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ANIMAL SCIENCE

The Collapsible Light Trap: a portable Pennsylvania Light Trap for collecting aquatic insects

JORGE LUIZ NESSIMIAN, ALLAN PAULO M. SANTOS, BRUNNO HENRIQUE L. SAMPAIO, LEANDRO L. DUMAS, ANA MARIA PES & NELSON FERREIRA-JR.

Abstract: A Collapsible Light Trap (CLT) for collecting insects, particularly aquatic insects, is described here. CLT is a modified Pennsylvania Light Trap with the advantage of being collapsible and lightweight to be carried in a small backpack and very easy to set up in the field. CLT is equipped with LED light strip wrapped around a PVC tube and can be connected to a regular 12 V / 7 Ah battery, running for more than 48 uninterrupted hours. Complete CLT weighs 0.8-1.0 kg, depending on the metal used, and the battery weighs around 2 kg, being easily transportable to more remote collecting areas. Over the years, CLTs have been used for collecting and describing the diversity of aquatic insects from Brazil, particularly caddisflies. Depending on the locality, only one trap for one night can collect over a thousand insect specimens and more than 200 individuals of caddisflies.

Key words: Adapted Pennsylvania, aquatic insects, field trip, insect survey, entomological collection.

INTRODUCTION

Aquatic insects include those insects with one or more life stages associated with aquatic habitats, especially freshwater bodies such as wetlands, swamps, ponds, lakes, rivers, and streams (Merritt & Cummins 1996). Currently, about 100,000 species are distributed in at least 12 extant insect orders, but they may result from more than 50 distinct invasions to aquatic habitats by terrestrial groups (Dijkstra et al. 2014). Five insect orders are primarily aquatic: Ephemeroptera (mayflies), Megaloptera (dobsonflies and alderflies), Odonata (dragonflies and damselflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), comprising together more than 27,000 species (Dijkstra et al. 2014). However, other orders such as Hemiptera (bugs; 4,800 aquatic species), Coleoptera (beetles; 16,600 species), and Diptera (true flies; 51,200 species) are also very abundant and diverse in freshwater habitats (Polhemus & Polhemus 2008, Morse et al. 2019). The taxonomic knowledge on aquatic insects is relatively poor, especially in the Neotropics, despite that they are more threatened when compared with terrestrial insects (Sánchez-Bayo & Wyckhuys 2019).

A variety of techniques are employed to collect insects, including the aquatic taxa, based on active or passive collecting, with focus on a particular habitat and taxon (e.g., Shimabukuro et al. 2015) or with a broader taxonomic perspective (e.g., Russo et al. 2011). Except for Odonata, most aquatic insects are crepuscular or nocturnal in adult stage, being usually attracted by light, even those in which the adults remain in the aquatic environment such as Coleoptera and Hemiptera. For this reason, some common techniques to collect these insects include: (1) the light sheet, with mercury vapor bulb or fluorescent tubes; (2) the Light Pan Trap (Calor & Mariano 2012, Pereira et al. 2021); (3) the traditional Pennsylvania Insect Light Trap (Frost 1957); and (4) the Center for Disease Control and Prevention Light Trap (CDC-LT), typically used for catching mosquitoes (Sudia & Chamberlain 1962).

Over the years, the team of the Lab of Entomology of Universidade Federal do Rio de Janeiro (LabENT/UFRJ) has been working to improve methods for collecting aquatic insects, with especial attention to light trapping to collect adults. In the early 2000's, the focus was to survey aquatic insects in remote mountainous areas in Southeastern Brazil, accessible only by long trails and with no electric source nearby. Then, in addition to the efficacy, the trap should be easy to transport, being compact and lightweight. Based on the traditional model of a Pennsylvania Insect Light Trap (Frost 1957), we made modifications using inexpensive material to make the trap collapsible, robust, and easy to carry in a backpack along hiking trails. The Collapsible Light Trap (CLT) described here is the current model, a result of improvements based on years of collecting aquatic insects in South America. Currently, this trap is widely used by Brazilian entomologists and after all these years, we formally describe the CLT here.

MATERIALS AND METHODS

Framework design and material

The main structure of the trap consists of a flat circular top and a bottom funnel, both with rigid internal support connected by four vertical baffles (Figures 1, 2, 3a-3b). Each internal support consists of a metallic circle (~34.5 cm

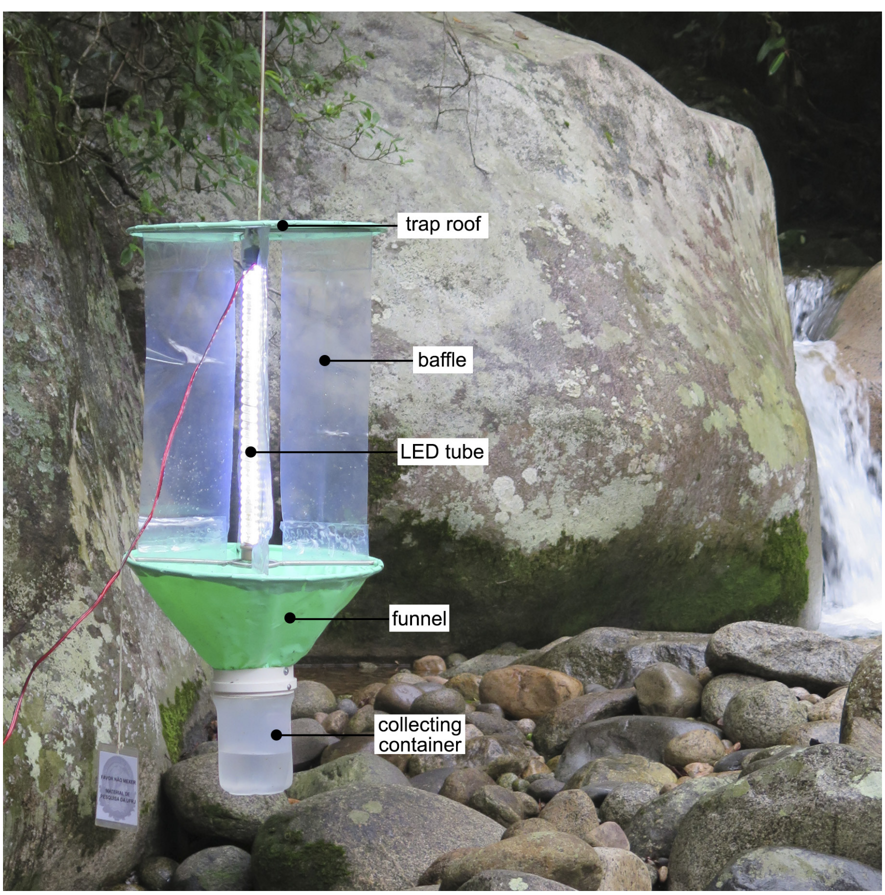

Figure 1. Collapsible Light Trap (CLT) set up and turned on near Rio Soberbo, Guapimirim municipality, Rio de Janeiro State, Brazil. Main parts of the trap are indicated.

in diameter) with four internal radii forming a cross, adding resistance (Figures 1, 2a-2b). The bottom support was modified to have a small concentric circle (~7.0 cm in diameter) in its structure to accommodate the light tube (Figure 2b). These metallic supports represent most of the trap weight. Steel rods (6.3 mm in diameter) or brass rods (6.7 mm in diameter) were originally used, in both cases with metal welding. Alternatively, to obtain a slighter and cheapest trap, hollow aluminum rods (10 mm in diameter) with rivets can be also used. The roof is made with a malleable, but resistant, PVC plastic sheet (0.2-0.3 mm thick) glued over the metallic support. The same plastic material is used to make the collapsible funnel at the bottom of the trap, covering the metallic support with a small concentric circle. The plastic used in the roof should be cut in a circle slightly larger than its respective metallic support (Figure 2c). For the funnel, the plastic is cut in a circular sector (31 cm in radius) with a smaller concentric circular sector (7 cm in radius) cut off (Figure 2d), resulting in a cone-shaped structure with an apical hole when glued over its respective internal support.

The vertical baffles (Figure 1) are made of transparent, malleable, PVC plastic sheets (0.5 mm thick, each 430 mm high, 115 mm wide), which were paired, following the four radii of top and bottom metallic supports. In the opening of the funnel, on the bottom, a PVC ring (100 mm in diameter, 20 mm high) is adhered with a pair of pins or screws on opposite sides

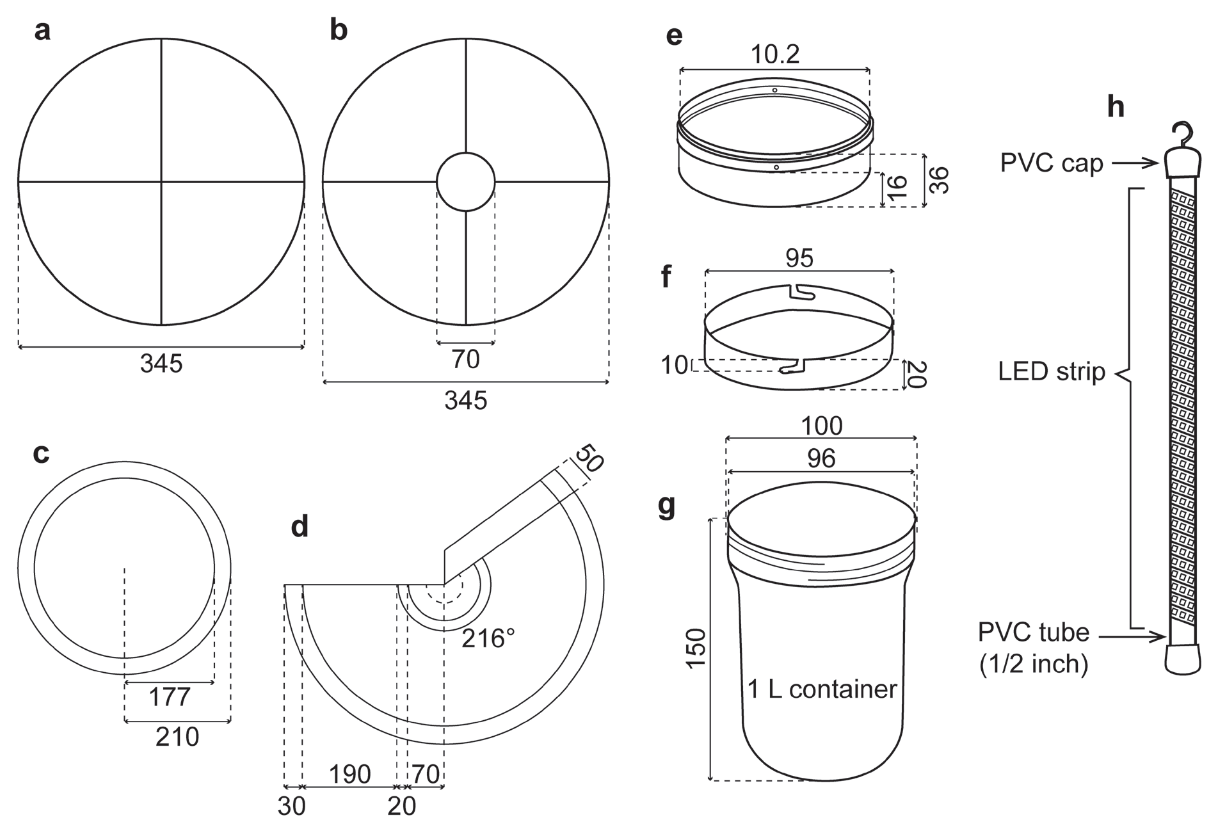

Figure 2. **Technical design of the Collapsible Light Trap (CLT). a: metallic support from roof top; b: metallic support from bottom funnel; c: plastic cover from roof top; d: plastic cover from bottom funnel; e: PVC ring glued to the inferior opening of the funnel; f: PVC ring glued to the opening of the collecting container; g: collecting container; h: LED tube, the LED strip has 2.5 meters outstretched. Main measures are indicated in millimeters.**

(Figures 2e and 3b). A one-liter vessel is used as the collecting container, which has an internal PVC ring for support and L-notches on opposite sides at the upper opening (Figures 1, 2f-2g and 3c). These notches allow attaching the container tightly to the funnel during the trap set up in the field (Figure 1). To assembly all plastic parts, commercial glue for flexible PVC is used, but other permanent glue can also be applied. A 5-10 m long braided multifiber polyester rope (6 mm in diameter) was attached to the top metallic support, going through the top cover, allowing to hang the whole trap in a tree or any available support in the field.

Light tube and battery

The first version of the CLT was equipped with a 15 W fluorescent tube (white or UV lights) with a reactor supplied with a 12 V / 7 Ah battery. Although this configuration was functional and used for some years, two main disadvantages are: (1) the mercury contained in the tube is potentially harmful to the environment and to the collector himself if released in the field; and (2) the relatively high current draw, resulting in an approximate run time of only 6-8 hours. In this way, there is a need to put the traps into operation close to dusk or to use some system for automatic triggering. Then, the fluorescent tubes were replaced by the white LED light. The light tube using LED is made of a PVC tube (2 cm in diameter, 50 cm long) and 2.5 m of cold white LED strip (5050 SMD, ~ 0.2 W each LED, ~ 150 LEDs per tube). The LED strip was then wrapped on the PVC tube (Figures 1, 2h and 3d) and connected to regular wire (5 m long). Nowadays, there are several commercial models of LED lamps, including some tubular ones, but usually the number of LEDs in these lamps, and consequently the amount of light emitted, is reduced compared to a tube with LED strip

Figure 3. **Main parts of the Collapsible Light Trap (CLT). a: main structure, showing the internal metallic supports, both superior and inferior; b: caudal view of the main structure, showing the PVC ring at the opening of the funnel; c: 1 L collecting container; d: LED tube with wire and plug (Brazilian type); e: PVC tube (optional) adapted with a power socket, allowing to connect 8 D batteries in series, to use instead of using an UPS battery.**

wrapped around it. Currently, UV LED strips are also easy to obtain, and they can be used to build the light tube instead of the white LED.

The energy source chosen was a battery used in uninterruptible power supply (UPS) or similar (Figure 4a), with 12 V / 7 Ah and weighing around 2 kg. These batteries are rechargeable, easy to find, and relatively inexpensive (around US$ 15 in Brazil). Alternatively, in trips when recharging the battery is not possible, 8 alkaline D batteries (each 1.5 V) can be used in series, resulting in the same 12 V, with between 1.3-1.4 kg in total. Although only used sporadically, a much more lightweight alternative is the use of 8 alkaline AA batteries (each 1.5 V), with around 0.2 kg in total. A PVC tube can be easily adapted to accommodate the D batteries (Figure 3e) or, in a smaller version, the AA batteries.

A fully charged UPS battery holds the LED tube running for more than 48 hours uninterruptedly, but it is possible to observe a decrease in luminosity after a few hours. D batteries hold the LED tube with apparently higher luminosity longer than the UPS battery, but this option generates a high amount of waste, besides being expensive. With AA batteries, the LED tube remains running for at least 24 hours uninterruptedly, being also an option when using a rechargeable battery is not possible. In any case, to ensure a high luminosity of the LED tube at night, during trap operation, or to allow using a same trap for several nights in a row, a 12 V photo switch (Figure 4a) can be coupled between the energy source and the light, keeping the trap off during daylight.

Setting up in field

The complete set of the CLT (including the battery and around 300 mL ethanol) easily fits in a medium backpack, making easy to walk

Figure 4. **Collapsible Light Trap (CLT) in field. a: Items needed to set up the CLT (total weigh-4.8 kg/steel version, including the backpack) – (i) 35 L backpack to carry all items, (ii) main supports, (iii) 7 Ah 12 V battery, (iv) photo switch (optional) with wire connections, (v) collecting container, (vi) bottle with 300 ml 96% ethanol, (vii) LED light tube; b: CLT set up with tree trunk found near the stream, at Ipoema, Itabira Municipality, Minas Gerais State, Brazil; c: CLT set up at Teresópolis municipality, Rio de Janeiro State, Brazil; d: CLT after collecting night at Tijuca National Park, Rio de Janeiro municipality, Rio de Janeiro State, Brazil.**

in the field (Figure 4a). A hiking backpack (35 L capacity) with the complete set of the CLT weighs 4.3 kg (~9.3 lb) in the aluminum version and 4.8 kg (~10.5 lb) in the steel version. The photo switch, if available, will add only around 0.2 kg to the total weigh. To set the CLT up in the field is necessary to find a good support, for example a tree or a bridge close to the water (Figures 4b-4d). In areas with no trees available or with sparce vegetation, we easily set up the trap using tripods with bamboo sticks or other available plants (Figure 4b). The trap can be easily hanged by the string and the plastic can be stretched manually, if necessary. Then, the light tube can be placed between the baffles and can be connected to the battery (and to the photo switch, if available). Finally, the collecting container can be attached to the bottom of the funnel and filled with ethanol (Figure 1). A detachable expansion can be used to prevent rainwater from entering the collecting container, for example, with a rigid plastic or even with material available in the forest, as large leaves.

Selected surveys

Comparing the efficiency of the CLT with other light traps designed to catch insects is beyond the purpose of this paper. The traditional Pennsylvania Insect Light Trap has been long known for its efficiency (Frost 1957). White LED light has also been tested for attracting insects (Pawson & Bader 2014, Price & Baker 2016). Therefore, we only present here the general numbers of recent insect surveys performed by our team using the CLT. Since most of the authors in this paper were more interested in caddisflies, we also add here some numbers of Trichoptera families collected by CLT. The readers should have in mind that today the use of CLT has spread among aquatic insect researchers in Brazil and the list of published studies using this trap is very long (e.g., Dumas & Nessimian 2023, Henriques-Oliveira et al. 2019, Rocha et al. 2017, Santos et al. 2022).

Numbers presented here are from one field trip to four localities in Tijuca National Park, Rio de Janeiro, Brazil, in March 2022. CLTs were set up near streams or waterfalls in the afternoon (~3-4 pm) and dissembled in the next morning (~9-10 am). In addition, we also present numbers for caddisflies families and genera from six localities in Serra do Cipó mountain range, Minas Gerais, Brazil. Data from Serra do Cipó are from a broader inventory of caddisfly fauna in this mountain range, and the localities presented here were selected randomly, just to represent the collecting power of CLT.

RESULTS & DISCUSSION

A lightweight CLT was designed based on the traditional Pennsylvania Insect Light Trap (Frost 1957). The design and accessories described here allow collecting insects, particularly the aquatic taxa, during the whole night, even in more remote areas. Material used in the trap construction is easy to find and low cost. With respect to the trap framework, the metallic supports are the most expensive and harder to be constructed (using brass or steel rods), but even they can be manually produced (with aluminum rods, for example). In fact, CLT model described here is quite versatile and can be easily adapted for specific purposes or focal taxa. For example, it can be easily adapted as a “Luiz de Queiroz” trap (Silveira-Neto et al. 1976), replacing the collecting container with a nylon mesh bag, allowing to preserve the insects dry instead of in alcohol.

LED lights became increasingly popular, and now they replace fluorescent or incandescent bulbs in a variety of situations, including the insect light traps. Studies comparing UV LEDs to fluorescent light tube indicated a similar efficiency between both in attracting insects, while white LEDs were relatively ineffective (Green et al. 2012). More recently, white LED lights have been shown to be efficient in attracting insects and color temperature does not appear to influence this attraction (Pawson & Bader 2014, Price & Baker 2016). Attractivity of LED light seems to be generally higher and less selective than the mercury-vapor lamp for caddisfly species, which may be caused by the emitted shorter wavelength spectra by this alternative light source (Szanyi et al. 2022). In any case, LED strips with different emission spectra can be easily adapted in the CLT.

The use of LED to replace fluorescent lamp tubes greatly improved the CLT, allowing a much longer lamp operating time on the same battery. While a fluorescent tube usually drains a 7 Ah battery in between 6-8 hours, the LED tube takes more than 48 hours with the same battery. In this way, a single trap can be used for at least two nights in a row without needing attention to replace the battery, for example. After changing fluorescent tubes for LED tubes, we did not observe qualitative or quantitative changes in insects usually collected, but we did not compare the exact numbers. Since we started using CLT, many surveys have been carried out, and the diversity of aquatic insects explored is always high (e.g., Dumas & Nessimian 2012, Henriques-Oliveira et al. 2019, Takiya et al. 2016, Santos et al. 2022).

Total number of insects by order collected in four localities in the National Park of Tijuca, Rio de Janeiro, Brazil, is given in Table I. Number of individuals by families is also presented for Plecoptera and Trichoptera. Of course, dragonflies and damselflies are rarely collected by CLT, since they are mainly diurnal and not usually attracted by light traps. Some terrestrial insects probably also can avoid falling in the collecting container, for example, terrestrial hemipterans usually come in smaller numbers in the CLT, although some aquatic bugs can come in high numbers in the same trap.

CLTs placed in localities with high diversity and abundance of aquatic insects usually take a high number of specimens in only one night. In Serra do Cipó mountain range, for example, only one trap caught 247 caddisfly specimens, representing 8 families and 14 genera (Table II). Sometimes, most of the individuals collected are from only one species. It may be a coincidence of the collecting night and the day of more activity of those individuals, which may be related to some reproductive behavior. This is probably the case of *Marilia huamanticoae* Dumas & Nessimian, 2009 with more than a hundred individuals collected by only one CLT, as indicated by Santos et al. (2022). Also, under favorable conditions, several species of specific groups (e.g., *Mortoniella* [Glossosomatidae], *Smicridea* [Hydropsychidae], *Chimarra* [Philopotamidae] – G.A. Jardim, unpublished master's thesis; I.C. Rocha, unpublished master's thesis) can locally reach high densities.

Remote localities, such as streams at high altitudes, impose difficulties for collecting insects using some traditional techniques, such as white sheet light trap, which require an electrical power source. Although Malaise traps are also lightweight (although it is voluminous) and usually catch a lot of flying insects, they require staying in the collecting site for long periods (days or weeks at least). Of course, other techniques as active collecting with entomological nets or other traps, like sticky traps or pan traps can always be used. However, light trapping strategies have been shown the most effective in sampling insects, particularly the aquatic groups (Calor & Mariano 2012, Pereira et al. 2021).

Type localities for several caddisfly species in southeastern Brazil (e.g., *Antarctoecia*

Table I. Specimens sampled with the collapsible light trap in four localities in the Tijuca National Park, Rio de Janeiro, Brazil (Atlantic Forest biome). At each collecting point, one trap was set up for one night (March 30, 2022). PNT01: Rio Tijuca (22°57'21"S 43°16'51", el. 495 m); PNT04: Riacho Bom Retiro (22°56'49"S 43°17'32", el. 645 m); PNT05: Cachoeira das Almas (22°56'56"S 43°17'09"W, el. 533 m); PNT10: Rio das Almas (22°57'15"S 43°17'15"W, el. 495 m).

TAXON	PNT01	PNT04	PNT05	PNT10
Blattodea	0	1	0	0
Coleoptera	47	79	45	115
Dermaptera	0	0	1	0
Diptera	317	1,055	1,067	827
Ephemeroptera	28	7	41	78
Hemiptera	12	16	5	1
Hymenoptera	51	80	32	45
Lepidoptera	6	20	5	13
Neuroptera	0	1	0	2
Orthoptera	3	1	1	1
Plecoptera				
Gripopterygidae	0	2	9	3
Perlidae	10	0	8	6
Trichoptera				
Calamoceratidae	0	3	0	1
Ecnomidae	0	1	0	1
Helicopsychidae	0	0	0	1
Hydrobiosidae	0	0	1	0
Hydropsychidae	34	0	7	58
Hydroptilidae	1	0	2	0
Leptoceridae	2	0	1	1
Philopotamidae	2	6	2	6
Xiphocentronidae	0	0	4	0
TOTAL	513	1,272	1,231	1,159

brasiliensis Huamantinco & Nessimian, 2003; *Anastomoneura guahybae* Huamantinco & Nessimian, 2004; *Neoatriplectides desiderata* Dumas & Nessimian, 2008 – all of them collected by CLT) are far from urban areas, requiring hours (or days) of hiking, which makes it difficult to return to the site and remove samples of a Malaise Trap. The Light Pan Trap (Calor & Mariano 2012) is, of course, a good option, but using it on rainy nights or in areas where placing a pan is not easy (a high bridge or without flat areas, for example) is a challenge. The LED-based Funnel Trap, or LFT, described by White et al. (2016), a modified Pennsylvania trap like the CLT, could be another option, being lightweight and low cost. However, as indicated by the authors, LFT is relatively fragile and requires more time and experience for assembling it in field (White et al. 2016). The CLT overcome all these challenges, being durable, easy to set up in field and with affordable cost (Table III). Over the last two decades, the CLT allowed the collection, identification, and description of several aquatic insects by Brazilian researchers.

Table II. **Caddisfly specimens sampled with the collapsible light trap in six localities in the Cerrado biome, Minas Gerais, Brazil. At each collecting point, one trap was set up for one night. C02: Rio Mascates (19°24'31"S 43°34'35"W, el. 807 m); C06: Rio Cipó (19°20'39"S 43°36'55"W, el. 790 m); C29: Rio Bocaina (19°20'45"S 43°35'27"W, el. 800 m); C51: 1st order stream (19°35'16"S 43°26'36"W, el. 615 m); C53: Córrego do Macuco (19°35'10"S 43°27'15"W, el. 617 m); C62: Córrego do Capão da Mata (19°19'55"S 43°31'12"W, el. 1,042 m). Data from A.A. Alves, unpublished master's thesis.**

TAXON	C02 Nov/2018	C06 Jan/2021	C29 Jan/2021	C51 Dec/2019	C53 Dec/2019	C62 Jan/2021
Ecnomidae						
Austrotinodes	2	0	1	0	0	0
Glossosomatidae		43♀	17♀		1♀	0
Itauara	0	0	0	0	3	0
Mortoniella	0	2	2	0	0	0
Protoptila	0	0	0	1	0	0
Helicopsychidae						
Helicopsyche	1	0	0	0	0	8
Hydrobiosidae						
Atopsyche	0	0	0	0	3	0
Hydropsychidae						
Leptonema	0	0	0	0	1	1
Macronema	0		1	0	0	0
Smicridea	0	3	38	0	143	19
Hydroptilidae	5♀		115♀	19♀	27♀	
Betrichia	0	0	0	0	1	0
Neotrichia	0	0	0	0	0	2
Oxyethira	0	0	0	1	0	0
Rhyacopsyche	0	0	0	0	2	0
Leptoceridae						
Grumichella	0	0	0	0	1	0
Nectopsyche	0	20	0	0	21	0
Oecetis	0	2	0	0	0	0
Triplectides	0	7	0	0	6	1
Odontoceridae						
Marilia	0	1	0	0	3	0
Philopotamidae						
Chimarra	0	1	1	2	3	1
Polycentropodidae						
Cernotina	0	0	0	5	3	0
Cyrnellus	0	9	2	1	11	0
Nyctiophylax	0	0	0	0	18	2
Polyplectropus	0	30	13	0	0	3
TOTAL	8	118	190	29	247	37

Table III. Comparisons among the traditional Pennsylvania light trap, light pan traps, LED-based Funnel Trap, and the Collapsible Light Trap.

Trap	Approximate Cost (including battery)	Trap weight (except alcohol and battery)	Power source	Advantage	Disadvantage
Pennsylvania (Frost 1957)	US$ 150*	1.8 kg (Frost 1957)	Regular power source	High resistance	Too heavy Too large Urban electrical source
Light pan trap (Calor & Mariano 2012)	US$ 17	0.3-0.5 kg	UPS battery 2.1 kg	Easy to set up Easy to carry	Flat area to set up Only with no rain Alcohol evaporation (?)
LED-based Funnel Trap (White et al. 2016)	US$ 28.50**	> 1.0 kg (including power source)**	Four 9 V batteries**	Lightweight Low cost	Only with no rain Not durable Difficult to assemble
Collapsible Light Trap (here)	steel or brass versions US$ 60 aluminum version US$ 37	steel or brass versions 1.1 kg aluminum version 0.9 kg	UPS battery 2.1 kg 8 D batteries 1.3 kg 8 AA batteries 0.2 kg	Easy to set up Easy to carry Usable in rain	A support to hang

***Estimate by Frost (1957) as US$ 15, considering the inflation, the value would be around US$ 150 in 2023.**
****White et al. (2016).**

The CLT became the main method for collecting adult aquatic insects by the team of the Lab of Entomology (UFRJ), being complemented with other techniques. Since then, the CLT was used during the development of at least 10 master's theses and 12 doctoral theses. We continue trying to improve this and other traps and we hope that other entomological teams can use and adapt this technique to their own goals.

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JORGE LUIZ NESSIMIAN[1]
https://orcid.org/0000-0001-8795-2538

ALLAN PAULO M. SANTOS[2]
https://orcid.org/0000-0001-5567-0149

BRUNNO HENRIQUE L. SAMPAIO[1]
https://orcid.org/0009-0007-3807-6798

LEANDRO L. DUMAS[3,5]
https://orcid.org/0000-0002-6590-3388

ANA MARIA PES[4]
https://orcid.org/0000-0003-0901-5965

NELSON FERREIRA-JR[1]
https://orcid.org/0000-0002-5932-7695

[1]Universidade Federal do Rio de Janeiro (UFRJ), Instituto de Biologia, Departamento de Zoologia, Laboratório de Entomologia (LABENT), Av. Carlos Chagas Filho, 373, sala A1-107, 21941-902 Rio de Janeiro, RJ, Brazil

[2]Universidade Federal do Estado do Rio de Janeiro (UNIRIO), Instituto de Biociências, Departamento de Zoologia, Laboratório de Sistemática de Insetos (LabSIN), Av. Pasteur 458, sala 309A, Urca, 22290-240 Rio de Janeiro, RJ, Brazil

[3]Universidade Federal Rural do Rio de Janeiro (UFRRJ), Instituto de Ciências Biológicas e da Saúde, Departamento de Biologia Animal, Laboratório de Insetos Aquáticos (LABIA), Rodovia BR 465, Km 7, Zona Rural, ICBS, sala 22D, 23890-000 Seropédica, RJ, Brazil

[4]Programa Pós-Graduação em Entomologia (PPGENT), Instituto Nacional de Pesquisas da Amazônia (INPA), Coordenação de Biodiversidade (COBio), Laboratório de Citotaxonomia e Insetos Aquáticos (LACIA), Av. André Araújo 2936, Petrópolis, 69067-375 Manaus, AM, Brazil

[5]Instituto Oswaldo Cruz, Fundação Oswaldo Cruz, Laboratório de Entomologia, Av. Brasil, 4365, Pavilhão Mourisco, sala 214, Manguinhos, 21040-360 Rio de Janeiro, RJ, Brazil

Correspondence to: **Allan Paulo Moreira Santos**
E-mail: allanpms@gmail.com

Author contributions

JORGE LUIZ NESSIMIAN: conceived and designed preliminary versions of the trap, conceived and designed parts of the CLT, collected and analyzed the data, write, reviewed drafts of the paper, and approved the final draft. ALLAN PAULO M. SANTOS and BRUNNO HENRIQUE L. SAMPAIO: conceived and designed parts of the CLT, collected and analyzed the data, prepared the illustrations, write, reviewed drafts of the paper, and approved the final draft. LEANDRO L. DUMAS, ANA MARIA PES and NELSON FERREIRA-JR.: conceived and designed parts of the CLT, collected and analyzed the data, write, reviewed drafts of the paper, and approved the final draft.