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Original scientific article

ENLARGEMENT OF THE PINE PROCESSIONARY MOTH (*THAUMETOPOEA PITYOCAMPA*) RANGE IN BULGARIA

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ABSTRACT: The pine processionary moth (*Thaumetopoea pityocampa*) was established for the first time in Bulgaria in 1906. From 1951 to 1972, the average attacked area amounted to 5163 ha. Its gradual increase began at the end of the 20th century when the affected area enlarged over five times. The attacks of the pest occurred in the region of its natural range where deciduous forests were replaced by *Pinus nigra* and *P. sylvestris* plantations. Since 1999, an expansion of *T. pityocampa* has been observed in the central part of Bulgaria. The species has extended its range by 46 km into the east with an average of 2.6 km a year along the southern slopes of the Balkan Range and Sredna gora Mt. In recent decades, the negative economic, environmental and social impact of the pine processionary moth has increased in the country. In high population densities, the pest is a serious defoliator in pine plantations. In addition to the direct economic losses, the pest has a hazardous effect due to its potential to cause an allergic and toxic reaction in humans and animals in recreational forests and forest parks. The success of the pest's spreading into new geographical areas requires favourable climatic conditions and presence of large areas afforested with *P. nigra* and *P. sylvesrtis*. Among the biological factors, the egg parasitoids appear to be the most important regulators of the pest number.
Keywords: *Thaumetopoea pityocampa*, expansion, pest, pine plantations, Bulgaria

1 INTRODUCTION

The pine processionary moth, *Thaumetopoea pityocampa* (Denis & Schiffermüller, 1775) (Lepidoptera: Notodontidae) was established for the first time in Bulgaria in 1906 by catching a male specimen in a light trap near Sofia [7]. One year later, a nest with *T. pityocampa* caterpillars was found in the region of Belovo [2]. Until the first half of the 20th century, a large number of new localities were established in Bulgaria and reported without any data about the size of attacked areas and population density in different biotopes [2, 3, 4, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31].

Since 1951, the specialized divisions of Forest Agency have carried out yearly monitoring on pest attacks and damages on forest vegetation. The obtained data allow the economic significance of *T. pityocampa* in pine forests, as well as the dynamics of its numbers and attacked areas, to be established.

Numbers of authors have determined the ecological niche of the species' development, defined by the impact of certain climatic factors: lethal winter temperatures -16 °C [6] or -24 °C [34]; realized feeding threshold and activation temperature [1]; required number of favorable winter days allowing the completion of the caterpillar development [15].

The aim of this paper is to examine the impact of some biotic and abiotic factors on pine processionary moth attacks and to establish the enlargement of its range since 1951.

2 MATERIAL AND RESEARCH METHODS

Data for the size of attacked by *T. pityocampa* areas in Bulgaria in the period 1950-2016 were taken from Forest State Agency (http://www.iag.bg/docs/lang/1/cat/6/index). The information about the areas attacked by the pest in zones of its expansion in the central part of Bulgaria was kindly provided by Forest Protection Station in Plovdiv. Climatic data were obtained from the public website (https://www.stringmeteo.com/synop/bg_climate.php).

The larval instar structure of *T. pityocampa* by regions was determined by checking all caterpillars from 10 nests in each investigated site. The caterpillars from each individual nest were placed in 75% ethanol. In the entomological laboratory of Forest Research Institute – Sofia, the larval instar was determined by the epicranium size [34].

3 RESEARCH RESULTS AND DISCUSSION

3.1 Expansion of *Thaumetopoea pityocampa*

The pine processionary moth is distributed in the mountains of Southern Bulgaria – Rila, Pirin, the Rhodopes, Osogovo, the Central Balkan Range, Sredna gora, along the valleys of the rivers Struma, Mesta, other smaller rivers and in the pine plantations of the hollows and the high plains of the western part of the country. It has not been found in the eastern part of Southern Bulgaria (Fig. 1). In the vertical respect, the species occurs at an altitude of up to 1200 m with northern exposures, and of up to 1350 m in Pirin Mt.

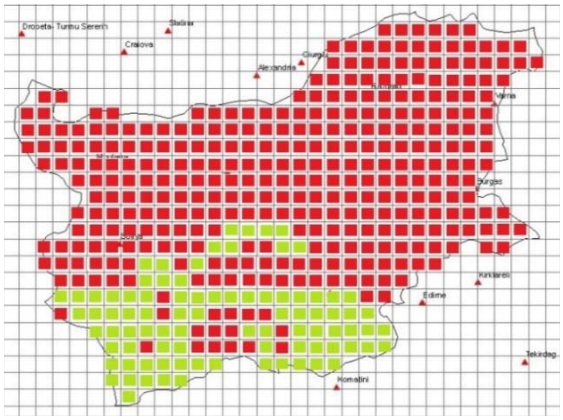

Figure 1: *Thaumetopoea pityocampa* range in Bulgaria

In 1951, the areas attacked by the pine processionary moth were 6800 ha (Fig. 2). Until 1972, they appeared to remain unchanged – an average of 5163 ha for the period 1951-1972. After that period, there was a gradual increase in their size: in 1979, they were 19 000 ha, 1982 – 30 000 ha, with a maximum in 1998 – 39 127 ha. For the 1973-2017 period, the average attacked area was 22 929 ha, that is an increase of 4.4 times compared to the preceding period. The number of fluctuations and the reduction of the areas attacked were mainly due to the aerial treatments, carried out

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with varying intensity through the years, with bacterial and biotechnical substances based on diflubenzuron.

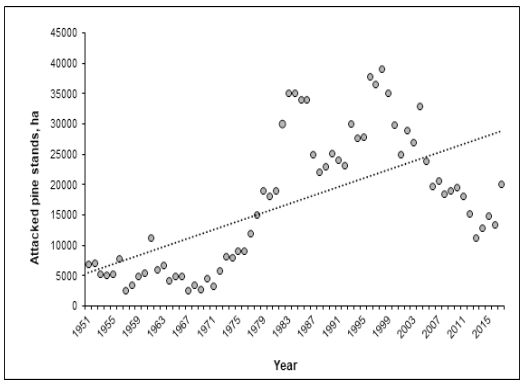

Figure 2: Pine forests infested by pine processionary moth

The average value of *T. pityocampa* attacks occurred in 1977-1999 period (27 282 ha), is 5.3 times more than in 1951-1972 period (Fig. 3).

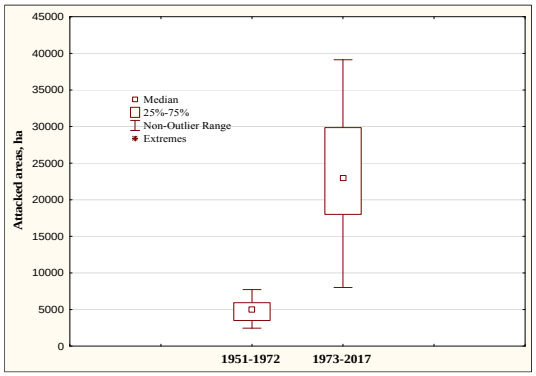

Figure 3: Pine forests infested by *Thaumetopoea pityocampa* during the periods 1951-1972 and 1973-2017

In the 66-year period (1951-2017), the pine processionary moth marked two stages in its expansion. After 1972, the attacked areas increased multiple times, but only within the limits of its range. The second stage appeared in 1999, when it topped the mountainous hills near the town of Kalofer and become to enlarge its area toward east. In the subsequent 18 years, the pest aggressively expanded its range (Fig. 4), infesting the pine stands on the southern slopes of Balkan Range.

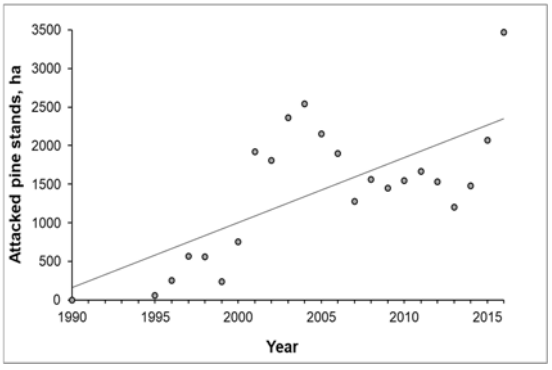

Figure 4: Pine forests attacked by *Thaumetopoea pityocampa* in Central Bulgaria

In 2017, the pine processionary moth was already registered in the region of town of Maglizh. For the period 1999-2017, it has moved to the east at an aerial distance of 46.3 km, or at an average annual pace of 2.6 km.

3.2 Factors determining the expansion of *Thaumetopoea pityocampa*

The presence of available trophical base of the pine processionary moth is one of the main factors for the range expansion of the species. The pine plantations in Bulgaria are 880 995 ha, from which 64% are *P. sylvesrtis*, and 36% - *P. nigra*. The predominate part of pine forests (88%) grow in Southern Bulgaria, where the pine processionary moth occurs. With an annual average of around 30 000 ha attacked, the available surface area of pine forests is a potential foundation for the pest expansion in the zones of its distribution.

The strong increase of the areas attacked in the 1972-1998 period was due to the afforestation carried out at a scale large for Bulgaria after 1960, primarily with *Pinus nigra* and *P. sylvesrtis* plantations (Fig. 5), most frequently on terrains with a southern exposure.

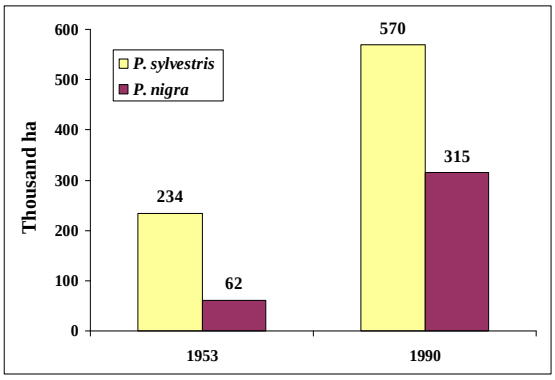

Figure 5: *Pinus sylvestris* and *P. nigra* areas in 1953 and 1990

The *P. sylvesrtis* plantations increased 2.5 times from 233 507 ha in 1953 to 569 793 ha in 1985, most of them being within the regions of the pine processionary moth distribution. In the region of Kardzaly (the Eastern Rhodopes), they increased 10 times in that period, in Kyustendil region - by 344%, and in Plovdiv region – by 240%. The same trend is observed for *P. nigra*. From 62 062 ha in 1953, they reached 314 612 ha in 1990. In Plovdiv, Kardzaly, and Kyustendil regions they increased by 310%, 272% and 174%, respectively [10].

The other main factors involved in range expansion of *T. pityocampa* are presence of appropriate climatic conditions. The low winter temperatures of below -16 ˚C are lethal for the pine processionary moth caterpillars [6, 34]. The climatic data from 1977 to 1991 showed that at varying frequencies during the period there were days with minimum temperatures below this norm in the area of the species distribution [12]. In this period, such temperatures were registered in 3 years in Southern Bulgaria, whereas in Northeastern Bulgaria (Shumen) and Northern Central Bulgaria (Pleven) they were 5 and 9 years, respectively. In this regard, Northern Bulgaria, particularly its central part, has a more distinct continental climate that is less suitable as a potential area for *T. pityocampa* expansion.

The other factor determining the survival of the species is the number of favourable days for larval feeding during

the cold period (November-February) - days with daily temperatures above +9 °C and night temperatures above 0 °C [1]. In the region of Sandansky (Marikostinovo vill.), the favourable for feeding days in some years reached up to 46, unlike Sofia region (Staro selo vill.) – 8 days, where larval mortality reached up 86% [15].

The climatic peculiarities determine the critical conditions for *T. pityocampa* development in Bulgaria. Nevertheless, the species is successfully developing and even expanding the area of its distribution. This is due to two main biological characteristics of the species. The first one is the presence of pupal diapause, when a part of the population remains in the soil for several years, overcoming the extreme conditions [5]. A field study showed that after the first year, 37% of the pupae remained in diapause.The second one is the specificity of its phenology. Summarizing data for various regions in Europe, North Africa, and the Near East, Schmidt [21] pointed out that the caterpillars go down in the soil for pupation from February but mostly in March and first half of April. In some regions in Bulgaria, an earlier hatching was observed, when the development of the larvae ended before the coming of winter, and they hibernate in the soil [33, 34]. Studies in mid-winter (January) showed that in the region of Hisarya (Central Bulgaria), 50% of the caterpillars hibernated in the soil, while in the Eastern Rhodopes the hibernation in the soil was 10-30% [13, 15]. In Central Bulgaria, an extended period of emergence has also been established [14].

The age structure of the caterpillars proves the great diversity in the phenology of the pine processionary moth in the various regions of the country. In the region of Sandansky (Southwestern Bulgaria), 25 September 2017 was the beginning of larval hatching, which is similar to that in Tassos Island in Greece. At this time in Central Southern Bulgaria, the caterpillars were already in 3-rd instar and in the Kirkovo region in the Eastern Rhodopes - in 5-th (final) instar (Fig. 6). This is an important adaptation peculiarity of the species, by which it overcomes the severe winters with lethal temperatures of below -16 °C or the insufficient number of favourable for feeding days.

Figure 6: Age structure of the caterpillars from the various regions of Bulgaria, by 25 September 2017; A – Sandanski Region (Southwestern Bulgaria); B – Maglizh Region (Central South Bulgaria;) C – Kirkovo Region (the Eastern Rhodopes Mt.)

In addition to abiotic factors, some biological factors also have a deterrent effect on population density of *T. pityocampa*. Egg parasitoids play a substantial regulatory role. The relative share of the parasitized eggs in individual habitats can reach 44%, and in individual egg batches – up to 89%. Seven egg parasitoids have been found in Bulgaria, the dominant ones being *Ooencyrtus pityocampae* (Mercet, 1921) (Hymenoptera: Encyrtidae) and *Baryscapus servadeii* (Domenichini, 1965) Hymenoptera: Eulophidae). The role of predators is insignificant; the eggs destroyed by them rarely exceed 1% [9, 11]. A virus was isolated from dead caterpillars from Southwestern Bulgaria [8, 32], and in an experiment carried out in laboratory conditions the mortality rate reached 90% [32]. However, there are no reports of epizooties observed in natural conditions.

3.3 Economic importance of *Thaumetopoea pityocampa*

The pine processionary moth has a substantial negative economic importance in Bulgaria. The stands attacked decrease in growth by height and diameter, become physiologically weak and susceptible to attacks by xylophages and diseases. This insect species, as well as the other two representatives of genus *Thaumetopoea* in Bulgaria (*T. processionea* and *T. solitaria*) are allergens hazardous for humans and animals (Fig. 7).

Figure 7: Allergy caused by *Thaumetopoea pityocampa*

The presence of the pine processionary moth reduces the recreational functions of forests. Unfortunately, it has already been found in city parks and SPA resorts of the country, such as Sandansky, Velingrad, the Tyulbeto Park near Kazanlak, Dupkata near Ivaylovgrad etc.

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