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Mutillidae (Hymenoptera) from Essex Co., Virginia: monthly changes in abundance and richness

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Abstract We analyzed the abundance and richness of velvet ants (Hymenoptera: Mutillidae) in Essex County, Virginia, USA. Also, to compare the species list in this study with the known diversity in the state of Virginia, we examined literature searches and collection inventories. Mutillidae specimens in Essex were sampled from March 26 to November 5, 1991, using 13 Malaise traps. The monthly abundance of each genus was then compared using Rayleigh and Mardia-Watson-Wheeler tests. Fieldwork yielded a total of 3302 specimens, distributed in 25 species, eight genera (*Dasymutilla* Ashmead, *Ephuta* Say, *Lomachaeta* Mickel, *Myrmosa* Latreille, *Photomorphus* Viereck, *Pseudomethoca* Ashmead, *Sphaeropthalma* Blake, and *Timulla* Ashmead), and three subfamilies (Myrmosinae, Mutillinae, and Sphaeropthalminae). The four most abundant genera were *Pseudomethoca* (789 specimens, four species), *Myrmosa* (778 specimens, one species), *Ephuta* (774 specimens, five species), *Sphaeropthalma* (662 specimens, one species). *Myrmosa unicolor* Say and *Sphaeropthalma pensylvanica* (Lepeletier) were the most abundant species, representing 44% of the collected specimens. The genera analyzed presented significant monthly abundance values, with maximum abundance values in June for *Sphaeropthalma*, July for *Timulla*, *Dasymutilla*, *Myrmosa*, and *Photomorphus*; August for *Ephuta*; and September for *Pseudomethoca*. Genera with similar patterns are *Timulla-Dasymutilla*, *Timulla-Photomorphus*, and *Dasymutilla-Photomorphus*. The 25 species recorded from Essex County in this study constitute 78.1% of the 32 species recorded from the state of Virginia. We concluded that the Mutillidae from Essex Co. displays large variations in abundance, with peaks of activity occurring from June to September. Although our study did not sample environmental variables, the monthly activity patterns observed are correlated with temperature patterns observed for Essex Co. in 1991. Finally, *Sphaerophthalma* (sic!) (*Photomorphus*) *rubroscutellatus* Bradley was recognized to be a junior synonym of *Photomorphus impar* (Melander).

Keywords: checklist, ecology, Nearctic velvet ants, taxonomy

1. Introduction

Mutillidae is a diverse family of aculeate wasps whose ecology is poorly understood and for which little information is known regarding their abundance, richness, and seasonal flight activity. Deyrup and Manley (1990) presented, so far, the only known information about the seasonal flight activity for mutillids in the eastern Nearctic Region, specifically in Central Florida. Subsequent works on the subject have been carried out in the Neotropical Region, specifically in Brazil (Aranda and Graciolli 2016), Panama (Cambra et al 2018; Añino et al 2020; Cambra et al 2021), and in arid habitats in the southwestern Nearctic Region, specifically in Nevada (Boehme et al 2012; Sadler et al 2017).

Mutillid species with similar morphology have historically been described based on differences in integumental or setal color (Brabant and Young 2010). Sexual dimorphism has also led to the description of numerous species based on one sex. In recent years, taxonomic research on North American Mutillidae have led to synonyms for species that have been recorded from Virginia. For example, Pitts and Manley (2007) presented two synonymies for *Ephuta pauxilla* Bradley, 1916; Pilgrim et al (2009) synonymized 14 species and two subspecies under *Dasymutilla quadriguttata* (Say, 1823); Brabant et al (2010) synonymized two species and one subspecies under *Photomorphus impar* (Melander, 1903); Williams et al (2019) mentioned *Lomachaeta hicksi* Mickel, 1936 as ranging from the Atlantic to Pacific Oceans, North to Massachussetts and South to Florida (USA) and Puebla (Mexico), and Brothers et al (2022) synonymized *Dasymutilla vesta* (Cresson, 1865) under *Dasymutilla ursus* (Fabricius, 1793).

Given the limited information on this topic, we aim to provide the first data on monthly abundance and species richness for Mutillidae in Essex County and present an updated species checklist in Virginia.

2. Materials and Methods

We follow the classification of Brothers and Lelej (2017), which includes Myrmosinae within the Mutillidae.

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The study site was in Essex County, near Tappanhock, Virginia, USA; specimens were collected from March 26 to November 5, 1991, using 13 malaise traps (Townes 1972). Information on the study site and sampling methods with malaise traps were discussed in Liu et al (2007). The collected mutillid specimens were pinned, labeled, identified species by RAC, and deposited in the Museo de Invertebrados GB Fairchild, University of Panama, Republic of Panama (MIUP). Type specimens of *Photomorphus* were examined by KAW from the Academy of Natural Sciences, Philadelphia, USA (ANSP), Cornell University Insect Collection, Ithaca, New York, USA (CUIC), and Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA (MCZC).

2.1. Statistical analysis

Considering that the samplings did not coincide with a uniform distribution between the study months (Table 1), we estimated the values corresponding to abundance for each of the sampling months using the following formula:

As= (Ni1/Ds1) * Dm1 + (Ni2/Ds2) * Dm2 +…

where: As = Estimated abundance, Ni = Number of individuals collected, Ds = Duration of sampling, and Dm = Number of days of sampling belonging to the corresponding month, the formula was executed using Microsoft Excel©.

A Rayleigh test (Zar 1999) was performed to verify if the monthly abundance patterns obtained were significant, using the CircStats package (Lund and Agostinelli 2018) in R (R CORE TEAM 2019). In addition, we execute the Mardia-Watson-Wheeler Test (Batschelet 1981) to detect if the samples differ from each other in a non-parametric way (Mendoza 2020) using the Circular package (Agostinelli and Lund 2017).

Table 1 Estimated monthly abundance of individuals by genera of Mutillidae collected. Period of days that comprise the samplings in 1991: May 25. -5 Jun., 6-14 Jun., 15-27Jun., 28 Jun -11 Jul., 12-26 Jul., 27 Jul.- 9 Aug.,10-26 Aug., 27 Aug.-16 Sep., 17 Sep.-10 Oct., 11 Oct.-5 Nov.

Genus	# Species	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
Ephuta	5	0	0	8	42	168	240	197	73	42
Timulla	4	0	0	0	2	34	32	15	3	0
Myrmosa	1	0	0	28	345	407	5	1	0	0
Dasymutilla	7	0	0	0	12	74	46	21	3	0
Photomorphus	2	0	0	3	6	30	27	9	2	1
Pseudomethoca	4	0	0	168	91	188	181	221	53	9
Sphaeropthalma	1	0	0	164	249	83	122	36	5	3
Lomachaeta	1	0	0	0	0	0	1	2	0	0

3. Results

A total of 3302 specimens distributed in 25 species, eight genera, and three subfamilies were collected (Table 1). The genera with the highest number of specimens were *Pseudomethoca* Ashmead, 1896 (789 specimens), *Myrmosa* Latreille, 1797 (778), *Ephuta* Say, 1836 (774), and *Sphaeropthalma* Blake, 1871 (662). The most abundant species were *Myrmosa* (*Myrmosa*) *unicolor* Say, 1834 and *Sphaeropthalma pensylvanica* (Lepeletier, 1845), representing 44% of the collected specimens. The genus *Lomachaeta* Mickel, 1936 was not included in the statistical analysis since only three specimens of *L. hicksi* Mickel were collected.

The seven genera analyzed, using the Rayleigh test, presented significantly different monthly abundance values, with the maximum abundance value in June for *Sphaeropthalma* (r = 0.83, $P < 0.001$) (Figures 2E-F), July for *Timulla* Ashmead, 1899 (r = 0.90, $P < 0.001$) (Figures 1 C-D), *Dasymutilla* Ashmead, 1899 (r = 0.90, $P < 0.001$) (Figures 1E-F), *Myrmosa* (r = 0.95, $P < 0.001$) (Figures 2A-B), and *Photomorphus* Viereck, 1903 (r = 0.86, $P < 0.001$) (Figures 2C-D); August for *Ephuta* (r = 0.80, $P < 0.001$) (Figures 1 A-B) and September for *Pseudomethoca* (r = 0.69, $P < 0.001$) (Figures 1G-H).

The Mardia-Watson-Wheeler Test for homogeneity indicates that the only genera with a similar monthly abundance pattern are *Timulla-Dasymutilla* (W = 1.8, df = 2, $P = 0.40$), *Timulla-Photomorphus* (W = 1.99, df = 2, $P = 0.37$) and *Dasymutilla-Photomorphus* (W = 0.98, df = 2, $P = 0.61$).

Before this study, three species of *Photomorphus* were known from Virginia (Krombein 1979), including the rare *P. rubroscutellatus* (Bradley, 1916), which is known from the male holotype only (Figure 4A). We studied this specimen and found it is structurally identical to *P. impar* (Melander, 1903) (Figures 4B-C), differing only in having the head and mesosoma blackened, except for the orange-brown mesoscutellum and metanotum. In the past 20 years, the authors have studied thousands of *Photomorphus* specimens, including at least 200 *P. impar* from various localities housed in various museums and 16 *P. impar* specimens from Virginia. No additional specimens of *P. rubroscutellatus* have been found. Males of the genus *Photomorphus*, particularly *P. impar*, *P. banksi*, and *P. alogus* Viereck, 1903, show a great deal of color variation in the head, mesosoma, legs, and tergum two. The difference in coloration between *P. rubroscutellatus* and *P. impar* is less extreme than the variation observed within *P. banksi*, whose males range from having the cuticle entirely black (Figure 4D) to almost entirely orange-brown (Figure 4E). Finally, the dark cuticle of the head and mesosoma in *P. rubroscutellatus* is

only darker reddish-brown, not purely black. This darkening is somewhat irregular, with the gena, vertex, and propodeum somewhat lightened (Figure 4A). Whether the apparently unique color pattern seen in the *P. rubroscutellatus* type is an example of an artificial specimen condition, a discolored mutant specimen, or natural color variation. The lack of structural differences between *P. rubroscutellatus* and *P. impar*, alongside the absence of additional specimens in the face of heavy sampling in the eastern USA, is adequate evidence to synonymize *P. rubroscutellatus* under *P. impar*. An amended synonymy list for *P. impar* is provided below:

Photomorphus impar (Melander, 1903)

Mutilla parvula Blake, 1886: 206. Holotype female: Alabama [ANSP]. Preoccupied by *Mutilla parvula* Fabricius, 1804.

Mutilla impar Melander, 1903: 321. Holotype female: Fedor, Texas, May 1901, G. Birkman coll. [ANSP].

Photomorphus johnsoni Viereck, 1903: 249. Holotype male: Riverton, Burlington Co., New Jersey, July 7, 1901, C.W. Johnson coll. [ANSP].

Sphaerophthalma (sic!) (*Photomorphus*) *rubroscutellata* Bradley, 1916: 332. Holotype male: Falls Church, Virginia, July 10, N. Banks coll. [MCZC]. New Synonym.

Photomorphus johnsoni var. *argentipilis* Schuster, 1944: 148. Holotype male: Stone Mt., Georgia, June 7, 1917 [CUIC].

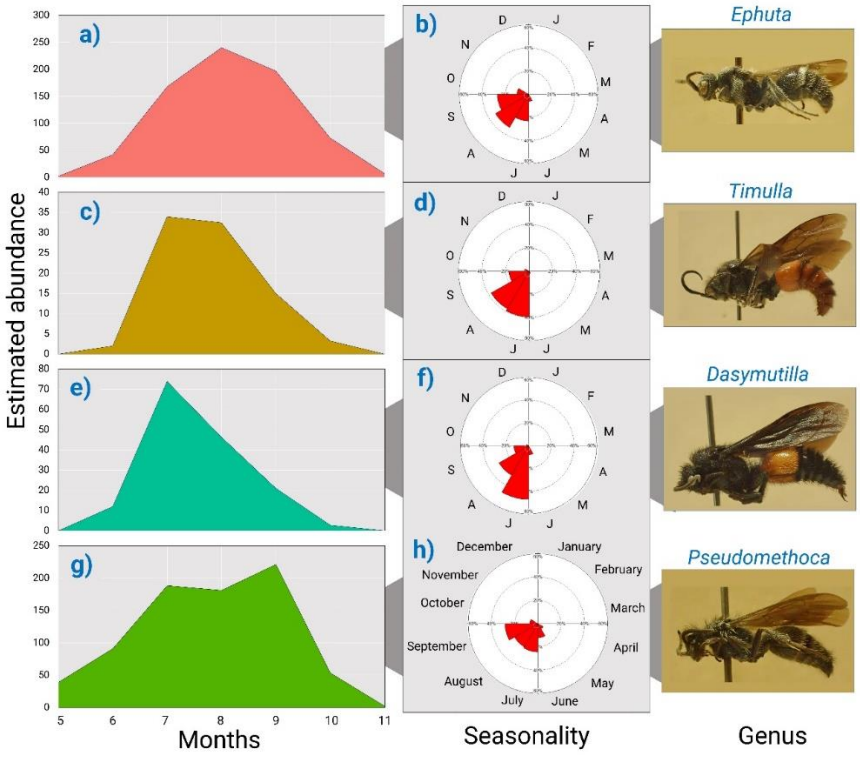

Figure 1 Estimated abundance and pattern of abundance per month in Mutillidae from Essex Co., Virginia: A, estimated of *Ephuta*; B, pattern of *Ephuta*; C, estimated of *Timulla*; D, pattern of *Timulla*; E, estimated of *Dasymutilla*; F, pattern of *Dasymutilla*; G; estimated of *Pseudomethoca*; H, pattern of *Pseudomethoca*.

4. Discussion

Deyrup and Manley (1990) collected, over four continuous years, two malaise traps in Archbold Biological Station, Florida, recording 2391 specimens in four genera and 19 species. These authors mentioned that many specimens of *Dasymutilla* were collected but not discussed because of problems with identifying some species. Saavedra (2014) sampled velvet ants for five continuous years using ten malaise traps in Barro Colorado Island, Panama, resulting in 2,060 specimens in 12 genera and 39 species. The above is consistent with the greater abundance of Mutillidae in the Nearctic region in contrast with greater diversity in the Neotropical region.

Myrmosa (Myrmosa) unicolor and *Sphaeropthalma pensylvanica* were the most abundant species due to their adaptation to temperature variation. Although our study did not sample environmental variables, the monthly activity patterns observed herein are consistent with temperature patterns observed for Essex County in 1991 (Figures 3A-C). This pattern shows that the highest temperatures in the area occurred between June and October, which coincided with the patterns of flight activity found for the species analyzed. Similar studies in the Neotropical region, such as Añino et al (2020) in Panama, also found an apparent relation between environmental parameters and the abundance of *Ephuta*. The authors reported that rainfall and temperature influenced the abundance of *Ephuta* specimens collected. In fact, the same study reported that the highest abundance occurred at higher temperatures in Panama between March and April. Another study in Panama with the genus *Dasymutilla* presented a similar pattern of high abundance in months with high temperatures (Cambra et al 2018), like the behavior of *Dasymutilla* in the Nearctic region. Deyrup and Manley (1990) also presented similar flight activity patterns in their study of velvet ants in Florida, although their conclusions were limited for some genera due to the non-inclusion of *Dasymutilla*. Although they used different

methods, including light traps, the studies in the western Nearctic Region (Boehme et al 2012; Sadler et al 2017) also found that mutillids were more abundant when higher temperatures.

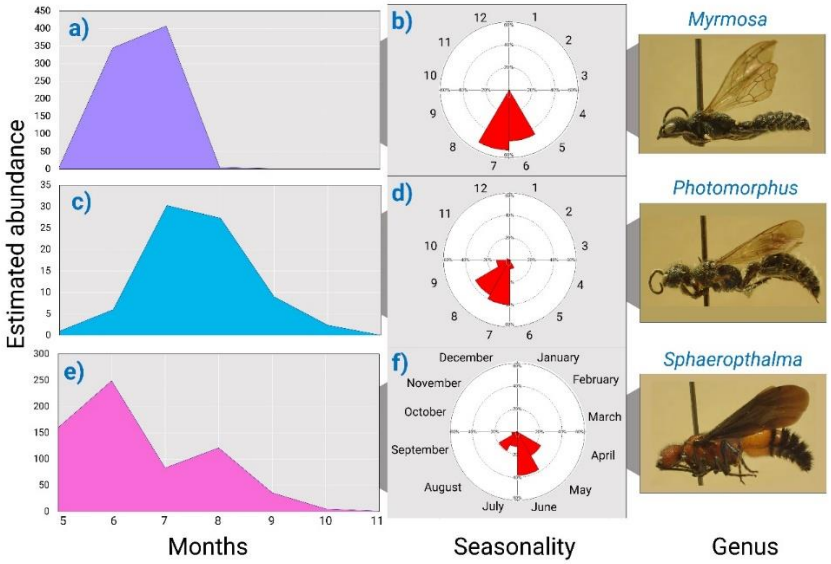

Figure 2 Estimated abundance and pattern of abundance per month in Mutillidae from Essex Co., Virginia: A, estimated of *Myrmosa*; B, pattern of *Myrmosa*; C, estimated of *Photomorphus*; D, pattern of *Photomorphus*; E, estimated of *Sphaeropthalma*; F, pattern of *Sphaeropthalma*.

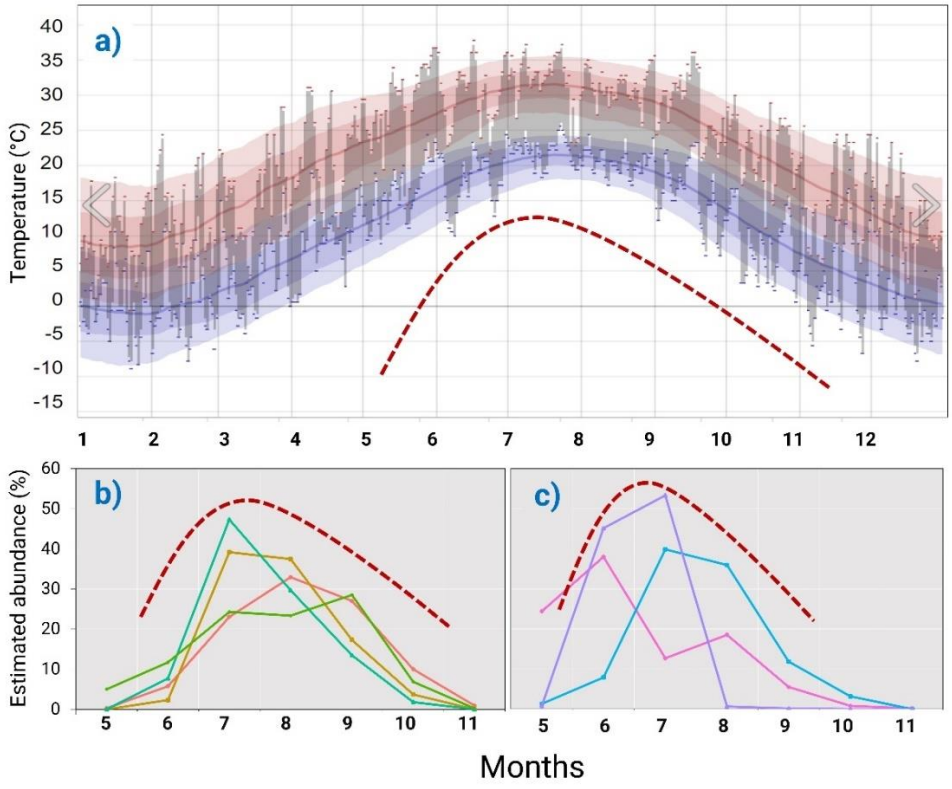

Figure 3 A, Temperature pattern in Essex County in 1991 (Richmond International Airport: https://es.weatherspark.com/h/y/147038/1991/Datos-hist%C3%B3ricos-meteorol%C3%B3gicos-de-1991-en-el-Aeropuerto-Internacional-de-Richmond-Virginia-Estados-Unidos#Figures-Temperature); B, monthly flight activity of *Ephuta, Timulla, Dasymutilla* and *Pseudomethoca*; C, monthly flight activity of *Photomorphus, Sphaeropthalma* and *Myrmosa.*

Environmental parameters, such as temperature, play an important role in the seasonal flight activity of velvet ants, which can directly influence their physiology to the point that, in adverse conditions, these wasps could enter diapause. Cambra et al (2021) presented a summary of the diapause cases reported in Mutillidae. Monthly patterns of abundance vary between the genera of Mutillidae; in our study, only *Timulla, Photomorphus* and *Dasymutill*a showed similar patterns. Variations in abundance patterns in Mutillidae may also be associated with the abundance of hosts (Aranda and Graciolli 2016; Añino et al 2020).

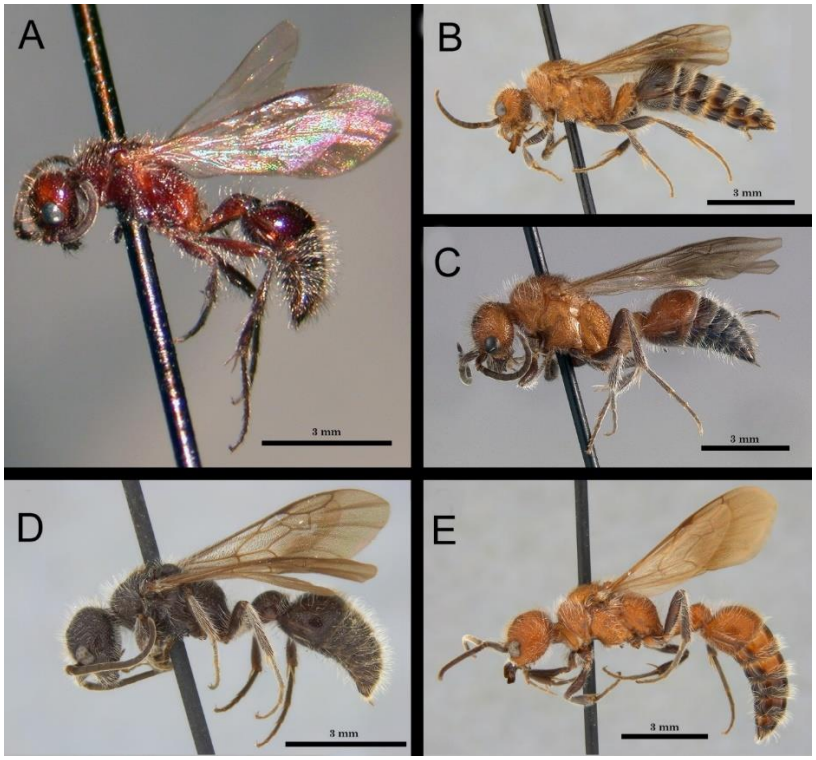

Figure 4 *Photomorphus* males, lateral habitus:
A, *Photomorphus rubroscutellatus*, Virginia;
B, *Photomorphus impar*, Arkansas, typical form seen in Virginia;
C, *Photomorphus impar*, Florida;
D, *Photomorphus banksi*, Mississippi, typical form seen in Virginia;
E, *Photomorphus banski*, Florida.

Thirty-two species have been registered from the state of Virginia (Table 2), including many synonyms in recent years (Krombein 1979; Pitts and Manley 2007; Pilgrim et al 2009; Brabant et al 2010; Williams et al 2019). The 25 mutillid species recorded from Essex County in this study constitute 78.1% of the species recorded for the state of Virginia. *Timulla compressicornis* Mickel, 1937 is recorded for first time from Virginia (two male specimens, Essex Co., Jul. 1991). Krombein (1979) mentioned that *Pseudomethoca oceola* (Blake, 1871) occurred from New Jersey to Florida and west to South Dakota and Arizona. No records of this species were found from Virginia in the literature.

Table 2 Checklist of Mutillidae recorded for the state of Virginia, USA.

Mutillinae	*Sphaeropthalminae*	*Myrmosinae*
Ephuta battlei Bradley, 1916. Known from male only.	*Dasymutilla asopus* (Cresson, 1865). Known from both sexes.	**Myrmosa blakei* Bradley New York, Virginia.Known from female only.
Ephuta pauxilla Bradley, 1916. Known from male only.	*Dasymutilla gibbosa* (Say, 1836). Known from both sexes.	*Myrmosa unicolor* Say, 1824. Known from both sexes.
Ephuta puteola (Blake, 1879). Known from female only.	**Dasymutilla bioculata* (Cresson, 1865) Massachussetts South to Florida. Known from both sexes.	**Myrmosula parvula* (Fox). District of Columbia South to Alabama. Known from both sexes.
Ephuta scrupea (Say, 1836). Known from both sexes.	*Dasymutilla nigripes* (Fabricius, 1787). Known from both sexes.	
Ephuta spinifera Schuster, 1951. Known from both sexes.	*Dasymutilla occidentalis* (Linnaeus, 1758). Known from both sexes.	
**Timulla barbigera* (Bradley, 1916) Virginia South to Florida. Known from both sexes.	*Dasymutilla quadriguttata* (Say, 1823). Known from both sexes.	
Timulla compressicornis Mickel, 1937. Known from male only. (First record from Virginia).	*Dasymutilla scaevola* (Blake, 1871). Known from both sexes.	
Timulla dubitata (Smith, 1855). Known from both sexes.	*Dasymutilla ursus* (Fabricius, 1793). Known from both sexes.	
**T. dubitatiformis* Mickel, 1937. Massachussetts South to Florida, known from female only.	*Lomachaeta hicksi* Mickel, 1936. Known from both sexes.	
**T. ferrugata* (Fabricius, 1805) New Jersey South to Florida. Known from both sexes.	*Photomorphus* (*Photomorphus*) *banksi* (Bradley, 1916). Known from both sexes.	
Timulla hollensis (Melander, 1903). Known from male only.	*Photomorphus* (*Photomorphus*) *impar* (Melander, 1903). Known from both sexes.	
**T. ornatipennis* (Bradley, 1916). New Jersey South to Florida. Known from both sexes.	*Pseudomethoca frigida* (Smith, 1855). Known from both sexes.	
Timulla vagans (Fabricius, 1798). Known from both sexes.	*Pseudomethoca sanbornii* (Blake, 1871). Known from both sexes.	
	Pseudomethoca simillima (Smith, 1855). Known from both sexes.	
	Pseudomethoca vanduzei Bradley, 1916. Known from both sexes.	
	Sphaeropthalma pensylvanica (Lepeletier, 1845). Known from both sexes.	

*Species recorded from Virginia but not collected in Essex Co. during this project.

5. Conclusions

Results of this study confirm monthly changes in the abundance and richness for Mutillidae from Essex County. Although our study did not sample environmental variables, the monthly activity variation observed herein is apparently correlated to months with higher temperatures between June and October, which coincided with the patterns of higher flight activity found for the species analyzed.

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Conflict of Interest

The authors declare no conflict of interest.

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