Comparative efficacy of small commercial traps for the capture of adult *Phlebotomus papatasi*

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ABSTRACT: We tested the performance of ten commercial mosquito traps with varying attractive features, against three CDC traps (an unlit model 512, an incandescently lit model 512, and a UV lit model 1212) as well as simple sticky paper, for their ability to attract and capture *Phlebotomus papatasi* in Israel. The commercial traps tested were the Sentinel 360, the Combo Trap, the Mega Catch Premier, the Bug Eater, the EcoTrap, the Galaxie Power-Vac, the Biter Fighter, the Black Hole, the Mosquito Trap, the Mosquito Catcher, the Sonic Web, the Solar Pest Killer, and a Bug Zapper. The four best performing traps with the highest nightly catches were the Sentinel 360 (85.96 ±19.34), the Combo Trap (70.00±7.78), the Mega Catch Premier (51.93±1.82) and the UV lit CDC 1212 trap (47.64±3.43). Five traps, the Mosquito Trap, the Mosquito Catcher, the Sonic Web, the Solar Pest Killer, and the Bug Zapper, performed exceptionally poorly, catching an average of less than two sand flies per day. To our knowledge, this is the first comprehensive attempt to evaluate commercial traps for their effectiveness in catching sand flies, and we show here that some traps that have been effective in catching mosquitoes are also effective in catching sand flies. ***Journal of Vector Ecology* 36 (Supplement 1): S172-S178. 2011.**

Keyword Index: Sand flies, *Phlebotomus papatasi*, sand fly traps, mosquito traps, Israel.

INTRODUCTION

Cutaneous leishmaniasis is endemic in large parts of Israel and the West Bank (Wasserburg et al. 2003, Al-Jawabreh et al. 2004, Jaffe et al. 2004) and is caused by transmission of the parasite *Leishmania major* through the bite of infected female *Phlebotomus papatasi* (Schlein 1982, Schlein 1984). The animal reservoirs of *L. major* in Israel are rodents, namely the fat sand rat *Psamomys obesus* (Cretzschmar) and the Sundevall's jird *Meriones crassus* (Sundevall). Wagner's gerbil, *Gerbillus dasyurus* (Wagner) is the only other species shown to harbor infection (Schlein et al. 1984, Wasserberg et al. 2002).

Cutaneous leishmaniasis is a resurging disease in the Middle East and is suspected to be due to human activities. Oumeish (1999) and Wasserberg and colleagues (2003a) showed that in the past ten years, there has been a significant increase of leishmaniasis cases in the Negev. It is believed that this increase is connected to the influx of human populations into zoonotic areas and to the resulting man-made environmental changes that favor both the reservoirs and the vector (Wasserberg et al. 2003b). Moreover, in recent years, common sand fly control methods, primarily the spraying of insecticide, have not been as effective in preventing disease transmission of leishmaniasis as they had been in the past (Orshan et al. 2006). Therefore, accurate surveillance of *P. papatasi* is critical to assess disease risk in a given area and is also critical in the assessment of control measures put into practice (Alexander and Maroli 2003).

The concept of using traps for the surveillance and study of biting insect populations is at least 60 years old (Bates 1944, Sudia and Chamberlain 1962), however, it was only in recent decades that traps were developed for private use, claiming they could provide relief from biting flies in back yards and indoors. The rise in popularity led companies to develop mosquito traps for private use and to date there are numerous brands and models on the market. These commercial traps were often designed for mosquitoes but most brands claim the traps will also catch other biting flies such as black flies, biting midges, and sand flies. CDC light traps and sticky traps remain the standard for monitoring sand flies (Alexander and Maroli 2003, Faiman et al. 2009), but the possibility of using commercial traps to control sand flies in and around human habitation has yet to be investigated.

In order to evaluate the effectiveness of commercial traps for catching sand flies, we compared ten units that use different combinations of visual and chemical attractive features to determine which combination, if any, attracts the most sand flies.

MATERIALS AND METHODS

Study site

The study took place in the lower Jordan Valley, Israel, at a large date plantation (latitude: 31.7414; longitude: 35.4586) that had been cleared of natural vegetation, near the western shore of the Dead Sea. This area is at an average altitude of 390 m below sea level and belongs to the Sahara-Arabian phyto-geographical zone (Zohary and Orshansky 1949). This region as a whole is an extreme desert with occasional marshland and artificial agricultural

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14. ABSTRACT
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oases created by irrigation. In these oases, conditions are defined as tropical (Danin 1988). The climate here is arid with an average humidity of 57% and annual winter rain fall average of 50-100 mm. The average temperature ranges from 20° C in September through April, to 30° C in May through August (Ashbel 1951). This plantation covers an area of approximately 10 ha and is surrounded mainly by reed thickets, Chenopodiaceae shrubs, and tamarisk bushes. Though the oasis is known for its rich mosquito fauna (Margalit et al. 1973) *P. papatasi* is practically the only *Phlebotomus* species found in this habitat (Müller and Schlein 2004).

Traps and experimental description

In this study, we tested ten commercial and four monitoring traps for their ability to catch male and female sand flies. Information about these traps is listed in Table 1 and their attractive features are listed in Table 2.

Baseline controls: Sticky papers were constructed from 8.5 x 11 in (white, plastic coated paper painted with castor oil which acts as the adhesive and unlighted CDC traps (model 512 with original light bulb removed), were used for their suction only. These control traps were hung 80 cm above the ground on tripods.

The traps were operated simultaneously and continuously, in a line parallel to a ditch, with a distance of 20 m between each trap. The traps were rotated clockwise to the next location at 1700 each day to eliminate positional bias. Insects drawn to the traps were collected early each morning at 0700 to prevent degradation. Traps were operated according to the manufacturer's instructions, and therefore, were with supplied baits if recommended by the manufacturer.

Statistical analysis

Statistical analyses were performed with GraphPad Prism 5.0 software (Graph Pad Software Inc., La Jolla,, CA, USA). The number and sex of individual sand flies per day in each trap were recorded. The overall difference between the mean number of sand flies and the number of each sex was analyzed using one-way Kruskal-Wallis nonparametric rank test. The comparison between individual trap types was carried out with the Wilcoxon nonparametric rank test. Both tests used Chi-Square approximation, assuming that the traps were designed to mimic potential hosts to specifically attract females. Significance was taken at $P < 0.05$.

RESULTS

Trap catches

During the 14 day experiment, in mid-September, 2009, a total of 5,948 female and 5,312 male sand flies were caught by the tested traps. The number of individual sand flies caught was significantly different between trap types ($\chi^2 = 167.2$; df = 5; $p < 0.001$). The Sentinel caught more sand flies than any other type of trap (Figure 1). The trap with the second largest mean nightly yield was the Combo Trap followed by the Mega Catch Premier and the UV-CDC Trap (model 1212). The mean catch per day of these four traps was significantly higher than all other traps tested (Table 3).

The Bug Eater trap, the incandescent-CDC trap (model 512), and the Eco Trap all performed well, but still had catches that were significantly lower than the top four traps. However, they do have catches that are significantly higher when these three traps are compared to the remaining traps (Table 3). There were also four traps whose mean catch was significantly lower than the other traps ($P < 0.05$ for each) and these were the Mosquito Trap, the Mosquito Catcher,

Table 1. List of traps and manufacturer information.

Trap Model	Manufacturer	Location
Sentinel	Intermatic	IL, USA
Combo-Trap	Westham Inc.	Tel Aviv, Israel
Mega Catch Premier	Envirosafe Technologies	New Zealand
UV-CDC-Trap (1212)	John W. Hock	FL, USA
Bug Eater	Envirosafe Technologies	New Zealand
Incandescent CDC-Trap (512)	John W. Hock	FL, USA
EcoTrap	Lentek, Koolatron	Toronto, Canada
Galaxie Power Vac	Flowtron	MA, USA
CDC unlighted (512)	John W. Hock	FL, USA
Sticky paper	"Home Made"	-
Biter Fighter	Ticks or Mosquitoes LLC	MO, USA
Black Hole	Korea Item Dev.	South Korea
Mosquito Trap	Lentek, Koolatron	Toronto, Canada
Mosquito Catcher	Rush Hampton, TekQuest	FL, USA
Sonic Web	Applica	FL, USA
Solar Pest Killer	Yiwu, Maxtop	Zhejiang, China
Bug Zapper	No-Name Brand	Guangzhou, China

Table 2. List of traps and attractive features listed in descending order of mean catch per night.

Trap Model	Heat	UV / Fluorescent	LED	Incandescent Light	Moisture	Attractant	Contrast
Sentinel	+	+	+	+	-	-	+
Combo-Trap	+	+	-	-	+	A	+
Mega Catch Premier	*	+	+	-	+	E	-
CDC-Trap (1212)	-	+	-	-	-	-	-
Bug Eater	-	+	-	-	+	-	-
CDC-Trap (512)	-	-	-	+	-	-	+
Eco Trap	+	-	-	-	+	B	+
Galaxie Power Vac	*	+	-	-	-	E	+
CDC unlighted (512)	-	-	-	-	-	-	-
Sticky paper	-	-	-	-	-	-	-
Biter Fighter	-	-	-	-	+	B	+
Black Hole	-	+	-	-	-	C	-
Mosquito Trap	+	-	+	-	-	E	-
Mosquito Catcher	+	-	+	-	-	E	-
Sonic Web	-	-	-	-	-	E,D	+
Solar Pest Killer	-	-	+	-	-	-	-
Bug Zapper	-	+	-	-	-	-	-

*Possible heat generated by light bulbs. [A]Liquid fermentation products. [B]Proprietary powder/ water. [C]Catalytic CO_2. [D]Sound. [E]Octenol. Note: LED's are solid blue, except for Sentinel (flickering purple, blue, orange, green).

the Sonic Web, the Solar Pest Killer and the Bug Zapper. The Pest Killer and the Bug Zapper models performed especially poorly, averaging less than one sand fly per day.

As a group, the traps caught significantly more females than males (Figure 1; $\chi^2 = 17.8$; df = 1; $p < 0.05$). More specific analysis of the nightly catch showed that the Sentinel captured significantly more females than males ($\chi^2 = 15.2$; df = 1; $p < 0.001$) as did the Eco Trap ($\chi^2 = 22.9$; df = 1; $p < 0.001$), the unlighted CDC 512 trap ($\chi^2 = 21.1$; df = 1; $p < 0.0001$) and the Biter Fighter ($\chi^2 = 19.9.1$; df = 1; $p < 0.001$), though the catches of these traps were generally low.

Interestingly, the Galaxie Power Vac, while performing only average among the tested traps, caught significantly more male ($\chi^2 = 76.9$; df = 6; $p < 0.001$). The remaining traps had no significant sex differences (Figure 2).

It is noteworthy that several traps also collected large numbers of non-target organisms, including non-biting flies and Lepidoptera. These traps were the Sentinel, Mega Catch Premier, the CDC Trap (Model 1212), the Bug Eater, the Black Hole and the Bug Zapper.

DISCUSSION

Biting flies including mosquitoes and sand flies are able to locate vertebrate hosts by responding to their chemical and physical cues (Clements 1999, Alexander 2000). Chemical cues include the release of carbon dioxide (CO_2), water vapor, and components of sweat such as lactic acid and octenol (1-octen-3-ol) (Cork 1996). Physical cues include heat release and visual stimuli such as contrast, color, shape and movement (Browne and Bennett 1981). Commercial mosquito traps have attempted to mimic vertebrate hosts by incorporating at least one or two of these cues in the design, but for the purposes of improving trap catches, some models have now incorporated several of these attractive features (Table 2).

In some studies, mosquito populations could be successfully controlled by operating traps over long periods of time (Kline 2007, Kaufman et al. 2008, Hoel et al. 2009) and there is no reason why this should not work for sand flies as well though to our best knowledge it was so far not attempted (Alexander 2000).

The unlighted CDC trap works only on suction, and the passive sticky paper can only catch sand flies that are directly landing on it or touch it by mistake both catch sand flies from a very short distance at random, probably without attracting them. Accordingly, their catches should be seen as a base line. When compared to each other based on mean catch per day, the unlighted CDC trap caught an average of 1.3 times more sand flies than the sticky paper. There was no statistically significant difference between these two baseline traps. The UV CDC trap (model 1212), on the other hand, was able to catch, on average, 1.6 times as many sand flies as the incandescent CDC trap (model 512), and 4.4 times as many sand flies as the unlighted CDC trap (model 512, light bulb removed). The incandescent CDC

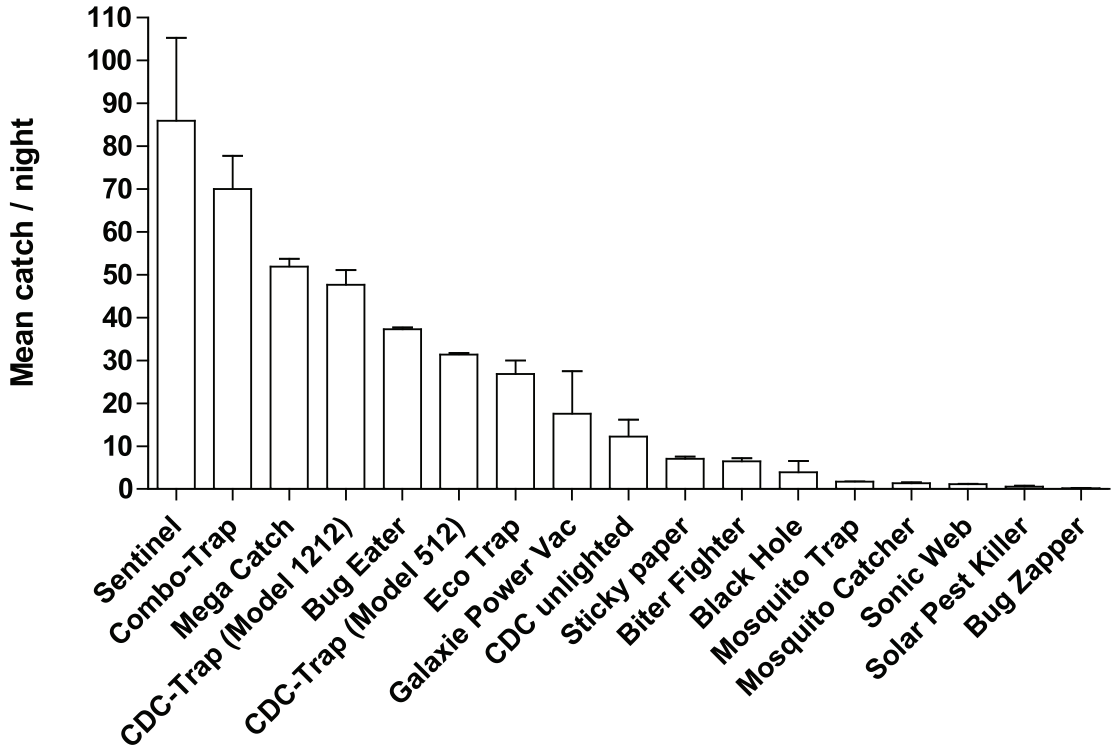

Figure 1. Mean number of sand flies caught by 14 commercial traps ± SEM.

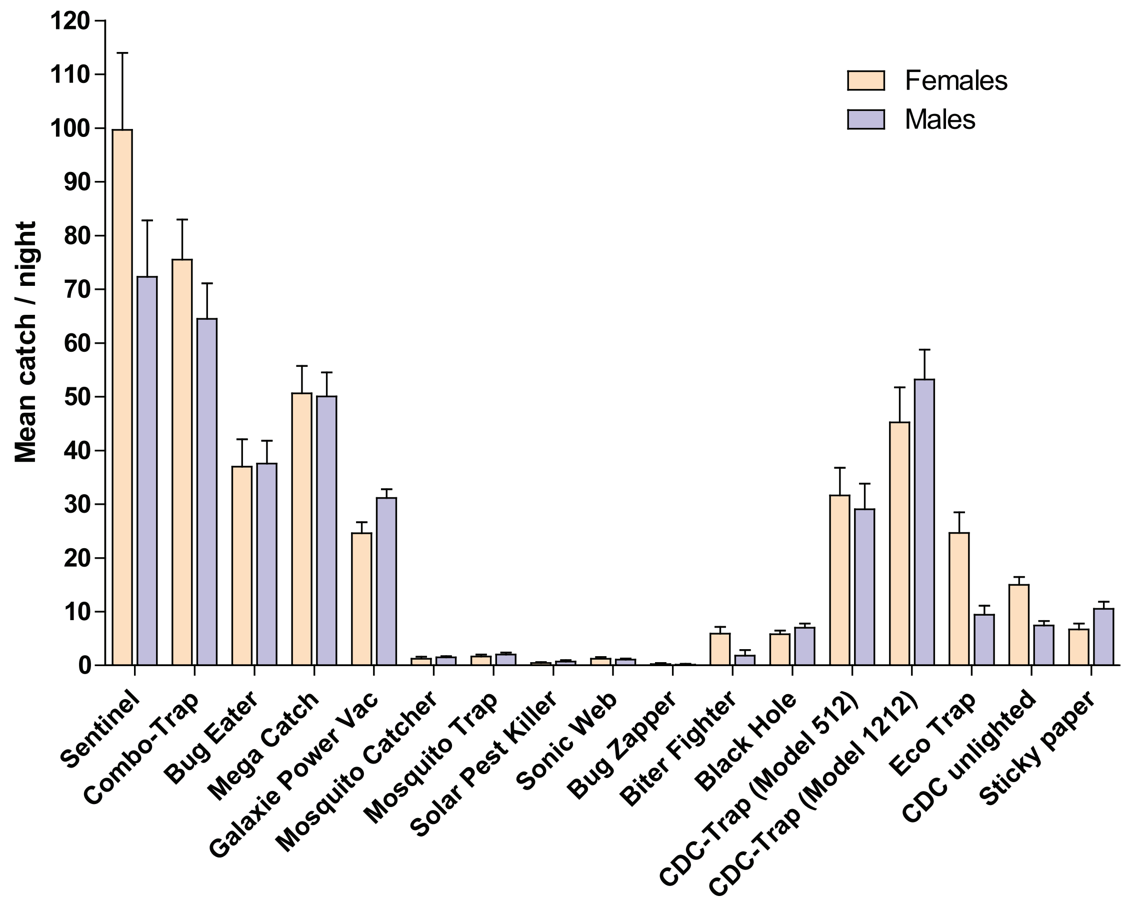

Figure 2. Mean catches of male and female sand flies by 14 commercial traps tested in this study ± SEM.

Table 3. Mean number of sand flies caught per trap listed in descending order by means ± SEM. Significant catches are indicated by an asterisk.

Trap Model	Average Catch	SEM
Sentinel	85.96***	19.34
Combo-Trap	70.00***	7.78
Mega Catch Premier	51.93***	1.82
CDC-Trap (1212)	47.64***	3.43
Bug Eater	37.29**	0.40
CDC-Trap (512)	31.39**	0.35
Eco Trap	26.86**	3.13
Galaxie Power Vac	17.54	9.95
CDC unlighted (512)	12.21	3.94
Sticky paper	7.07	0.51
Biter Fighter	6.46	0.76
Black Hole	3.89	2.68
Mosquito Trap	1.71*	0.10
Mosquito Catcher	1.36*	0.20
Sonic Web	1.14*	0.10
Solar Pest Killer	0.57*	0.20
Bug Zapper	0.18*	0.05

*** Highly significant (Wilcoxon rank test, $P < 0.001$)
** Significant (Wilcoxon rank test, $P < 0.05$)
* Significantly *lower* than the other traps

trap caught 2.7 times as many sand flies as the unlighted trap (Figure 1).

Similar results were obtained by Orshan et al. (2010) comparing CDC- like traps in the Judean Desert with *Phlebotomus sergentii* as the dominant sand fly species (90%). Traps baited with CO_2 caught 69 times more sand flies than non-baited (unlighted) CDC traps, UV lighted traps caught 5.4 times more than unlighted traps, and incandescently lit CDC traps caught 2.5 times as many sand flies as the unlighted CDC traps used for suction only. Carbon dioxide is known as the single most powerful attractant for most biting flies including mosquitoes and sand flies (Day and Sjogren 1994, Pates and Curtis 2005). Light, especially UV, on the other hand, is not an attractant *per se* it knocks out the orientation of night active insects (Nowinszky 2004) and as a result, they are drawn into the light source while at the same time, they are handicapped and unable to escape the catching/ killing mechanisms of traps.

The goal of this study was to identify the best performing *commercial, non-combustion* traps (Figure 1) for catching sand flies specifically, and we found clear differences in the performance of the 14 traps tested (Table 3). Principally, traps that intend to control insect populations have to achieve two things, first they must attract insects and second, they have to catch and / or kill them. The least effective traps (in descending order), Biter Fighter, Black Hole, Mosquito Trap, Mosquito Catcher, Sonic Web, Solar Pest Killer and a Bug Zapper, might have attracted sand flies, but if they did, they were not able to catch them in significant numbers. This could be a severe problem if these traps are indeed drawing sand flies from a distance close to human habitation or to areas they are supposed to protect, and then they are unable to remove them.

The performance of the Black Hole was especially disappointing, bearing in mind that this trap claims to produce sufficient amounts of CO_2 to attract biting flies through a catalytic process with TiO_2. Though it is additionally equipped with a UV tube, it caught significantly less sand flies than the UV CDC trap and even the CDC trap with incandescent light. Apart from doubting that the output of the CO_2 is sufficient, the strong air turbulence created by the strong ventilator might deter the flies.

The low average catch of the Sonic Web seems to indicate that sound does not help to improve the catch of sticky paper. In fact, the Sonic Web caught fewer sand flies than the baseline control passive sticky paper (Figure 1). Sand flies accumulated only on the black parts of the sticker and the low catches could be because other sand flies might have been diverted to other black parts of the Web's distinctive color pattern which were not sticky.

Among the traps with the poorest performance was the Bug Zapper and though it uses UV light, most zappers have an electromagnetic field which can repel mosquitoes and sand flies that can lead to the paradox result that biting flies are attracted, but finally, are not killed (unpublished data of the authors).

In our study, it appeared that also octenol did not improve the catch of *P. papatasi*. This is in agreement with a study in Egypt in which octenol alone, or in combination with CO_2, did not increase catches of sand flies (Beavers et al. 2004). On the other hand, some sand fly species in South America and in Florida were apparently attracted to octenol (Andrade et al. 2008, unpublished data of the authors). This is not surprising, bearing in mind that also not all mosquito species are attracted to this lure either (Kline et al. 1991). Two of the tested traps the Mosquito Catcher and the Mosquito Trap did not catch significantly greater numbers of sand flies than the two baseline controls (unlighted CDC 512 and sticky paper) though they use among others heat and optical cues as attractants. This is surprising because in several experiments we observed that heat is significantly attractive for sand flies especially if combined with black color (unpublished data of the authors). The failure of these two traps to catch sand flies might be due to an unsuitable heat pattern (temperatures either too low or high) or because of an insufficient capture mechanism.

The best mid-range performance trap (Table 3), the Eco Trap, caught 2.0 times more sand flies than the passive sticky paper, and is also the only trap which caught significantly more females than males. The Eco Trap uses heat, moisture, contrasting color pattern and a proprietary powder that claims to generate CO_2 and multiple other chemical attractants through yeast fermentation. Although the Biter Fighter, with its distinctive color contrast, uses a proprietary powder purported to generate CO_2 in addition to chemical attractants and moisture, the Eco Trap caught 4.4 times more sand flies than this trap. Moisture alone is known to attract sand flies in arid environment in significant numbers (Schlein et al. 1989). It is more surprising that the biter fighter does not catch more flies than the simple sticky paper.

The best performing traps apparently have a balanced combination of attractive and capture features, and can improve their catch with UV light while, for the poorer performing traps, UV probably does not help much for reasons discussed above. The four beat performing traps were the Sentinel 360 (85.96 ±19.34), the Combo Trap (70.00±7.78), the Mega Catch Premier (51.93±1.82) and the UV lit CDC 1212 trap (47.64±3.43). It is interesting to note that all of these traps are lit with UV and all except the CDC 1212 use heat. Though these traps perform exceptionally well at catching sand flies, the Mega Catch Premier is large and with blinking LED lights, it is unsuitable for use indoors. The combo trap, on the other hand, is small, compact, and can be operated as well outdoors as indoors. Though it had no blinking LED's, the liquid fermentation products provided as a food grade attractant might have compensate in increasing the catch of the Combo Trap.

The Sentinel, which caught the most sand flies, male and female, employs UV and incandescent white lights, as well as purple, blue, orange, and green light emitting diodes (LEDs) for attraction. The average catch of this trap was significantly greater than the others that used either a single LED or no light at all. Burkett and colleagues (1998) showed that LED's of different colors could differentially attract mosquitoes. Some colors were particularly effective for attracting certain mosquito species. For example, colors in the blue-green spectrum were attractive while other colors, such as in the yellow-red light spectrum, did not increase the trap catches or vice versa according to species. Sand flies on the other hand, were found to be more attracted to the yellow-red spectrum of lights than the blue-green, but even blue-green light caught more sand flies than white light alone (Hoel et al. 2007). This could partially explain the good performance of this trap in catching both mosquitoes (Kaufman et al. 2008) and sand flies in the current study.

It is also noteworthy that several traps, especially the Sentinel, collected also large numbers of small non-target diptera and other flying insects like moths which increased the mean catch of insects (apart from sand flies) about ten fold. This is not surprising considering that it has long been known that UV and fluorescent lights attract significant amounts of flying night active insects in numbers great enough to be a nuisance to home and business owners (National Pest Control Association 1986, Pinto 1991). Even if partially recognized by consumers as non-biting flies and mosquitoes it still gives the consumer the impression of much bigger catches and consequently a high performance of the trap.

In this study, we identified three *commercial* traps, the Sentinel, the Combo Trap and the Mega Catch Premier, that caught more sand flies than the UV lighted CDC (1212) trap and the lighted and unlighted CDC (512) traps used for sand fly surveillance. In future studies, it would be interesting to see if these traps could be used to reduce sand fly populations in a given area. Moreover, all of the traps except for the Sentinel, the Galaxie Power Vac, and the Sonic Web, can be also operated indoors. To our knowledge, this is the first comprehensive attempt to evaluate commercial traps for their effectiveness in attracting and catching sand flies. Further studies are needed to determine if these traps can actually control sand flies in significant numbers, but we show here that some traps that have been effective in catching mosquitoes are also effective in catching sand flies.

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