The Technical and Performance Characteristics of a Low-Cost, Simply Constructed, Black Light Moth Trap

Peter J. T. White,1,2 Katharine Glover,3 Joel Stewart,3 and Amanda Rice3

1Department of Entomology, Michigan State University, 288 Farm Lane, Room 448, East Lansing, MI 48824-1115 (pwhite@msu.edu), 2Corresponding author, e-mail: pwhite@msu.edu, and 3Lyman Briggs College, Michigan State University, 919 East Shaw Lane, Room E-39, East Lansing, MI 48825-1107 (gloverka@msu.edu; stewa508@msu.edu; riceama2@msu.edu)

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Abstract

The universal mercury vapor black light trap is an effective device used for collecting moth specimens in a wide variety of habitats; yet, they can present challenges for researchers. The mercury vapor trap is often powered by a heavy automotive battery making it difficult to conduct extensive surveys in remote regions. The mercury vapor trap also carries a considerable financial cost per trap unit, making trapping challenging with low research budgets. Here, we describe the development and trapping properties of a lighter, simply constructed, and less expensive trap. The LED funnel trap consists of a funnel, soda bottles with plastic vanes, and is powered by rechargeable 9-V batteries. Two strips of low-wavelength LEDs are used as attractants. We tested the trapping parameters of this trap design compared to a standard mercury vapor trap over 10 trap nights in a suburban woodlot in the summer of 2015. The mercury vapor trap caught significantly more moth individuals than the LED trap (average of 78 vs 40 moths per trap night; \( P < 0.05 \)), and significantly more species than the LED trap (23 vs 15 per trap night; \( P < 0.05 \)); the mercury vapor trap caught a total of 104 macromoth species over the duration of the study, compared to a total of 87 by the LED trap. Despite the lower yields, the low cost of the LED trap (\(<$30\) ea.) makes it superior to the mercury vapor trap in cost-acquisition per moth species and per moth individual trapped. The LED trap may be a viable alternative to the standard mercury vapor trap, facilitating insect trapping in more diverse settings.

Key words: Lepidoptera, insect trap, moth, black light, LED

Mercury vapor black light funnel traps (MVTs) are one of the most common means for surveying night-flying insects. They have consistently caught a higher abundance and greater variety of insects than other standard methods (Muirhead-Thomson 1991). Their key feature is the low-wavelength light attractant, which lures a diversity of flying insects from the surrounding habitat. They are generally preferred to flight-intercept traps (which typically lack an attractant, e.g., Hill and Cermak 1997), bait and pheromone traps (which are typically species- or guild-specific, e.g., Furlong et al. 1995), and traps that incorporate sticky surfaces (which can damage specimens, making identification difficult, e.g., Bacon et al. 1976). The most common type of light trap has a funnel, vanes, a mercury vapor light source, and a collection container (Frost 1957). Night-flying insects fly toward the light source, strike the light, or a vane, and fall into the funnel trap below where they can be killed, or kept alive (as preferred by the investigator), until collected. This style of trap tends to yield high-quality, minimally damaged specimens, and large quantities of insects with relatively little sampling effort (Baker 1985, Beck and Linsenmair 2006). These traps are used for a variety of purposes, ranging from investigations in biodiversity, to pest monitoring, to taxonomic collections; they are used for surveying a wide range of insect taxa, including the Diptera, Homoptera, Hemiptera, Coleoptera, and Lepidoptera, among other groups (Baker 1985, Beck and Linsenmair 2006).

Despite their effectiveness, MVTs are not always optimal research tools because of their cost and because of the logistics required to deploy them. Biological equipment supply companies (e.g., BioQuip or LepTraps.com) sell MVTs for between $200 and $500 (including an automotive battery). In one of the earliest accounts of this type of trap, Frost (1957) estimated the materials cost of a MVT to be at around $130.* This, slightly more modest price tag, assumes that a research investigator has expertise to build a set of traps from sourced materials. Research projects using this style of trap often require multiple traps be deployed across a defined geographical range; this quickly raises the material cost of a research project into

* In his 1957 paper, Frost cites the materials cost of the trap as being $15.00. Once inflation is accounted for, this equates to approximately $130, in 2015.
the range of thousands-of-dollars. In an age of shrinking research budgets, this can be prohibitive.

A second problem with MVTs is the difficulty they present when surveying in remote regions. The MVT black light bulb is typically powered by a car- or motorcycle-battery, which can weigh up to 40 pounds (18 kg). Therefore, to set up a dozen traps (a reasonable number for a large-scale sampling effort) may require the transport of nearly a quarter ton of equipment. Furthermore, these batteries need to be recharged after two to three nights of use; a conventional car battery (i.e., 12 V and 40 Ah) will power a mercury vapor bulb for approximately three nights, depending on whether or not a timing device is used to shut off the light during the daytime. These challenges can make it very difficult to survey night-flying insects in remote regions and across rugged terrain.

In this article, we detail the construction, light properties, and capturing efficiency of a LED-based funnel trap (LFT). The use of LEDs in insect capturing is not itself novel; LEDs have been adapted for use in pest monitoring in recent years (Cohnstaedt et al. 2008, Duehl et al. 2011, Yanase et al. 2014, Zheng et al. 2014), but its application in Lepidoptera trapping has not been well explored. In lab settings, LEDs have shown promise as Lepidoptera attractants (Cho and Lee 2012, Kim and Lee 2014). This is the first project, to our knowledge, to test LED lights using a simply constructed light trap design, with the goal of surveying a local Lepidoptera assemblage. We deployed LED traps for 10 trap nights in the summer of 2015 in a suburban woodlot in southern Michigan. In this article, we present our data and compare the LFT to a standard 12 V MVT.

Materials and Methods

The LFT
We constructed a LFT using the same basic design as the MVT. The LFT consists of 1) a light source, 2) a power source, 3) a vane assembly, 4) a funnel assembly, and 5) final assembly (Fig. 1).

(1) Light source
A 5 m long waterproof LED ultraviolet black light “night fishing strip” was purchased for use in the LFTs. This type of strip is designed so that smaller strips of LEDs can be cut off the main strip without damaging the lights. As such, two 15 cm strips were cut and glued together (back-to-back) to create a bank of 18 LEDs, with nine facing one direction and nine facing the opposite direction (Fig. 1a). Each LED strip had a viewing angle of 120°, and a light wavelength of 395–405 nm. A total of thirty-two 15 cm strips could therefore, theoretically, be made from one 5 m strip; enough LEDs for 16 LFTs.

(2) Power source
Four 9 V batteries, connected in series, powered the LED light bank. These batteries were snapped together forming a “battery-pack,” and were connected to the lights using snap connectors (Fig. 1a). Prior to testing our LFT in the field, we ran our LED banks for more than 100 h using this 36 V power configuration (i.e., four 9 V batteries, connected in series) with no noticeable damage to the diodes or measurable change in light output. One side of the snap connector snapped onto the battery terminals, the other side was soldered to the lead of the light bank. In this way, four solder connections were used per LFT. Shrink tubing was used to cover the exposed solder around the battery terminals and light bank terminals.

(3) Vane assembly
LFT vane were made by cutting apart low-grade “dollar store” Tupperware-style containers. The containers measured 21.5 by 23.5 by 11 cm, allowing for three flat vanes to be made per trap, measuring approximately 10 cm by 16 cm, each. Translucent packaging tape and hot glue were used to secure the three plastic vanes evenly around a 500 ml soda bottle; the bottle is intended to hang with the cap end down (Fig. 1b). Translucent packaging tape was used to further secure the vanes. A hole was cut into the noncap end of the soda bottle through which the LED light banks were inserted. The connecting wires were then run out of the hole and connected to the 9 V battery-pack. The battery packs were taped with translucent packaging tape to the flat portion of the 500 ml bottle, covering the hole where the LED lights were inserted (Fig. 1b).

(4) Funnel assembly
A standard 56 by 71 cm piece of poster board was used to make the funnel of the trap. The funnel radius measured 34 cm at the top and 5 cm at the bottom. The top lip of the funnel was reinforced with packaging tape. A collecting bucket was made using the bottom half of an empty 2 liter soda bottle, attached to the funnel with adhesive Velcro strips. Pest strips (18.6% dichlorvos (2,2-dichlorovinyl dimethyl phosphate)) were used in the collecting buckets to kill moths that were collected in the trap (Fig. 1c).

(5) Final assembly
The vane assembly was connected to the funnel assembly using three pieces of twine. The funnel assembly hung 8–10 cm below the vane assembly. Additional holes were made in the 500 ml soda bottle so that the trap could be hung from a tree branch upon deployment (Fig. 1d). During testing, traps were hung approximately 1 m off the ground.

The MVT
We tested our LFTs against the performance and parameters of a BioQuip Inc. Universal Mercury Vapor Black Light trap, product 2851U and 2851A (i.e., the “MVT”). This trap kit includes a metal funnel, a five-gallon (18.95 liter) bucket with drain, three plastic vanes with vane connectors and a 12 W ‘U’ black light mercury vapor bulb. The MVT was powered by a 12 V, 14 Ah motorcycle battery. The mercury vapor bulb used in the MVT emits low wavelength light, typically peaking between 350 and 400 nm. A tripod-style was constructed to suspend the MVT approximately 1 m off the ground (Fig. 2).

Characterizing trap parameters
We quantified and compared the costs of the two trap types, along with their illumination properties. For a cost comparison, we summed the total parts cost for our LFT and compared it to the parts cost of the 12 W BioQuip 2851U/2851A trap. Cost comparison was calculated based on the total equipment and materials required to make 16 traps. Some equipment (e.g., battery charger, soldering gun, glue gun, etc.) can be used for many traps; calculating a per-trap cost therefore reflected this. The standard length of the black light LED strip that we were able to purchase was 5 m. A single LFT uses two 15 cm strips; a 5 m strip would therefore provide enough LEDs for 16.67 traps (hence the decision to calculate the cost based on 16 traps). We also calculated the cost of the Plexiglas Rigid Vanes 15 W black light trap available from Leptraps (Georgetown, KY) (http://www.leptraps.com); this trap is comparable to the Bio Quip (Rancho, Dominguez, CA) 2851 trap; it is included to provide a third trap for price comparison.
The illumination properties of the 12 W mercury vapor bulb were compared to that of the 18-light LED light bank. We measured the number of lumens per square meter (lux) that each light source emitted at 0, 0.1, 0.25, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0 m, using a Dr. Meter® Digital Illuminance Light Meter LX1330B. Although light traps are cited to have an attraction radius up to 30 m (Muirhead-Thomson 1991, Merckx and Slade 2014), we determined a priori that our light sources did not emit light greater than 0.1 lux (the minimum reading on our light meter) at a distance greater than 4.0 m. The wavelength of each light type was verified to be low-wavelength using an EISCO High Resolution Quantitative Spectroscope (Part Number PH101QA-HBAR).

Moth trapping: location and effort
Trapping was conducted in the Hudson Woodland, a 7.7 ha mixed-age woodlot, located at 42° 41'38" N, 84° 28'32" N. The woodland surrounded by agricultural fields, located on the southern rural portion Michigan State University’s campus, in East Lansing, MI, USA. The tree composition of the woodlot is primarily sugar maple (Acer saccharum Marshall), beech (Fagus grandifolia Ehrh.), red oak (Quercus rubra L.), and basswood (Tilia americana L.). The average annual temperature of East Lansing is 8.2°C, ranging from an average of ~4.5°C in winter months to an average of 20.3°C in summer months; the average annual rainfall is 785 mm.

Trapping was conducted on 10 nights in the summer of 2015: 26 and 30 June, 10, 15, 16, 23, 28, 29, 30, and 31 July. One MVT and one LFT were set in the woodlot on each of these days; their respective lights were not connected to a timer and thus ran from when the traps were set (~6 p.m.) until the morning of the following day (~9 a.m.) (Table 1). Moths were emptied from the traps after each trap night, and batteries were replaced with charged units. On two of the dates above, 30 June and 10 July, four traps were set in the

Fig. 1. The LED funnel trap (a) light source and power source, (b) vane assembly, (c) funnel assembly, and (d) final assembly.
woodlot, two MVTs and two LFTs. On trapping nights, traps were positioned at least 30 m away from the woodlot edge, and at least 100 m away from an adjacent trap.

Moth identification
Moths were separated from other insects and the by-catch was discarded. Macromoths were identified using available field guides and by comparing samples to the Lepidoptera collection available at the A.J. Cook Research Collection at Michigan State University (MSUC). Two guides for eastern North American moths were used: Field Guide to Moths of North Eastern North America (Beadle and Leckie 2012), and Les Papillons du Quebec (Handfield 2011). In instances where moth individuals could not be positively identified to species, they were compared to moth specimens housed in the MSUC, which contains over 163,000 specimens, many of which were obtained in the Great Lakes Region. Micromoth species were identified when possible, but this was not often the case for want of a comprehensive identification guide. Micromoths were nonetheless added to the total abundance catch for each trap on each night. Voucher specimens of each moth species were kept along with a digital photograph taken with a Canon EOS Rebel T3i camera fitted with a macro-lens. For the purposes of this work, individuals from the taxonomic families Apatelodidae, Drepanidae, Erebidae, Geometridae, Lasiocampidae, Noctuidae, Saturniidae, and Sphingidae were classified as macromoths; all other individuals were classified as micromoths.

Characterizing trap performance
Macromoth richness, macromoth abundance, and total moth abundance (including macro- and microlepidoptera) were calculated for each trap on each date. We define richness as the number of different species collected; we define abundance as the number of moth individuals collected. Differences in richness and abundance between the two trap types were tested with a two-tailed Mann–Whitney U-test. The conditional probability of detection (CPD; Nichols et al. 2000) was calculated for each trap type for any moth Fig. 2. A standard 12 V mercury vapor black light trap (MVT).
species where 10 or more individuals were captured. Finally, we calculated the acquisition cost of species for each trap type as the total number of species caught by a trap divided by the cost of the trap. Similarly, the acquisition cost of moth individuals (macro and micro) was calculated for each trap as the total number of moth individuals caught divided by the cost of the trap.

Results

Trap parameters: cost comparison

The material cost for the LFT was considerably cheaper than the BioQuip trap and the LepTraps trap. LFTs were $28.50 per unit, compared to $214.30 and $661.75 per unit for the BioQuip and LepTraps MVTs (respectively; Table 2). Based on these calculations, it would be over $2,900 cheaper to construct 16 LFTs than to construct 16 BioQuip MVTs; it would be over $10,500 cheaper to construct 16 LFTs compared to 16 LepTraps MVTs.

Trap parameters: illumination characteristics

The 12 W mercury vapor bulb peaked at 1,650 lux at a distance of 0.0 m, and diminished to 0.3 lux at 3.5 m. The LED light bank peaked at 490 lux at a distance of 0.0 m, and diminished to 0.13 lux at 3.0 m (Fig. 3). This corresponds to an average luminous flux of 46 lumens for the mercury vapor bulb and 23 lumens for the LED bank.

Trap performance: moth abundance and richness

Over 80 h of trapping, the MVT caught significantly more macromoth species than the LFT (Table 1; $t$-test, $t = 2.57, P = 0.019$) and more macromoth individuals than the LFT (Table 1, $t$-test, $t = 2.4, P = 0.027$). The difference in the number of micromoths captured by the two trap types was not significantly different (Table 1, $t$-test, $t = 1.86, P = 0.079$). Each trap type primarily collected individuals from the Erebidae, Geometridae, and Noctuidae families. The MVT collected a higher percentage of Geometridae whereas the LFT captured higher percentages of Erebidae and Noctuidae ($\chi^2 = 24.3, P < 0.0001$; Fig. 4).

Among these, there was a high degree of similarity in the most abundant species caught with each trap type (Table 4). *Pseudolestrotia carneola* was the most abundant species surveyed, yielding 23 and 25% of individuals caught with the MVT and LFT, respectively. The next most abundant species, *Remia factosalis* represented 11 and 12% of individuals caught with the MVT and LFT, respectively. The third most abundant species, *Eugonobapta nivosaria* represented 12% of individuals with the MVT, but only 2% of individuals with the LFT. Fourth, *Hypoprepia fucosa tricolor* represented 5 and 4% of individuals with the MVT and LFTs, respectively. The fifth most abundant species, *Riella propinqualis* represented 5% of moths caught with the MVT, but was not detected by the LFT.

Acquisition cost of moths

Given its cost and trapping performance, the LFT yielded one macromoth species per $0.33 spent, and one macromoth individual per $0.06 spent (Table 3). In contrast, the MVT yielded one macromoth species per $2.06 spent and one macromoth individual per $0.23 spent. Micromoth acquisition was also cheaper for the LFT trap ($0.04 per micromoth caught) compared to the MVT trap ($0.14 per micromoth caught).

Discussion

The LFT compared favorably to the MVT. Although the LFT did not catch as many moth species or as many moth individuals as the commercially available MVT, the LFT appears to be a more cost efficient unit. LFTs cost around $28 per unit whereas the MVTs cost around $214 per unit; the LFT therefore caught more moth species and moth individuals per dollar spent on moth trap equipment (Table 3). Similarly, the MVT had a higher conditional probability of moth detection than the LFT (0.45 vs 0.29), however, this has to be evaluated in context; the financial cost of an MVT cost is more than seven times that of an LFT. Of the 135 species caught in our target woodlot, only 56 were caught by both trap types; the MVT

| Date       | Hours of darkness | Average nighttime temp (°C) | Hours of moonlight | % Moon illumination | Macro richness per trap | Macro abundance per trap | Micro abundance per trap |
|------------|-------------------|-----------------------------|--------------------|---------------------|------------------------|-------------------------|--------------------------|
|            | MVT               | LFT                         | MVT                | LFT                 | MVT                    | LFT                     | MVT                      |
| 26 June    | 7.5               | 15.1                        | 4.5                | 61%                 | 29                     | 10                      | 87                       | 28                       |
| 30 June    | 7.6               | 15.3                        | 6.0                | 97%                 | 21                     | 12                      | 58                       | 22                       |
| 10 July    | 7.8               | 13.8                        | 3.5                | 41%                 | 23                     | 14                      | 76                       | 30                       |
| 15 July    | 7.9               | 16.5                        | 0.0                | 0%                  | 10                     | 13                      | 19                       | 35                       |
| 16 July    | 7.9               | 12.2                        | 0.0                | 0%                  | 26                     | 19                      | 60                       | 41                       |
| 23 July    | 8.1               | 14.1                        | 2.3                | 45%                 | 19                     | 18                      | 97                       | 63                       |
| 28 July    | 8.3               | 17.8                        | 6.0                | 90%                 | 36                     | 14                      | 155                      | 22                       |
| 29 July    | 8.3               | 19.9                        | 7.0                | 96%                 | 10                     | 23                      | 16                       | 58                       |
| 30 July    | 8.4               | 18.8                        | 8.1                | 99%                 | 30                     | 19                      | 128                      | 95                       |
| 31 July    | 8.4               | 18.7                        | 8.4                | 100%                | 28                     | 14                      | 113                      | 31                       |
| Average    | 8.0               | 16.2                        | 4.6                | 63%                 | 23.2                   | 15.6                    | 80.9                     | 42.5                     |
|            | MVT               | LFT                         | MVT                | LFT                 | MVT                    | LFT                     | MVT                      |

There was a significant difference in average macromoth richness captured by the two traps ($t$-test, $t = 2.57, P = 0.019$) and in average macro abundance captured by the two traps ($t$-test, $t = 2.41, P = 0.027$). The difference in the micromoth yield of the two traps was not statistically significant ($t$-test, $t = 1.86, P = 0.079$).

$^a$Two traps of each type were set out on this night. Catch metrics on these dates are therefore the average of two traps.
caught a higher percentage of Erebidae and Noctuidae individuals whereas the LFT caught a higher percentage of Geometridae individuals (Fig. 4). Each trap type therefore caught a unique assemblage of Lepidoptera. There was also considerable variation in the abundance and richness caught each night. For example, the MVT caught between 16 and 155 moth individuals each night whereas LFT caught to between 22 and 95 moth individuals each night (Table 1). Light trap yield can be affected by moonlight, ambient temperature

Table 2. Cost comparison of (A) LFTs and (B and C) two styles of popular, commercially available MVTs

| Trap Type | Unit cost | Units required for 16 traps | Cost for 16 traps |
|-----------|-----------|-----------------------------|-------------------|
| (A) LEDF trap | | | |
| 1 liter soda bottles | $1.00 | 16 | $16.00 |
| 500 ml soda or water bottles | $0.75 | 16 | $12.00 |
| Poster board | $0.69 | 16 | $11.04 |
| Twine (100 yards) | $2.00 | 1 | $2.00 |
| LED black light strip (5 m) | $25.00 | 1 | $25.00 |
| Batteries (NiMH, ~250 mAh, rechargeable) | $3.75 | 64 | $240.00 |
| 9 V NiMH battery charger (4 bays) | $15.00 | 4 | $60.00 |
| Soldering gun/wand | $15.00 | 1 | $15.00 |
| Solder | $7.00 | 1 | $7.00 |
| 9 V snap caps | $0.50 | 32 | $16.00 |
| Wire Shrink Tubing 150 pc Kit | $10.00 | 1 | $10.00 |
| Tupperware for vanes | $1.00 | 16 | $16.00 |
| Velcro (3 m strip) | $15.00 | 1 | $15.00 |
| Hot glue gun | $3.00 | 1 | $3.00 |
| Hot glue sticks | $7.00 | 1 | $7.00 |
| Roll of packaging tape | $1.00 | 1 | $1.00 |
| Total for 16 traps | $456.04 | | |
| Estimated construction time per trap | 45 min | | |
| Cost per trap | $28.50 | | |
| (B) BioQuip 281SU/A MVT 12 W Trap | | | |
| 2851U Kit (Light, Vanes, Ballast) | $88.10 | 16 | $1,409.60 |
| 2851A Kit (Funnel, Lid, Drain, Cord) | $71.45 | 16 | $1,143.20 |
| Automotive battery (12 V, 14 Ah) | $40.00 | 16 | $640.00 |
| Battery charger (12 V, 4-bank) | $140.00 | 1 | $140.00 |
| Wood and fixtures for stand | $6.00 | 16 | $96.00 |
| Total for 16 traps | $3,428.80 | | |
| Estimated construction time per trap* | 30 min | | |
| Cost per trap | $214.30 | | |
| (C) LepTraps MVT 15 W Trap | | | |
| 15 W, 12 V, Plexiglas Rigid Vane Trap | $429.00 | 16 | $6,864.00 |
| Automotive battery (12 V, 18 Ah) | $35.00 | 16 | $560.00 |
| Battery charger (12 V, 4-bank) | $140.00 | 1 | $140.00 |
| 24* stand | $189.00 | 16 | $3,024.00 |
| Total for 16 traps | $10,588.00 | | |
| Cost per trap | $661.75 | | |

*This estimate includes the time required to build a suitable stand, like the one pictured in Fig. 2.

Table 3. Moth capturing performance comparison of the MVT and the LFT

| Trap type | MVT | LFT |
|-----------|-----|-----|
| Cost per trap | $214.30 | $28.50 |
| Macromoth richness | 104 | 87 |
| Cost of acquisition per species | $2.06 | $0.33 |
| Macromoth abundance | 941 | 481 |
| Cost of acquisition per macromoth | $0.23 | $0.06 |
| Micromoth abundance | 1,512 | 755 |
| Cost of acquisition per micromoth | $0.14 | $0.04 |
| No. of singleton species | 35 | 41 |
| No. of doubleton species | 19 | 15 |
| Shannon’s diversity | 4.98 | 4.75 |
| Chao1 diversity estimate ± SE | 136 ± 13 | 143 ± 36 |
| No. of species unique to trap type | 48 | 31 |
| Average CPD | 0.45 | 0.29 |

CPD, conditional probability of detection.

Fig. 3. Light properties of the MVT and LFT.
and wind speed (McGeachie 1989), however, we are unsure why these parameters might impact one light trap type more than another. An investigation of how environmental characteristics impact MVT versus LFT effectiveness will require a longer-term study.

Drawbacks of the LFT

Although the LFT presents itself as a viable alternative to the MVT, it has a few drawbacks that should be considered. First, it is not as durable as the commercially made MVTs. The LFT (as we have constructed it) may be more prone to damage from wind and rain, particularly with a funnel made from poster board. This can be solved by using durable 1 mm plastic/vinyl sheets for the funnel. It can also be noted that the short-term nature of this project means that the long-term durability of the LFT has not been tested compared to the MVT. For example, we have not tested how the LED light bank would hold up to one or more seasons of field work as compared to a mercury vapor bulb. Anecdotally, the mercury vapor bulbs that we use in our other Lepidoptera research projects rarely last more than 2 or 3 years; they are fragile and prone to cracking. While we expect the LED light bank to have a similar (or longer) lifespan, we do not have empirical data to inform this supposition. The LFT, being considerably lighter, may be more easily jostled about by wind gusts which may lead to trap damage; though it should be noted that insect trapping is typically best conducted on calm, rain-free nights. Second, the LFT requires an additional assembly burden, compared to the MVT. Basic soldering skills are required, along with a basic understanding of electrotechnics associated with 9V batteries. Our light strips withstood 36 V of direct current for more than 180 h (100 h testing in 80 h trapping). With light strips that are less robust, a different battery configuration may be desired (e.g., two separate, smaller battery packs to power each side of the LED light bank). Because of the variety of parts that are required for the LFT, it also takes more time to assemble (~45 min per trap) than a standard MVT that is typically shipped ready-to-assemble from the manufacturer (~30 min per MVT trap plus stand).

Applications of the LFT

The development of a low-cost insect trap may provide the research community with new opportunities for insect monitoring and biodiversity studies in remote areas. The LFT vane and funnel assemblies can be easily set up in the field and, ensemble, weighs less than 2 pounds. By comparison, a standard MVT, powered by a car battery, can weigh between 40 and 50 pounds (18–23 kg), depending on the battery. As climate change pushes species northward, there remains a strong interest to survey remote northern areas within the boreal forests and tundra of the Palearctic and Nearctic (Jepsen et al. 2013, Hunter et al. 2014, Kozlov et al. 2015, Vallières et al. 2015).
The LFT may provide additional advantages in instances where a trap is damaged due to unexpected severe weather, or wildlife animals; all of the LFT components are cheap and simple to repair or replace. Finally, this trap can be easily adapted to use longer wavelengths of light (simply by using a different color LED light strip); longer wavelengths may be optimal depending on the species or taxonomic group of interest (Goff and Nault 1984, Nabli et al. 1999, van Langevelde et al. 2011, Somers-Yeates et al. 2013).

A second application of the LFT is that of insect monitoring by amateur Lepidopterists. Insect collection of Lepidoptera has historically tended to gravitate towards the collection of colorful butterflies instead of their cryptic and sometimes drab cousins, the moths. Citizen scientists have made significant contributions to Lepidopteran ecology in the past (Swengel 1990, Kocher and Williams 2000, Bhattacharjee 2005, Carlson et al. 2012), though concern has been raised about a decline in public participation (Hopkins and Freckleton 2002).

Finally, a low-cost and effective LED-style funnel trap may facilitate Lepidoptera research within the education-sphere where there has been a call for the incorporation of research tools, providing students an opportunity to “learn science by doing science” (Krajcik et al. 1998, Krajcik and Blumenfeld 2006). This educational approach has suggested for many more decades (Schwab 1960, Krajcik et al. 1994, Blumenfeld et al. 2000), but seems to have gained only moderate traction in K-12 education settings. In higher education, some institutions have had more success implementing this type of educational approach, designing lab courses to focus on collecting authentic data and exploring genuine scientific questions, though some note that this approach is probably more the exception that the rule (Healey and Jenkins 2009). Cost-effective insect traps that survey a wide variety of insects may provide a pathway for this type of learning. With the LFTs, students can be engaged in nearly every aspect of the scientific venture, from proposing authentic scientific questions, to constructing traps, to collecting and analyzing data. While we have a general sense of the impacts of human disturbance (and urbanization) on natural Lepidoptera communities (Rice and White 2015), there are many unanswered context-specific questions that students can focus on. For example: How do moth communities differ in the inner-city compared to the suburbs? How does proximity and density of artificial light sources effect moth trap efficiency? How does the diversity and composition of immediate host plants impact site-specific moth richness and abundance? How does moth richness and abundance scale with human population density? The answers to these (and other) questions may vary by city and by region, depending on the site-specific parameters and the overarching ecological communities. In this way, student-turned-into-citizen-scientists, can be valuable participants in the scientific enterprise.

Undeniably, the MVT is superior to the LFT as we have constructed it; if money and transportability are not limiting to research, the traditional MVT trap will yield a more abundant, and speciose Lepidoptera assemblage. However, when cost and transportability are taken into account, the LFT provides an effective alternative for surveying the night-flying Lepidoptera assemblage.

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