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Monitoring of *Matsucoccus feytaudi* (Hemiptera: Matsucoccidae) and its natural enemies in Spain using sticky tapes and pheromone traps

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Key words. Hemiptera, Matsucoccidae, *Matsucoccus feytaudi*, Spain, Neuroptera, Hemerobiidae, *Hemerobius stigma*, Hemiptera, Anthocoridae, *Elatophilus nigricornis*, Coleoptera, Malachiidae, *Malachiomimus pectinatus*, natural enemies, predators, host plant, *Pinus pinaster*, survey, phenology

Abstract. The maritime pine bast scale, *Matsucoccus feytaudi* Ducasse (Hemiptera: Matsucoccidae), occurs in the western part of the Mediterranean basin and is a sap sucking insect that feeds only on maritime pine (*Pinus pinaster* Aiton). It causes damage in SE France and Italy, where it was accidentally introduced. In Spain information is scarce and, moreover, almost nothing is known about the predators of this species. This study was designed to determine the seasonal trends in abundance of *M. feytaudi* and its major predators, which might help to improve the biological control of this pest in other areas. Natural *P. pinaster* stands in the Valencian Community (Spain) were surveyed in 2004. In addition, the seasonal trends in abundance of *M. feytaudi* and its natural enemies were monitored in three stands over a period of three years (2002, 2005 and 2006). The monitoring was carried by wrapping sticky tapes around tree trunks and using delta traps baited with sexual pheromone. The maritime pine bast scale was detected in all the stands surveyed. At almost all the sites surveyed, three species of predators were captured: *Elatophilus nigricornis* Zetterstedt (Hemiptera: Anthocoridae), *Hemerobius stigma* Stephens (Neuroptera: Hemerobiidae) and *Malachiomimus pectinatus* (Kiesenwetter) (Coleoptera: Malachiidae). The presence of *M. pectinatus* is noteworthy as this is the first record of this species as a possible predator of *M. feytaudi*. The results show that *M. feytaudi*, although differing in its phenology depending on the location, is univoltine in the study area. The prepupae, pupae and adults of *M. feytaudi* appeared between December and March in colder areas and between October and February in warmer areas. *E. nigricornis* nymphs are important predators of *M. feytaudi*, and were abundant when the scale insect (crawlers, prepupae, pupae, male and female adults) was present. The flight period of *E. nigricornis* and the hemerobiid *H. stigma* ranged from May to October. However, these flight patterns did not correlate with the presence of the different stages of the bast scale (crawlers, prepupae, pupae, male and female adults) on the surface of tree trunks. The presence of *M. pectinatus* in large numbers in some stands suggests it might be an important natural regulator, which helps to keep *M. feytaudi* populations at low densities in the areas of Spain studied. This malachiid shows a strong kairomonal attraction to the sexual pheromone of *M. feytaudi* and its flight activity is significantly correlated with the presence of crawlers of bast scale.

INTRODUCTION

The maritime bast scale, *Matsucoccus feytaudi* Ducasse 1941 (Hemiptera: Matsucoccidae), feeds only on maritime pine, *Pinus pinaster* Aiton. In the western part of the Mediterranean basin, *M. feytaudi* is considered to be endemic and does not cause significant injury to maritime pine (Riom & Gerbinot, 1977). In some of the areas where this insect has been accidentally introduced it causes severe damage, e.g., SE France, N Italy and Corsica. This species was implicated in the decline of 120,000 ha of maritime pine in SE France between 1960 and 1970 (Carle, 1974; Riom & Tacon, 1994). More recently, *M. feytaudi* has become a serious pest in N Italy (Liguria) where it was introduced in the late 1970s (Arzone & Vidano, 1981; Covassi & Binazzi, 1992) and Corsica where it was detected for the first time in 1994 (Jactel et al., 1996, 1998, 2006).

M. feytaudi is considered to be univoltine (Riom & Gerbinot, 1977; Arzone & Vidano, 1981; Covassi & Binazzi, 1992), however, in Portugal, Branco et al. (2001) report that most are univoltine but a few are bivoltine.

All the known natural enemies of *M. feytaudi* are predators. No parasitoid has ever been recorded for any species of the genus *Matsucoccus*. The predators belong mainly to the families Coccinellidae, Dasytidae, Rhaphididae, Chrysopidae, Hemerobiidae and Anthocoridae (Fabre et al., 2000; Binazzi et al., 2002; Mendel et al., 2003; Foldi, 2005; Branco et al., 2006, 2011; Raimundo et al., 2006). The sexual pheromone of *M. feytaudi* has been identified and synthesized (Einhorn et al., 1990) and this resulted in new studies on the life history and spread of this scale and its natural enemies. Moreover, it has been shown that the sexual pheromone has a strong kairomonal attraction over its predators: e.g., *Elatophilus* sp. or *Hemerobius* sp. (Branco et al., 2001, 2006, 2011; Binazzi et al., 2002; Mendel et al., 2004). According to Mendel et al. (2004), most species of pine bast scales occur at extremely low densities in their natural environment and, therefore, there is either no or little information on their principal natural enemies.

For the eastern Iberian Peninsula there is little information on the distribution, density and life cycle of *M. fey-*

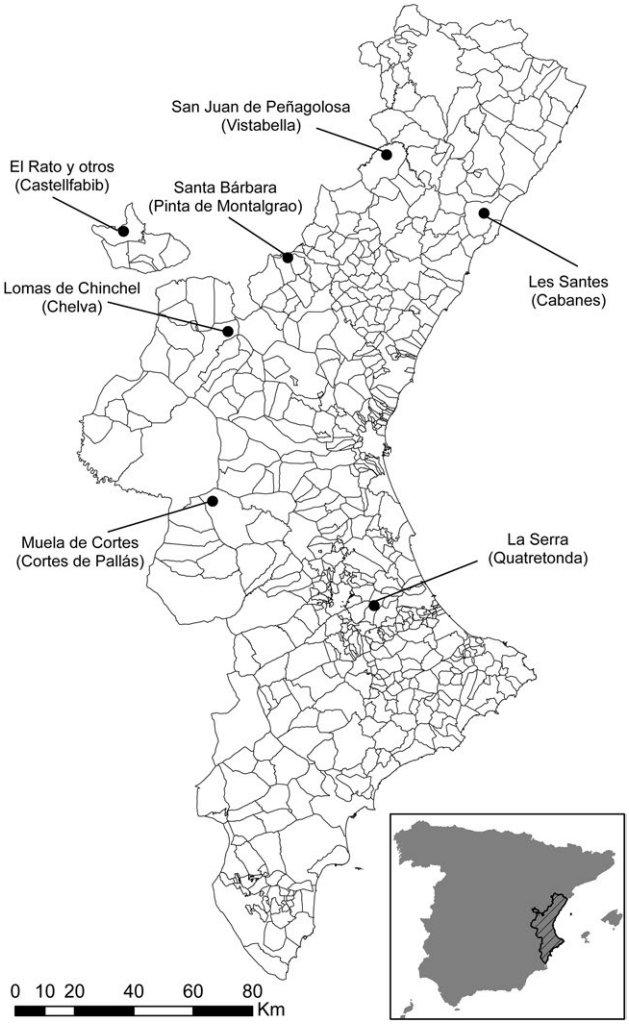

Fig. 1. Location of the natural stands of *P. pinaster* surveyed in the Valencian Community in 2004 using traps baited with the sexual pheromone of *M. feytaudi*.

taudi (Cadahia & Montoya, 1968) and even less on its natural enemies. Cadahia & Montoya (1967) erroneously report that *Elatophilus nigrellus* (Zetterstedt 1838) (Hemiptera: Anthocoridae) is a natural enemy of *M. feytaudi*. In France, another species, *E. nigricornis* (Zetterstedt 1838) (Hemiptera: Anthocoridae), is considered to be an important natural enemy of *M. feytaudi*. *E. crassicornis* (Reuter, 1875) is reported to be attracted to the sex pheromone of *M. feytaudi* in maritime pine stands in Portugal (Branco et al., 2006). However, only a few specimens of *E. nigricornis* have been found in Spain (Pericart, 1972; Ribes, 1986; Ribes & Ribes, 2000) and this insect's biology is unknown.

This study was carried out in the Valencian Community (E Spain), located in the western part of the Mediterranean basin. The main objective was to determine whether *M. feytaudi* and its natural enemies are present in several maritime pine stands located in the Valencian Community. In addition, the phenology of *M. feytaudi* and its native natural enemies were determined.

MATERIAL AND METHODS

Sampling sites and time periods

In 2004, a survey of the maritime pine bast scale was carried out in natural stands of *P. pinaster* in the Valencian Community (Alía et al., 1996). The objective of the survey was to determine if bast scale was present. Seven natural stands were sampled (Table 1, Fig. 1) using delta traps baited with the sexual pheromone of bast scale. Samples were collected every 15 days from the beginning of February to the end of April 2004.

Three study areas were selected for studying the phenology of *M. feytaudi* and its natural enemies, namely Muela de Cortes, Lomas del Chinchel and La Serra. Muela de Cortes was where we detected the maritime pine bast scale for the first time and studied its life cycle from January to September 2002. This area is located inland of the province of Valencia at a height of 830 m above sea level (a.s.l.) and the average temperature there was 14.8°C in 2002.

Subsequently, based on the results obtained in the 2004 survey, two more areas, La Serra and Lomas del Chinchel (Valencia, Spain), were chosen (Table 1, Fig. 1). These areas have different features and denser stands of *P. pinaster*. La Serra is located near the coast at an altitude of 452 m a.s.l., while Lomas del Chinchel is located inland of the province and at 971 m a.s.l. The distance between these two areas is 140 km. The average annual temperature during the year of the study also differed: 17°C at La Serra and 11.8°C at Lomas del Chinchel. The sampling period at La Serra and Lomas del Chinchel was from January 2005 to March 2006. At Muela de Cortes, Lomas del Chinchel and La Serra, sticky tapes placed round the trunks of trees were used. In addition delta traps baited with sexual pheromone were used at La Serra and Lomas del Chinchel. The details of the sampling methods are given in the next section.

TABLE 1. Natural stands of *P. pinaster* in the Valencian Community that were surveyed in 2004 using traps baited with the sexual pheromone of *M. feytaudi*.

Mountain	Natural stands [a]	UTM coordinates	A[b] – ht pines [c]
Santa Bárbara (Pina Montalgrao) [d]	Sierra Espadán	30T 724800E 460000N	1170 m – 10 m
El Rato y otros (Castellfabib) [d]	Albarracín	30T 643386E 449561N	1160 m – 4 m
La Serra (Quatretonda) [d]	La Safor	30S 729024E 317025N	480 m – 7 m
Muela Cortes (Cortes de Pallás) [d]	Levante	30S 675273E 342910N	865 m – 5 m
Lomas Chinchel (Chelva) [d]	Serranía de Cuenca	30S 674300E 408040N	930 m – 8 m
San Juan (Vistabella) [d]	Maestrazgo	30T 701600E 433700N	1400 m – 10 m
Les Santes (Cabanes) [d]	Benicàssim	31T 758900E 443600N	350 m – 5 m

[a] Names assigned to the natural stands of *P. pinaster* in the Valencian Community based on the genetic, climatic, geographic and soil characteristics of the pine forests (Alia et al., 1996); [b] altitude (m); [c] average height of the pines (m); [d] municipality.

Meteorological data were obtained from representative stations in towns located near each study area (Muela de Cortes, Aras de los Olmos and Lluxent). Temperature data were adjusted to a sinusoidal function, as this pattern was observed in the data. The aim was to determine whether there are correlations between biological cycles and temperature. Sinusoidal function is given by the formula:

$$T(d) = A + B * \sin\left[\tfrac{2\pi}{365}(d + C)\right]$$

d: day of year (*d* = 1 indicates January). *A* is the average of the mean daily temperature, *B* is amplitude and *C* is a fitting parameter.

Sampling methods

Sticky tapes

At the three study areas, the phenology of *M. feytaudi* and its natural enemies was studied using sticky tapes placed round the trunks of trees. The aim was to capture both the mobile stages of the scale insect and its predators that were moving on the trunks of trees. For sampling purposes, 5-cm wide plastic tape, with adhesive on both sides (tesa®, Beiersdorf AG, Hamburg, Germany), was used and placed around tree trunks at a height of 1.6–1.7 m above the ground. This kind of trap has been used to capture the mobile stages [mobile phase of first larval stage (crawlers) and prepupae], pupae, male and female adults of *M. feytaudi* as well as adults and nymphs of *E. nigricornis* (Riom & Gerbinot, 1977; Riom, 1979; Fabre et al., 2000).

At Muela de Cortes, 40 trees showing some signs of distress were chosen. Tapes were removed every 10 days, except from July to September when they were removed monthly. Once separated from the tree, tapes were wrapped in transparent polyethylene film and taken to the laboratory. The insects captured were then counted and recorded using a stereomicroscope and the stages of the bast scale, males and females, along with the nymphs and adults of *E. nigricornis*, were distinguished. The insects found on the side of the tape that was in contact with the environment (exterior) and those in contact with the tree trunk (interior) were recorded separately. *E. nigricornis* was identified using the key of Pericart (1972).

At La Serra and Lomas del Chinchel, 13 and 18 trees, respectively, were chosen. In these areas, the insects captured on both sides of the tape were counted together. Tapes were replaced every 15 days during the sampling period.

Traps baited with the sexual pheromone of *M. feytaudi*

For the survey and the study of the phenology of *M. feytaudi* and its natural enemies at La Serra and Lomas del Chinchel, the sexual pheromone of the bast scale was used. Three delta traps with 18.5 × 20 cm sticky plates were placed in each sampling area (seven surveyed stands and La Serra and Lomas del Chinchel). Two of the three traps were baited with the sexual pheromone of *M. feytaudi* and the third lacked pheromone and was the control. Lures consisted of a rubber septum impregnated with 200 µg of the pheromone, which was provided by INRA (Institute National de la Recherche Agronomique, Versailles, France). Traps were replaced every 15 days and the pheromone lure every 30 days.

Traps were fastened individually by wire to tree trunks at approximately 1.50 m above the ground. Sticky plates were taken to the laboratory where the captured *M. feytaudi* males and their natural enemies were counted and recorded using a stereomicroscope. Natural enemies were extracted from the trap using Histoclear® and kept in glass vials containing 70% alcohol. The specimens collected were identified by specialists. *E. nigricornis* was identified by M. Baena, *Hemerobius stigma* Stephens 1836 (Neuroptera: Hemerobiidae) by V. Monserrat and *Malachiomimus pectinatus* (Kiesenwetter, 1866) (Coleoptera: Malachiidae) by R. Constantin.

Statistical analysis

At La Serra and Lomas del Chinchel the relationships between natural enemies (*E. nigricornis* nymphs and *E. nigricornis*, *H. stigma* and *M. pectinatus* adults) and the stages of the bast scale (crawlers, prepupae, pupae, male and female adults) present in crevices in the bark, were studied. For this purpose a simple linear regression analysis was performed using the catches of the different stages of *M. feytaudi* and its natural enemies and the data analyzed using ANOVA. The numbers of the different stages of scale, *E. nigricornis* nymphs and adults, *H. stigma* and *M. pectinatus* were transformed using log (x + 1). All the statistical analyses were done using Statgraphics 5.1.

RESULTS

Survey of *M. feytaudi* and its natural enemies in the Valencian Community

The traps baited with the sexual pheromone of *M. feytaudi* caught maritime bast scales in all the *P. pinaster* stands studied in the Valencian Community (Table 2). The total number of males captured was approximately 8,000, and the largest number was captured in the first two weeks of February in all the stands. No males were caught by the control traps.

The traps baited with the sexual pheromone of *M. feytaudi* caught three other species of insect, namely *E. nigricornis*, *H. stigma* and *M. pectinatus* (Table 2). The catches of *M. pectinatus* were particularly noteworthy making up approximately 90% of the catch.

Comparing the catches on the internal and external surfaces of the sticky tapes

At Muela de Cortes a total of approximately 8,400 specimens of *M. feytaudi* were captured during the sam-

TABLE 2. Total numbers of males of *M. feytaudi* and natural enemies caught from February to April 2004 in a survey of all the natural maritime pine forests in the Valencian Community using traps baited with the sexual pheromone of the scale.

	M. feytaudi males	*H. stigma*	*E. nigricornis*	*M. pectinatus*
Santa Bárbara	849	15	5	613
El Rato and others	2361	62	7	340
La Serra	381	12	34	1161
Muela Cortes	385	5	1	3
Lomas Chinchel	1157	18	7	452
San Juan	1209	41	0	2
Les Santes	1823	37	0	10
Total insects	8165	190	54	2581

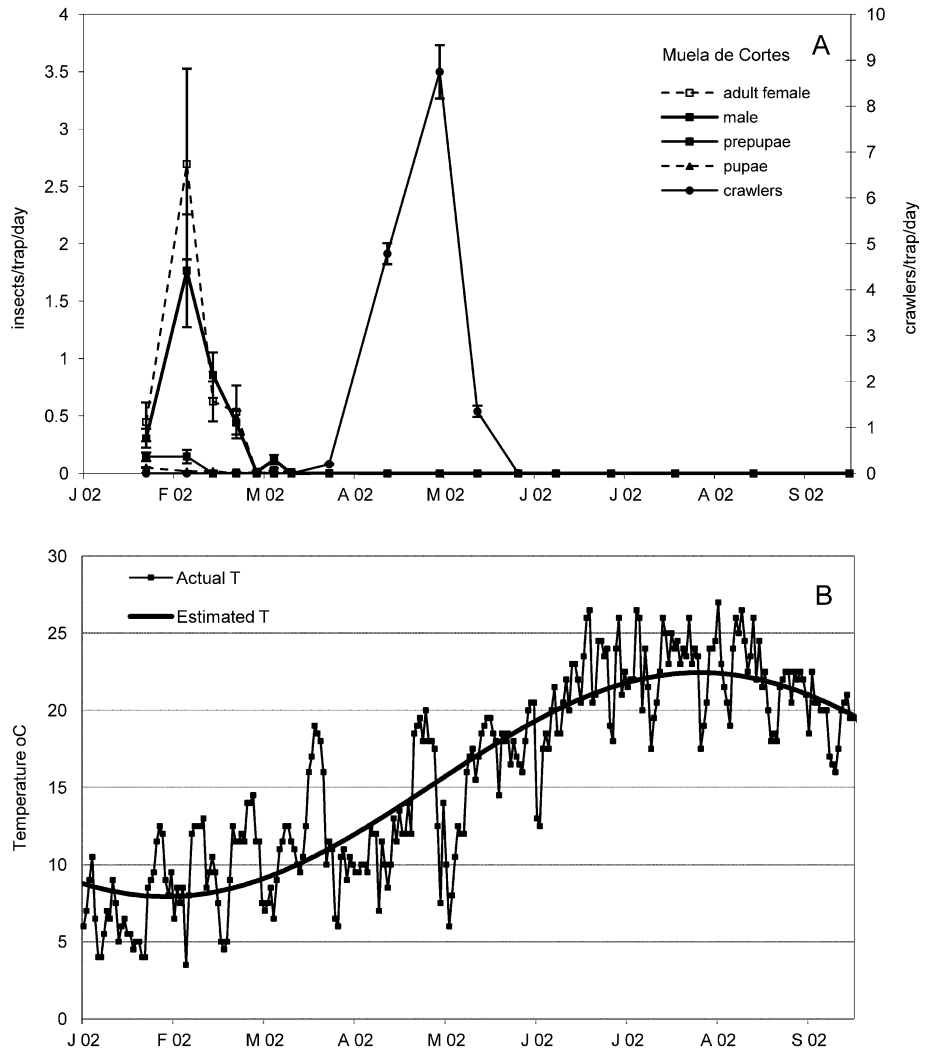

Fig. 2. A – Phenology of *M. feytaudi* at Muela de Cortes in 2002 based on seasonal trends in the numbers of different stages of the scale caught by sticky tapes. Bars represent standard errors. B – Temperature data adjusted to a sinusoidal function given by the formula: $T(d) = A + B * \sin\left[\frac{2\pi}{365}(d + C)\right]$, d: day of year (d = 1 indicates January), A = 15.1842, B = –7.2584, C = –302.8203, coefficient of correlation (R^2) = 0.7853.

pling period. Most individuals were crawlers, making up 81% of the individuals captured. The remaining stages, prepupae-pupae, males and females made up 1.3%, 7.8% and 9.9%, respectively. In addition, 900 specimens of *E. nigricornis* (nymphs and adults) were also captured. More nymphs of *E. nigricornis* were caught than adults, making up 92% of the total catch of this species.

There were differences in the number of insects captured on each surface of the sticky tape (Table 3). Adult male *M. feytaudi* were mainly caught on the external surface (in contact with the environment) and the other stages on the internal surface (next to the bark of the tree). More *E. nigricornis* nymphs and adults were also on the internal than the external surfaces of the tapes. This is logical because these insects forage in the crevices of the bark in search of scales and other insects to feed on.

The phenology of *M. feytaudi* and its predators

The catches on the sticky tapes at Muela de Cortes revealed that the crawlers were only present from March to the end of May, with maximum catches between the end of April and the beginning of May (Fig. 2a). Prepupae, pupae, males and females of the maritime bast scale

TABLE 3. Percentage of the *M. feytaudi* mobile instars, nymphs and adults of *E. nigricornis* caught on the two surfaces of sticky tapes attached to trees at Muela de Cortes over the period January to September 2002.

Tape side	*M. feytaudi*						*E. nigricornis*		
	Total insects	Crawlers (%)	Prepupae (%)	Pupae (%)	Males (%)	Females (%)	Total insects	Nymphs (%)	Adults (%)
Internal	7684	98	92	100	2	89	883	99,5	80
External	730	2	8	0	75	11	18	0,5	20

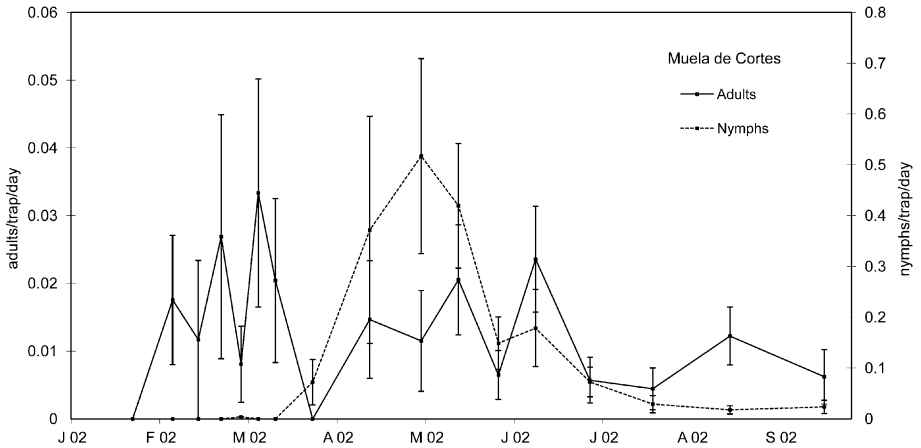

Fig. 3. Seasonal trends in numbers of nymphs and adults of *E. nigricorni* caught by sticky tapes at Muela de Cortes in 2002. Bars represent standard errors.

were caught between January and March, with maximum catches of males and females in the first two weeks of February

The number of nymphs of the anthocorid *E. nigricornis* caught by the traps at Muela de Cortes (Fig. 3) increased in April and May, but adults were caught throughout the sampling period, with no clear maximum abundance, which indicates several generations each year.

The life cycle of the scale differed at La Serra and Lomas del Chinchel. The flight periods of the males did not coincide in both areas (Figs 4–5). At La Serra, the flight of males clearly occurred between October 2005 and January 2006, and peaked in November 2005 (Fig. 4a). The same Figure also shows that males were also caught in January and February 2005. We presume that this is the end of the previous year's flight. However we do not know when the 2004 flight period started or the time of the peak flight in that year. At Lomas del Chinchel the flight of males occurred later, from the end of winter to the beginning of spring, i.e., in February and March (Fig. 5a)

Sticky traps around the trunks detected the presence of different stages and adult females of the bast scale. Thus at La Serra, prepupae, pupae and adult females were caught by these traps between October and December 2005 (Fig. 4a). These stages were not caught at the beginning of the year, so we assume that they were present at the same time as the previous year or a little later because the flight of males lasted until January 2005. At Lomas del Chinchel, prepupae, pupae and adult females were caught at a later date, between December and March, which is in accordance with the flight of males in this area (Fig. 5a). At La Serra, crawlers were caught in March and April, at the same time as at Muela de Cortes. Fig. 4a illustrates that the period over which prepupae, pupae, female and male adults were caught was shorter at La Serra (October – January) than Lomas del Chinchel (October – March) (Fig. 5a).

It is possible to relate the catches of bast scale stages with temperature. The average daily temperature data was adjusted to a regular sine curve. At La Serra, the peak catches of crawlers occurred when the temperature was about 15°C (Figs 4a, b). This peak occurred in mid- and late April. Compared to Muela de Cortes, the peak catches of crawlers occurred in late April and also coincided with a temperature of about 15°C (Figs 2a, b).

Approximately 10,000 specimens of *H. stigma*, *E. nigricornis* and *M. pectinatus* were caught by the delta traps at La Serra and Lomas del Chinchel (Table 4). All them were caught by the pheromone baited traps. *H. stigma* was more abundant at Lomas del Chinchel, whereas *E. nigricornis* and *M. pectinatus* were more abundant at La Serra.

Table 5 shows the results of fitting a linear model to describe the temporal relationships between *M. feytaudi* (crawlers, prepupae, pupae, females and males) and its natural enemies (*E. nigricornis* nymphs and *E. nigricornis*, *H. stigma* and *M. pectinatus* adults) at La Serra and Lomas del Chinchel. It is possible to explain these relationships by analyzing the flight and seasonal patterns of the predators (Fig. 6) and comparing them with those of the scale (Fig. 4a, 5a). A single flight period of adult *M. pectinatus* was recorded at the two sampling areas (Fig. 6). At La Serra, flight occurred in March and April, but did so a month later (April and May) at Lomas de Chinchel. At La Serra, the flight period clearly coincided with the peak catches of *M. feytaudi* crawlers. Nonetheless at Lomas del Chinchel crawler emergence was not detected, which could explain the lack of a significant relationship between *M. pectinatus* and *M. feytaudi* in this area (Table 5).

TABLE 4. Total number of predators caught in the two sampling areas, la Serra and Lomas del Chinchel using sticky tapes and traps baited with sexual pheromone in 2005.

Predators	La Serra	Lomas del Chinchel
H. stigma [a]	2651	3563
M. pectinatus [a]	1006	527
E. nigricornis [a]	1755	336
Nymphs of *E. nigricornis* [b]	56	37
Total insects	5468	4463

[a] Adult insects caught by delta traps; [b] Nymphs caught by sticky traps placed around the trunks of trees.

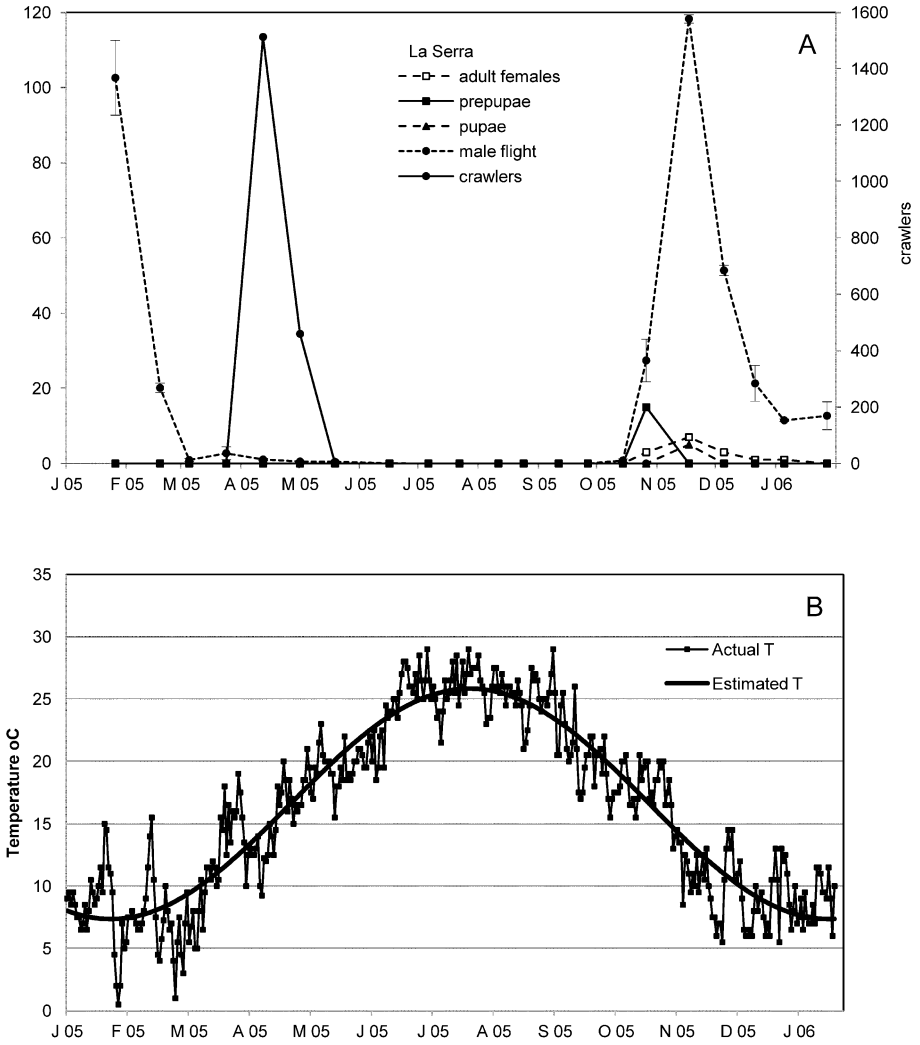

Fig. 4. A – Phenology of *M. feytaudi* at La Serra based on data collected in 2005–2006: flight of males based on the catches of traps baited with the scale's sexual pheromone and seasonal trends in the numbers of crawlers, prepupae, pupae and females caught by the sticky tapes. Bars represent standard errors. B – Temperature data adjusted to a sinusoidal function given by the formula: $T(d) = A + B * \sin\left[\frac{2\pi}{365}(d + C)\right]$, d: day of year (d = 1 indicates January), A = 16.5937, B = 9.2382, C = –479.4497, correlation coefficient (R^2) = 0.8769.

At La Serra, there were three periods when *E. nigricornis* nymphs were abundant: spring (March to May), summer (August) and winter (from October to January) (Fig. 6). The beginning of the first period when *E. nigricornis* nymphs were abundant coincided with the increase in the catches of *M. feytaudi* crawlers and that of the third with the increase in catches of the other stages of the scale (prepupae, pupae, females and males). The second peak was less important than the other two. At Lomas del Chinchel, *E. nigricornis* nymphs were most abundant when the prepupae and pupae, male and female adults of *M. feytaudi* were present. These coincidences in the two areas between the presence of *E. nigricornis* nymphs and the stages of *M. feytaudi* (crawler, prepupae, pupae, males and females) are also supported by the statistically significant relationship between the species (Table 5).

The flight periods of *E. nigricornis* and *H. stigma* were longer at La Serra than at Lomas del Chinchel (Fig. 6). In the first area, there were two peaks in the flight activity of *E. nigricornis* one in mid-June and another in mid- September both of which followed peaks in the numbers of nymphs caught. In this area, the flight period of *H. stigma* was from March to October. In the second area, the main flight of *E. nigricornis* was recorded from June to September and that of *H. stigma* from July to August. The relationship between *M. feytaudi* and *H. stigma* adults at La Serra was not significant (Table 5). However, there was a negative correlation between *E. nigricornis* and *H. stigma* adults and *M. feytaudi* in the two areas studied. This negative correlation indicates that these insects are present when the bast scale is not being caught by the sticky traps on the trunks of the trees.

DISCUSSION

This is the first comprehensive study of the phenology of *M. feytaudi* and its natural enemies in the eastern part of the Iberian Peninsula. In this work all the natural *P. pinaster* stands in the Valencian Community were surveyed and bast scale was detected in all of them. Until this study was carried out, the natural enemies of *M. fey-*

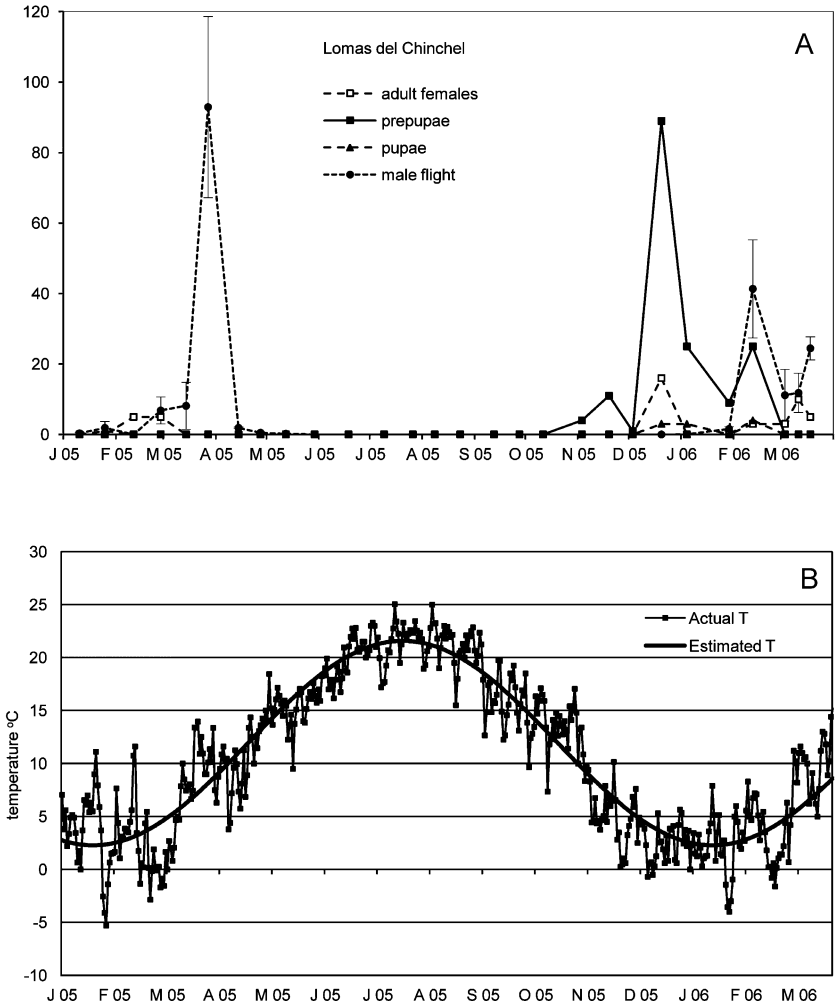

Fig. 5. A – Phenology of *M. feytaudi* at Lomas del Chinchel based on data collected in 2005–2006: flight of males based on the catches of traps baited with the scale's sexual pheromone and seasonal trends in the numbers of prepupae, pupae and females caught by sticky tapes. Bars represent standard errors. B – Temperature data adjusted to a sinusoidal function given by the formula: $T(d) = A + B * \sin\left[\frac{2\pi}{365}(d + C)\right]$, d: day of year (d = 1 indicates January) A = 11.9311, B = –9.6493, C = –292.9806, correlation coefficient (R^2) = 0.8552.

taudi in this region were unknown. From this study it can be inferred that there is a complex of natural enemies in the Valencian Community consisting of three native natural enemies: *E. nigricornis*, *H. stigma* and *M. pectinatus*, as all three species are attracted by sexual pheromone of *M. feytaudi*. The first two species are natural enemies of *M. feytaudi* in other parts of the world. However, this is the first time that *M. pectinatus* has been cited as a possible natural enemy of *M. feytaudi*, which is especially interesting as little is known about the biology of this species.

Based on the captures of the mobile stages, pupae and females and the flight period of males, it can be concluded that the maritime pine bast scale has a single

TABLE 5. Results of fitting a linear model to the relationship between the numbers of *M. feytaudi* (crawlers, prepupae, pupae, females and males) and its natural enemies caught at La Serra and Lomas del Chinchel in 2005.

	La Serra					Lomas del Chinchel				
	n [a]	*F*	*df*	*P* [b]	*r* [c]	n [a]	*F*	*df*	*P* [b]	*r* [c]
M. feytaudi – nymphs [d]	21	10.09	1	0.005	0.59	29	19.15	1	0.0002	0.64
M. feytaudi – *E. nigricorni* [e]	21	7.06	1	0.015	–0.52	29	7.78	1	0.0095	–0.47
M. feytaudi – *H. stigma* [e]	21	2.34	1	0.14	–0.33	29	19.66	1	0.0001	–0.65
M. feytaudi – *M. pectinatus* [e]	21	5.23	1	0.03	0.46	29	2.71	1	0.11	–0.3

[a] Number of values for each pair of variables used to compute each coefficient for the Lomas del Chinchel and La Serra data; [b] When the P-value in the ANOVA table is less than 0.05, there is a statistically significant relationship between *M. feytaudi* and its natural enemy at the 95% confidence level. [c] r – correlation coefficient; [d] *E. nigricornis* nymphs; [e] adults.

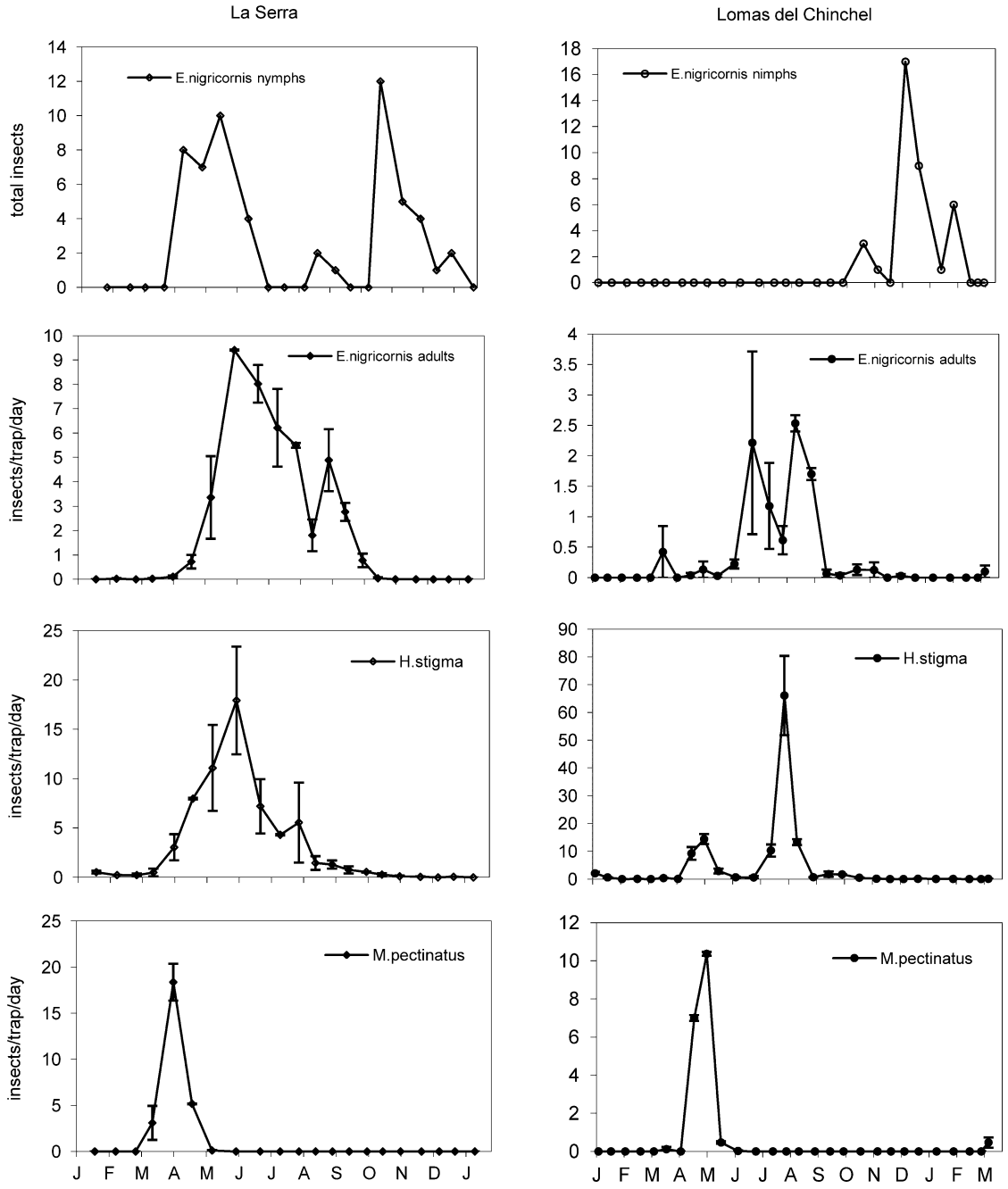

Fig. 6. Numbers of *E. nigricornis* nymphs caught each month in 2005–2006 by sticky tapes and the flight patterns of *E. nigricornis*, *H. stigma* and *M. pectinatus* based on catches of the traps baited with the sexual pheromone of *M. feytaudi*. Bars represent standard errors.

annual generation in natural *P. pinaster* stands in the Valencian Community (E Spain). This is in accordance with that reported by authors in other areas like France (Riom & Gerbinot, 1977) and Italy (Arzone & Vidano, 1981; Covassi & Binazzi, 1992) but differs from that reported for Portugal (Branco et al., 2001), where males are recorded flying throughout the year, whereas we recorded a single annual flight of males in the three areas studied.

The life cycle of the scale varied depending on the area studied. In two of the three areas prepupae, pupae and females were caught mainly between December and March and the flight of males occurred from the end of winter to the beginning of spring, i.e., between February and March. Similar results are reported for other countries (Riom & Gerbinot, 1977; Arzone & Vidano, 1981; Schvester & Fabre, 2001; Binazzi et al., 2002; Mendel et al., 2004). However at La Serra, males and females were caught on the trunks of trees and the flight of males took place between October and January, which is earlier than at other areas. As regards temperature, males and females were caught in the three areas when the average daily temperature was below 15°C. Crawlers were caught between April and May at Muela de Cortes and La Serra,

mainly when the temperature was 15°C and the numbers caught decreased at higher temperatures. Temperature is an important factor in the life cycle of bast scale. Riom & Fabre (1977) report that a temperature of 15°C is a critical value because higher temperatures induce first instar nymphs to aestivate.

Very little is known about the natural enemies of the bast scale in Spain and this is the first study on the natural enemies of *M. feytaudi* in this country. Only a few specimens of *E. nigricornis* were previously recorded in this country (Pericart, 1972; Ribes, 1986; Ribes & Ribes, 2000) and thus the life cycle of this species was unknown. At La Serra, we caught a large number of *E. nigricornis* nymphs in spring, summer and winter, suggesting that this species has three generations per year. In France *E. nigricornis* is an important natural enemy of *M. feytaudi* and it completes three generations per year there. Nevertheless, adults and nymphs were not recorded on the trunks of trees from December to March in France, unlike in our study (Fabre et al., 1982, 2000).

The flight periods of *E. nigricornis* and *H. stigma* ranged from May to October and they display a clear kairomonal attraction to the sexual pheromone of the scale, as reported in other studies (Branco et al., 2001, 2006; Nelson et al., 2001; Binazzi et al., 2002; Mendel et al., 2004). According to our results, *E. nigricornis* nymphs could feed on the stages of *M. feytaudi* (crawlers, prepupae, pupae, males and females) while they were present on the tree surface. In summer, however, *E. nigricornis* and *H. stigma* adults and *E. nigricornis* nymphs could feed on the bast scale in the crevices in the bark (fixed phase of first larval stage and second stage or cyst) and from other insects that were also present there.

According to Mendel et al. (2004), the numbers of this scale insect in natural *P. pinaster* stands could be low due to the action of a complex group of natural enemies, some of which are unknown. A new natural enemy could be *M. pectinatus*, a species endemic to Spain (Plata Negrache & Santiago Hernández, 1990).

M. pectinatus is thought to be an extremely rare species and very little is known about it. According to Plata Negrache & Santiago Hernández (1990) only a few male specimens collected from pines in Central Spain (Sierra de Guadarrama, Madrid) and more recently, two females collected at Teruel, Spain (Plata Negrache & Santiago Hernández, 1990) have been recorded. In this study, *M. pectinatus* was commonly caught by traps: this insect was captured in all the sampling areas and only in the traps with the sexual pheromone. It is noteworthy that pheromones of pests can act as kairomones and attract their predators. Hence pheromones can be used to detect new natural enemies, as in this study. A predator of the Dasytidae family, near to Malachiidae, was also seen to be attracted to the *M. feytaudi* pheromone by Branco et al. (2011).

M. pectinatus' biology is also poorly known. Generally, the larvae of the Malachiidae family display carnivorous habits, and enter excavated galleries of bark to feed on the insects living there. In this study *M. pectinatus* adults were caught by the traps only in spring so it is thought they have only one flight period per year. At La Serra, the flight of *M. pectinatus* coincided very clearly with the appearance of the crawlers of the scale. At Lomas del Chinchel, crawler emergence was not detected, but it is assumed that it would coincide with the flight of this malachiid. In support of this hypothesis there is relevant information on the length of the life cycle of *M. feytaudi* in the literature (Riom & Fabre, 1977; Branco et al., 2001; Schvester & Fabre, 2001). According to these authors, if we take into account the time required for mating, oviposition and the eggs to hatch, the eggs should hatch 1–2 months after the beginning of the flight of the male *M. feytaudi*. This is consistent with our results, which reveal that male malachiids started flying one and half months after the beginning of male flight of the scale. Moreover the peak in malachiid flight activity occurred when the temperature was about 15°C, the temperature at which the crawlers emerged.

The results of this study indicate that *M. pectinatus* may be a natural enemy of *M. feytaudi* in Spain. This insect is one of the natural enemies attacking *M. feytaudi* in Spain, the action of all of which might reduce bast scale population density. In this complex, *M. pectinatus* could play a relevant role. Evidence of this has been shown by catches in large numbers, *M. pectinatus*' strong kairomonal attraction to the sexual *M. feytaudi* pheromone and by the adult flight coinciding with the presence of *M. feytaudi* crawlers. It remains to be seen if *M. pectinatus* is present in other areas in which *M. feytaudi* occurs. However, laboratory tests are needed to determine the diet of the adults and larvae of *M. pectinatus* and its role as a natural enemy of *M. feytaudi*.

CONCLUSION

Knowing the temperature at which the new annual generation of *M. feytaudi* begins to develop and the composition of the complex of natural enemies attacking it facilitates the development management programs that can be used to control the maritime pine bast scale in areas in which pine trees are seriously damaged. According to our results, the movement of male and female *M. feytaudi* and their mating and reproducing on the surface of the trunks must occur at temperatures below 15°C and emergence of crawlers at a temperature of about 15°C. Currently, the complete complex of natural enemies of the scale is unknown. Two common predators of scale, *E. nigricornis* and *H. stigma*, occur in Spain. However, we record here for the first time that *M. pectinatus* is also a natural enemy of this scale insect. This malachiid is widely distributed throughout the study area, displays a strong kairomonal attraction to the sexual pheromone of the scale, and the only flight of the year occurs at a temperature about 15°C, which coincides with the crawler emergence of the scale.

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