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Observations on the flight activity of the Pine processionary moth *Thaumetopoea pityocampa* (Den. & Schiff.) in Greece, using synthetic sex-pheromone and light traps (Insecta Lepidoptera Thaumetopoeidae) (*)

Abstract - The flight activities of the pine processionary moth, *Thaumetopoea pityocampa* were observed using sex pheromone and light traps in the summer of 1990 in the Taigetos Mts. (Greece) at altitudes from 800 to 1450 m. Sex pheromones synthesized in Italy and Spain were successfully used in the traps in Greece. A new model of pasteboard traps was astonishingly effective. Altitude was found to have a major impact on the timing and duration of adult emergence and larval hatching. Above 1300 m, hatching began as early as June, most probably in order to utilize the period of favourable weather in summer and autumn for embryonic and post-embryonic development. The circadian rhythm of the moths involved activity late in the evening, slowing down toward midnight. Although a couple of gravid moths were caught in the light trap, females were not observed to be capable of flight.

Riassunto - *Osservazioni sul volo della processionaria del pino* Thaumetopoea pityocama *(Den. & Schiff.) in Grecia rilevato con feromoni e trappola luminosa.*

Con l'ausilio di trappole a feromoni e di una trappola luminosa, nell'estate del 1990, sono stati seguiti gli sfarfallamenti della processionaria del pino *Thaumetopoea pityocampa* (Den. & Schiff.) sui monti Taigetos (Grecia), da 800 a 1450 m/slm. Al riguardo è stato osservato che l'altitudine svolge un ruolo predominante sull'inizio e sulla fine dello sfarfallamento, cosí come sulla fuoriuscita delle larve. Al di sopra del 1300 m/slm la comparsa degli adulti inizia già in giugno, la gran parte utilizza il clima favorevole dell'estate e dell'autunno per lo sviluppo embrionale e post-embrionale, fatto che potrebbe spiegare la strategia di sviluppo degli animali adattati al

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ritmo autunnale di tale regione geografica. Nell'attività di questi lepidotteri, il ritmo circadiano rivela un picco nella tarda serata e un calo verso la mezzanotte. Nel corso delle indagini, l'efficacia delle trappole in cartone si è rivelata sorprendentemente elevata e si è verificato che il feromone sessuale sintetizzato in Italia ed in Spagna può essere utilizzato con successo anche in Grecia. Le femmine di questa specie non dovrebbero essere in grado di volare, tuttavia una coppia di femmine gravide è stata rintracciata nella trappola luminosa.

Zusammenfassung - *Beobachtungen zur Flugaktivität des Pinien-Prozessionsspinners* Thaumetopoea pityocampa *(Den. & Schiff.) in Griechenland unter Verwendung synthetischer Sexualpheromone und Lichtfang (Insecta Lepidoptera Thaumetopoeidae).*

Im Sommer 1990 wurde die Flugaktivität des Kiefernprozessionsspinners, *Thaumetopoea pityocampa*, mit Hilfe von Pheromon- und Lichtfallen in einer Höhe von 800 - 1450 m im Taigetos (Griechenland) untersucht. Fangerfolge brachten sowohl das in Italien, als auch das in Spanien synthetisierte Weibchen-Pheromon. Als besonders effektiv erwiesen sich dabei die aus Pappe angefertigten Pheromonfallen. Der jahreszeitliche Beginn und das Ende des Falterfluges sowie der nachfolgende Larvenschlupf waren abhängig von der Höhe: In 1300 m traten die Falter bereits im Juni auf, was einen günstigen Entwicklungsvorsprung vor dem relativ kühlen Winter und damit das Überleben in diesen Höhen sichert. Die tägliche Flugaktivität erreichte ihren Höhepunkt in den späten Abendstunden - um Mitternacht war eine deutliche Abnahme zu registrieren. Die Weibchen zeigten keine nennenswerte Flugtätigkeit; nur wenige Tiere erreichten die Lichtfang-Anlage.

Key words: *Thaumetopoea pityocampa*, Greece, sex pheromone, pheromone traps, light traps.

INTRODUCTION

The pine processionary moth *Thaumetopoea pityocampa* (Den. & Schiff.) is widespread in Southern Europe and North Africa. Vast surfaces of pine forests in the Mediterranean are defoliated every year by the caterpillars of this species. This forest pest attacks not only its ecological hosts, (eg *Pinus nigra* Arn., *P. halepensis* Mill., *P. brutia* Tenore) but also introduced species such as *P. insignis* Dougl. (= *P. radiata* D. Don) (Breuer et al., 1989; Devkota & Schmidt, 1990). The caterpillars, whose voracity goes on increasing in the successive instars, pose a great threat to the forest economy of the host countries.

Because defoliation occurs in winter, the reserves stored in the needles are taken away by the caterpillars; consequently wood growth of the host plant can be retarded by 40% and crown growth by 60% (Halperin, 1970). In 1977-78 in

Spain the damage caused by the caterpillars amounted as high as US$ 10 millions (Cuevas et al., 1983) when 21% of the total pine stand was defoliated.

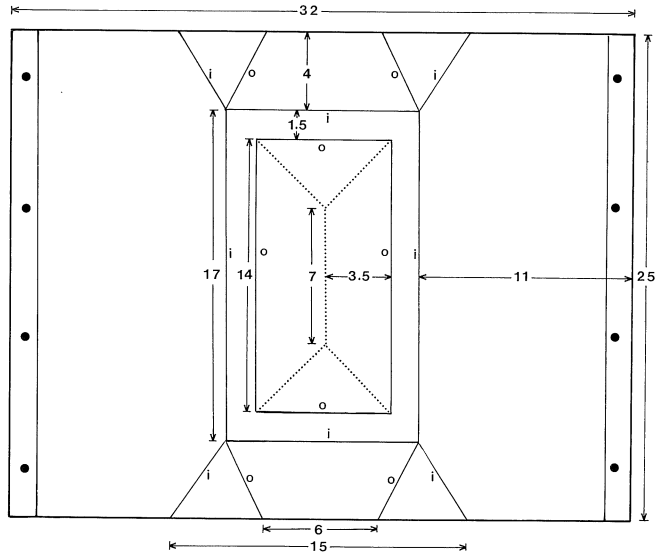
The times of adult emergence, egg laying and larval hatching vary from place to place. Altitude plays a key role in determining the onset and duration of adult eclosion and larval hatching (Tiberi & Niccoli, 1984). The adults start to appear in early or mid summer at higher altitudes but only in autumn at sea level (Schmidt et al. 1990b). In order to register the onset and duration of the flight period in any region, female sex pheromones (Guerrero et al., 1981) can be used to attract the male moths. Such monitoring makes it possible to forecast the time of larval hatching, the peak period of defoliation and the approximate economic loss, so that effective control measures can be undertaken in proper time to keep the populations of this pest below the economic threshold. The literature provides information on the flight period of these moths in Morocco (Graf, 1990), Spain (Cuevas et al., 1983), France (Einhorn et al., 1983) and Italy (Carpita et al., 1983). Moreover, it has been shown that gravid females of *T. pityocampa* in France (Demolin, 1969) and *T. wilkinsoni* (Tams) in Israel (Halperin, pers. comm.) are capable of flight. The present investigation was undertaken to determine whether the female pheromones effective in Morocco, Spain, France and Italy also attract male moths in Greece, and whether the gravid female moths in this area can also fly.

MATERIALS AND METHODS

In summer 1990, 21 pheromone dispensers were installed in the pine stands in the Taigetos mountains of the Peloponnese (Greece). Three of the pheromone capsules were prepared in Italy (Instituto Guido Donegani, Novara, Italy), and the others were made in Spain by the Departmento de Chimica Organica Biologica, Centre d'Investigacio i Desenvolupament, Barcelona. Among the traps themselves, four were made of plastic (see Montoya 1984) by the Instituto Nacional para la Conservacion de la Naturaleza (ICONA) and the rest were constructed using pasteboard by the Department of Zoology-Entomology, University of Hannover, FRG (fig. 1), modified after the triangular model of Lewis & Macaulay (1976).

These traps were hung in pine trees about 2 m from the ground. Pine stands occurring between 850 and 1450 m above sea level were chosen as study plots to monitor the differences in flight activity at various altitudes. Traps were not installed below 850 m because there is no pine forest on the lower portion of the slope toward the Gulf of Messene.

The male moths captured in the pheromone traps were collected and counted every three days. Above 1200 m of altitude, egg batches were collected



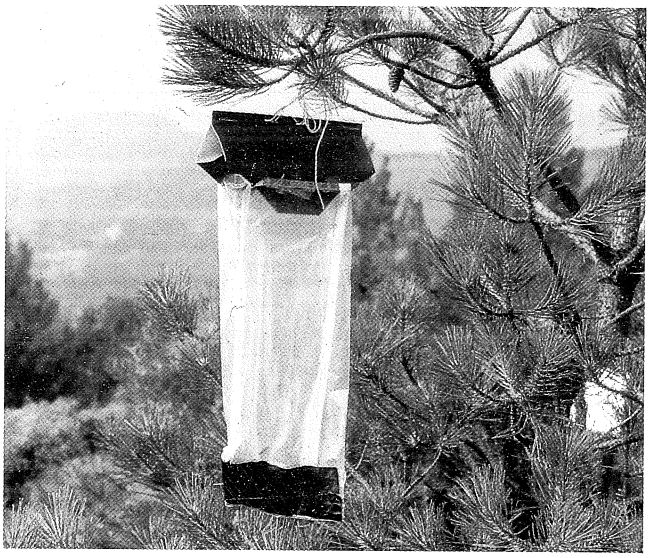


Fig. 1 - Pheromone trap constructed by the Department of Zoology-Entomology, University of Hannover (FRG).
a. Scheme of pasteboard trap before folding. All measurements are in cm.
..... : Cut
——— : Fold, o - outside; i - inside
b. Folded trap hung in a pine tree. The plastic bag, the lower part (ca. 5 cm) of which was painted black, was fixed with adhesive tape.

and brought to Hannover in order to register the hatching of the larvae and thus calculate the onset of adult emergence at high altitude.

The degree of defoliation in the vicinity of each pheromone trap was categorised (using a scale from 1 to 5 for ascending defoliation) and noted in order to determine whether the number of moths captured in each trap and the degree of defoliation exhibit any positive relationship.

Furthermore, the circadian rhythms of activity of the moths were recorded using light traps (2 superactinic TL 20W/05 Philips tube lights with high UV radiation, 2 black light fluorescent tubes and 1 Osram HWL 250W lamp). The sites for light trapping were selected based on altitude. The wing span and the body length of the moths captured in the light traps, both male and female, were measured.

At 1350 m a thermohygrograph was installed to register the temperature and humidity around the clock throughout study.

RESULTS

Altitude and eclosion of moths

The eclosion of the adults starts in summer and lasts until mid autumn, depending on the altitude and climate. The different rates of capture of male moths in the different traps clearly demonstrate the influence of altitude on eclosion in the Greek Taigetos mountains (fig. 2). At 800-1000 m, eclosion was still in full swing in the first week of August, whereas above 1200 m the peak of the eclosion seemed to have already passed. The number of moths counted on the 1st of August from 1000-1200 m and from above 1400 m correspond to that on 4th and 7th August from 800-1000 m, respectively.

Moreover, on August 3rd, at an altitude of 1300-1400 m, newly hatched larvae were seen feeding on the needles of *P. nigra*. From the egg batches collected at this altitude, hatching continued on the 4th, 7th, 8th and 10th of August. Assuming 36-38 days as the normal duration for embryonic development (Schmidt et al., 1990), late June seemed to be the time when these eggs were laid, i.e. the time of eclosion of female moths.

From the egg batches collected at 1200 m of altitude and brought to Hannover, hatching began in the laboratory in mid August and continued for 2 weeks. Peak eclosion of adults at this altitude were determined to be in mid July.

Degree of defoliation and catches

At higher altitudes, the degree of defoliation was higher, but the activity of the moths was clearly lower. Because eclosion of the moths at the higher

altitudes was already finished, no clear relationship between the degree of defoliation and the number of moths caught in the pheromone traps could be found. No significant difference could be observed between the catches in pine forests located at the same altitude but suffering from different degrees of defoliation.

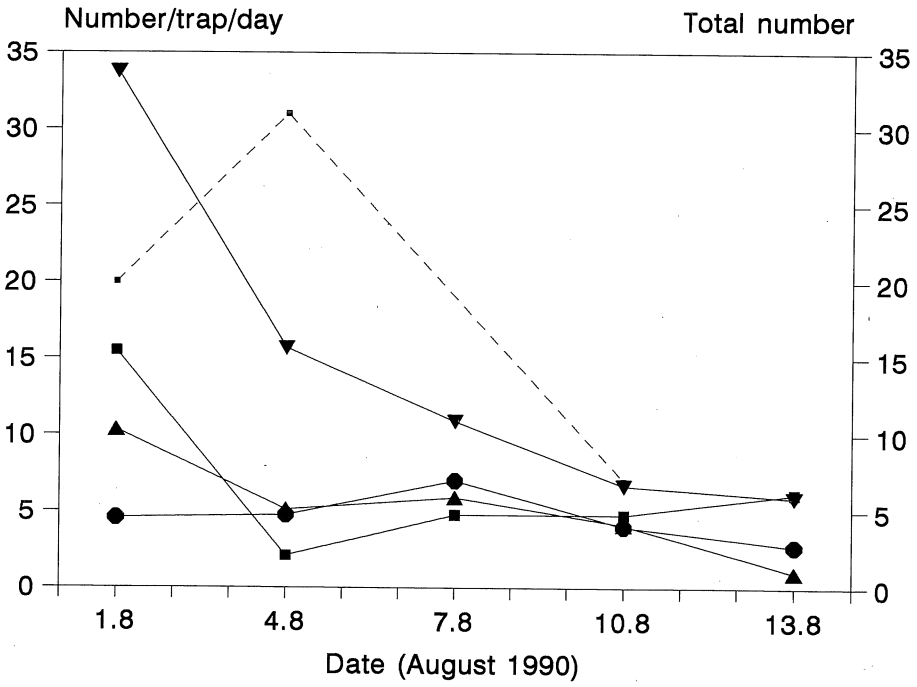


Fig. 2 - Mean number of male moths per trap and day captured in pheromone traps (Y1-axis) during the period of investigation (30th July - 13th August 1990) cleared on the given days at different altitudes: -▼- 800 - 1000 m; -■- 1000-1200 m; -●- 1200 - 1400 m; -▲- over 1400 m. Y2-axis (--▪--) represents the total moths flown to the light traps on the given days.

Temperature and humidity

The atmospheric temperature and humidity, recorded daily within the period of field study, seemed to have no influence on the number of moths caught.

Effectiveness of pheromone traps

The number of moths caught in the ICONA and pasteboard traps, hung at the same altitudes and in equally defoliated pine stands, showed the relative

effectiveness of the two types of trap. Surprisingly enough, significantly more moths were found in the pasteboard traps (Table 1).

Table 1 - Moths caught in the ICONA and pasteboard traps during the study period. Average number of moths per trap at the given altitude.

Altitude [m]	ICONA traps	pasteboards traps
1140	66	109,5
1350	33,5	89,4
1400	55	76

One trap was hung on a tree other than a pine, some 35-40 m away from the nearest pine tree (at an altitude of 1000 m), to determine how far the pheromone can diffuse and whether it remains effective to attract the male moths from a distance. The number of male moths flown to this trap was well in accordance with the average at that altitude.

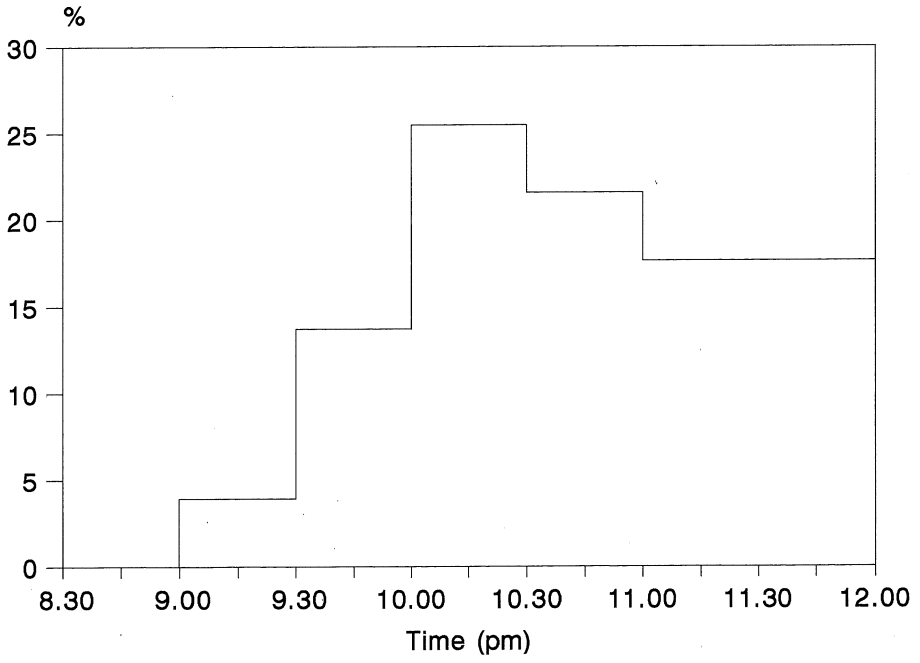


Fig. 3 - Percentage of male moths flown to the light traps in every 30 minutes in the evening (till midnight).

Wasps *Paravespula vulgaris* (L.) and *P. germanica* (Fabr.) were found preying on the moths captured in the pheromone traps. A small centipede was also found in one of the traps.

Light trapping

The activity of the moths began at about 9.15 pm and reached a maximum at 10.00 to 10.30 pm when about 25% of the total number of captured moths flew into the illuminated traps at 1400 m and 1450 m of altitude (fig. 3). Towards midnight the flight activity of the moths was found to be decreasing. The second y axis of fig. 2 shows the total catches in three consecutive nights of light trapping.

On August 4th, three female moths, still full of eggs, were attracted to the trap soon after the lamps were lit (between 9.10 and 10.10 pm). These 3 moths had an average wingspan of 51.1 ± 1.2 mm and body length of 23.03 ± 0.2 mm. No other female moths were ever caught in the light traps.

The mean wing span and body length of male moths caught in the light traps, were found to be 38.9 ± 1.6 mm and 15.3 ± 1.0 mm, over all altitudes; no significant differences were found between the moths caught at different altitudes.

DISCUSSION

This study verifies that the eclosion of the moths starts earlier at higher altitudes in Greece. In the lower regions the flight of the moths begins later: the animals escape the hot and dry summer of the Mediterranean through diapause as pupae, buried in the soil at a mean depth of 10-12 cm (Schmidt et al., 1990a). At higher altitudes, the summer is more moderate and the unfavourably cold winter begins earlier and lasts longer; therefore, the insects must utilize as much as possible of the period of favourable weather in summer and autumn for their post-embryonic development. The animals have thus adapted to the climate at high altitude by decreasing the length of the diapause period. Above 1400 m, the adults seem to have begun emerging in the end of June but the peak period of eclosion was in early July; at 1200 m this peak was calculated to occur later, in mid July. In the Atlas mountains of Morocco Graf (1990) found the maximum eclosion to be in the second week of July in areas above 1200 m and in the third week of July at altitudes of 600-1200 m. Cuevas et al. (1983) reported higher eclosion rates at altitude in early July in Mora de Rabielos, Teruel, Spain; Camps et al. (1988) found similar results in the same region. In the laboratory, Devkota & Schmidt (1990) have observed the onset of eclosion on June 26th after a diapause period of only 6 months. However not all the

moths hatch in the same year (Demolin, 1969; Devkota & Schmidt, 1990); diapause can last up to 4 years in *T. pityocampa* (Demolin, 1969) – *T. wilkinsoni*, a sister species, can pass up to 6 years in the hypogeal stage (Halperin, 1970; 1990). The moths hatching early in the summer might therefore also have undergone a diapause of several years.

The ambient temperature and humidity was not found to influence the eclosion of the moths. The degree of defoliation was higher at higher altitudes but the catches in the traps were not. Nevertheless, the peak time of eclosion of adults at higher altitudes was before the study period (see above). If this experiment had been done at the beginning of July, perhaps a positive relationship between the catches of adults and degree of defoliation could have been demonstrated. The catches from various pine stands at the same altitude but suffering different degrees of defoliation showed no relationship between the number of adults and the amount of damage to the forest. This may be due to the unreliability of pheromone trapping as a method for forecasting infestation levels. Indeed, Tiberi & Niccoli (1984) and Roversi (1985) have shown that pheromone trapping does not reflect the actual level of infestation in an area. By contrast, Halperin et al. (1984) described the population density as a major factor affecting the efficacy of mass trapping of *T. wilkinsoni*.

The female sex pheromones from Italy and Spain were effective in Greece, as well. Perhaps the larger opening of the pasteboard traps (12.0 sq.cm), constructed in Hannover, was more suitable for the diffusion of the pheromone and permitted astonishingly higher catches than the ICONA traps with an opening of only 4.8 sq.cm. Cuevas et al (1983) tested four other types of traps, in addition to ICONA traps, in a pine stand in Alicante, Spain, and found the ICONA traps less effective than the others. Carpita et al. (1983) in Italy found no great difference between the efficiencies of delta and funnel traps.

In the present field study, no females were observed to be capable of flight. On August 4th, three gravid females were caught in a light trap placed under a thick pine stand. These female moths must have either emerged very near to the light trap or glided down from the pine branches. A wing span of 51.1 ± 1.2 mm is probably not enough to lift the gravid moths for flight. In previous studies in Kassandra (Chalkidiki, Northern Greece) no females were caught in the light traps, but a female was observed flying after laying her eggs. Demolin (1969) observed *T. pityocampa* female moths capable of flying more than 2 km at a speed of 10-15 km/h. The females of another east mediterranean vicarious species *T. wilkinsoni* are also capable of flight (Halperin, personal communication). No significant relationship was found between altitude and the wing span of the male moths.

The circadian rhythm in the flight activity of these moths in the Taigetos mountains (altitude ca. 1400 m) was quite similar to that observed by Demolin

(1969) at Mont Ventoux (altitude 500 m) in France. In both cases, most of the animals were active in the late evening. A previous study in Kassandra (Chalkidiki, North Greece) also showed a maximal flight activity of male moths in the late evening (9-11 pm).

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