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EFFICIENCY OF LIGHT-TRAPS INFLUENCED BY ENVIRONMENTAL FACTORS

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ABSTRACT
We mean the percentage of species on the efficiency of light traps, captured a number of species present in the environment. Daily changes in the efficiency were studied in connection with the weather elements and moon phases in nine years of collecting material of light-traps operating in Kámon Botanic Garden (Szombathely, Hungary). The first catching day of a particular species is called the appearance, and after the day of the last specimen caught is called disappearance. The difference of the number of species appearing and the disappearing ones means the present species. The number of caught species in the percentage of present ones is the efficiency of light- trap. The light trapping efficiency was investigated with combined data for 9 years. It was examined separately according to each aspects assigned to daily temperature, wind speed, precipitation, relative humidity, cloud height, cloud amount data and the polarized moonlight. The relationships were examined by fitting different models. We found that the efficiency of light traps increases in all aspects with higher temperature and a high proportion of polarized moonlight, but the same can be seen only in the spring and summer aspects at a little cloud, in the autumn and winter aspects a lot of cloud and in the autumn and winter aspects a higher relative humidity causes similar effect. There is a lower efficiency in all aspects because of rain, strong winds, low clouds and high humidity in the spring and summer aspects. Strong influences of abiotic factors cause irregular fluctuations in the efficiency values for each day.

KEY WORDS: efficacy, light-trap, abiotic influences etc.

INTRODUCTION

The first catching day of a particular species is called the appearance, and after the day of the last specimen caught is called disappearance. The difference of the number of species appearing and the disappearing ones means the present species. The number of caught species in the percentage of present ones is the efficiency of light-trap. Our interpretation is without antecedent in the special literature. We stated its theoretical base in our former study (Nowinszky and Puskás, 2011) and we investigate its practical adaptability in present paper. Researchers have examined the influence of the various weather elements on collecting by light-trap all over the world. We confine ourselves to referring to some of the works that illustrate the nature of the research carried out in the world over the past decades (Williams, 1940 Persson, 1972, Járfás, 1979, Honek and Kraus, 1981, Logiswaran and Mohanasundaram, 1987, Matalin 1998). Here are a few points of interest in the results of many years of research. Light-trap effectiveness was enhanced while bait trap effectiveness was not by growing cloudiness. 14 of the 20 noctuid (Noctuidae) and geometrid (Geometridae) species were in positive correlation with temperature and 11 in negative correlation with rain (Holyoak et al., 1997). 15-20 days after the onset of monsoon rain, Sharma et al. (2002) in India observed a positive correlation between rain and relative vapour content on the one hand and the catch by light-trap of *Mythimna separata* Walker on the other. At the same time, evaporation, solar radiation, and the number of sunny hours and wind speed were in negative correlation with the number of insects trapped. A significant negative correlation was established in India between the number of specimens captivated by light-trap of *Scirpophaga incertulas* Walker and relative vapour content (Pandey et al., 2001). The efficiency of light-trap was not earlier investigated in relationship with environmental factors.

MATERIAL AND METHODS

The chosen light-trap, on purpose of examinations, operated in Kámon Botanic Garden at Szombathely (Hungary) between 1962 and 1970. We used the whole Macrolepidoptera data for investigation of connection between the environmental factors and efficiency. There were caught altogether the specimen of 549 different Macrolepidoptera species by light-trap during 9 years. The yearly catching period of light-trap, the number of caught species and swarming are shown in Table 1.

TABLE 1 Light-trap catching periods in Kámon Botanic Garden (Szombathely) as well as the number of caught species and swarming

Years	Catching periods	Number of species	Number of swarming
1962	03. 05. - 11. 21.	343	435
1963	03. 08. - 12. 03.	349	472
1964	03. 23. - 12. 19.	354	463
1965	03. 14. - 12. 21.	205	242
1966	02. 02. - 12. 02.	153	191
1967	02. 03. - 11. 19.	261	312
1968	02. 20. - 11. 26.	296	418
1969	03. 13. - 11. 27.	316	427
1970	02. 03. - 11.30.	323	437

The weather data was collected from year-book of Hungarian Meteorological Service. The data of polarized moonlight was got from our former study (Nowinszky, 2008). The method of calculation of daily efficiency values was the same as it was written in our former study (Nowinszky and Puskás, 2011). Trap effectiveness was calculated on every day of the 9-year period from the Macrolepidoptera material of the light-trap Szombathely. The number of individuals of the respective species was not considered on a daily basis, it was only examined whether certain species was present on a particular day. Data on more-generation species were processed separately according to generations. On the other hand if between the swarming times of two generations vagile or migrating individuals between the swarming periods of two generations could be easily observed, these were considered as independent generation. And if the two generations were not to be separated unambiguously from each other, the procedure used with one-generation species was followed. The trapping data of the first sample of a given generation is called appearance, and the day following trapping data of the last individual is called disappearance. The frequency of appearance and disappearance of all generations of species were summarised day by day, then it was cumulated and illustrated. The difference between the cumulated appearance (A) and the disappearance (D) was calculated. This way we obtained the number of species present (P) in the surrounding of the trap (P=A-D) as a function of time. The number of species trapped daily (T) was determined from the light-trap record and displayed with the species present (P). The individual species of course appear and disappear continuously, thus the aspects following each other cannot be sharply distinguished. We have determined the division lines of aspects through the following procedure: from appearing (A) and disappearing (D) curves of species one can look at most steep slope, *i.e.* the most dynamic variations in time. These were compared with (P) curves and the approximate time data of aspect changes could be read. Finally ratio of entrapped individuals compared with those present in the vicinity was calculated in percentages. This result is what we considered to be the effectiveness of the trap (E). Regression models were fitted and statistically evaluated with PASW18 software. The explained variances (R^2) were calculated. The models were tested with ANOVA and the parameters were tested with t-test. The normality of the residuals was verified by Kolmogorov-Smirnov test with Lillieford correction at p>0.1 level.

1. The efficiency depending on the amount of precipitation was fitted with a decreasing exponential model:

$$Y = p_1 + p_2\left(1 - \exp(-p_3 * X)\right) + \varepsilon \qquad (1)$$

where Y is for efficiency, X is for precipitation amount, p_1 is the model parameter for the case $X = 0$, p_2 is the descending value of the model, p_3 is a speed factor of the model and ε is a normally distributed error term with zero expectation.

2. The efficiency depending on the cloudiness of the sky (okta) was expressed by a third degree polynomial model:

$$Y = p_0 + p_2X^2 + p_3X^3 + \varepsilon \qquad (2)$$

where Y is for efficiency, X is for cloudiness (okta), p_0, p_2 and p_3 are model parameters. We omitted the first-degree term because it was insignificant (p>0.1). We distinguished the spring-summer time from the fall-autumn one and calculated different parameters of the model.

3. The altitude effect on the efficiency was modeled with a growing exponential model of the form (1), X is for altitude.
4. The efficiency has a strong linear correlation with moon phases which can be described with a linear model of the form $Y = p_0 + p_1X + \varepsilon$, X is for moon phases.
5. The temperature affects on efficiency through a logarithmic model: $Y = p_0 + p_1 \ln X + \varepsilon$, X is for temperature. We calculated the optimal parameters separately for each season. The model parameters were very similar for winter and spring, so we merge these data and calculated the parameters again.
6. The efficiency can also be modeled with an exponential model $Y = p_0 * \exp(p_1X) + \varepsilon$ where X is for wind speed.
7. The efficiency depending on relative humidity was fitted by a third degree polynomial model of form

$$Y = p_0 + p_1X + p_2X^2 + p_3X^3 + \varepsilon,$$

X is for relative humidity. We distinguished the spring-summer time from the fall-autumn one and calculated different parameters of the model.

The estimated model parameters, their significance level, the F values of the ANOVA tests for the models with their significance level and the explained variance (R^2) are presented in Table 1.

TABLE 2: The estimated model parameters, their significance level, the F values of the ANOVA tests for the models with their significance level and the explained variance (R^2)

Explaining factor	Model	estimated parameter		Sig.	F	Sig.	R^2
1. precipitation	$Y = p_1 + p_2(1 - \exp(-p_3 * X)) + \varepsilon$	p_1	0.307	<0.001	3921.21	<0.001	0.945
		p_2	-0.079	<0.001			
		p_3	0.179	<0.01			
2.1 cloud-cover spring-summer	$Y = p_0 + p_2X^2 + p_3X^3 + \varepsilon$	p_0	0.330	<0.001	65.34	<0.001	0.956
		p_2	-0.005	<0.001			
		p_3	0.001	<0.01			
2.2 cloud-cover fall-autumn	$Y = p_0 + p_2X^2 + p_3X^3 + \varepsilon$	p_0	0.302	<0.001	43.27	<0.001	0.935
		p_2	0.000	<0.001			
		p_3	-0.002	<0.01			
3. cloud altitude	$Y = p_1 + p_2(1 - \exp(-p_3 * X)) + \varepsilon$	p_1	0.222	<0.001	1516.60	<0.001	0.893
		p_2	0.085	<0.001			
		p_3	0.002	<0.05			
4. moon phases	$Y = p_0 + p_1X + \varepsilon$	p_0	0.264	<0.001	33.68	<0.001	0.584
		p_1	0.007	<0.001			
5. 1 temperature spring	$Y = p_0 + p_1 \ln X + \varepsilon$	p_0	0.259	<0.001	42.73	<0.001	0.767
		p_1	0.038	<0.001			
5.2 temperature summer	$Y = p_1 \ln X + \varepsilon$	p_1	0.104	<0.001	2851.57	<0.001	0.750
5.3 temperature fall	$Y = p_0 + p_1 \ln X + \varepsilon$	p_0	0.204	<0.001	11.56	<0.01	0.536
		p_1	0.037	<0.01			
5.4 temperature winter	$Y = p_0 + p_1 \ln X + \varepsilon$	p_0	0.240	<0.001	29.57	<0.001	0.767
		p_1	0.049	<0.001			
5.5 temperature winter-spring	$Y = p_0 + p_1 \ln X + \varepsilon$	p_0	0.254	<0.001	75.32	<0.001	0.758
		p_1	0.041	<0.001			
6. wind speed	$Y = p_0 * \exp(p_1X) + \varepsilon$	p_0	0.001	<0.001	166.16	<0.001	0.943
		p_1	-0.049	<0.001			
7.1 relative humidity spring-summer	$Y = p_0 + p_1X + p_2X^2 + p_3 * X^3 + \varepsilon$	p_0	2,472	<0,001	8566.46	<0.001	0.977
		p_1	-0,096	<0,001			
		p_2	0,001	<0,001			
		p_3	-6.494E-6	<0,001			
7.2 relative humidity fall-winter	$Y = p_0 + p_1X + p_2X^2 + p_3 * X^3 + \varepsilon$	p_0	8.892E-6	ns	1443.16	<0.001	0.637
		p_1	0.172	ns			
		p_2	-4.313	ns			
		p_3	-0.002	ns			

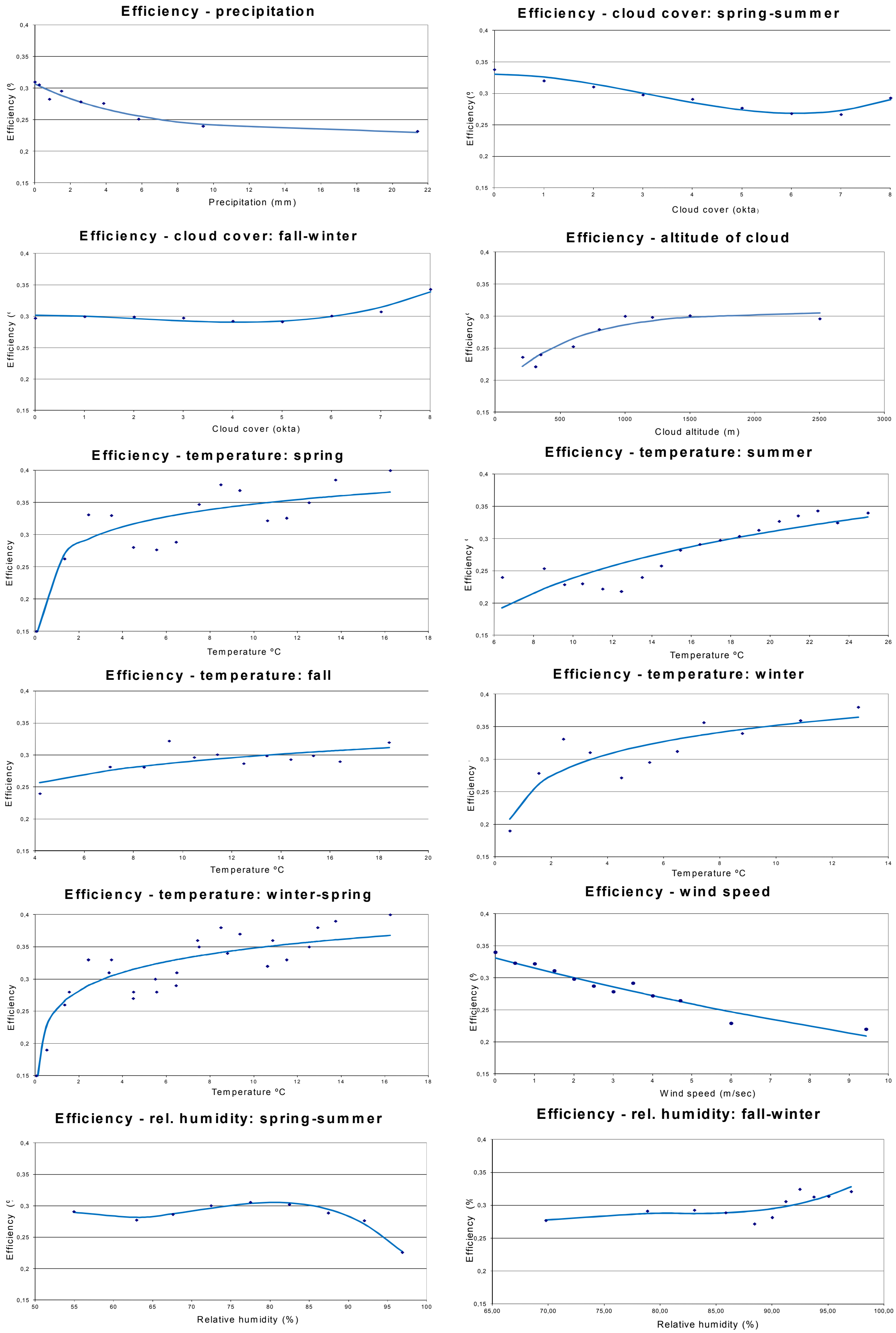

FIGURE 1: Observed data (dots) and models (lines) fitted to the efficiency (%) with predictive factors precipitation (mm), cloud cover (okta), altitude of cloud (m), temperature (°C), wind speed (m/sec) and relative humidity (%)

DISCUSSION

Higher temperature belongs to higher efficiency in all the four aspects. The wind speed is clearly reduces the efficiency of light traps in all aspects. The precipitation also caused efficiency loss, especially over the amount of 5 mm. The relative humidity of air drastically reduces the efficiency of light traps when it is above 80% in the spring and summer aspects. However, the highest efficiency is in the autumn and winter aspects if the humidity is above 90%. Probably the cause of this apparently unexpected result is the significantly higher moisture content of the air in the autumn and winter, because it was only 88.2 % and 77.1 % during spring and summer. The Macrolepidoptera species, flying in these periods, could adapt to these circumstances, thus the higher humidity is more favorable for them.

The threshold can be observed in all aspects at 1000 meters altitude clouds. The light trapping efficiency is lower below and higher above this altitude. The efficiency is high in spring and summer aspects at unclouded sky or if there is less cloud, but the efficiency decreases when sky is overcast. It is interesting that the efficiency is also high at full overcast sky (okta = 8). Probably this is because of the largest collection distance which is well used by the good flying species. The efficiency rises sharply in the autumn and winter aspects if the overcast value is above 6. The reason may be also because of the increased collection distance, and partly the higher relative humidity at cloudy sky.

The growing percentage values of polarized moonlight clearly increase the efficiency of light-traps in all aspects. This result confirms our previous statements we got about the number of moth specimens caught by light traps, also in the context of polarized moonlight (Nowinszky, 2008).

Our results show that the efficiency of light traps, similarly to the number of individuals captured, significantly changes because of the influence of environmental factors.

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