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Urban ecology: comparison of the effectiveness of five traps commonly used to study the biodiversity of flying insects

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ABSTRACT In this paper, we compare five different types of traps currently used in biodiversity studies to collect flying insects. Our aim is to evaluate the potentials and the limits of these traps in the assessment of insect biodiversity. Hence, we compared the diversity of insects caught by a malaise trap, a yellow pan trap, a blue pan trap, a suction trap and a light trap in six different locations in Brussels. We showed that these traps caught nearly only insects: more than 98.3% of all collected organisms were insects. Only the blue pan trap caught, in higher proportions, other arthropods such as isopods or spiders. The Malaise trap was generally the most effective trap capturing the majority of Homoptera, Heteroptera, Psocoptera, Diptera, Trichoptera and Hymenoptera. The yellow pan trap was often the second most effective trap particularly for Hymenoptera, Diptera and Homoptera. Without surprise, the light trap caught nearly all Lepidoptera (Heterocera). Some combinations of two different traps were very effective. However, none of these combinations were the most effective for all families of insects. Moreover, the combination of the two most effective traps (Malaise and yellow pan traps) was not the best combination. We discuss about the effectiveness of traps and the usefulness of their association. Finally, we raise the particular case of urban environment which needs the use of discreet traps.

KEY WORDS Malaise trap; pan traps; suction trap; light trap; complementary traps; biodiversity.

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INTRODUCTION

Since the Earth summit in 1992, the conservation of nature has taken more and more importance in the world. The creation of an international day for biological diversity is a symbolic fact of the communication of the problem of the loss of biodiversity. At the same time, many actions were developed to fend off this trend. For example, the involvement to halt the loss of biodiversity by 2010 shows that more people feel concerned about the conservation of natural heritage (Delbaere, 2004; EEA, 2007).

However, it is often difficult to explain why biodiversity is important and why we should be bothered with conserving it. Moreover, conservation of biodiversity creates constraints for people who can not see immediate outcomes. Some new political decisions, aimed decreasing the discrepancy between the knowledge of scientists and general understanding of people, have been introduced (in France, scientific foundation for biodiversity was launched in 2008). It can be very difficult for a non-specialist to understand that in order to make a success of the big challenge to halt the loss of biodiversity by 2010, the first step of these studies includes the requirement to kill organisms. Indeed, to analyse biodiversity, scientists have to make inventories of organisms in each locality. For numerous classes of small animals (for example insects), the making of such inventories implies that organisms have to be killed. During such research, the killing of animals is generally not specific and is indiscriminate thus there is a risk that rare species may be destroyed. Moreover, the traps designed to kill insects could potentially kill other animals (Pendola & New, 2007). Fortunately, many species can be inventoried without killing (generally the vertebrates, and some insects like Orthoptera). However for the majority of insects, death is unavoidable during capture. Besides, insects are often used in ecological studies as indicators species of biodiversity (Duelli et al., 1999; Duelli & Obrist, 2003; EEA, 2007), of fragmentation or urbanisation of an environment (Kremen et al., 1993, Abensperg-Traun et al., 1996; Bolger et al., 2000; Nelson, 2007). Consequently, biodiversity studies are often confronted by this paradox: to study biodiversity in order to improve our knowledge, and thus to increase our abilities to protect and conserve it, specimens have to be killed. In the extension of this paradox, some papers asked for the development of ecological ethics or raised interesting ideas about the ethics of killing organisms for the purposes of scientific studies (Lockwood, 1987; Lockwood, 1988; Minteer & Collins, 2005a; Minteer & Collins, 2005b).

Most studies concerning biodiversity need not collect every species in a location. Indeed, researchers have developed several methods and strategies. In this respect, different methods are available to estimate species richness in an area: the use of a correlation with determination level (Andersen, 1995; Oliver & Beattie, 1996a; Oliver & Beattie, 1996b; Andersen, 1997), the use of indicator species (Rodriguez et al., 1998 but see McIntyre et al., 2001; Kotze & Samways, 1999; Osborn et al., 1999), the use of statistical methods to infer the species richness from a sample (Colwell & Coddington, 1994). However, if the aim is to take inventory of animals in a location then the observation and the capture of at least one organism of each species is necessary. Several ways are possible to limit the death of insects. One of the ways is the use of effective traps to limit the sampling frequencies. In this respect, some studies were carried out to evaluate the best trap design (Abensperg-Traun & Steven, 1995; Wang et al., 2001; Koivula et al., 2003; Pendola & New, 2007), the best number of necessary traps (Brose, 2002) or to compare effectiveness and the complementarities of different traps (Lewis, 1959; Obrist & Duelli, 1996; Duelli et al., 1999; Agosti et al., 2000; Campbell & Hanula, 2007). However, many of these studies focused on one or two species and were not dedicated to global biodiversity estimation (Brunner et al., 2007; Hossain et al., 2007; Hardwick & Harens, 2007; Magina et al., 2007; Wu et al., 2007; Blackmer et al., 2008). The studies aiming at studying trapping methods in biodiversity evaluation are marginal compared to the literature about biodiversity generally. In this paper, we seek to compare 5 traps commonly used in biodiversity studies to collect flying insects in order to evaluate their potential and their limits in the assessment of insect biodiversity. In this paper, a trap was considered as most effective when it captures more number of insects or number of families of insects. Hence, it is attempted to define the effectiveness of a trap as a function of their captures (abundance of insects) and not from an economic point of view.

MATERIAL AND METHODS

The locations of trapping

The study was carried out in 6 locations in Brussels. These sites were chosen according to their biological potential, it means their assumed probability to have a high biodiversity. Three categories of biological potential were defined as a function of the urban location of the site (if it is at the urban periphery or not), the management of the site (strong human impact or not) and the previous estimation and information given to us by the IBGE (Institut Bruxellois pour la Gestion de l'Environnement - the Brussels institute for the environmental management). Consequently, 2 locations were supposed to have a great biological potential and hence a high biodiversity (the Massart botanic Garden, and the Zavelenberg area), 2 locations, a mean biological potential (the Tenbosch park and an abandoned private garden at Simonis street) and 2 locations, a poor biological potential (the highly maintained garden of the Palais des academies and a very urban private garden at Berceau street).

It is apparent that these sites are not directly comparable. Indeed, the private gardens are very small compared with the urban parks. However, the aim of this study was to compare the effectiveness of different kinds of traps and not to compare biodiversity of different locations. Moreover, the use of different urban green spaces should allow the study to conclude about a potential generalisation of the results.

Traps

In each site studied, 5 different traps, designed to preferentially capture flying insects, were utilised and compared:

- A suction trap was used (Fig. 1) for 30 minutes in daylight (unfortunately, due to the noise of such a trap, we were not able to use it during the night). This trap consisted of a leaf blower/vacuum (PARTNER-BV24 / nominal air flow = 0.142m^3/s) directed toward the sky. A 2.5 metre high pipe (12 cm diameter) was adapted in order to increase the height of capture. A funnel with a collecting bottle was inserted into the pipe to allow the collection of insects.
- A Malaise trap was used for 24 hours. This was a classic 2 metre high Malaise trap (S&S entrap net company: http://www.geocities.com/ssentrap/).
- A light trap, put directly on the ground, for 7 hours during the night was utilised (Vermandel Entomologie Speciaalzaak: http://www.vermandel.com/). Attention was paid for the light trap so that it was not impaired by artificial lighting.
- 2 coloured pan traps (15x12x5cm) were utilised: one yellow and one blue were put directly on the ground in each site for 48 hours. In these pans, soapy water was used to kill insects.

This study was carried out during a hot, sunny week from 3 to 6 of September 2002. The nights were dark since the new moon was the 7th of September 2002.

Hence, each location was sampled once with every trap. On each site, traps were used simultaneously but with different durations of working. In this respect, it was possible to compare different traps with a particular methodology.

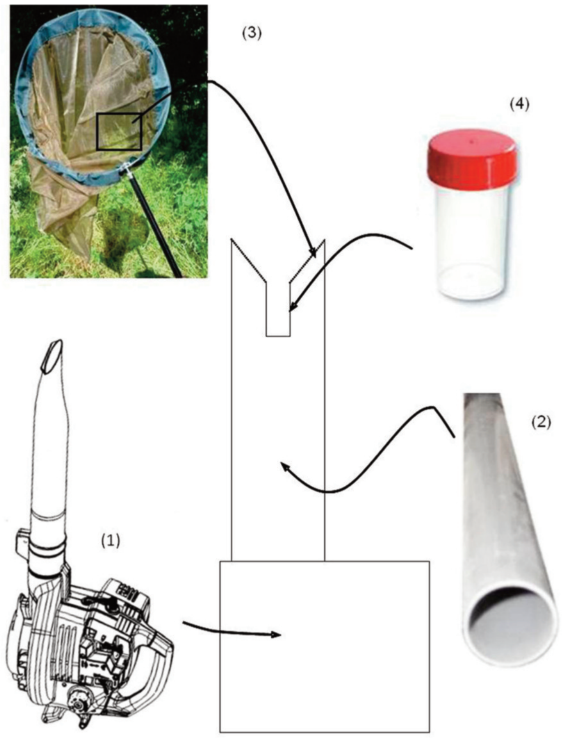

Figure 1. Suction trap. This trap consisted of a leaf blower/vacuum (1) (PARTNER-BV24) directed toward the sky. A 2.5 metre high pipe (2) was adapted (12cm diameter) in order to increase the height of capture. A funnel (made with a piece of net (3)) with a collecting bottle (4) was inserted into the pipe to allow the collection of insects.

RESULTS

Global analysis

First of all, the results demonstrate large differences in the effectiveness of the traps (Table 1). If the effectiveness of a trap is considered as a function of the number of organisms caught, it can be concluded that the Malaise trap is the most effective trap. Indeed, this trap caught twice more animals than the second most effective trap, the yellow pan trap (Table 1). Nevertheless, the durations of working of traps were different. Hence, if the number of capture per hour of working is observed, the suction trap is by far the most effective trap (Table 1).
Secondly, regardless of the type of trap used, more than 86% of organisms caught were insects (Table 1). Furthermore, most traps caught only insects, for example Malaise traps seem specific for insects (Table 1). However there are a higher number of

other arthropods (mainly isopods and spiders) in blue pan traps.

During the period of this study, 1746 specimens were collected. Among these it was possible to determine the families of 1597 specimens. Due to deterioration or difficulty of determination, the remaining 149 specimens were identified as 15 Lepidoptera, 64 Trichoptera, 2 Diptera, 5 Hymenoptera, 18 Heteroptera, 44 Homoptera and 1 totally undetermined. This corresponded to a 5 to 13% of the total insects collected in four traps. Only in the light trap, 23% of the insects collected were assigned to the order mainly due to the difficulty of determination of Lepidotera (Heterocera). Indeed, in this last trap, many slugs were caught and their mucus damaged the collected insects.

Henceforth, when the study refers to insect order, the number of specimens considered is 1745 and when the study refers to insect families, the number of specimens considered is 1597.

During the trapping period, 72 insect families were collected and determined (Table 2). The results show that the Malaise trap caught more than 76% of the families collected (Table 2). The second most effective trap is the yellow pan trap which caught 61.1% of the families which is not significantly different to the Malaise trap (Fisher exact test, p= 0.072). The other traps caught less than 50% of the families determined which is significantly different from the two other traps (Fisher exact test, p<0.02). Both traps, Malaise and yellow pan, caught together 87.5% of the families. According to our results, to capture 90% of the families the use of three complementary traps would be necessary: the combination Malaise + yellow pan + blue pan traps (90.3%) or the combination Malaise + yellow pan + suction traps (93.1%).

The Malaise trap also seemed to show more specificity in captures since 12.5% of the families were caught by this trap only (Table 2). In contrast, less than 5% of the families were caught in each other trap individually. However, due to the weak level of specificity of the traps, no significant statistical results was found (Fisher exact test, p>0.07). More precisely, Diptera (Stratiomyidae, Empididae, Tanipezidae, Pipunculidae, Lonchaeidae, Sciomyzidae, Tephritidae), Hymenoptera (Halictidae) and Psocoptera (Stenopsocidae) were only caught by the Malaise trap (Table 3).

Generally, the Malaise trap is the most effective for Homoptera, Heteroptera, Psocoptera, Diptera. Malaise and yellow pan traps are equally the most effective in the capture of Hymenoptera (Fig. 2). For Coleoptera and Lepidoptera, the light trap was the most effective. Due to the small number of captures, the statistical analyses was possible only for Homoptera, Hymenoptera, Diptera and Trichoptera. There is a high significant statistical difference between the traps for these 4 orders of insects (χ^2 test, p< 0.005 for each order).

In the captures, diversity in families was very small for Orthoptera, Thysanoptera and Homoptera with only one family determined and for Psocoptera with only 3 families. Hence, at the family level,

Type of traps	*Number of insects caught*	*Number of non-insects caught*	*Total number of insects and non-insects caught*	*Proportion of insects caught (%)*	*Average number of insects caught per hour*
Light trap	129	2	131	98.5	18.43
Blue pan	90	14	104	86.5	1.88
Yellow pan	350	5	355	98.6	7.29
Malaise trap	939	1	940	99.9	39.13
Suction trap	238	8	246	96.7	476
Total	1746	30	1776	98.3	

Table 1. Number of individuals caught in the different traps used.

	Light trap	Blue pan trap	Yellow pan trap	Malaise trap	Suction trap	Total number of families caught
Proportion of families caught by traps	26.4 %^{b}	40.3 %^{b}	61.1 %^{a}	76.4 %^{a}	36.1 %^{b}	72
Proportion of families caught by one trap only	4.2 %	2.8 %	2.8 %	12.5%	4.2 %	72

Table 2. Specificity of each trap and effectiveness of traps that means proportion of families caught by the different traps. Proportions with different letter were significantly different ($p<0.05$; Fisher exact test). Due to small number of families, statistical test was impossible for the proportion of families caught by one trap only.

	Diptera	**Hymenoptera**	**Psocoptera**	**Coleoptera**
Malaise traps	Stratiomyidae Empididae Tanipezidae Pipunculidae Lonchaeidae Sciomyzidae Tephritidae	Halictidae	Stenopsocidae	
Yellow traps		Ceraphronidae		Curculionidae
Blue traps	Platypezidae			Hydrophilidae
Light traps	Chaoboridae			Nitidulidae Smicripidae
Suction traps	Scatopsidae	Torymidae Scelionidae		

Table 3. Specificity of capture. Insect families only caught in one kind of trap.

comparisons between traps are possible for Coleoptera (9 families caught), Diptera (38 families) and Hymenoptera (19 families).

Light traps caught a higher proportion of coleopteran families but it is not significant (Table 4). Malaise traps caught the majority of Diptera and Hymenoptera with 89.5% and 68.4% of families, respectively (χ^2 test; $\chi^2=40.7$, df=4, $p<0.0001$ and $\chi^2=18.7$, df=4, $p<0.001$, respectively). For each of these three groups, the yellow pan trap was the second most effective (Table 4). Different combinations of traps improved the captures. For example, the combination light trap/yellow pan trap caught all the 9 families of Coleoptera together. For Diptera, the combination light trap/Malaise trap or the combination suction trap/Malaise trap caught 94.7% of families.

The combination of the two most effective traps: yellow pan trap/Malaise trap was not the best since it caught 89.5% of captures (difference was not significant). For Hymenoptera, the best combination was suction trap/Malaise trap with a total of 94.7% of captures; the second most effective combination was suction trap/yellow pan trap with a total of 89.5% of captures. Once more, the combination yellow pan trap/Malaise trap was not the best since with 84.2% of catch that is the third combination (difference was not significant). 100% of captures of Hymenoptera families were obtained with the combination of three traps: Malaise trap, suction trap and yellow pan trap.

Analysis of trapping constancy

The comparison of effectiveness of traps between sites enables to check if the observations were constant from one site to another, and hence if some generalisations could be possible.

In proportions of insects caught during the trapping period (Fig. 3), the Malaise trap is the most effective for 4 out of 6 sites studied (χ^2 goodness-of-fit test; all $p<0.001$). For the two other sites, the Yellow pan trap is the most effective (χ^2 goodness-of-fit test; all $p<0.001$). However, the results did not show significant constancy in the proportion of insects caught by the different traps between the sites (heterogeneity χ^2 analysis, $\chi^2 = 236.5$, df =20, $p<0.0001$).

In proportions of families, the Malaise trap is the most effective since it caught a higher proportion of

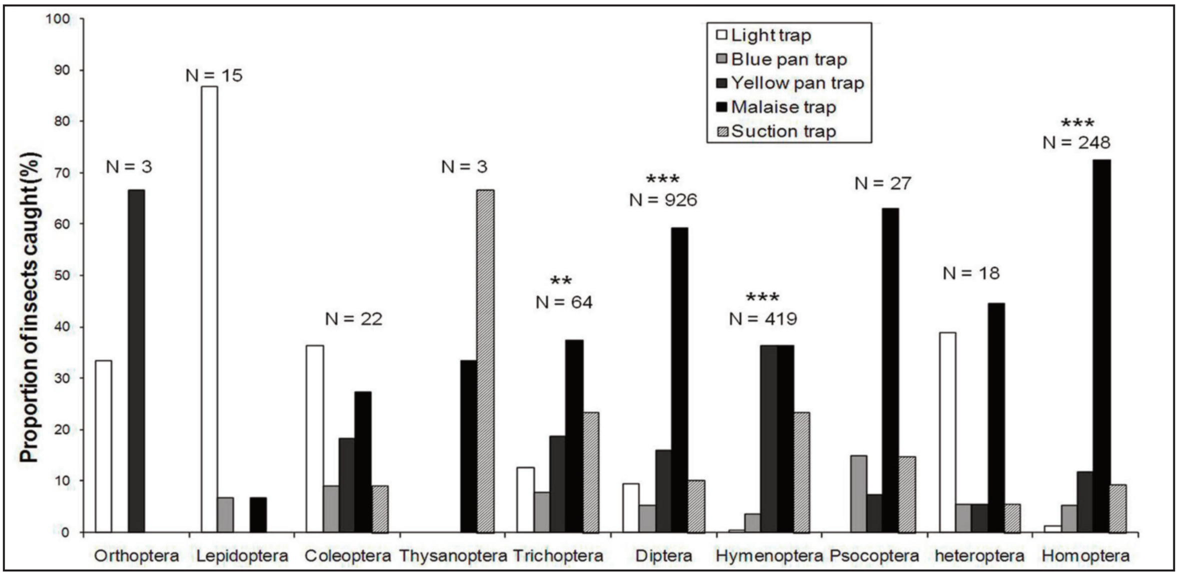

Figure 2. Proportion of insects caught by the different traps. N=total number of insects caught in each order. χ^2 goodness-of-fit tests were carried out for Trichoptera, Diptera, Hymenoptera and Homoptera (the number of insects in the other orders was too small to permit the analysis) to determine the highlight the differences between the traps. ** = $p<0.005$, *** = $p<0.001$.

	Light trap	Blue pan trap	Yellow pan trap	Malaise trap	Suction trap	Total number of families caught
Coleoptera	55.6 %	11.1 %	44.4 %	33.3 %	11.1 %	9
Diptera	26.3 %	47.4 %	60.5 %	89.5%	28.9 %	38
Hymenoptera	10.5 %	36.8 %	68.4 %	68.4 %	57.9 %	19

Table 4. Effectiveness of traps that means the proportion of families caught by each traps.

families in 5 out of 6 sites studied (Fig. 4). The yellow pan trap is the second most effective trap in these 5 sites and the most effective in the sixth one. In each location, the blue pan trap and light trap were the least effective in the collecting of numerous families of insects. In this respect, from one site to another one, no differences were found between proportion of families caught by each trap (heterogeneity χ^2 analysis, $\chi^2 = 9.6$, df =20, $p>0.05$). Hence, the results showed constancy in the proportion of families caught by the traps in each location.

More precisely, concerning the constancy of captures, the results show that only Diptera were caught in every site by each trap. Hymenoptera and Ho-

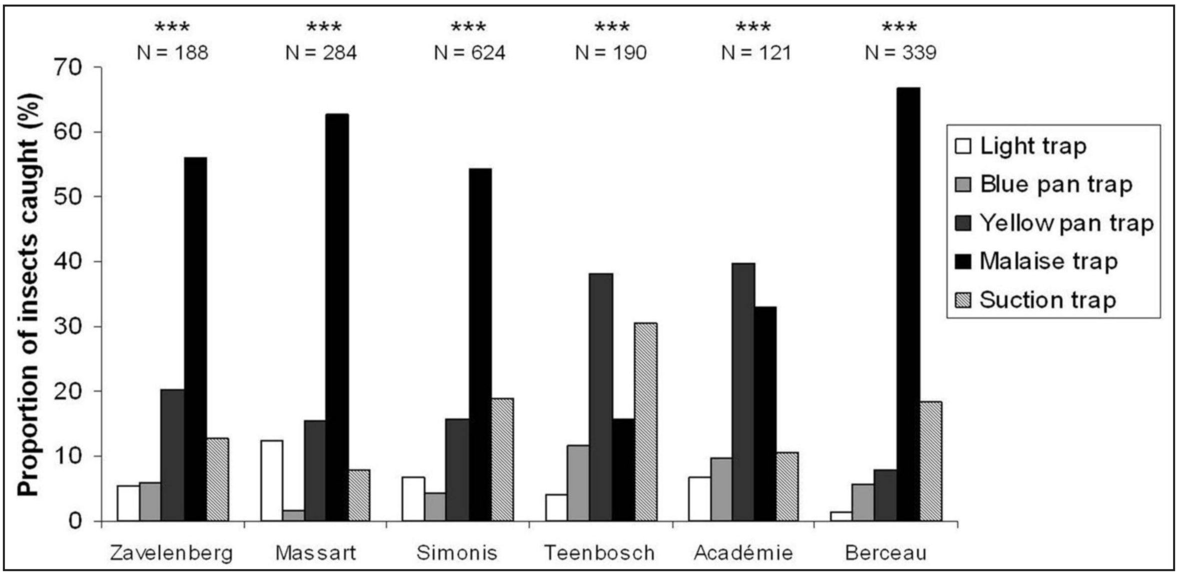

Figure 3. Proportion of insects caught by the different traps as a function of the trapping sites. χ^2 goodness-of-fit tests were carried out for each location to highlight the differences between the traps in each site. *** = $p<0.001$.

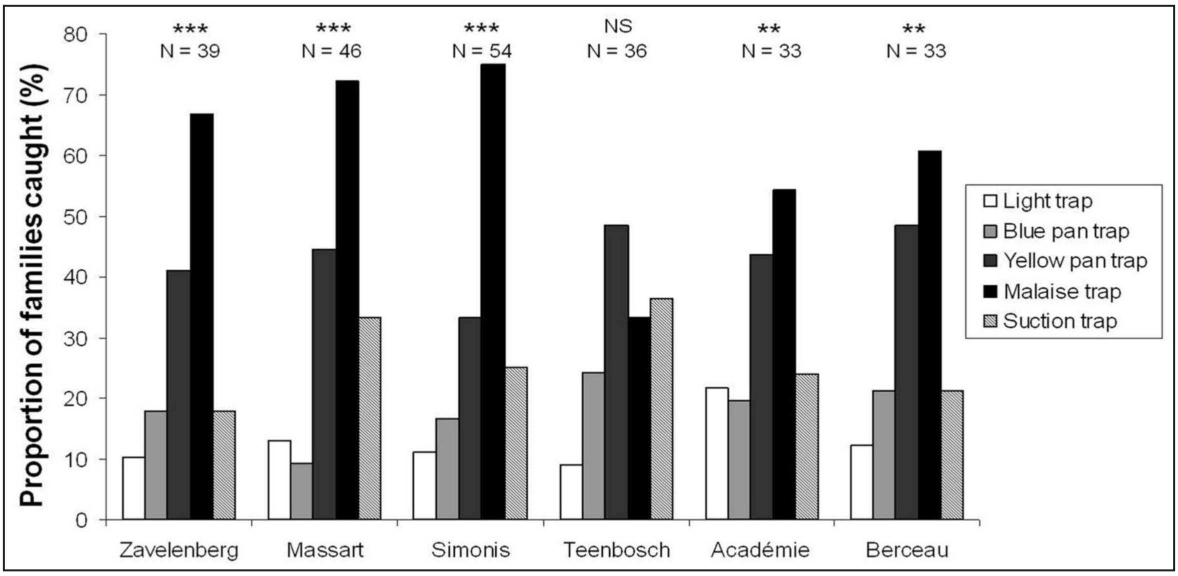

Figure 4. Proportion of families caught by the different traps as a function of the trapping sites. χ^2 goodness-of-fit tests were carried out for each location to highlight the differences in between the traps in each site. NS = Not Significant ** = $p<0.01$, *** = $p<0.001$.

moptera were collected in every site by Malaise, yellow pan and suction traps. Coleoptera were caught in 3 sites by Malaise, yellow pan and light traps. With the exception of one specimen caught in the Malaise trap and another in the blue pan trap, only light traps caught Lepidoptera (Heterocera).

Malaise traps were particularly effective in collecting some Diptera: Sciaridae, Phoridae, Muscidae and Sphaeroceridae, and some Homoptera: Aphididae. Indeed, these 5 families were found in the malaise trap in each location. In contrast, the other traps showed less consistency. Indeed, only two families (Hymenoptera: Pteromalidae and Mymaridae) were found in each suction trap. Similarly, only one family of Hymenoptera (Braconidae) and one family of Diptera (Ceratopogonidae) were caught in every location by yellow pan trap and light trap respectively.

DISCUSSION

In this study, the Malaise trap was most effective in terms of the largest catch of individuals and families when compared to the other traps. Moreover, more than 10% of insect families were caught by the Malaise trap only whereas the specificity of the other traps reached at maximum of 4% of insect families. Therefore, the better trap seems to be the Malaise trap. However, this trap is big and highly visible which could impede its use in urban locations because of potential vandalism acts. The same problem occurs with the light trap which could improve the trapping of nocturnal insects (for example Lepidoptera) but which is by definition visible because it is illuminated. The suction trap is very effective since it caught nearly 30% of Diptera and 60% of Hymenoptera while it was only used for 30 minutes. In a way, it can be concluded that this trap is the most effective since it captured a lot of insects in a very short period. However, this trap, in its design, is very noisy and thus could be difficult to use for a long time in urban areas. In summary, in some circumstances (e.g. residential urban areas), researchers may wish to choose the less effective traps as there is less risk from vandalism or causing disturbance.

In this study, different traps were used with very different durations of working. Indeed, the suction trap was working only 30 minutes whereas the pan traps were left on the ground during 48 hours. That could be a problem in analysis of their comparison. However, the comparison of different traps with same duration would not be useful. For example if the aim is to compare the effectiveness between the Malaise trap and the suction trap, the use of Malaise trap during 30 minutes would be useless, or in contrast, the use of suction trap during 24h would be too damaging for the environment by depleting uselessly the abundance of insects. Hence, for further studies it is suggested that it is better to compare different traps used in their best methodology (Campbell & Hanula, 2007; Hardwick & Harens, 2007; Pendola & New, 2007; Blackmer et al., 2008) and not necessarily in the same methodology.

The results show that no trap alone is able to catch all insect families that we have captured during the trapping period. Indeed even if the suction trap is really effective it will capture only small airborne insects constituting the aerial plankton. However, some combinations are potentially very useful to improve trapping. Indeed, the combination suction trap/Malaise trap caught more than 94% of families of Diptera and Hymenoptera. The combination of the two most effective traps did not give better results, proving that same families could be caught by these two traps. More studies would be necessary to compare the numerous trap systems (Southwood, 1978) and the effectiveness of their association.

This study can be considered as very limited since the determination was carried out only at a family level. Hence, further studies are needed to verify whether the same holds true at genus and species level. However, the advantage of such broad generalizations is that trends can be quickly identified (Gaston & Williams, 1993; Andersen, 1995). Indeed, the study seems to indicate that some families (which could represent several hundred of species) are only caught by one trap. For example, if Malaise traps were not used in our samplings, more than 10% of insect families captured during the study could not be observed. Scientists and technical professionals need to have standardised observation methods (Agosti et al., 2000 but see Melbourne, 1999).

This standardisation should allow comparison to be made between sites, at the same sites at different time periods and by different people. Indeed, it must be kept in mind that results from one kind of habitat could be different from another. For example, the results present some differences with those from other studies: the captures by the blue pan traps are very poor whereas these traps could be highly effective in catching Hymenoptera pollinators (Campbell & Hanula, 2007). Therefore, every site has specific attributes and the choice of traps based on a range of features (e.g. trapping efficiency but also resistance to the deterioration) could not be prone to "blind" standardisation methods. On the basis of the results of this study, it would be extremely beneficial to continue studies comparing the effectiveness of traps to help improve monitoring of insect biodiversity.

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