1. Introduction

Meropetuber Newmann, 1838, known as earwigflies or forcepsflies, are uncommonly collected and have fascinated entomologists since their discovery in 1837 (Figure 1). This fascination was initially due to their presumed rarity—only 16 specimens were collected between their discovery and 1904 [1]. Since then, they have continued to receive attention due to their previously assumed basal phylogenetic position within Mecoptera, relatively unknown life history, undescribed larvae, and odd appearance relative to other Mecoptera (e.g., flattened body, opisthognathous head, and broad wings folded over the abdomen) [2, 3].

Only two other extant meropeids exist: Austromerope poultoni Killington, 1933 [4], from Western Australia and Austromerope brasiliensis Machado et al., 2013 [3], from Brazil. One extinct species, Boreomerope antiqua Novoschonov, 1995 [5], is known from Middle Jurassic lacustrine claystone near Kubekovo Village in Siberia. Four extinct species of Thaumatomerope (i.e., T. madygenica Rasnitsyn, 1974, T. minuta Rasnitsyn, 1974, T. oligoneura Rasnitsyn, 1974, and T. sogdiana Rasnitsyn, 1974) were originally assigned to Meropidae but were later reassigned to Thaumatomeropidae [6, 7].

Collections of M. tuber continue to be infrequent. Prior to 1954, it was reported only from areas in or east of the Appalachian Mountains. Since then, the known range has been extended north to southern Ontario [8–10], west to Minnesota [11, 12], Iowa [13], Missouri [14–16], Arkansas [13, 16, 17], and Kansas [13], and south to Alabama [18], Georgia [17], and Florida [19, 20]. Rather than true emigration, this range expansion is best explained by the increased use of various passive trapping techniques [14]. Meropetuber have been collected using Malaise traps, picric acid traps, European chafer traps, carbon dioxide traps, molasses traps, and glue traps [2, 12, 21], with the most effective being Malaise traps [22].

Little is known about the life history of M. tuber. Adults are nocturnal and attracted to light at night and spend daylight hours under logs and stones [1, 21]. They seem to be associated with moist deciduous woodlands near water [21, 23], although they are occasionally caught in dry grasslands far from any stream or creek [10]. Feeding preferences are unknown, although they may be attracted to carrion [2] similar to another mecopteran, Notiothauma redei McLachlan, 1877, which has been reported from vertebrate carrion [24]. Adults stridulate by rubbing the jugum of the forewing against the metanotum [25]. The larvae of all meropeids, including M. tuber, remain undescribed [26] and their discovery “is certainly the most exciting thing left to be done in the study of North American Mecoptera” [14].
The flight period of *M. tuber* lasts throughout the summer with some variation depending on latitude. They have been reported to occur in June through October in Connecticut [27], June through September in Maryland [28], July through September in Ohio [26], May through September in Alabama [18], and April through December in Florida [19, 20].

Few studies have reported *M. tuber* in significant numbers, but, in those that do, the sex ratio appears to be female biased. Scarbrough [30] collected 8 males and 18 females (1 male : 2.25 females) in two Malaise traps over a period of three years. Maier [27] collected 26 males and 43 females (1 male : 1.65 females) in a single Malaise trap over three years. Barrows and Flint [28], in six Malaise traps over the course of seven months, caught no males and 35 females. Johnson [26], in a single Malaise trap over two years, caught 61 males and 102 females (1 male : 1.67 females), the largest number of earwigflies yet reported from a single site. It is not known whether the sex ratio is truly skewed or if sampling bias is the cause.

Unlike life history, much is known about the morphology of *M. tuber*, with both internal and external anatomy of both sexes being well documented [31–34]. Males have elongated genital styli (= claspers) that are thought to be used in mating as in other Mecoptera, either holding the female during copulation, fighting rival males, or both [26]. A bimodal distribution in clasper size has been demonstrated for at least one population with differential mating strategies being suggested as a possible cause [26].

### 2. Materials and Methods

As part of a more extensive arthropod sampling project, five blocks were established at a 4 ha plot located at Steel Creek along the Buffalo National River in Arkansas (Figure 2). In each block, five pan traps (one of each color: blue, red, green, yellow, and white) were randomly arranged under a terrestrial Malaise trap (MegaView Science Co., Ltd., Taichung, Taiwan), which was placed in perceived flight paths. In addition, three Lindgren funnel traps (ChemTica Internacional, S.A., Heredia, Costa Rica) (one of each color: green, purple, and black) were suspended nonrandomly from large trees 4–10 meters from the ground in the lower canopy.
Table 1: Total number of *Meropetuber* collected per trap type per block, with subtotals of trap type and block.

| Trap type          | Block     | Number of females caught | Number of males caught | Total caught |
|--------------------|-----------|--------------------------|------------------------|-------------|
| Malaise trap       | 1         | 0                        | 0                      | 0           |
| Pan trap (purple)  | 1         | 1                        | 1                      | 2           |
| Pan trap (yellow)  | 1         | 0                        | 0                      | 1           |
| Pan trap (blue)    | 1         | 0                        | 0                      | 0           |
| Pan trap (white)   | 1         | 1                        | 0                      | 1           |
| Pan trap (red)     | 1         | 0                        | 0                      | 0           |
| Malaise trap       | 2         | 0                        | 1                      | 1           |
| Pan trap (purple)  | 2         | 2                        | 0                      | 2           |
| Pan trap (yellow)  | 2         | 1                        | 0                      | 1           |
| Pan trap (blue)    | 2         | 2                        | 1                      | 3           |
| Pan trap (white)   | 2         | 2                        | 1                      | 3           |
| Pan trap (red)     | 2         | 4                        | 1                      | 5           |
| Malaise trap       | 3         | 0                        | 0                      | 0           |
| Pan trap (purple)  | 3         | 2                        | 0                      | 2           |
| Pan trap (yellow)  | 3         | 0                        | 0                      | 0           |
| Pan trap (blue)    | 3         | 0                        | 1                      | 1           |
| Pan trap (white)   | 3         | 1                        | 0                      | 1           |
| Pan trap (red)     | 3         | 1                        | 1                      | 2           |
| Malaise trap       | 4         | 0                        | 0                      | 0           |
| Pan trap (purple)  | 4         | 5                        | 3                      | 8           |
| Pan trap (yellow)  | 4         | 8                        | 2                      | 10          |
| Pan trap (blue)    | 4         | 7                        | 3                      | 10          |
| Pan trap (white)   | 4         | 2                        | 2                      | 4           |
| Pan trap (red)     | 4         | 2                        | 1                      | 3           |
| Malaise trap       | 5         | 1                        | 0                      | 1           |
| Pan trap (purple)  | 5         | 2                        | 3                      | 5           |
| Pan trap (yellow)  | 5         | 5                        | 1                      | 6           |
| Pan trap (blue)    | 5         | 2                        | 1                      | 3           |
| Pan trap (white)   | 5         | 4                        | 0                      | 4           |
| Pan trap (red)     | 5         | 2                        | 1                      | 3           |
| Trap subtotal      |           |                          |                        |             |
| Malaise trap       |           | 1                        | 1                      | 2           |
| Pan trap (purple)  |           | 12                       | 7                      | 19          |
| Pan trap (yellow)  |           | 15                       | 3                      | 18          |
| Pan trap (blue)    |           | 11                       | 6                      | 17          |
| Pan trap (white)   |           | 10                       | 3                      | 13          |
| Pan trap (red)     |           | 9                        | 4                      | 13          |
| Block subtotal     |           |                          |                        |             |
| —                  | 1         | 3                        | 1                      | 4           |
| —                  | 2         | 11                       | 4                      | 15          |
| —                  | 3         | 4                        | 2                      | 6           |
| —                  | 4         | 24                       | 11                     | 35          |
| —                  | 5         | 16                       | 6                      | 22          |
| Total              |           | 58                       | 24                     | 82          |
Table 2: Minimum, maximum, and mean measurements of various body parts and results of Shapiro-Wilk goodness-of-fit tests on the same.

P < 0.05 is considered significant. Significant values are indicated by an asterisk (*).

| Measurement          | Sex    | Minimum (mm) | Maximum (mm) | Mean (mm) | SD (mm) | W     | Prob. < W |
|----------------------|--------|--------------|--------------|-----------|---------|-------|-----------|
| Head width           | Female | 0.8          | 1.32         | 1.1       | 0.12    | 0.97  | 0.247     |
| Pronotum width       | Female | 1.06         | 1.69         | 1.41      | 0.16    | 0.97  | 0.396     |
| Forewing length      | Female | 8.86         | 13.28        | 11.66     | 0.9     | 0.98  | 0.337     |
| Abdomen length       | Female | 4.1          | 8.96         | 6.44      | 1.3     | 0.97  | 0.153     |
| Head width           | Male   | 0.77         | 1.39         | 1.11      | 0.15    | 0.96  | 0.534     |
| Pronotum width       | Male   | 0.95         | 1.63         | 1.31      | 0.17    | 0.97  | 0.756     |
| Forewing length      | Male   | 9.52         | 13.39        | 11.82     | 1.04    | 0.971 | 0.695     |
| Abdomen length       | Male   | 4.07         | 7.61         | 5.8       | 0.78    | 0.95  | 0.206     |
| Basistylus length    | Male   | 2.21         | 5.09         | 4.05      | 0.77    | 0.95  | 0.265     |
| Dististylus length   | Male   | 1.47         | 2.91         | 2.34      | 0.43    | 0.91  | 0.036*    |
| Clasper total length | Male   | 3.68         | 7.97         | 6.38      | 1.17    | 0.94  | 0.138     |

Four blocks contained a SLAM (Sea, Land, and Air Malaise, MegaView Science Co., Ltd., Taichung, Taiwan) trap (with top and bottom collectors counted as separate traps). Three blocks contained pitfall trap sets placed every five meters along a transect centered on a Malaise trap. Two of these blocks contained eight pitfall trap sets and one block contained a single set.

Pitfall traps were modified from a design proposed by Nordlander [35], which Lemieux and Lindgren [36] demonstrated that it catches carabids in similar numbers but is more efficient at excluding small vertebrate bycatch. Rather than cutting circular entrances in the sides of pitfall traps, we cut three slots, 2 cm tall × 9.3 cm wide and 2 cm under the rim in the sides of plastic soup containers leaving three 1.5 cm posts, equidistant apart, resulting in a 28 cm collecting surface. Diameter at the base of slots is approximately 10.5 cm and the cups are 10.5 cm deep below these slots, resulting in a collecting volume of 2,988 cm³. This allowed the matching lid to be secured to the cup instead of using a separate cover. A single cup was placed on either side of a 30.5 cm × 15.5 cm aluminum fence to make a pitfall trap set and the catch from both cups was combined and treated as a single sample.

Propylene glycol (Peak RV & Marine Antifreeze) (Old World Industries, LLC, Northbrook, IL) was used as a preservative in all trap types. Traps were placed on March 13, 2013, taken down on December 4, 2013, and collected approximately every two weeks. Trap catch was sieved in the field and stored in Whirl-Pak bags (Nasco, Fort Atkinson, WI) in 90% ethanol until sorting. After sorting, specimens were stored individually in 2 mL microtubes (VWR International, LLC, Randor, PA) in 70% ethanol. Voucher specimens have been submitted to the University of Arkansas Arthropod Museum.

Head width, pronotum width, wing length, and abdomen length were measured for both sexes. The lengths of the basistylus and dististylus (Figure 3) were measured on the right side of males and combined to measure total clasper length.

Measurements were made in the following manner: photographs of a millimeter ruler and dorsal and ventral aspect of each specimen were taken through the eyepiece of a Leica MZ 16 stereomicroscope with the camera on an HTC Droid Incredible 4 G LTE; zoom was not adjusted between photographs to ensure they were to the same scale. All photographs were exported onto a desktop computer, opened in ImageJ [37], and measurements were taken by tracing the structures. Measurements were recorded in Microsoft Excel (Redmond, WA).

Shapiro-Wilk goodness-of-fit tests (α = 0.05) were performed in JMP (SAS Institute, Cary, NC) to test normality of previously described measurements. An F-test for significance was performed by creating a generalized linear model (GLM) with a Gaussian distribution (α = 0.05). Count data were not normally distributed and required transformation. Because the data contained many zeroes, one was added to each count and before a natural log transformation. Because five pan traps were placed with a single Malaise trap, trap types could not be compared due to extremely skewed sample sizes. Instead, Malaise traps were considered a “color” in analyses and tested against each pan trap color. This simultaneously allowed for comparisons among variables of equal sample sizes for both trap type and pan color.

3. Results and Conclusions

All totaled eighty-two earwigflies—24 males and 58 females (1 male : 2.42 females)—were collected (Table 1). This female-biased collection is in line with previous studies [26–28, 30]. Earwigflies were first collected in late June, with the largest collection occurring in July, followed by low, but consistent, numbers caught until late October (Figure 4). The beginning and end of the flight period were consistent with other areas at similar latitudes [19, 26–28].

Only a single body measurement, the dististylus, differed significantly from a normal distribution, but not in a bimodal manner (Table 2). These results are in contrast to previous studies, which found a bimodal distribution in the size of male basistyli, dististyli, and total clasper length [26]. As the use of the claspers is unknown, the significance of this is also unknown.

Earwigflies were not caught in SLAM traps, Lindgren funnel traps, or pitfall trap sets; therefore, these traps were excluded from analyses. Significantly fewer M. tuber were caught in Malaise traps compared to pan traps (t = –2.455,
d.f. = 1, \( P = 0.0145 \)), although pan trap colors were
not significantly different from each other. This is the first
report of earwigflies being collected in pan traps; however,
previous studies which reported large collections of *M. tuber*
traditionally used Malaise traps alone. It should be noted
that, because pan traps were directly under Malaise traps,
it is unknown whether those pan trap-collected individuals
would have been captured in the Malaise trap collecting head,
had pan traps not been present.

Significantly more earwigflies were caught in blocks 4
\( (t = 4.307, \text{d.f.} = 1, P = 0.00002) \) and 5 \( (t = 2.479, \text{d.f.} = 1,
P = 0.0136) \) than in blocks 1, 2, and 3. This suggests that trap
placement and microhabitat, even within a relatively small
area of a few hectares, are important factors when collecting
earwigflies. If earwigflies are specifically targeted, we suggest
placing multiple traps in an area of known occurrence in
order to maximize the microhabitats sampled and increase
the chance of collecting these enigmatic insects.

**Conflict of Interests**

The authors declare that there is no conflict of interests
regarding the publication of this paper.

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