

## Predators and Parasitoids of Pine Processionary Moth (*Thaumetopoea wilkinsoni* Tams) in Western Mediterranean Region in Turkey

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**Abstract:** The pine processionary moth, *Thaumetopoea wilkinsoni* Tams, 1924 (Lepidoptera: Notodontidae) is the most important defoliator pest of pine forests in the Mediterranean Basin and Turkey. Natural enemies of the pine processionary moth are various species of predators and parasitoids. In this study, field studies were performed in nine study areas which were chosen from four provinces (Isparta, Burdur, Antalya, Muğla) in the Western Mediterranean Region of Turkey to determine the potential predators, larva and egg parasitoids of pine processionary moth. Wintering nests and egg batches of the pine processionary caterpillars were sampled from selected study stations throughout 2018. *Calosoma sycophanta* (L.) and *Forficula smyrnensis* Serville were determined as predator species and *Phryxe caudata* (Rondani), *Trichogramma* sp., *Ooencyrtus pityocampae* (Mercet) and *Anastatus bifasciatus* (Geoffroy) were determined as parasitoids. *Forficula smyrnensis* is recorded for the first time as a predator of *T. wilkinsoni*. Results may contribute to the literature on ecology, forestry studies and biological control efforts

**Keywords:** *Forficula smyrnensis*, parasitoid, pine processionary moth, *Thaumetopoea wilkinsoni*, western mediterranean region.

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### 1. INTRODUCTION

Pine Processionary Moth (PPM), *Thaumetopoea wilkinsoni* Tams, (Lepidoptera: Notodontidae) is the most important leaf defoliator pest of Southwest Europe, North Africa and the Near East (Battisti et al., 2000). It is the common pest in the Mediterranean Basin and in southern, western and northern parts of Turkey. Pine processionary larvae feed with pine needles in forest ecosystems, weaken the pines and make them vulnerable to secondary pests. Although PPM causes damage to other pine species, its main host is Turkish red pine (*Pinus brutia* Ten.) and its development on each pine species varies (Hodar et al., 2002). In addition to causing serious economic and ecological losses, the setae of the larvae cause allergic reactions and respiratory disorders such as asthma in humans and mammals (Ziprkowski and Roland, 1966; Lamy, 1990). Two species distributed in Turkey are *Thaumetopoea pityocampa* (Den. & Schiff.) and *T. wilkinsoni* (Barbaro and Battisti, 2011). *Thaumetopoea wilkinsoni* is mostly found in pine forests in the south, west and north of Anatolia, while *T. pityocampa* generally occurs in Thrace and northwestern Anatolia, and there is a potential hybrid zone of these two twin species in this region (İpekdal et al., 2015).

In the studies to determine the parasitoids using PPM as a host, nine species of egg parasitoid, all belonging to Hymenoptera, were identified. The most common two egg parasitoids are generalist *Ooencyrtus pityocampae* (Merc.) (Hymenoptera, Encyrtidae) and host specific *Baryscapus servadeii* (Dom.) (Hym., Eulophidae). *Anastatus bifasciatus* (Fonsc.) (Hym., Eupelmidae), *Trichogramma embryophagum* (Hbg.) (Hym., Trichogrammatidae), *Trichogramma dendrolimi* Matsumura (Hym., Trichogrammatidae), *Baryscapus transversalis* Graham (Hym., Eulophidae), *Pediobius bruchicida* (Rondani) (Hym., Eulophidae), *Eupelmus (Macroneura) seculata* (Ferrière) (Hym., Eulophidae) and *Eupelmus (Macroneura) vesicularis* (Retzius) (Hym., Eulophidae) are parasitoid species with a lower frequency (Tsankov, 1990; Tsankov et al., 1999; Öztemiz et al., 2013; Battisti et al., 2015).

The known larva parasitoids are *Phryxe caudata* (Rondani) (Diptera, Tachinidae), *Compsilura concinnata* (Meigen) (Dipt., Tachinidae), *Exorista segregata* (Rondani) (Dipt., Tachinidae), *Erigorgus femorator* Aubert (Hym., Ichneumonidae), *Cotesia vestalis* (Haliday) (Hym., Braconidae), *Pteromalus chrysos* Walker (Hym.,

Chalcididae) and *Dibrachys lignicola* Graham (Hym., Chalcididae) belonging to Hymenoptera and Diptera (Battisti et al., 2015). Pupa parasitoids are determined in the previous studies as *Villa brunnea* Beck. (Dipt., Bombyliidae), *Coelichneumon rudis* (Fonscolombe) (Hym., Ichneumonidae) and *Conomorium pityocampae* Graham (Hym., Pteromalidae) (Battisti et al., 2015).

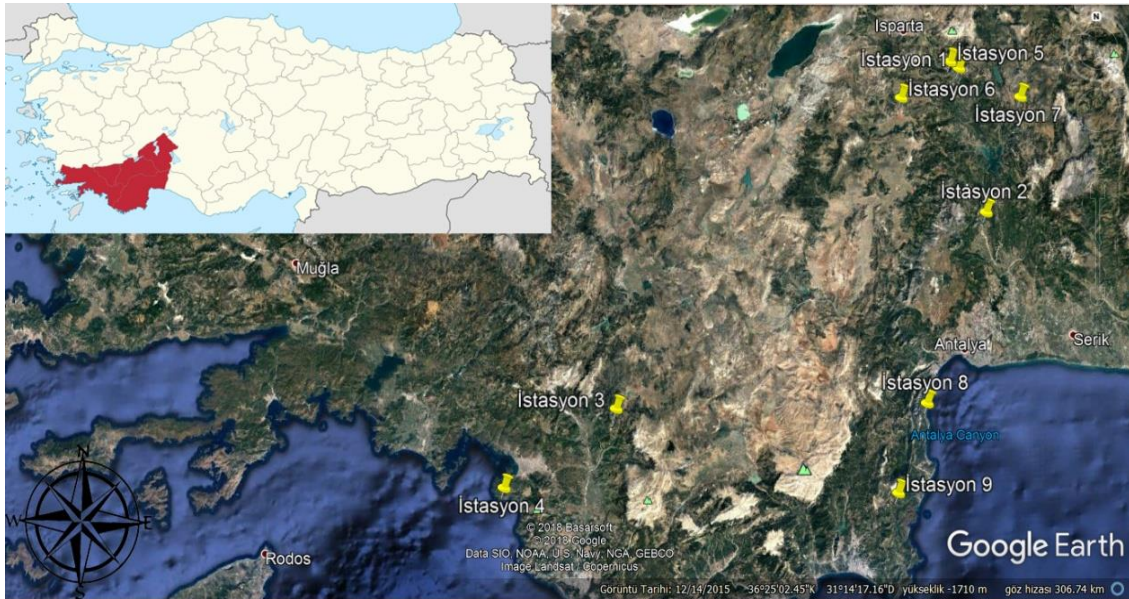
The known natural predators of the PPM include some birds, amphibians, reptiles, spiders and predator insects. *Upupa epops* and *Clamator glandarius* (Aves), *Bufo viridis* and *Hyla arborea* (Amphibia) *Agamia stellio* (Reptilia), *Thomisus citrinellus* (Arachnida), *Carabus graecus*, *Calosoma sycophanta*, *Chrysoperla carnea*, *Coccinella septempunctata*, *Chilocorus bipustulatus*, *Synbarmonia conglobata*, *Forficula auricularia*, *Formica rufa*, *Monomorium dentiger*, *M. gracillimum*, *Ephippiger ephippiger*, *Dermestes lardarius*, *Sphodromantis viridis*, *Labidura riparia* and Tettigonidae species of Insecta are predators of PPM (Mirchev and Tsankov, 2005). Pathogens include a variety of viruses, bacteria and fungi (Battisti et al., 2015). In the Mediterranean basin, extensive control studies are conducted with vertebrate and invertebrate predators, pathogens such as *Bacillus thuringiensis kurstaki* and pesticides such as insect growth inhibitors in the control against PPM (Barbaro and Battisti, 2011). However, it is stated that these predators and pathogens do not have a significant effect on population control except epidemic periods (Way et al., 1999). Pesticides have various damages

in biological control. Pesticides can also have adverse effects on non-target organisms, target natural predators of the pest and cause phytophagous insect to develop resistance (Jansen and Sabelis, 1995). For these reasons, parasitoid species should be preferred in biological control. Parasitoids do not have the disadvantages of pesticides and have an important role in controlling harmful herbivore insect populations (Lewis et al., 1997; Stiling and Cornelissen 2005). In fact, it was determined that egg parasitoids increase PPM mortality by 72% (Mirchev et al., 2004).

In this study, it is aimed to determine the potential parasitoids and predators of *T. wilkinsoni* that uses Turkish red pines as hosts in the western Mediterranean region of Turkey.

## 2. MATERIALS AND METHODS

Nine study stations selected from the Western Mediterranean region were visited during 2018 in order to collect samples from PPM (*Thaumetopoea wilkinsoni* Tams), taking into account the density of red pine (*Pinus brutia* Ten.). The stations were selected from three different elevation intervals (0-100 m, 400-650 m and 900-1100 m) within four different provinces (Isparta, Burdur, Antalya, and Mugla). Map of nine selected study stations are shown in Figure 1.



**Figure 1.** Satellite image of study stations.

Sampling date, localities, coordinates, altitude and area characteristics of nine study stations are shown in Table 1.

**Table 1.** Localities and area characteristics of study stations.

St.No	Sampling Date	Location	Coordinates and Altitude	Area Characteristics
1	18.02.2018	Isparta-Antalya highway 30th km	37°37'29" N 30°43'58" E 600-630 m	Near highway, pine forest
2	18.02.2018	Isparta-Antalya highway 80th km	37°13'53" N 30°48'7" E 90-100 m	Near highway, pine forest
3	10.03.2018	Burdur-Fethiye highway	36°45'36" N 29°27'31" E 980 m	Short pines on highway edge, clear area
4	10.03.2018	Fethiye, Gemiler	36°33'49" N 29°3'6" E 0-70 m	Sloping terrain, dense pine forest
5	23.03.2018	Burdur, Ağlasun	37°38'35" N 30°42'7" E 1020 m	Near highway, sloping area
6	23.03.2018	Budur, Ağlasun	37°33'12" N 30°31'8" E 940 m	Near highway, short pines
7	13.02.2018	Isparta, Sütçüler	37°32'14" N 30°56'44" E 1080 m	Sloping area, near marble quarry
8	02.03.2018	Antalya-Kemer highway	36°43'42" N 30°33'23" E 10 m	Near highway and urban area, sparse pine forest
9	02.03.2018	Beycik Village, Kemer	36°29'32" K 30°26'11" D 440-600 m	Pine forest on a slope

Samplings were carried out at nine selected stations in the Western Mediterranean region during 2018. In February and March, nests containing last instar larvae of PPM were collected. Pupae were sampled in May and June. Eggs were collected in August and September.

At each station, one nest from each 15 pine trees infested with PPM was collected with the help of high branch pruning shears and taken to three-liter pet bins. The 30x30 cm cut tulle were stretched to the openings of the bins by using rubber for the insects can continue to breathe. The pupae were searched by digging pits at a depth of 20 cm at the bottom of the infested trees. The pupae were taken together with the soil in which they were placed and put in 1 L canisters. Eggs in cylindrical clusters on the young pine needles were plucked together with the leaves and kept in 1 L bins with tulle on their openings. Samples were brought to Süleyman Demirel University, Faculty of Arts and Sciences, Entomology Laboratory within the same day.

The larvae and nests of PPM larvae were kept in bins in the climate chamber at 25 °C and 55% humidity. In order to observe parasitoid emergence, larvae were conserved under suitable conditions. Therefore, in addition to establishing

favorable conditions, the larvae were regularly fed with *Pinus brutia* needles. The collected pupae and egg clusters were also stored under the same conditions.

A predator coleopteran and a dermapteran species, which were observed to be fed by larvae in nests, prepared for identification. In addition, larva parasitoids (Diptera:Tachinidae) were sampled from the nests that brought to the laboratory and hymenopteran parasitoids were obtained from egg containers and kept for identification. Samples were sent to experts for identification. Also Chopard (1922), Jeannel (1941), Askew and Aldrey (2004) and Samra et al. (2018) were used as diagnostic keys.

### 3. RESULTS

During 2018, 24,660 larvae from 135 nests of *Thaumetopoea wilkinsoni*, 40 pupae and 58 egg clusters were sampled from nine stations. Some of the pupae mature under laboratory conditions. As a result, six species were determined as the natural enemies of *Thaumetopoea wilkinsoni*. One of them is *Calosoma sycophanta* (L., 1758), a natural predator of the PPM. Another potential

predator species is *Forficula smyrnensis* Serville, 1839. *Phryxe caudata* (Róndani, 1859) is a larval parasitoid. *Trichogramma* Westwood, 1833 sp., *Ooencyrtus pityocampae* (Mercet, 1921) and *Anastatus bifasciatus* (Geoffroy, 1785) are egg parasitoids. No pupae parasitoid emergence was observed from 40 pupae collected.

#### ***Calosoma sycophanta* (L., 1758) (Coleoptera: Carabidae)**

Preys: *Lymantria dispar* L., *L. monacha* L., *Dendrolimus pini* L., *Thaumetopoea processionea* L., *T. pityocampa* (Denis ve Schiffermüller, 1775), *T. wilkinsoni* Tams, 1924, *T. solitaria* (Freyer, 1838), *Euproctis chrysorrhoea* L., *Dasychira pudibunda* L., *Hyphantria cunea* (Drury, 1773), *Tortrix viridana* L. (Weseloh, 1985; Mirchev and Tsankov, 2005; Kanat and Mol, 2008; Goertz and Hoch, 2013).

Geographical distribution: European countries, Western Palearctic, Nearctic, Near East, Mid-Asia, Northern Africa (Kanat and Özbolet 2006; Stolbov et al., 2018).

#### ***Forficula smyrnensis* Serville, 1839 (Dermaptera: Forficulidae)**

Preys: According to some researchers, it is thought to be herbivorous, but other authors believe that it is omnivorous (plant material, aphids, spiders, insect eggs, dead insects) species like *Forficula auricularia* L. (Haas and Henderickx, 2002; Tezcan and Kocarek, 2009).

Geographical distribution: Turkey (terra typica), Albania, Bulgaria, Greece, Iran, Israel, Lebanon, Syria, former Yugoslavia (Albouy and Caussanel, 1990; Haas and Henderickx, 2002).

#### ***Phryxe caudata* (Róndani, 1859) (Diptera: Tachinidae)**

Hosts: *Thaumetopoea pityocampa* (Denis and Schiffermüller, 1775), *Traumatocampa ispartaensis* (Doğanlar and Avcı, 2001) (Pekel, 1999; Avcı and Kara, 2002; Mirchev and Tsankov, 2005).

Geographical distribution: Mediterranean countries, Southern Europe and Northern Africa (Lutovinovas et al., 2018).

#### ***Trichogramma* sp. Westwood, 1833 (Hymenoptera: Trichogrammatidae)**

Hosts: *Cydia pomonella* L., *Cydia molesta* (Busck, 1916), *Hedya nubiferana* (Haw. 1811), *Spilonota ocellana* (Denis and Schiffermüller, 1775), *Thaumetopoea pityocampa* (Denis and Schiffermüller, 1775), *T. processionea* L., *Archips* Hubner, 1822 spp. (Mirchev and Tsankov, 2005; Öztemiz and., 2013).

Geographical distribution: Cosmopolitan (Buchori vd., 2010).

#### ***Ooencyrtus pityocampae* (Mercet, 1921) (Hymenoptera: Encyrtidae)**

Hosts: *Stenozygum coloratum* (Klug, 1845), *Thaumetopoea pityocampa* (Denis and Schiffermüller, 1775), *T. wilkinsoni* Tams, 1924, *T. bonjeani* (Powell, 1922) (Mirchev and Tsankov, 2005; Samra et al., 2018).

Geographical distribution: Eastern Mediterranean, Middle East ve Eastern Africa (Samra et al., 2018).

#### ***Anastatus bifasciatus* (Geoffroy, 1785) (Hymenoptera: Eupelmidae)**

Hosts: *Thaumetopoea pityocampa* (Denis and Schiffermüller, 1775), *T. wilkinsoni* Tams, 1924, *T. processionea* L., *Lymantria dispar* L. (Mirchev and Tsankov, 2005; Avcı, 2009).

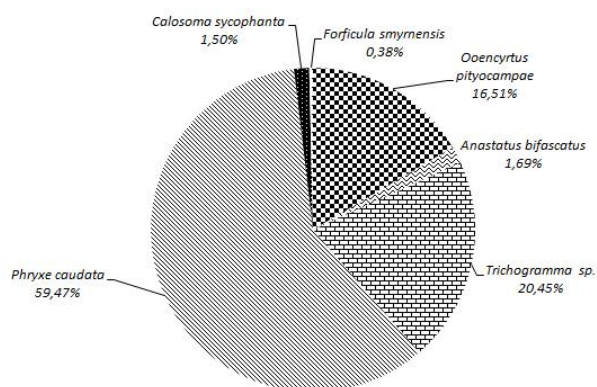
Geographical distribution: Europe, Asia and Africa (Narendran, 2009).

Table 2 shows the number of sampled parasitoid and predator species in the study stations.

Table 2. Sampled natural enemies in nine study stations.

Station	1	2	3	4	5	6	7	8	9
<i>Ooencyrtus pityocampae</i>	-	-	24	4	1	1	-	3	-
<i>Anastatus bifasciatus</i>	-	-	8	1	-	-	-	-	-
<i>Trichogramma</i> sp.	-	-	10	1	-	-	-	-	-
<i>Phryxe caudata</i>	21	3	60	5	4	4	-	3	2
<i>Calosoma sycophanta</i>	2	2	3	1	-	-	-	-	-
<i>Forficula smyrnensis</i>	-	-	-	-	-	-	-	2	-

The 3<sup>rd</sup> station was determined to have the highest parasitoid density, while station 7 was the only area without natural enemies. This may be caused by antropogenic activities (marble mine) nearby. Nearly all *Trichogramma* individuals were sampled from 3<sup>rd</sup> station. *Forficula smyrnensis* was sampled only from 8<sup>th</sup> station. Percentages of individuals belonging to parasitoid and predator species were given in Figure 2.



**Figure 2.** Percentages of individuals belonging to six natural enemy species.

The most frequent parasitoid species was *Phryxe caudata* (59.47%) and was emerged from the eggs in all study stations except Number 7.

#### 4. DISCUSSION AND CONCLUSIONS

The PPM has a wide range of natural enemies in terms of predators and parasitoids. Six of them were sampled in this study. Mirchev and Tsankov (2005) published a checklist and according to this checklist natural enemies that recorded from Turkey are *Ooencyrtus pityocampae*, *Baryscapus (Eutetrastichus) servadeii*, *B. (E.) transversalis*, *Anastatus bifasciatus* and *Trichogramma sp.* In addition, tachinid parasitoids *Exorista segregata* and *Phryxe caudata* were found in Turkey by Pekel (1999) and Avcı and Kara (2002). *Ooencyrtus pityocampae* is recorded by Mirshev et al. (2004) in southwestern Anatolia. Kanat and Mol (2008) stated that *Calosoma sycophanta* is used as an effective predator in the biological control of PPM in our country. In addition, Özçankaya and Can (2004) reported *Forficula* species in the PPM nests.

*Calosoma sycophanta*, which is frequently used in the biological control of this pest in Turkey (Kanat and Özbolat, 2006; Stolbov et al., 2018), is the first predator species obtained from field studies. Eight individuals from four areas were found. According to Mirchev and Tsankov (2005), this species is the larvae predator of the PPM. However, it is known to feed on pupa (Kanat and Özbolat 2006; Toprak, 2014). *C. sycophanta* larvae fed by another harmful lepidopteran *Lymantria dispar* L. pupa has been demonstrated by Weseloh (1985).

Another predator species found in this study is *Forficula smyrnensis*, sampled in Kemer, Antalya with two individuals. Özçankaya and Can (2004), found *Forficula sp.* individuals on the PPM nests. They reported that they did not observe the feeding event, so they could not comment on whether they were predators or not. But it was known that these insects were omnivorous and therefore fed with soft bodied insects. On the other hand, it was reported by Kailidis (1962) in Greece that *Forficula auricularia* was a PPM predator and listed as a predator on the check-list of Mirchev and Tsankov (2005). Haas and Hendrickx (2002), in their study of the intestinal contents of the collected

dermapterans, found some plant materials in the gut of *F. smyrnensis*, so they speculate that the species may be herbivore contrary to its close relatives. However, Tezcan and Kocarek (2009) emphasized that such an interpretation cannot be made from the intestinal contents of a single individual and *F. smyrnensis* is most likely omnivorous like *F. auricularia*. For this reason, *F. smyrnensis*, sampled in a larval nest in Kemer during field surveys, could potentially be a PPM predator and it is recorded for the first time.

*Phryxe caudata*, which is one of the most common tachinid species in Turkey (Lutovinovas et al., 2018) is sampled from all study sites except 7<sup>th</sup> station. Adults began to be observed in containers in which the nests were kept in the laboratory in June. Avcı and Kara (2002) also stated that adults emerged in the second half of June. In terms of the number of individuals, this species was the most sampled with 317 individuals.

*Trichogramma* species are egg parasitoids of PPM (Mirchev and Tsankov, 2005) and in this study 109 individuals were collected. The members of this Hymenopteran genus cause taxonomic difficulties due to their small size and are difficult to identify (Nagarkatti and Nagaraja, 1977). Thus, *Trichogramma* specimens sampled in this study could not be identified to species level. But only two species occur in Turkey, *T. embryophagum* and *T. dendrolimi* are parasitoids of PPM (Öztemiz et al., 2013), so the sampled specimens are likely to belong to one of these two species.

*Ooencyrtus pityocampae* is another hymenopteran egg parasitoid sampled in this study. Samra et al. (2018) determined that three species of *Ooencyrtus* (*O. zoeae*, *O. telenomicida* and *O. pityocampae*) are distributed in Turkey. They emphasized that *O. pityocampae* is a generalist parasitoid, using both Hemiptera and Lepidoptera members as hosts, and also one of the best known natural enemies of *T. pityocampa* and *T. wilkinsoni* in the Mediterranean Basin. In this study, 88 individuals of this species were collected.

Finally, hymenopteran egg parasitoid *Anastatus bifasciatus* was represented in this study with 9 individuals. *Anastatus bifasciatus* is listed on the checklist of Mirchev and Tsankov (2005) and previously sampled in Turkey by Pekel (1990).

Results of this study may contribute to the literature on pest ecology, forestry and biological control efforts.

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