will not survive desiccation.

Larva and pupa: The larvae of *Anopheles spp.* do not have breathing siphons that are seen in larvae of all other mosquito genera. The larvae must come to the surface and lay horizontally in order to breathe. The larval habitat for *Anopheles quadrimaculatus* is clean slow moving waters of cypress and other freshwater swamps, backwaters of rivers and streams.

Adult: Peak populations of adult *An. quadrimaculatus* occur in the hot summer months of July and August, and a decline in the numbers of adults are begin in late August and early September. The females feed primarily in the evening and are highly attracted to large mammals such as horses, cattle, and humans. Adults are the overwintering stage and will spend this time in protected dark areas such as large tree-holes, the ceilings and high corners of old buildings and barns, and under bridges.

Medical Importance: Vector of malaria.

Presence: Frequent.

**Anopheles quadrimaculatus* was the primary vector of malaria in the southeastern United States prior to the decline of malaria in the 1950s. In the 1990s, Reinert *et al.* (1997) discovered that what was previously known as a singular species, *An. quadrimaculatus*, was actually 5 different species, now known as the *Anopheles quadrimaculatus* Species Complex, that are morphologically similar, but differ in the larval habitats, geographic distribution, and their ability to produce viable offspring when cross-mated. Initially, there were several methods developed to distinguish the species, but there were no reliable morphological characters that could be used for identification. In 1997, Reinert *et al.* produced a taxonomic key based on morphology; however, to see the characters used in the key, a pristine specimen must be used. The primary distinguishing feature is the number of setae on thorax which can be numerous. Most of the adult specimens that were collected came from a light trap where setae are invariably knocked off making the morphological key unreliable. When species in the

Complex cannot be determined using the morphological keys or through DNA determination or other techniques, they are identified as *An. quadrimaculatus sensu lato* (in the general sense). When a positive identification is made using one of the published techniques, they are referred to as *An. quadrimaculatus sensu stricto* Say (in the strictest sense), *An. diluvialis* Reinert 1997, *An. inundatus* Reinert 1997, *An. maverlius* Reinert 1997, or *An. smaragdinus* Reinert 1997. The specimens collected for the ATBI were not identified to the strict species, but rather in the broad sense. It is possible that there are more than one species of the Complex established in the GSMNP.

Genus: *Coquillettidia*

Sub-genus: *Coquillettidia*

Species: *perturbans*

Author: (Walker 1856)

Distribution: Darsie and Ward (2005): Mexico; Eastern, Central, Northwest United States, Canada. GSMNP: Tennessee.

Egg: Laid on water surface around heavy emergent vegetation where cattails (*Typha spp.*) are present.

Larva and pupa: Overwinter as larva or pupa. Larvae attach to the roots or stems of cattails with their serrated breathing siphon and so remain submerged throughout their immature aquatic stages.

Adult: Emerge in spring and summer. Most active (feeding) during early evening hours; strong fliers; pests in areas with aquatic, emergent vegetation.

Medical Importance: EEE

Presence: Very Rare.

One adult female was collected by Reeves (Reeves *et al.* 2004); however this species requires emergent aquatic vegetation (cattails, *Typha spp*) for the larvae and pupae to develop.

Genus: *Culex*

Sub-genus: *Melanoconion*

Species: *erraticus*

Author: (Dyar & Knab 1906)

Distribution: Darsie and Ward (2005): Neotropical; Southeast, Central United States. GSMNP: North Carolina, Tennessee.

Egg: Eggs are laid in rafts on the water surface. Eggs of *Cx. erraticus* will not survive desiccation.

Larva and pupa: Margins of ponds, lakes, streams in the grassy shallow areas. Aquatic stage most abundant May to October.

Adult: Occasionally feed on humans, but prefer avian hosts.

Medical Importance: Possible vector of West Nile virus.

Presence: Occasional.

Genus: *Culex*

Sub-genus: *Culex*

Species: *nigripalpus*

Author: Theobald 1901

Distribution: Darsie and Ward (2005): Neotropical; Southeast United States.
GSMNP: Tennessee.

Egg: Laid in rafts on water surface; cannot survive desiccation.

Larva and pupa: Ditches, grassy pools, marshes, occasionally in containers; agricultural furrows.

Adult: Females will feed on a variety of blood sources including avian and mammalian hosts. The adults are most active when relative humidity is greater than 80%.

Medical Importance: Vector of eastern equine encephalitis virus, St. Louis encephalitis virus, and West Nile virus.

Presence: **Rare.**

One specimen was identified from Tennessee collections. However, it is likely that this species is established in several habitats in the Park and that collection of the one specimen was not accidental.

Genus: *Culex*

Sub-genus: *Culex*

Species: *pipiens*

Author: Linnaeus 1758

Distribution: Darsie and Ward (2005): Palearctic, Neotropical S, Subsarhara S.; Northern Unites States. GSMNP: North Carolina, Tennessee.

Egg: Eggs laid in rafts on the water surface; cannot withstand desiccation.

Larva and pupa: Water with high organic content, polluted water in ditches, catch basins, mad-made containers, sewage treatment lagoons, and settling ponds associated with dairy and livestock operations.

Adult: Overwinter as females inside protected areas including storm drains, caves, outbuildings, and basements. Will feed on a variety of avian and mammalian hosts.

Medical Importance: Vector of St. Louis encephalitis virus and West Nile virus.

Presence: Occasional.

The *Culex pipiens* complex includes *Cx. pipiens pipiens*, *Cx. pipiens quinquefasciatus* Say, and their hybrids. In North America between 36° and 39° North, both species and their hybrids occur (Barr 1957). Reeves *et al.* (2004) used the male genitalia to determine the species, however, it is not clear what taxonomic key was used. It is possible that the hybrids and both species occur in the GSMNP. This species is medically important and should be studied in further detail.

Genus: *Culex*

Sub-genus: *Culex*

Species: *restuans*

Author: Theobald 1901

Distribution: Darsie and Ward (2005): Mexico; Eastern, Central United States, Canada. GSMNP: North Carolina, Tennessee.

Egg: Laid in rafts on the water surface; cannot survive desiccation.

Larva and pupa: Ditches, woodland pools, man-made containers, pools in streams.

Adult: Spring and early summer.

Presence: Frequent.

Genus: *Culex*

Sub-genus: *Culex*

Species: *salinarius*

Author: Coquillett 1904

Distribution: Darsie and Ward (2005): Mexico; Eastern and Central United States; GSMNP: Tennessee

Egg: Eggs are laid in rafts on the water surface.

Larva and pupa: Fresh and polluted water of grassy pools, ponds, and ditches. Can survive in brackish water.

Adult: Feeds on humans and large mammals. Will rest in shaded, shelters during the day. Adults can be found from late Spring through the Fall.

Medical Importance: Vector of eastern equine encephalitis virus, St. Louis encephalitis virus, and West Nile virus.

Presence: Rare.

Genus: *Culex*

Sub-genus: *Neoculex*

Species: *territans*

Author: Walker 1856

Distribution: Darsie and Ward (2005): Palearctic; Eastern, Central, Northwest United States, Canada. GSMNP: Tennessee.

Egg: Rafts of 100 or more eggs are laid on the water surface. *Culex territans* can lay eggs on moist soil where rising water will float the egg raft into suitable aquatic environment.

Larva and pupa: Permanent and semi-permanent pools in streams, ponds, and swamps. Prefer clear water with emergent vegetation. Sometimes found in rock pools associated with *Aedes atropalpus*.

Adult: Prefer to feed on cold-blooded animals, especially frogs. Overwinter as females in cool climates.

Presence: Infrequent.

Note: Bartlett-Healy *et al.* (2008, 2009) found that *Culex territans* adult females were attracted to frog calls of *Pseudacris crucifer* (Wied-Neuwied) (spring peepers), *Hyla versicolor* LeConte (northern gray tree frog), *Bufo americanus* Holbrook (American toad), and *Rana clamitans* Latrielle, (the green frog), and that the larvae were associated both temporally and spatially with *R. clamitans*, in New Jersey.

Genus: *Culiseta*

Sub-genus: *Culiseta*

Species: *inornata*

Author: (Williston 1893)

Distribution: Darsie and Ward (2005): Mexico; United States, Canada. GSMNP: North Carolina.

Egg: Egg rafts laid on the water surface.

Larva and pupa: Ground pools and ditches; brackish, sometimes polluted water.

Adult: Fall, winter and spring – rarely in summer. Overwinter as adults. Prefer to feed on large mammals (livestock)

Presence: Infrequent.

Genus: *Orthopodomyia*

Sub-genus: N/A

Species: *signifera*

Author: (Coquillett 1896)

Distribution: Darsie and Ward (2005): Caribbean, Mexico; Southeast, Central United States. GSMNP: Tennessee.

Egg: Laid on sides of water-holding cavity/container just above the waterline.

Larva and pupa: Overwinter as larvae. Water-filled rot cavities of trees; occasionally in wooden water-holding containers. Slow developers; two or more generations often found in same water source.

Adult: Feed on birds; not known to feed on humans. Adults often found resting on tree trunks near the larval habitat.

Presence: Scarce.

Orthopodomyia signifera larvae occur in tree-holes that are high in the canopy and they feed primarily on avian hosts. Due to the location of the larval habitats, and the behavior of the adult mosquitoes such that they are not often collected in standard mosquito traps, the occurrence of this species in the GSMNP is likely more abundant than what is reported here.

Genus: *Psorophora*

Sub-genus: *Grabhamia*

Species: *columbiae*

Author: (Dyar & Knab 1906)

Distribution: Darsie and Ward (2005): Caribbean, Mexico; Eastern, Southwest United States. GSMNP: North Carolina.

Egg: Eggs laid on damp soil subject to flooding from rain, stream overflow, and irrigation; in depressions made by animal hooves and tires, and in agricultural areas utilizing furrows or ditches.

Larva and pupa: Lasts only 4 – 10 days, the shortest being during the warmer months.

Adult: Persistent pests that feed during daylight and evening hours; can be very abundant; prefer to feed on humans and large mammals. Highest populations are seen after significant rainfall events.

Presence: Infrequent.

Genus: *Toxorhynchites*

Sub-genus: *Lynchiella*

Species: *rutilus septentrionalis*

Author: (Dyar & Knab 1906)

Distribution: Darsie and Ward (2005): Indigenous; Southeast United States. This species is found throughout the southeastern US, but it is not abundant. GSMNP: North Carolina, Tennessee.

Egg: Laid singly on the water surface, large white oval.

Larva and pupa: Tree holes, rot cavities of trees, containers. Predators of mosquito larvae. Larval stage is very long – weeks to months.

Adult: Proboscis is strongly curved downward; females do not feed on blood; males and females feed on plant juices and nectar of flowers. Adults are in the group of the largest mosquitoes; colorful metallic scales.

Presence: Infrequent.

Table 1. Mosquito species from the GSMNP: abundance and aquatic habitat.

	PRESENCE / ABUNDANCE	LARVAL HABITAT
<i>Aedes aegypti</i>	vr	Containers (natural and manufactured)
<i>Aedes albopictus</i>	f	Containers (natural and manufactured)
<i>Aedes atropalpus</i>	f	Rock pools
<i>Aedes canadensis</i>	f	Woodland pools
<i>Aedes cinereus</i>	r	Woodland and temporary pools
<i>Aedes hendersoni</i>	o	Tree holes
<i>Aedes infirmatus</i>	o	Temporary rain-filled pools
<i>Aedes japonicus</i>	c	Puddles, rock pools, containers (natural and manufactured)
<i>Aedes sticticus</i>	o	Woodland pools, rain filled pools
<i>Aedes triseriatus</i>	f	Tree holes
<i>Aedes vexans</i>	c	Temporary pools, floodwater pools
<i>Anopheles perplexens</i>	i	Intermittently flooded swamps, springs
<i>Anopheles punctipennis</i>	f	Ponds, temporary pools, springs, pools in intermittent streams, borrow pits, roadside puddles, margins of flowing streams, rainwater barrels and other containers
<i>Anopheles quadrimaculatus</i>	f	Fresh water cypress swamps, slow moving backwaters of rivers and lakes
<i>Coquillettidia perturbans</i>	vr	Emergent aquatic vegetation – <i>Typha spp.</i>
<i>Culex erraticus</i>	o	Margins of ponds, lakes, streams in the grassy shallow areas
<i>Culex nigripalpus</i>	r	Clean or polluted water, ditches, furrows, containers
<i>Culex pipiens</i>	o	Polluted, highly organic water
<i>Culex restuans</i>	f	Ditches, woodland pools, man-made containers, pools in streams
<i>Culex salinarius</i>	r	Fresh and polluted water in ditches and grassy pools
<i>Culex territans</i>	i	Permanent and semi-permanent pools in streams, ponds, and swamps
<i>Culiseta inornata</i>	i	Ground pools and ditches; sometimes in polluted water
<i>Orthopodomyia signifera</i>	s	Tree holes
<i>Psorophora columbiae</i>	i	Flooded, low lying areas, pastures
<i>Toxorhynchites rutilus septentrionalis</i>	i	Tree holes

Medical Importance of Mosquito Species from the GSMNP

Mosquito Species of Historical Importance

Many mosquito species documented in the survey of the GSMNP from 1999 - 2009 are species that were medically important prior to the 1950s because they are vectors of pathogens that cause dengue, malaria, and yellow fever. These diseases have essentially been eliminated from the United States. However, it is important to take seriously the presence of these vector species in the GSMNP. As long as the vector mosquito species are present, there is a possibility that they can become infected by feeding on infected hosts and starting a cycle of disease transmission. Malaria, dengue, and yellow fever are “one-host diseases,” – the circulation of the pathogen is from human to mosquito to human. Typically, the source of infected hosts are from non-US citizens who visit the US while the pathogen is circulating in their blood, or from US citizens who travel abroad to areas where mosquito-borne diseases are present, and become infected while out of the country. Some examples of the seriousness of these historically important mosquito species can be seen from 2003 when eight cases of locally acquired malaria occurred in Palm Beach County, FL (Centers for Disease Control 2004), and in 2009 when 20 cases of dengue were reported from Key West, Florida (Florida Department of Health 2009). Dengue has not been reported in local citizens since the 1930s, but the results of a serum survey from residents of Key West in 2009 indicated that 41% were positive for dengue virus or dengue antibodies; this highlights the potential of an epidemic in an area that is frequented by tourists.

Endemic Mosquito-Borne Diseases

In 2010, the most important mosquito-borne diseases in the Southeastern United States are those that have the potential to cause encephalitis and even death. The encephalitis-causing pathogens that are mosquito-transmitted are viruses and include the following: eastern equine encephalitis virus (EEEV), LaCrosse encephalitis virus (LACV), St. Louis encephalitis virus (SLEV), and West Nile virus (WNV). The encephalitis viruses that are endemic in the Southeastern United States circulate in a “two-host disease” cycle that is more complicated than dengue, malaria and yellow fever. The viruses are circulated from birds (for EEE, SLE, and WN) and chipmunks and squirrels (LACV) to mosquitoes to humans (and horses for EEE and WN). Mosquito vectors of EEE, LACV, SLEV, and WNV were collected from the GSMNP during 1999-2009, however, there was no testing conducted related to virus presence in the mosquitoes.

Table 2. Mosquito species from the GSMNP: medical importance.

	HISTORICAL	ENDEMIC	NOT KNOWN TO BE MEDICALLY IMPORTANT IN THE SOUTHEASTERN US
<i>Aedes aegypti</i>	YF, DEN		
<i>Aedes albopictus</i>	DEN		
<i>Aedes atropalpus</i>			✓
<i>Aedes canadensis</i>			✓
<i>Aedes cinereus</i>			✓
<i>Aedes hendersoni</i>			✓
<i>Aedes infirmatus</i>			✓
<i>Aedes japonicus</i>			✓
<i>Aedes sticticus</i>			✓
<i>Aedes triseriatus</i>		LAC	
<i>Aedes vexans</i>			✓
<i>Anopheles perplexens</i>			✓
<i>Anopheles punctipennis</i>	MAL		
<i>Anopheles quadrimaculatus</i>	MAL		
<i>Coquillettidia perturbans</i>		EEE	
<i>Culex erraticus</i>		WN	
<i>Culex nigripalpus</i>		SLE, WN	
<i>Culex pipiens</i>		SLE, WN	
<i>Culex restuans</i>		SLE, WN	
<i>Culex salinarius</i>		EEE, SLE, WN	
<i>Culex territans</i>			✓
<i>Culiseta inornata</i>			✓
<i>Orthopodomyia signifera</i>			✓
<i>Psorophora columbiae</i>			✓
<i>Toxorhynchites rutilus septentrionalis</i>			✓

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Appendix 1. Terms for species abundance. Taken from the Discover Life in America:
<http://www.dlia.org/atbi/species/Plantae/key.shtml>

Abundance		
c	Common	characteristic and dominant
f	Frequent	generally encountered
o	Occasional	well distributed, but nowhere abundant
i	Infrequent	scattered locales throughout park
s	Scarce	several locales or scattered small populations
r	Rare	one or two locales, small populations
vr	Very rare	single locale, few individuals
h	Historic	documented in Park's flora, but not seen for at least 50 years
x	Extirpated	not seen for at least 50 years