ASSESSMENT OF *Pseudaletia unipuncta* (HAWORTH) (LEPIDOPTERA: NOCTUIDAE) POPULATIONS IN AZOREAN PASTURES BY LIGHT AND PHEROMONE TRAPS

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The number of larvae and seasonal flight activity of the true armyworm, *Pseudaletia unipuncta* (Haworth) (Lepidoptera, Noctuidae), were monitored during three consecutive years (1992-1994) in pastures in S. Miguel island. *P. unipuncta* adult flight activity, monitored by light and pheromone traps, varied significantly with altitude, year or season, but was positively correlated between these two trapping systems. The adult sex ratio did not deviate significantly from 1:1. The number of adults captured influenced the performance of the two types of traps, with pheromone trap being more effective at low density of moths. Temperature affected the number of adults captured in light and pheromone traps. Consistent patterns occur year after year, especially between July and October, months with high temperatures associated with some rainfall, corresponding to conditions that are suitable for the growth of the armyworm. The highest number of adults and larvae was observed during the summer and in early autumn. The number of larvae was significantly correlated to the number of adults caught in pheromone traps and in light traps, at all the localities. The use of light and particularly pheromone traps can be very useful for monitoring the population abundance of *P. unipuncta* in Azorean pastures, as part of integrated pest management programs.

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INTRODUCTION

The true armyworm, *Pseudaletia* (=*Mythimna*) *unipuncta* (Haworth) (Lepidoptera, Noctuidae) is considered a seasonal migrant and a polyphagous pest of agricultural crops in North America (BREELAND 1958; GUPPY 1961; FIELDS & MCNEIL 1984; MCNEIL 1987) and in Europe (BUES et al. 1986). It is one of the most serious pests of the pastures in the Azores, where cattle breeding is a major industry (TAVARES 1989; TAVARES et al. 1992).

High infestations by *P. unipuncta* in summer and early autumn (TAVARES 1989; TAVARES et al. 1992) cause considerable financial damage, estimated at 8% of the annual vegetal production, valued at EUR 5 million (TAVARES 1989, 1992). A small number of entomopathogenic agents, predators and parasitoids usually regulate populations of *P. unipuncta* (TAVARES 1989; OLIVEIRA 1996; VIEIRA 1999; MEDEIROS et al. 2000), but occasionally insecticides are required (TAVARES 1989; VIEIRA 1992).

In the Azores, adult abundance is estimated using light (TAVARES 1989; TAVARES et al. 1992; VIEIRA et al. 1994) and pheromone traps (TAVARES 1989; VIEIRA et al. 1990), while larval abundance has been quantified by weekly sampling (TAVARES 1989; OLIVEIRA 1996; SILVA et al. 1996, 2003). Nevertheless, so far the efficiency of the trapping systems and the impact of climatic variability have not been established for the population assessment of *P. unipuncta*.

The most effective use of pheromone and light traps in monitoring pest populations occurs when there is a good correlation between adults caught and subsequent larval damage (TURGEON et al. 1983; SILVAIN & TI-A-HING 1985; BUES et al. 1986). However, the interpretation of trap capture is often difficult, as numerous factors may directly or indirectly affect the behavioral response of adults to different trap designs or trapping systems, such as the environmental conditions prevailing at the time of sampling (MUIRHEAD-THOMSON 1991; YELA & HOLYOAK 1997; DELISLE et al. 1998). One way to improve the evaluation of trap efficiency is the simultaneous use of several sampling methods (OLOUMI-SADEGHI et al. 1975).

Knowledge of the pattern of occurrence of *P. unipuncta* in time and space will help to identify some of the key factors that influence their population dynamics, which could provide the basis for successful population management. In this context, we undertook a three-year project to study the efficiency of light and sex pheromone trapping systems, at three different sites on the island of S. Miguel to determine: (i) the reliability of light and/or pheromone trap catch data to predict subsequent *P. unipuncta* larval outbreaks; and (ii) the effects of temperature, rainfall and altitude, on the efficiency of both trap types.

MATERIAL AND METHODS

Sampling. Three localities on S. Miguel island were selected: Relva (37°45'N and 25° 40'W; altitude 100 m), Chã da Macela (37°46'N and 25° 32'W; altitude 300 m) and Cerrado dos Bezerros (37°47'N and 25° 21'W; altitude 550 m). Weekly samples of adult and larval populations were made during 1992, 1993 and 1994 (i.e. 156 weeks). Adults were monitored from dusk (18:00) to dawn (06:00) using omnidirectional light traps, equipped with 18-Watt blacklight tubes, according to the methodology used by TAVARES (1989). Male activity was also evaluated with pheromone traps (*piège à eau*, INRA 1988) baited with 300 µg of (Z)-11-hexadecenyl acetate, containing 0.2 to 0.5% (Z)-11-hexadecenol (STECK et al. 1982; TURGEON et al. 1983).

At each locality, one light trap and one pheromone trap, spaced 300 m apart, were installed 1.5 m above ground level at the margin of a permanent grass pasture (e.g. *Lolium*, *Holcus*, *Bromus*). Throughout the study, adults were collected weekly in both trap types and lures changed once a month.

Larvae were surveyed weekly by counting the number of individuals in twenty $0.25m^2$ (= $5m^2$) randomly chosen sites at each locality, using the methods proposed by TAVARES (1989) and SILVA et al. (1996, 2003).

Weather variables. Meteorological data for each locality was obtained from the Institute of Meteorology/Azores. Calendar weekly averages of temperature and rainfall were calculated from the daily reading taken at 12:00 GMT at each site.

Statistical analysis. The number of adults caught in the traps and number of observed larvae, were log (x+1) transformed to homogenize the variance (ZAR 1996). Data from pheromone traps, light traps and larval sampling, were subjected to an analysis of variance (NESTED ANOVA), with locality and season nested within year as main effects. Seasons were defined by the following periods: winter (January to March), spring (April to June), summer (July to September), and fall (October to December). At each locality, the number of males caught in both trap types was analyzed using a 2-way ANOVA, with year and trap type as main effects. A similar analysis was carried out comparing male and female captures in the light traps, with year and sex as main effects. Relationships between the numbers of larvae, adult abundance from light (males and females) and pheromone traps with the meteorological variables were determined using non-parametric Spearmann rank correlation (r_S) analyses (ZAR 1996). Spearmann rank correlation (r_S) analyses were also performed between the number of adults captured (for light and pheromone traps) each month and the number of larvae observed in the subsequent month, to test the predictive value of each type of adult traps. All analyses were performed using SPSS 6.1 (NORUSIS 1994) for the Macintosh system.

RESULTS

Throughout the three-year trials, the number of trapped adults was consistently higher during the warmer seasons (summer and early autumn). Generally, after three remarkable peaks of captures in early July, August and September, there was a gradual decline to the lowest values in mid-October, aside from the low number of captured adults (null in some weeks) early in the winter and in the spring (Figs. 1, 2 and 3). The number of adults captured in the different traps varied significantly depending on locality and season nested within year (Table 1).

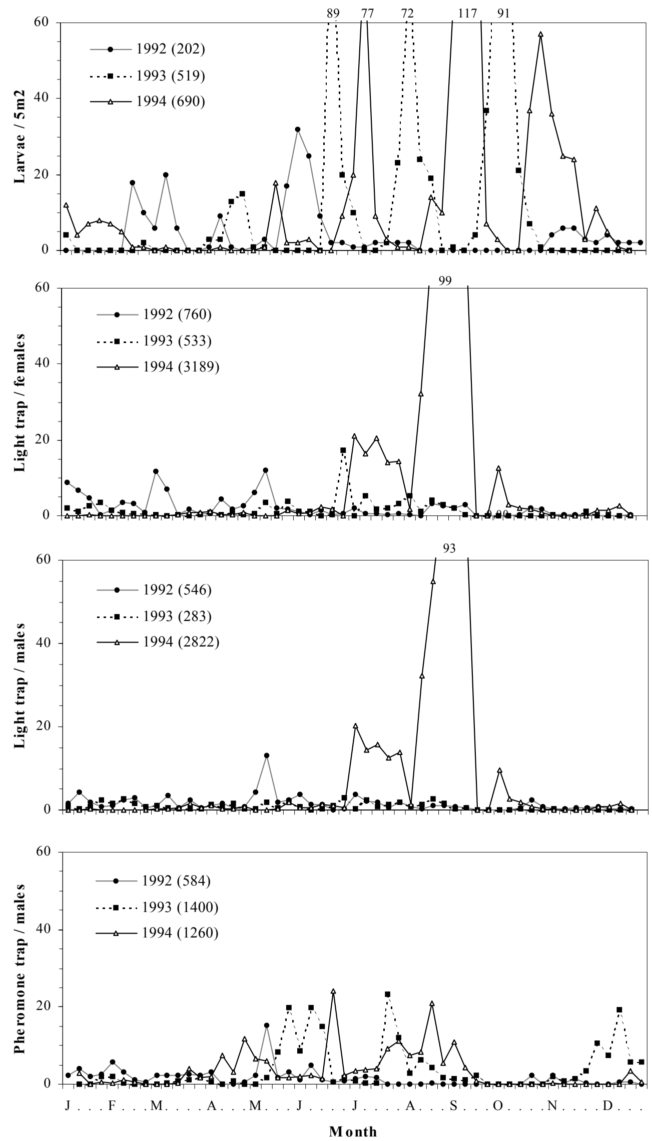

Fig. 1. Number of larvae per $5m^2$ and weekly averages of adult catches of *P. unipuncta*, using blacklight (males and females) and sex pheromone traps at Relva (S. Miguel island, Azores), from 1992 to 1994. The total number of larvae or adults caught is indicated in each graph between parentheses.

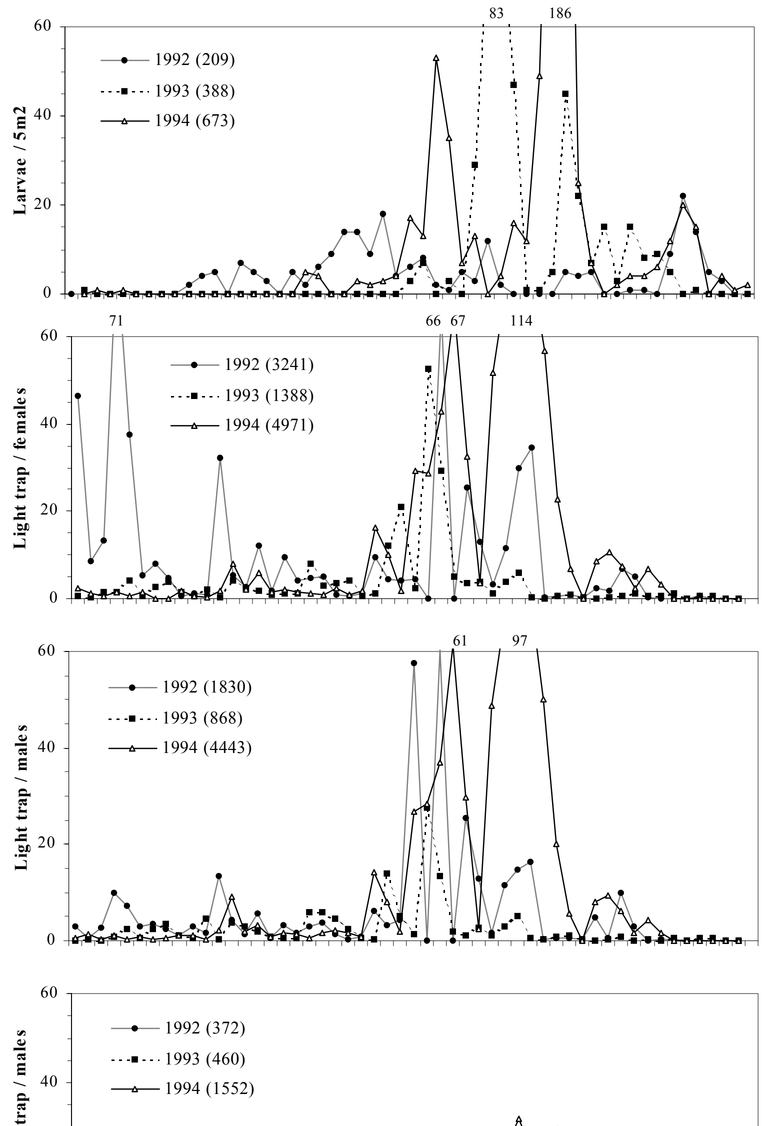

Fig. 2. Number of larvae per $5m^2$ and weekly averages of adult catches of *P. unipuncta*, using blacklight (males and females) and sex pheromone traps at Chã da Macela (S. Miguel island, Azores), from 1992 to 1994. The total number of larvae or adults caught is indicated in each graph between parentheses.

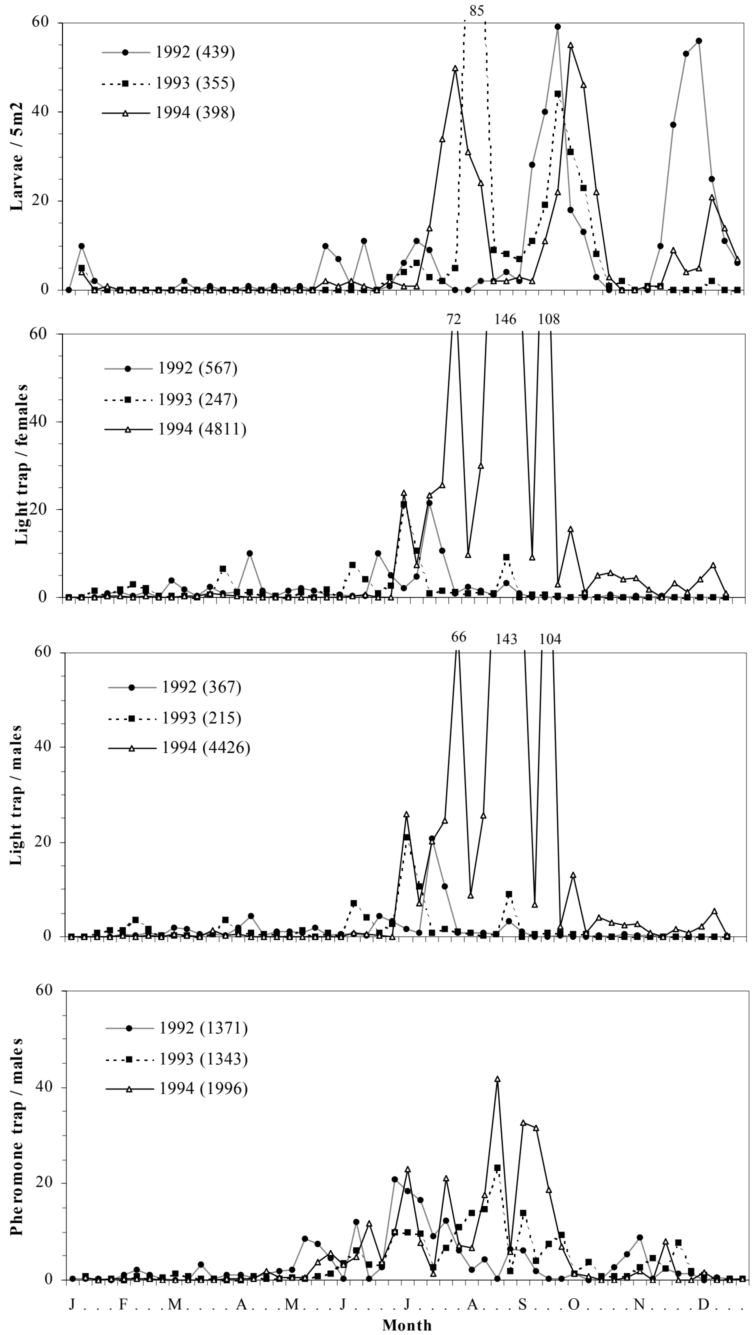

Fig. 3. Number of larvae per $5m^2$ and weekly averages of adult catches of *P. unipuncta*, using blacklight (males and females) and sex pheromone traps at Cerrado dos Bezerros (S. Miguel island, Azores), from 1992 to 1994. The total number of larvae or adults caught is indicated in each graph between parentheses.

Table 1
Analysis of variance (NESTED ANOVA) for the number of larvae, light and pheromone traps data sets for *P. unipuncta* at 3 sites on S. Miguel (Azores) in 1992-1994, with locality and season nested within year as main effects.

Source of variation	df	Number of larvae F	Number of larvae *P*	Light trap F	Light trap *P*	Pheromone trap F	Pheromone trap *P*
Locality	2	0.06	0.938	34.05	0.000	11.75	0.000
Year(Season)	11	18.23	0.000	47.54	0.000	27.50	0.000
Locality*Year(Season)	22	2.53	0.000	2.42	0.000	4.35	0.000
Residual	440						

The 2-way ANOVA analysis showed significant differences in male captures with year and trap type (Table 2). Male captures from light traps were significantly higher than from pheromone traps for the localities at medium and high altitudes (Chã da Macela and Cerrado dos Bezerros, respectively) (Figs. 2 and 3, Table 2). The interaction between these two factors (year and trap type) was only significant at the locality of lowest altitude (Relva) (Table 2).

Female catches increased over the warmer seasons and all peaks of activity were well synchronized with those of males (Figs. 1, 2 and 3). There were significant differences between years in the number of captured adults at Relva, Chã da Macela and Cerrado dos Bezerros, but not between the number of males and females (Table 3). Further, also the interaction between these two factors was not significant at the three localities (Table 3).

Table 2
Two-way ANOVA for the number of males of *P. unipuncta* caught at 3 sites on S. Miguel (Azores) in 1992-1994, with year and trap type as main effects.

Source of variation	df	Relva F	Relva *P*	Chã da Macela F	Chã da Macela *P*	Cerrado dos Bezerros F	Cerrado dos Bezerros *P*
Year (Y)	2	3.35	0.0364	7.32	0.0008	3.64	0.0273
Trap type(T)	1	3.62	0.0580	18.24	<0.0001	6.70	0.0101
Y*T	2	3.73	0.0250	1.94	0.1449	2.49	0.0847
Residual	312						

Table 3
Two-way ANOVA for the number of males and females of *P. unipuncta* caught in light traps at 3 sites on S. Miguel (Azores) in 1992-1994, with year and sex as main effects.

Source of variation	df	Relva F	Relva *P*	Chã da Macela F	Chã da Macela *P*	Cerrado dos Bezerros F	Cerrado dos Bezerros *P*
Year (Y)	2	7.12	0.0009	9.30	<0.0001	11.92	<0.0001
Sex (S)	1	1.25	0.2653	2.99	<0.0851	0.70	0.4022
Y*S	2	0.04	0.9568	0.21	0.8145	0.12	0.8855
Residual	312						

Throughout the study period, light and pheromone trap catches showed similar flight activity patterns (Figs. 1, 2 and 3), confirmed by significant Spearmann's rank correlations. The number of collected larvae was significantly correlated to the number of adults caught in pheromone and in light traps (Table 4).

Generally, the number of trapped adults of *P. unipuncta* was positively correlated with temperature of the environment in light and pheromone traps, as well with the number of larvae, particularly at the localities of higher altitudes (Chã da Macela and Cerrado dos Bezerros) (Figs. 2 and 3, Table 5).

The number of adults captured in light traps was negatively correlated with rainfall but was only significant at the medium altitude locality (i.e. Chã da Macela). The number of males from pheromone traps was significantly negatively correlated with rainfall at the localities of Relva and Chã da Macela (Table 5).

Table 4
Spearman's rank correlations between the numbers of adults of *P. unipuncta* caught in pheromone, light traps and the number of larvae, at 3 sites on S. Miguel (Azores) in 1992-1994.

Correlation	Relva	Chã da Macela	Cerrado dos Bezerros
Larvae abundance *vs.*			
Pheromone trap	0.24**	0.29**	0.54**
Light trap	0.17*	0.35**	0.34**
Pheromone trap *vs.*			
Light trap			
- males	0.31**	0.46**	0.35**
- females	0.32**	0.44**	0.32**

Significance levels for correlations are as follows: *, *P*<0.05; **, *P*<0.01.

Table 5
Spearman's rank correlations for the numbers of larvae and of adults of *P. unipuncta* caught in pheromone traps and light traps with temperature and rainfall, at 3 sites on S. Miguel (Azores) in 1992-1994.

Correlation	Relva	Chã da Macela	Cerrado dos Bezerros
Temperature (ºC) *vs.*			
Pheromone trap	0.01 ns	0.37**	0.60**
Light trap	0.33**	0.34**	0.49**
Larvae abundance	0.16*	0.50**	0.56**
Rainfall (l/m2) *vs.*			
Pheromone trap	-0.17*	-0.30**	-0.13 ns
Light trap	-0.10 ns	-0.24**	-0.13 ns
Larvae abundance	-0.01 ns	-0.02 ns	0.01 ns

Significance levels for correlations are as follows: ns, *P*>0.05; *, *P*<0.05; **, *P*<0.01.

DISCUSSION

Results show that the armyworm flight patterns given by pheromone and light traps, at medium and high altitude, present several peaks suggesting that adults move up and down in response to habitat quality, especially in summer, when the pastures at lower altitudes become very dry (VIEIRA et al. 2003). The temporal variability in the numbers of adults captured in light and pheromone traps at different altitudes on São Miguel indicates the existence of at least two or three summer generations of *P. unipuncta* (TAVARES et al. 1992; VIEIRA et al. 1994). The low numbers of larvae and adults of *P. unipuncta* observed from 1992 through 1994, during winter and spring, probably reflects populations with a small number of individuals, as well as a low rate of population increase during this period, similar to that observed in previous studies (ANUNCIADA 1983; TAVARES 1989; VIEIRA et al. 1994).

CAMPBELL et al. (1992) and DELISLE et al. (1998) reported for other species that pheromone traps are generally more efficient than light traps in attracting moths early in the season, when the populations are low, while the reverse is true when the density of moths is at its highest level. After that, pheromone trap catches decline gradually and remain low for several days at a time when light trap catches increase (HERBERT et al. 1991; DELISLE et al. 1998).

According to VIEIRA & PINTUREAU (1994) males of *P. unipuncta* are sexually mature upon emergence. This could be a reason why at the beginning of a flight period pheromone traps are quite efficient. However, when more females are present, a reduction of the pheromone trap efficiency could be a result of increased competition by unmated females for males, as suggested by CAMPBELL et al. (1992) and DELISLE et al. (1998). Similarly, our results show that in S. Miguel the seasonal changes and the total number of males caught in pheromone traps at each altitude, during the 3-year sampling period, was higher at the beginning of the flight activity period of *P. unipuncta*, when moth density was low. After the beginning of the flight period, the catches in pheromone traps of *P. unipuncta* tended to decline, as light trap catches increased.

Several abiotic factors play a significant role in the behavioral responses to both pheromone traps and calling females (for a review see MCNEIL 1991). However, the influence of such variables on the performance of different traps operating simultaneously has received little attention (DENT & PAWAR 1988; YELA & HOLYOAK 1997; DELISLE et al. 1998). Despite having first been reported by WILLIAMS (1940), temperature and rainfall effects have been largely ignored in ecological and pest management studies that use data from light and pheromone traps. In fact, our results show that consistent patterns occur year after year for the number of captures of *P. unipuncta* in both light and pheromone traps, especially between July and October, months with high temperatures associated with some rainfall, corresponding to conditions that are suitable for the growth of the armyworm.

Both trap types used in the present study rely on relative methods for population estimation (SOUTHWOOD 1978). According to WILLSON et al. (1981) and DELISLE et al. (1998), pheromone traps have generally been preferred to light traps, because they have a high specificity, are easy to maintain and, as they do not need a power source, they have great flexibility with respect to trap location.

Our results show that pheromone traps started to catch adults earlier in the flight period of *P. unipuncta*. However, when moth abundance increased, e.g. during the peaks of flight activity, the number of moth catches in light traps seemed to be higher than pheromone traps. The fact that in light traps the sex ratio does not deviate from 1:1 indicates that the increase of male and female individuals within the populations occurs similarly in the course of time, being one advantage for the use of pheromone traps, as pointed out by SILVAIN & TI-A-HING (1985) and TURGEON et al. (1983). Positive correlations were found between pheromone and light trap catches and the number of larvae, indicating that both trapping systems can be used to predict seasonal increases of larval populations. Obviously, the two trapping methods complement each other, therefore they should both be considered in Azorean agroecosystems to: (i) detect the presence of adults of *P. unipuncta*, and (ii) predict seasonal increases of larval populations in annual crops (i.e. wheat, maize) or improved Graminae pastures. Nevertheless, results show that abiotic factors, particularly temperature, should be taken into consideration when evaluating population dynamics for monitoring programs of this economically important pest.

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