PRELIMINARY CHECKLIST OF CAVE-DWELLING INSECTS IN GUNUNG SENYUM CAVE, PAHANG, MALAYSIA

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ABSTRACT

A preliminary study of cave-dwelling insects were conducted in Gunung Senyum Cave, Pahang to identify diurnal insect present in the cave environment. The objective of this study is to make a preliminary checklist of diurnal cave-dwelling insects found within Gunung Senyum Cave, Pahang. This study is done in order to fill in the knowledge gap regarding cave insects which is very sparse in Malaysia. Gunung Senyum Cave is a limestone cave estimated to be around 3000 years old. The insects were collected by four different traps which were pitfall trap, light trap, impact trap and sticky trap. The light trap was set up at 3 m high above the ground. Pitfall trap and impact trap were placed on cave floor while sticky trap were stick flat on the cave wall. A total of 2291 individuals from six orders (Coleoptera, Lepidoptera, Hymenoptera, Diptera, Ephemeroptera and Orthoptera) and 21 families were successfully collected. The most abundance individuals identified were from family Formicidae, from order Hymenoptera (57.18%), family Ripiphoridae, from order Coleoptera (25.70%), family Simuliidae from order Diptera (5.85%) and family Ephemeridae from order Ephemeroptera (4.58%). Most insect collected are considered as trogloxene and troglophile insect.

Keywords: Cave insect, insect community, Peninsular Malaysia

ABSTRAK

Kajian awal mengenai serangga yang mendiami gua telah dilakukan di Gua Gunung Senyum, Pahang untuk mengenal pasti serangga diurnal yang terdapat di dalam gua tersebut. Objektif kajian ini adalah untuk menghasilkan senarai awal bagi serangga diurnal yang wujud di dalam Gua Gunung Senyum. Gua Gunung Senyum adalah gua batu kapur yang dianggarkan berumur sekitar 3000 tahun. Serangga dari gua dikumpul menggunakan empat jenis perangkap iaitu perangkap lubang, perangkap lampu, perangkap langgar jatuh dan perangkap lekatan. Perangkap lampu diletakkan pada jarak 3m dari lantai gua. Perangkap lubang dan perangkap langgar jatuh diletakkan di atas lantai gua manakala perangkap lekatan dilekatkan pada dinding gua. Sejumlah 2291 individu dari 6 order (Coleoptera, Lepidoptera, Hymenoptera, Diptera, Ephemeroptera dan Orthoptera) dan 21 famili berjaya dikumpulkan. Bilangan individu yang paling banyak ditemui adalah dari famili Formicidae daripada order Hymenoptera (57.18%), famili Ripophiridae daripada order Coleoptera (25.70%), famili Simuliidae daripada order

Diptera (5.85%) dan famili Ephemeridae daripada order Ephemeroptera (4.58%). Kebanyakan serangga yang diperoleh adalah daripada kumpulan trogloxene dan troglofil.

Kata Kunci: Serangga gua, komuniti serangga, Semenanjung Malaysia

INTRODUCTION

Cave is a natural opening in rocky mountain which allow entrance of living organism (Gunn 2004). Formation of cave begins when carbonate rocks or limestone reacts weakly with acidic groundwater, dissolving the limestone structure in between fractures and bedding partings that grows over time to become large space (Palmer 1991). The most common cave is the limestone cave (Palmer 1991). Speleothems are typical characteristic of limestone cave where secondary minerals are deposited forming unique structure in cave landscape. A limestone cave may feature speleothems such as stalagtite, stalagmite, column, curtain and corals (Davies & Morgan 1991). The open space in cave may provide shelter to organisms ranging from microscopic invertebrates to larger mammals such as mountain goat (Price 2004). Even when Malaysia have quite a number of caves, the record of cave fauna in this country is very limited. All records of cave-dwelling insect in Malaysia are unfortunately based on only one cave which is the Batu Caves, Selangor. Study of cave dwelling insect only started in this country at Batu Caves in 1920s by (Dover 1929). This study are then continued by (McClure et al.1967) in 1959. The checklist of cave fauna in the same cave are than being updated and checked for errors by (Moseley et al. 2012).

The most important source of organic matter for cave fauna is from bat droppings known as guano. With guano as energy source, a complex food web of invertebrate comprises of detritivores and its predators thrive in the cave (Ferreira & Martins 1999). These food web may include various detritivores insect such as booklice, beetle, moth, crickets and cockcroaches. The predators of detritivores insect such as pseudoscorpions, spiders and Reduviidae keep the cave fauna ecosystem in balance (Ferreira et al. 2000). Cave fauna can be categorized into three different groups which are troglobite, troglophile and trogloxene (Trajano 2012). Troglobites are obligatory cave animals that very much adapt to cave environment where they can only survive inside the cave. There are 50, 000 to 100,000 species of troglobites all around the world (Wynne & Pleyteyz 2005). These may include the eyeless shrimp, blind flatworms, eyeless fish, isopods, copepods as well as the invertebrates. A troglophile animal on the other hand spend their entire life in cave but may survive in the outside environment. A beetle, *Notospeophenus jasperensis vivinus* found in a cave in Bungonia is classified as troglophile insect (Hamilton-Smitch 1971). Trogloxene is considered as a guest in the cave where they habitually found in cave but does not complete the whole life cycle in the cave environment. Most of the time the trogloxene organism use cave for roosting and hibernation site (Howarth 2009).

Gunung Senyum Cave is a cave made up of limestone and rock, estimated to be around 3,000 years old (Tourism Pahang Malaysia 2018). Bats can be seen roosting in the crooks and crevices inside the cave, leaving piles of guano on the cave floor. The landscape consisted of multiple zone of different light intensity ranging from a total dark area to naturally bright area during the day. Stalactites and stalagmites of various sizes and shapes are well developed in the cave (Adriansyah et al. 2015). As insect known to be the most diverse groups of animals on earth, it is plausible to record its existence all around the world including the cave. Data recorded for insect in cave unfortunately is still scanty due to practical difficulties in conducting survey especially in taxonomy (Moseley 2009). Shahar et al. (2011) have recorded the presence

of sandfly in caves of Western Malaysia including Gunung Senyum Cave but it does not comprise of other cave-dwelling insect while other studies done on cave-dwelling insect are confined within Batu Caves only. This study is an attempt in recording the insect fauna in Gunung Senyum Cave, Pahang. However, due to safety reason, this study only limited to the recording of diurnal insect family within cave environment. Hence, the objective of this study is to make a preliminary checklist of diurnal cave-dwelling insect family found within Gunung Senyum Cave. This is in order to fill the gap of knowledge regarding cave insect which is indeed very sparse in Malaysia.

MATERIALS AND METHOD

Location

The sampling was conducted at Gunung Senyum (3º 43'04.21"N, 102º 26'00.31"E) which is located within Jengka Forest Reserve, Kuala Krau, Pahang. The Jengka Forest Reserve covers an area of 794 hectares and surrounded by oil palm plantations of Jengka Felda scheme. Gunung Senyum has more than hundred caves developed at different levels. Most of the caves are connected to one another. However, the main cave of Gunung Senyum, Gua Terang Bulan was selected for this study as it is easily accessible. The area within Gua Terang Bulan is approximately 35 m x 50 m (Zakaria et al. 2004). The size of Gua Terang Bulan gives an appropriate space for the set up of sampling equipment. The height of the cave is between 60 m to 80 m.

Sampling Method

Sampling of insect fauna was done using four types of trap which were; pitfall trap, light trap, sticky trap and impact trap. Light trap, sticky trap, impact trap and pitfall trap were placed inside the cave in an effort to sample insect from all dimension. Ten pitfall trap, 1 light trap, 2 sticky trap and 1 impact trap were placed randomly inside the cave area where it is accessible. The light trap was set up at 3 m high above the ground. Pitfall trap and impact trap were placed on cave floor while sticky trap were stick flat on the cave wall. All trap were placed randomly within the space available with an average distance of 4 m. The sampling was conducted once a month for three consecutive months from June to August 2015. All traps were set up at 8 a.m in the morning and collected at 6 p.m in the evening. Samples collected were brought back to laboratory for identification using Triplehorn & Johnson (2005).

RESULTS

There are a total of 2291 individuals of insect were collected in Gunung Senyum Cave, Pahang between June and August 2015. From the total collection, the insect were then classified into six order of insect which are Coleoptera, Lepidoptera, Hymenoptera, Diptera, Ephemeroptera and Orthoptera. A total of 21 families of insect were then identified from each of insect order (Table 1).

Table 1. List of order, family and number of individual cave-dwelling insects in Gunung Senyum Cave.

Order	Family	Code	Total	Percentages
Coleoptera	Ripiphoridae	ColRipi	589	25.70
	Ptiliidae	ColPtil	27	1.18
	Haliplidae	ColHali	8	0.35
	Elateridae	ColElat	2	0.09
Lepidoptera	Micropterigidae	LepMicr	12	0.52
Hymenoptera	Formicidae	HymForm	1310	57.18
	Orussidae	HymOrus	1	0.04
Diptera	Drosophilidae	DipDros	8	0.35
	Ceratopogonidae	DipCera	23	1.00
	Simuliidae	DipSimu	134	5.85
	Culicidae	DipCuli	18	0.79
	Tabanidae	DipTaba	3	0.13
	Stratiomyidae	DipStra	10	0.44
	Tachinidae	DipTach	1	0.04
	Piophilidae	DipPiop	2	0.09
Ephemeroptera	Polymitarcyidae	EphPoly	17	0.74
	Ephemeridae	EphEphe	105	4.58
	Baetiscidae	EphBaet	1	0.04
	Heptageniidae	EphHept	1	0.04
	Ephemellidae	EphEphem	15	0.65
Orthoptera	Rhaphidophoridae	OrtRhap	4	0.17
Total			**2291**	**100%**

Based on the table, order Coleoptera consist of four families which are Ripiphoridae, Ptiliidae, Haliplidae and Elateridae; order Hymenoptera consist of two families (Formicidae and Orussidae); order Diptera have eight families (Drosophilidae, Ceratopogonidae, Simuliidae, Culicidae, Tabanidae, Stratiomyidae, Tachinidae and Piophilidae); order Ephemeroptera have five number of families which are (Polymitarcyidae, Ephemeridae, Baetiscidae, Heptageniidae and Ephemellidae); order Lepidoptera and order Orthoptera, both represented only by one family for each of them known as Micropterigidae and Rhaphidophoridae, respectively.

Order Hymenoptera is the most dominant and abundant group of insect according to their number of individuals (1311 individuals) (Table 1) and comprised of 59 % from the insect composition in Gunung Senyum Cave (Figure 1) and family Formicidae contributes the most abundant family in this order with 1320 individuals (Table 1). Meanwhile, order Coleoptera is the second most abundant insect order in Gunung Senyum Cave with 627 individuals (Table 1) and comprised 27% of insect composition with the most abundant family represented by family Ripiphoridae (589 individuals). This is followed by Simuliidae (Order Diptera) (5.85%) and Ephemeriidae (Order Ephemeroptera) (4.58%). The general characteristic of each insect family sampled in this study were described in (Table 2).

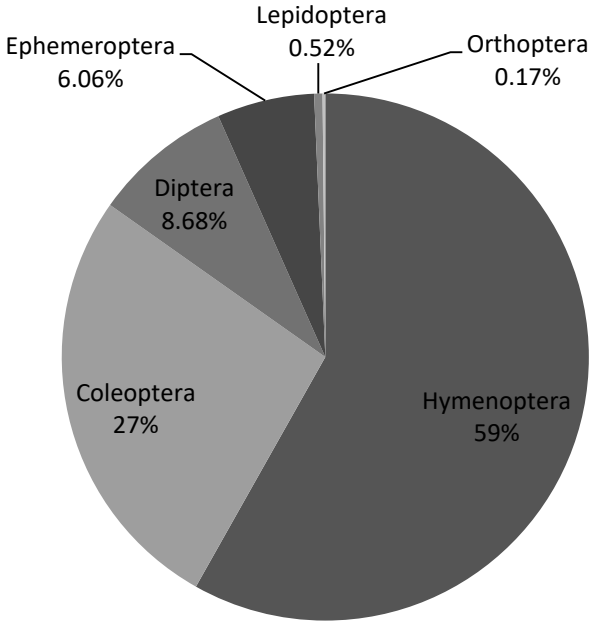

Figure 1. Order composition of cave-dwelling insects in Gunung Senyum Cave

DISCUSSION

As there is a severe lack of knowledge regarding cave-dwelling insects in this country, local comparison may only be done with records found in Batu Caves (Dover et al. 1929; McClure at al. 1967; Mosely et al. 2012; Price 2004) and Gunung Senyum Cave (Shahar et al. 2011). Ant (Formicidae) is a spatio-temporal dominant species as its distribution are at large in various habitat. The presence of Formicidae in the cave may be associated to the guano littered environment of the cave (Bernath & Kunz 1981). In Batu Caves, *Pheidole fervens*, were recorded to build tunnels from the forest leading up to floor and wall of the caves (McClure at al. 1967; Mosely et al. 2012). The same genera can also be found in abundance outside cave in Brazil (Dáttilo et al. 2012). Ant may enter a cave to collect guano and carry it back to their nest as food source (Moulds 2006). Guano, the excretion of the bat have nutritional value which can be a good food source for the ants (Bernath & Kunz 1981). The main genera of Formidae found in Brazil were *Camponatus* sp. and *Pheidole* sp. which can be found in abundance outside cave (Dáttilo et al. 2012). The high abundance of *Crematogaster* sp. inside cave in the Philipines, were due to the presence of vegetation in the surrounding area of karst limestone landscape (Figueras & Nuneza 2013). Gunung Senyum Cave is also surrounded by various vegetations and adjacent to an oil palm plantation. This may lead to the colonization of insect species into the cave environment. Up to these days, record of troglobitic ant were scarce except for *Leptogenys khammouanensis* recorded in two caves of Laos (Roncin & Deharverg 2003). The morphological character of this ant species is strikingly adaptive to cave environment where it bears a very slender body with light pigmentation and reduced eyes raising a possibility with it being troglobite cave species. Orussidae wasp on the other hand seems to be an accidental occurence in the cave since their main source of food is dead wood commonly found outside of the cave.

Out of all beetle family sampled in Gunung Senyum Cave, only Elateridae was similarly found in Batu Caves. The family Ptilidae and Elateridae are detritivores as they feed on decayed materials (Triplehorn & Johnson 2005). Both family have been recorded in caves in Cuba as

Troglophile and Trogloxene species of beetle respectively (Peck et al. 1998). In Canada, Ptilidae were found in caves of Nova Scotia and Cape Breton Island and being consired as guanophiles (Moseley 2009). This shows that both Ptilidae and Elateridae might have an association to guano piles on the floor of Gunung Senyum Cave. Ripiphoridae on the other hand are believed to use Gunung Senyum Cave as their shelter. This family of beetle are known to parasitized bees, cockcroaches as well as other wood-boring beetles (Batelka & Hoehn 2007, Arnette et al. 2002). The landscape surrounding Gunung Senyum Cave are of forest reserve which may holds diversity of insect, thus providing variety of host to this particular beetle family. Nevertheless, a longer study period will give more information regarding behaviour and ecology of Riphiphoridae inside the cave. This will help in gaining more understanding on how this beetle family related to the cave ecosystem.

Black flies (Simuliidae) on the other hand are geographically and widely distributed worldwide (Duncan et al. 2004; Sriphirom et al. 2014). About 2000 nominal species are currently recognized and occurring in all continent except Antartica, Hawaii, the Falkland Island and isolated desert island, however certain geographical region remain undiscovered (Currie & Adler 2007). Based on previous study, Simuliidae have not yet been recorded in cave of Malaysia. However, there are two species of Simuliidae namely *Prosimulium saltus* and *Simulium parnassium* managed to be recorded from limestones caves in Georgia, USA (Reeves 2000). According to (Sriphirom et al. 2014), Simuliidae are medically and ecologically significant insect. Black flies are among the few insects which capable to kill animals through direct attacks by exsanguination or toxic shock that caused a disease known as simuliotoxicosis. There are about seven black flies species and all developing in large rivers that highly contributed and responsible for large-scale of livestock death. *Simulium colombaschense* was known as the most dangerous species in the world by killing animals beyond Danuba river for centuries (Adler et al. 2016). As a holometabolous insect, black flies undergo four stages of lifecyle which are egg, larvae, pupa and adult. The first three stages are associated with the running waters and can range in size between tiny headwaters to large rivers depending on species (Currie & Adler 2007). The location of Pahang Riverbank is near to the cave, thus this river might be the most convenient habitat of the larvae. Ecologically, the black flies larvae plays an important role of biological indicator in aspects of stream ecology such as nutrient turn over since they are major components of stream macro-invertebrate (Sriphirom et al. 2014). This is supported by (Hamid et al. 2016) which finds that Simuliidae are easily affected by physio-chemical parameter indicating water quality such as the total dissolve solids and conductivity. The other fly family such as Drosophilidae, Ceratopogonidae, Culicidae, Tabanidae and Stratiomyidae are common Dipteran family in outside environment which have also been recorded in limestone cave of Brazillian Saavannah (Simoes et al. 2015). However, only Culicidae, Drosophilidae, Tachinidae and Ceratopogonidae had been recorded in Batu Caves, Malaysia. Culicidae had been noted to be a trogloxene insect in Batu Caves as there were no larvae found within the cave area (McClure at al. 1967).

Mayflies particularly lives in freshwater in all continents except Antartica and consist of more than 3000 species from 42 families (Gatolliat et al. 2015). Ephemeroptera had been recorded in Batu Caves as *Cleon* sp. from family of Cloeonidae (McClure at al. 1967, Mosely et al. 2012).The larvae strictly depend on freshwater (Gatolliat et al. 2015). Restricted requirement and limited tolerance of the larvae towards the environmental conditions yielded to the information about the characteristics of the freshwater through responses to any small changes in their immediate environment (Towns 1987). Ephemeroptera crucial in the water-quality monitoring programs besides also important to the food web of stream, river and lake ecosystem (Funk, Sweeney & Jackson 2010). The adult only able to live from a few hours to a

few days which is not more than 2-3 days (Towns 1987; Gatolliat et al. 2015). A mayflies genus from family Leptophlebiidae which is *Paraleptophlebia* sp. Newton have been recorded and listed as cave fauna of the Buffalo National River located in northwest Arkansas within Marion, Newton and Searcy counties (Graening et al. 2006). Meanwhile, in one study conducted by Peck (1985) regarding cave faunas of Tropical American caves which is located in Jumandi Cave, Ecuador, genus *Euthyplocia* sp. from family Ephemeridae (trogloxene) have been identified from the stomach of the cave catfish. The same species was identified at nearby stream. Therefore, the presence and abundance of Ephemeridae in Gunung Senyum Cave will indirectly indicate the stability of food web of aquatic ecosystem faunas especially in Pahang Riverbank nearby and associated with the cave.

It is also important to note the presence of the cave cricket, Raphidophoridae in this study. This insect family have also never been recorded in cave of Malaysia before. Rhaphidophoridae have a strong connection with guano where species such as *Ceuthophilus* are commonly found in bat guano area (Lavoie et al. 2007). Certain species of Raphidophoridae such as *Troglophilus neglectus* is troglophile while other such as *Dolichopoda araneiformis* is troglobite cave-dweller (Strauß & Stritih 2017). The troglobite cave-cricket have reduced pigmentation, wings and visual capability though it develop an advance mode of chemoreception with elongated appendages for adaptation to live in cave (Konec et al. 2015). Raphidophoridae can be seen on the wall and floor of the cave. As such, Raphidophoridae are sampled through the use of pitfall and sticky trap. However, this family is strictly nocturnal as they will roost inside the cave and remain inactive during the day (Stephenson et al. 2007). Since the set up of the insect trap are limited to daytime, the number of Raphidophoridae sampled in this study is very low as the crickets are not mobile. It is suggested for the trap to be set up in 24 hours time frame for a more comprehensive record.

CONCLUSION

This study managed to identify and provide the diurnal cave-dwelling insect checklist in Gunung Senyum Cave as a preliminary references for others studies on the same interest. The insect community found in this cave were different compared to study done in Batu Caves, Selangor. This shows the need for thorough survey of various caves in Malaysia for a complete record of cave-dwelling insects in this country. Further and more detailed identification until the species level will be necessary for more valuable and accurate inventory of the cave-dwelling insects. A longer study period will help in detailed understanding of cave-dwelling insects community and its ecology.

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APPENDICES

Table 2. List of family and their biology, habitat and feeding habits

Family	Biology & Identification	Habitat	Feeding Guild
Ripiphoridae	Wedge-shaped beetles, length of body (4-15 mm), similar to Mordellidae, but have the abdomen blunt instead of pointed at the apex. Antennae of female is serrate while male is pectinate.	Sometimes found in burrows of halictid bees.	Adults feed on flowers particularly goldenrod. Larvae can be parasitic on various wasps (Vespidae, Scoliidae and Tiphiidae) and bees (Halictidae and Apidae).
Ptiliidae	Feather-winged beetles, smallest beetle, body length: less 0.5 mm (many), exceed 1mm (few), body is oval, hind wings bear whorls of long hairs.	Live in rotting woods, dung and leaf litter.	Feed chiefly on fungus spores.
Haliplidae	Aquatic beetles, swimming or slow moving, two common genera can be separated by the presence/absence of the two black spots at the base of pronotum, spots are present in *Peltodytes* and absent in *Halipus.*	Common in ponds. Frequently lives in masses of vegetation near the surface of water.	Adults are phytophagous while larvae are predaceous.
Elateridae	Click beetles, able to "click" possible by the flexible union of prothorax and mesothorax and by prosternal spine that fits into a groove on the mesosternum. Adult body is elongate, usuallya parallel-sided and rounded at each end, antennae is usually serrate, legth of body (12 mm-30 mm). Larvae are hard bodied, shiny and called 'wireworms'.	Adults live on flowers, under bark or on vegetation. Larvae live in rotting logs.	Adults are phytophagous. Many species larvae feeding on newly planted seeds and the roots of beans, cotton, potatoes, corn and cereals. Some of the larvae also feed on other insects.
Micropterigidae	Size ranging from 5 to 12 mm wingspan with golden or purple iridescence.	Commonly found in shady places, edge of forest clearings.	Pollinator

Formicidae	Ants. Common and widespread group. Pedicel of the metasoma which is 1 or 2 segmented and bears an upright lobe: 1 distinctive structural feature of ants. Most colonies have 3 castes: queens, males and workers. Queens are larger than other castes & usually winged. Males are winged but smaller than the queen.	Occur everywhere in terrestrial habitats.	Many are carnivorous, feeding on the flesh of other animals (living/dead), some feed on plants, fungi, many feed on sap, nectar, honeydew and secretion of other individual (in nest).
Drosophilidae	Pomace flies or small fruit flies. 3-4 mm long and yellowish in color. Large group (consist of 182 North American species). Short life span for several species.	Found around decaying vegetation and fruits. Larvae live in decaying fruits and fungi.	Larvae feed on yeasts growing in the fruits. Larvae also considered as ectoparasitic (on caterpillars) or predaceous (on mealybugs and other small Hemiptera).
Ceratopogonidae	Biting Midges. Small flies.	Particularly along the seashore or along the shores of rivers and lakes.	Blood-sucking of other insects as an ectoparasites.
Simuliidae	Black flies or buffalo gnats. Small flies, dark-colored insects with short legs, broad wings and humpbacked appearance. 165 species, wide distribution but most numerous in the north temperate and subarctic region. Adults appear in late spring and early summer. Larvae are club-shaped, swollen posteriorly and move like measuring-worm and sometimes extremely abundant. Pupate in cone-shaped cases, attach to object in the water.	Larvae live in streams, attach to stones. Adults frequently near the stream where the larvae live.	Female is bloodsucking, sometimes attacking livestock.
Culicidae	Mosquitoes. Large, abundant and well known group of flies. Adults can be recognized by characteristic wing venation, the scales along the wing veins and long proboscis.	Larval or wrigglers are aquatic: ponds, pools, tree holes. Each species usually lives only in a particular type of aquatic	Larvae feed on algae and organic debris, but few are predaceous and feed on other mosquito larvae. Adult female is

		habitat. Pupae or tumblers are aquatic. Adults spend the day in hollow trees, under culverts or in similar resting places.	bloodsucking while adult male feed on nectar and other plant juices.
Tabanidae	Horse flies and Deer flies. 350 species occur in North America and quite common. Medium-sized to large. Two sexes easily separated by eyes. Eyes are often brightly colored or iridescent	Adults lives near swamps, marshes, ponds. Male often found on flower. Larvae are aquatic	Females is bloodsucking insect and serious pests of livestock and people. Males mostly feed chiefly on pollen and nectar, while the larvae are predaceous.
Stratiomyidae	Soldier flies. Large group (260 species in North America) of medium-sized or larger (to about 18 mm) fly. Brightly in color and wasplike in appearance. Easily recognized by their wing venation.	Usually found on flowers. Larvae live in variety conditions: some are aquatic and some live in dung or decaying material, some live under bark	Some larvae feed on algae, decaying materials and small aquatic animals.
Tachinidae	Second largest family in the order. 1350 known North American species. Many tachinids similar in general appearance to muscids and flesh flies. Many are large, bristly and bee-like or wasplike in appearance.	Found almost everywhere.	Larvae are parasites of other insects (feed on internal organ of caterpillars).
Piophilidae	Skipper flies. Usually less than 5 mm long and metallic black or bluish in color. 'Skipper' refers to the ability of the flies to jump.	Some or larvae live in cheese and meats	Larvae are scavengers
Polymitarcyidae	(*Mayflies*) Similar to the Ephemeridae, but have the middle and hind legs of the male, and all legs of the female, greatly reduced of vestigial. Some have a dense network of margital veinlets and the genital	Aquatic; river, stream and lakes.	Nymphs are filter feeders, burrowing in riverbeds and feed on organis matter.

	forceps of the male have four segments. Other have few marginal veinlets and the genital forceps of the male only have two segments.		
Ephemeridae	(Mayflies) are medium to large sized (front wings 10-25 mm), with 2 or 3 caudal filaments, wings are hyaline or brownish and in have dark spots in *Ephemera*	Nymphs are burrowing in aquatic habitat. Occur in the sand or silt at the bottoms of streams and lakes, sometimes in fairly deep water. Adults usually emerge from lakes.	Predators and filter feeders.
Baetiscidae	(Mayflies) small to medium-sized (front wing 8-12 mm), with 2 caudal filaments which are usually shorter than the body. Wings are basally and often reddish or orange. Front wing lacks cubital intercalaries and has 1A extending to the outer margin of the wing.	Nymph occur in cool, fairly rapid streams.	Predators and filter feeders.
Heptageniidae	(Mayflies) The second largest family in North America. Common and widely distributed. Nymphs are sprawling forms, dark-colored with head and body flattened. The hind tarsi are 5 segmented.	Most species occur on the underside of stones in streams.	Predators and filter feeders.
Ephemerellidae	(Mayflies) are medium sized (front wings 6-19 mm), brownish, 3 caudal filaments, short and basally detached marginal veinlets along the outer margin of the front wings and the coastal crossveins are reduced.Common and widely distributed.	Nymph lives in variaty of aquatic habitat, usually under rocks or in debris in cool, clear nad rapid streams or in small and clear lakes.	Predators and filter feeders.
Rhaphidophoridae	Cave or camel crickets. Brownish humpbacked in appearance. Long antennae.	Lives in caves, in hollow trees, under logs and stones, and dark and moist places.	Predators of smaller insect.

	89 species from genus *Ceuthopilus* in United States and Canada.

Source: Triplehorn & Johnson 2005, Sekine et al. 2013, McCafferty & Gillies 1979, Hubbell & Norton 1978.