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ATTRACTION OF FLYING INSECTS TO LIGHT OF DIFFERENT WAVELENGTHS IN A JAMAICAN CAVE

by

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I - INTRODUCTION

A striking aspect of many Jamaican caves containing numerous bats and large deposits of their guano is the presence of many small flying Diptera. These flies can be a nuisance when attracted to light in such numbers that they get into the eyes, mouths and noses of people visiting the caves. At present some tourist are taken through the caves by local guides using flaming torches, which burn up the attracted flies and reduce the probleme. However, we are concerned that the use of such torches, especially as cave-tourism grows, may have an adverse effect on the ecology of the caves and cause damage from soot, excess carbon dioxide and heat. Here we explore the use of light of different wavelengths to find which are least attractive to these insects in the hope that lights equipped with suitable filters may enable people to see the caves whilst minimizing the fly nuisance. We used narrow band interference filters with approximately the same relative number of photons per second passing through each of the visible light filters. This was done for comparative purposes, because insect eyes respond proportionally to the number of photons and not energy (see review by CARLSON and CHI, 1979).

Our experiments were conducted in a dark chamber of Dromilly Cave where there is an unusually large concentration of web-building mycetophilid fly larvae. This is an undercribed species of *Neoditomyia* endemic to Jamaica (E. I. COHER, pers. comm., 1992), but relatively little is known about its biology (STRINGER and MEYER-ROCHOW, 1993). The larvae build webs with sticky vertical fishing lines similar to those of some ceroplatine fly larvae (LANE and STURM, 1958; PECK and RUSSEL, 1976; STURM, 1973). Flying insects trapped in the fishing lines are hauled up and eaten by the larvae. Several adults were found during each visit of ours to Dromilly Cave, but these adults often seemed reluctant to respond to light from a flashlight. An additional aim of the experiments was, therefore, to find out if these adult mycetophilids were attracted to light of any wavelength.

II - MATERIAL AND METHODS

All attraction tests were done within 3 m of a small central excavation in the largest chamber of Dromilly Cave, Trelawny (JSD map 2, 1:50,000; E738 N920). This cave is only visited occasionally for small scale guano extraction by local farmers. The chamber used is 48 m from the entrance and has a floor area of approximately 8000 m^2 (FINCHAM *et al.*, 1977). No daylight appeared to reach it.

Insects flying in the absence of artificial illumination were trapped on acetate sheets (14 cm long by 20.3 cm wide) covered on both sides with 'Tangle-trap' (R), supplied by "The Tanglefoot Co., Grand Rapids, U.S.A.". The sheets were suspended approximately 15 cm above the ground from wires pushed into the guano floor of the cave. Insects attracted to light were trapped on acetate sheets with a collection area 9 cm high by 9.3 cm wide, consisting of a thin layer of 'Tanglefoot' (R). These sheets were hung, adhesive side outermost, immediately in front of a flashlight clamped horizontally 15 cm above the floor of the cave. A filter holder fixed in front of the light allowed interference filters (Ealing, U.K.) and their appropriate neutral density filters to be changed. The latter were made by exposing and developing negative film. Relative outputs from the torch, filters, and adhesive sheets were measured with a photometer (SSP-3; Optec Inc., Iowell, MI., U.S.A.) and are given in table 1.

New batteries were provided for each experiment. These gave no detectable change in output over a period of two hours. An infrared filter without neutral density filters was used as a control to estimate the numbers of flies caught in the absence of attractive wavelengths. Filters took a few seconds to change in the cave using a flashlight covered with red cellophane.

Acetate sheets were wrapped individually in white paper after being used for trapping insects. The insects were later identified in the lab and counted under a binocular microscope.

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Tabl. 1 - Characteristics of the light produced by a flashlight equipped with Ealing interference filters and neutral density filters. *Catalogue number, Ealing Co; **Mean of 4 readings after adjusting with neutral density filters.

Filter Number*	Maximun wave length (nm)	Band width (nm)	relative number of photons**
35-4811	1001.3	131	6706
35-3979	651.8	124	1227
35-3813	591.2	9.2	1345
35-3615	531.1	94	1296
35-3516	501.8	68	1290
35-3433	471.0	63	1316
35-3250	411.7	98	1333

III - RESULTS

III. 1 - Adhesive trapping in the absence of artificial illumination

Scatopsid flies were the predominant insects caught in five adhesive traps set in the chamber over a period of 23 hours (Tabl. 2). These were caught at a mean rate of 617 flies/m^2/hr followed by phorid flies at a mean rate of 29.2 flies/m^2/hr and Milichiidae at a mean rate of 5.4 flies/m^2/hr. Minor components of the catches were Sciaridae, Streblidae, Scelionidae, one especies of *Atheta* (Staphylinidae: Aleocharinae) and an described species of *Proterospastis* (Tineidae).

Tabl. 2 - Numbers of insects caught in five adhesive traps set over 23 hours in the largest chamber of Dromilly cave (21-22/11/1992). Each trap had an adhesive area of 568 cm2. *Total in five traps.

MAJOR COMPONENTS			MINOR COMPONENTS	
Family	mean	S.D.	Family	Total number*
Scatopsidae	816	639	Staphylinidae	8
Phoridae	38.2	12.8	Scelionidae	10
Milichiidae	7.0	7.0	Sciaridae	2
			Streblidae	3
			Tineidae	2

III. 2 - Light attraction trials

The first light attraction experiment consisted of two randomized sequences of five minute light exposures run on consecutive days. Light of each wavelength (Tabl. 1) was used once per sequence. The majority of insects attracted to all wavelengths tested were Scatopsidae (overall total 90.5%) followed by Phoridae (8.3%) and Milichiidae (0.8%). Scatopsidae and Phoridae both showed maximun responses to blue-green light although other wavelengths except for infrared and red were also relatively attractive (Fig. 1). Most Milichiidae were attracted to blue-green, blue and violet lights. A small number of Sciaridae and one winged ant were also caught together with some Scelionidae which were mostly attracted to light of 531 nm (Tabl. 3).

Tabl. 3 - Total numbers of insects attracted to light of different wavelengths in Dromilly Cave between 5th and 6th December, 1992. Each light was exposed for 5 minutes on 2 succesive days.

Number of insects caught during 10 minutes							
Maximum wavelength	1001	652	591	531	502	471	412
Scatopsidae	18	246	899	1442	1683	1263	1171
Phoridae	1	3	27	29	32	28	30
Milichiidae	0	0	1	8	14	14	20
Scelionidae	0	3	2	13	2	5	3
Sciaridae	0	0	2	0	3	2	0
Formicidae	0	0	0	0	1	0	0

A series of four neutral density filters with increasing transmittances were exposed immediately following both sequences with colour filters. The Scatopsidae caught generally increased with increasing light intensity, although the rate of increase diminished at higher light intensities and even decreased on the 6/12/92 (Fig. 2).

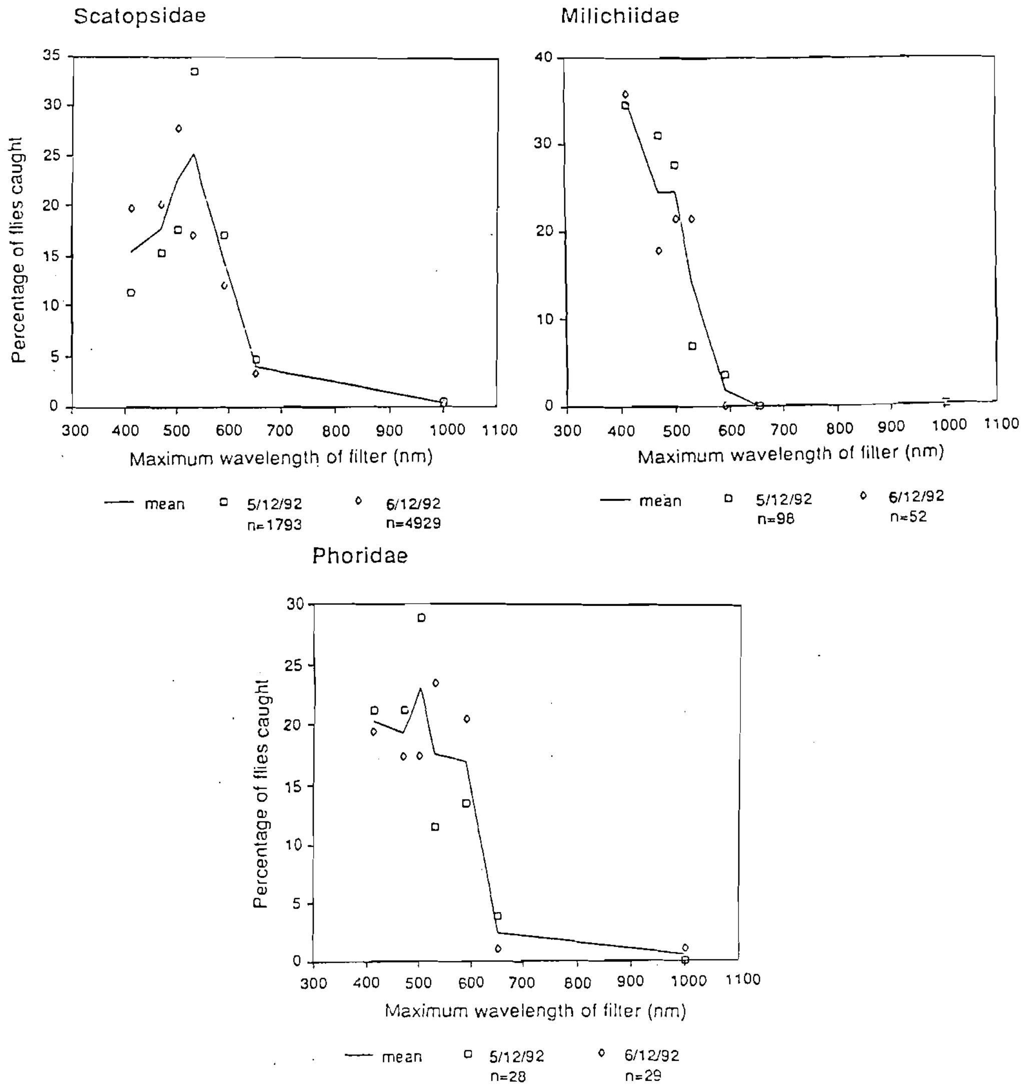

Fig. 1 - Mean percentage of flies attracted to 5 minutes exposures of light of different wavelenghts in Dromilly cave. Each light was exposed once in a random sequence on two days commencing at 15:14 on 5/12/92 and 11:30 on 6/12/92. Visible light sources produced similar relative numbers of photons and the IR light produced about 5 times more. Percentages are given with respect to the total number caught in each family each day.

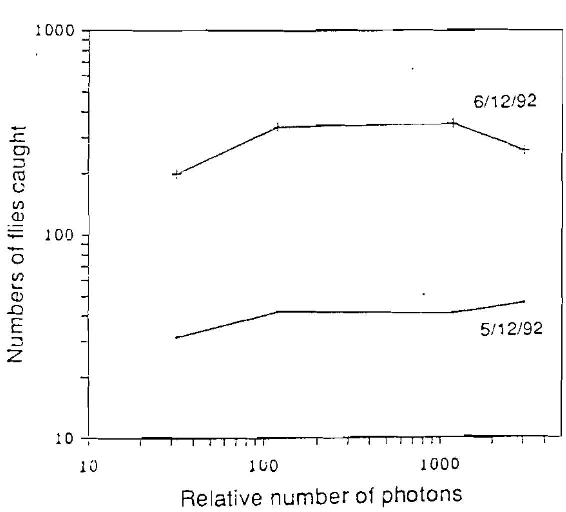

Fig. 2 - Numbers of flies attracted per minute to a flashlight shone trough different neutral density filtrers. Each exposure was for 5 minutes on 5.12.92 and for 3 minutes on 6.12.92.

Relatively few other insects were attracted to light shone through these neutral density filters and their numbers do not show consistent responses to increasing light intensity (Tabl. 4). These minor catches are possibly influenced largely by chance and this may have masked their responses to light of increasing intensity. The reponses of Scatopsidae, however, indicate that either light trapping influenced subsequent catches or that the number of flies caught approached a saturation level at higher light intensities or that light above a certain intensity was less attractive to these flies (even brief exposures to very bright light can cause loss of photopigment and reduced visual sensitivity).

A second experiment was therefore run using conservatively small exposure times in order to reduce some of these effects and to substantiate the first results. This experiment involved running three randomized sequences of one minute exposures to lights of different wavelengths in succession on the same day. The total light exposure time of 21 minutes was therefore 60% of one sequence from the first experiment. This seemed a sufficiently conservative time because 50% to 62% of the flies in the first experiment were trapped following the first 20 minutes oif exposure, so it seemed unlikely that the pool of available flies should bie reduced much in 21 minutes of light exposure.

Tabl. 4 - Numbers of minor groups of insects attracted to neutral density filters. Filters were exposed in order of increasing transmittance for 5 minutes on 5/12/92 and for 3 minutes on 6/12/92.

Number of flies trapped per minute				
Relative number photons through filter	32	120	1178	3032
Phoridae (5/12)	3.4	2.4	1.8	2.2
(6/12)	1.4	3.3	4.3	6.3
Milichiidae (5/12)	0.8	0.2	0.4	0
(6/12)	1.8	3.3	2.0	1.3
Scelionidae (5/12)	0.2	0.2	0.8	0.4
(6/12)	0.3	1.3	0.3	0.3
Sciaridae (5/12)	0.2	0.6	0.4	0
(6/12)	0	0	0	1.0
Staphylinidae (5/12)	0	0	0.2	0

The proportions of flies attracted to light of different wavelengths during the second experiment were similar to those in the first experiment. Scatopsidae again predominated overall (98.0%) in the second experiment, followed by Milichiidae (1.5%) and Phoridae (0.5%) (Tabl. 5).

Tabl. 5 - Total numbers of insects caught during three exposures of light of different wavelength on 26/12/1992. Each exposure was for 1 minute.

Number of insects							
Maximum wavelength	1001	652	592	531	502	471	412
Scatopsidae	79	644	875	2153	1783	1809	1244
Phoridae	2	5	4	5	10	13	9
Milichiidae	2	2	4	18	24	48	31
Scelionidae	0	0	0	0	2	1	2
Streblidae	0	0	0	0	1	0	0

All Diptera responded to a broad range of wavelengths with maximal responses of 531 nm for Scatopsidae, 471 nm for Phoridae, and 412 nm for Milichiidae (Fig. 3). Small numbers of Scelionidae were attracted to violet, blue, and blue-green light and one streblid was caught with blue-green light (Tabl. 5).

IV - DISCUSSION

Flies like *Musca domestica*, for instance, use considerably greater force to cling to the substrate when it is dark (MEYER-ROCHOW and HARIYAMA, 1993) and according to KIRSCHFELD and VOGT (1985) a flash of light most likely initiates flight of the animal. This flight reflex has a short latency, but depends upon the light intensity of the flash. The number of flies caught by us in the cave may, therefore, not only indicate attractiveness of the test light, but also be a reflection of the percentage of flies stimulated sufficiently to let go of the sustrate and take to the air at the onset of the test light.

The overall composition of most insect families attracted to light was similar to the composition of the insects flying in the absence of light as indicated by catches from adhesive traps left overnight (Tabl. 6). Tineidae and Staphylinidae were the only insects that were caught in adhesive traps, but not in light traps. In addition, no web-spinning mycetophilids were attracted to either light traps or adhesive traps. All three groups of insects were relatively rare components of the flying fauna and this may have accounted for their absences from trap catches (all three do possess eyes). Unfortunately such absences provide no information as to whether light is unattractive to them or if they were not caught because of a relatively low level of flight activity. The light traps may also have been set at times when these insects were inactive. Certainly the *Neoditomyia* adults seldom flew when observed with a flashlight during daytime and they were neither strong nor fast fliers when they did fly.

The numbers of Scatopsidae caught during the light trapping experiments varied markedly on different dates. A total of 1793 were caught in the first sequence of experiment 1 compared with 4929 the following day and 8587 during experiment 2. The first sequence started at 15.14 h whereas the others started at 11.30 h and 10.45 h, respectively, suggesting that these flies may have a daily flight activity cycle that is greater in the middle of the day than towards dusk. Although it appears strange that insects living in constant darkness should show such a daily activity rhythm, one could nevertheless be linked with the activity cycles of the bats in the cave. There were certainly noticeably more bats flying about by the time the first sequence finished at 16.56 h, about half an hour before dusk, than at the other times.

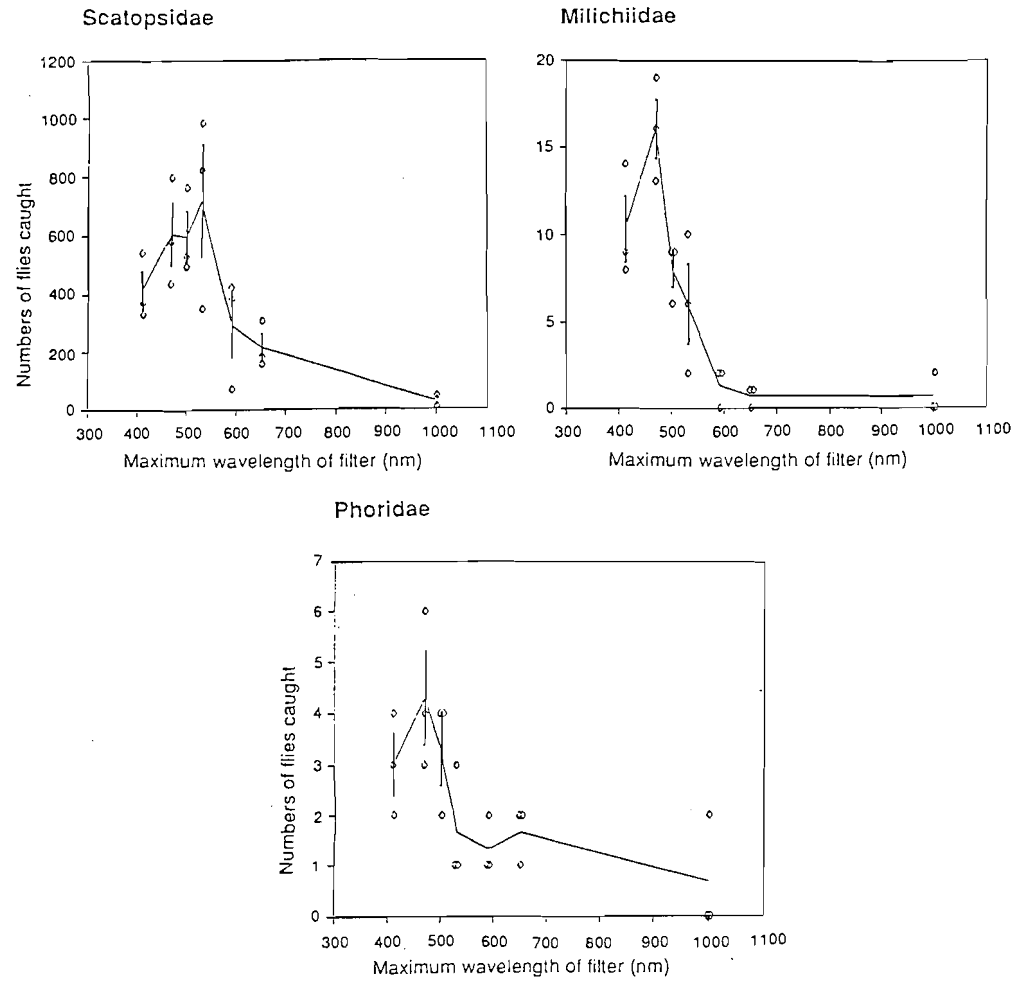

Fig. 3 - Numbers of flies attracted to one minute exposures of light of different wavelengths in Dromilly cave. Each light was exposed a total of three times in a randomised box design trial commencing at 10:45 on 28.12.92. All visible light sources produced similar relative numbers of photons whereas the IR light produced about 5 times molre. Bars indicate ± S.E.

Most of the insects observed by flashlight were relatively slow fliers so the advantage of such a flight activity period during the middle of the day could be that it coincides with a period of calm air when the bats roost. It is also possible that this could be an antipredatory strategy to avoid being eaten by bats although this seems less likely. The Scatopsidae caught rarely reached 2 mm in length anf few of the other insects exceeded 3.5 mm, so that they may not be worth hunting because of the small amount of food each would provide for a bat. On the other hand, such small insects would almost certainly be detected by the bats' sonar system, because some bats are known to be able to locate wires of 0.3 mm or smaller in diameter (GRIFFIN, 1958; GUSTAFSON and SCHNITZLER, 1979).

Tabl. 6 - Composition of adhesive trap catches in the presence and absence of coloured light. Data from tables 2,3 (experiment 1) and 5 (experiment 2).

	Percentage of total catch		
	No light	Expt 1	Expt 2
Scatopsidae	94.2	90.5	97.9
Phoridae	4.4	8.3	0.5
Milichiidae	0.8	0.8	1.5
Scelionidae	0.2	0.3	0.1
Others	0.4	0.1	0.0

The catch rates of Scatopsidae at infra-red light (191 to 5140 flies/m^2/min) were considerably higher than those of adhesive traps set out in the dark (2.7 to 7.5 flies/m^2/min). Although infra-red sensitivity is a remote possibility (it has been reported once in the compound eye of an opossum shrimp in a deep, brownish lake:

LINDSTROM and MEYER-ROCHOW, 1987), we noticed that many of these insects were caught while the filters and acetate sheets were being changed. This suggested that this represented background error rather than an indication of attraction to infra-red light. These catches may also have been influenced by possibly higher numbers of insects than usual being present near the light trap, because of attraction towards previously exposed lights.

More accurate estimates of relative responses to visible light frequencies could, therefore, probably be obtained from deducting the number caught at infra-red light. In most cases except for red light, this correlation was minor because of the far greater numbers attracted to light of visible wavelengths. Interestingly, red (652 nm) and orange lights (591 nm) attracted appreciable numbers of Scatopsidae (overall 5.4% and 11.5%, respectively) even after deduction of the infra-red catch, indicating that these flies have a very wide spectral response. Milichiidae had no appeciable responses to those wavelengths, but Phoridae showed a 4.4% response to orange light. We are aware that with very large numbers of flies trapped in front of the colour filter, spectral and absolute intensities could become slightly different, but little can be done about this what we think is a minor problem.

Insect spectral receptor types can usually be classified into three groups, namely UV, blue, and green receptors as reviewed by MENZEL (1979). Red receptors, known from a few butterflies and discovered by HORRIDGE *et al.* (1983) in *Papilio aegus*, have never been reported in Diptera (AGEE and PATTERSON, 1983). Flies appear to discriminate colours mainly by their hue; brightness playing a subsidiary role (FUKUSHI, 1990). Sensitizing, or so-called 'antenna pigments', have been found in the eyes of some Diptera, where they could broaden the spectral range of photoreceptors and, thus, increase the eyes' overall sensitivity (KIRSCHFELD *et al.*, 1977). It is tempting to think that the Scatopsidae and Phoridae in our study possessed these antenna pigments or even a receptor with sensitivity into the red.

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SUMMARY

Responses of flying insects to light of seven narrow-band wavelengths were examined using adhesive traps. Visible light with maxima at 652, 561, 531, 502, 471, and 412 nm was tested using approximately the same relative number of photons. An infra-red light source (maximum 1001 nm) with 5 times as many photons as the visible light sources was also tested. Diptera comprised the majority of catches on each of three occasions. Overall catches comprised 97.1% Scatopsidae, 1.77% Milichiidae, 0.6% Phoridae, and 0.19% Sciaridae. Similar proportions were caught in adhesive traps without light. 67% of Scatopsidae were attracted to wavelengths of 471 nm to 531 nm and other Diptera were mostly attracted to lights between 412 nm and 502 nm. Scelionid wasps (0.04% of catches) were similary attracted to wavelengths from 412 nm to 531 nm. An undescribed species of *Neoditomyia* (Mycetophilidae: Ceroplatinae) with predatory web-building larvae was present, but no adults were caught in either light or adhesive traps.

Key-words : Biospeology; Cave ecosystem; Phototaxis; Population; Sensory ecology; Diptera (Insecta); Vision.

RESUME

La réponse d'Insects volants à des lumières de sept bandes de longueur d'ondes différentes et étroites a été étudiée au moyen de pièges adhésifs. Des éclairements dans le visible, avec des maxima à 652, 561, 531, 502, 471 et 412 nm ont été testés en utilisant le même nombre approximatif de photons. Une source de lumière infra-rouge (maximum 1001 nm) avec 5 fois autant de photons que les sources de lumière visible a aussi été utilisée. Les Diptères constituent la majorité des individus collectés dans ces séries d'expériences. L'ensemble des captures se compose de 97,1% de Scatopidae, 1,77% de Milichiidae, 0,6% de Phoridae, et 0,19% de Sciaridae. Des proportions similaires ont été obtenues avec des pièges adhésifs sans lumière. 67% des Scatopsidae ont été attirés par des longueurs d'onde de 471 à 531 nm et les autres Diptères l'ont été principalement par des longueurs d'onde entre 412 et 502 nm. Les Scelionidae (0,04%) ont également été attirés par des longueurs d'onde de 412 à 531 nm. Une espèce non décrite de *Neoditomya* (Mycetophilidae : Ceroplatinae) était présente par ses larves sur des toiles prédatrices, mais aucun adulte n'a été capturé.

Mots-clé : Biospéologie ; Ecosytème souterrain ; Phototaxis ; Population ; Ecologie sensorielle ; Diptera (Insecta) ; Vision.

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