

8.3. Population dynamics of the pine processionary moth: responses to climate changes and forest management

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Abstract

The data compiled in Andalusia indicate that the pine processionary moth (*Thaumetopoea pityocampa*) is spreading and intensifying the outbreak frequency over the last few decades. The pine forests of Sierra Nevada are situated at an elevation at which the processionary can be favoured by rises in temperatures. Therefore, we propose a prevention strategy based on the habitat management, planning the promotion of forest stands that are diverse both spatially and in species composition, making them more resilient to infestations and other forest-decay processes.

> Aims and methodology

The pine processionary moth (*Thaumetopoea pityocampa*) exemplifies the way in which some defoliators of Spanish forests benefit from global warming [11]. The larvae of this species develop during the winter and therefore it can be expected that higher temperatures will have a positive effect, accelerating its development. To test this hypothesis, a demographic monitoring system was set up for the processionary in Sierra Nevada, to evaluate the hatching of caterpillars, their processions and burial, and the emergence of the moths. Three locations

were chosen for sampling within the Sierra Nevada Protected Area, considering orientation, elevation, and dominant forest species. At each location, three sampling areas were established over the elevational range of the pines. The summer monitoring, from moth emergence to egg hatching (July-September), was conducted with pheromone traps for moths and surveillance of 30 egg masses at each elevation of the study area. The winter monitoring went from the time that the caterpillars leave trees (November-December) to the end of the burials (March-

April). For this purpose, interception traps were set at the trunks of 30 trees per location, and the number of burials found in 1 km-long transects were recorded during each visit. The sampling frequency was 2-3 times weekly.

> Results

Although the defoliation by the pine processionary moth was visually alarming, the final effect on the attacked trees is limited, and the pines generally recovered well, so long as they did not suffer several defoliations in a row. The relationship between the defoliation by the processionary and temperature has long been known, in particular mild winters, so that in the context of global warming this species would be expected to colonize zones that, for latitude and elevation, have until now been free of this pest. These predictions have been confirmed

in several studies [11-12]. In Sierra Nevada, the captures with pheromone traps show a clear relationship between the average temperatures of the previous spring and the median date of moth emergence in the season (Figure 1). A similar effect has been noted for the precipitation of the previous spring. In this sense, a reduction in spring precipitation, higher temperatures, or both, would encourage earlier emergence of the moths. Given that the temperature between the laying and hatching hardly varies, and that the recently hatched larvae are more sensitive to

climatic conditions as well as to the quality of the food available, earlier hatching by several weeks would represent a considerable advantage for the larvae, which would then enter the winter in a more advanced state of development with presumably better conditions to survive. However, in part of its distribution area, the processionary follows five- to six-year infestation cycles, the length and duration of which appear to be regulated by biotic factors.



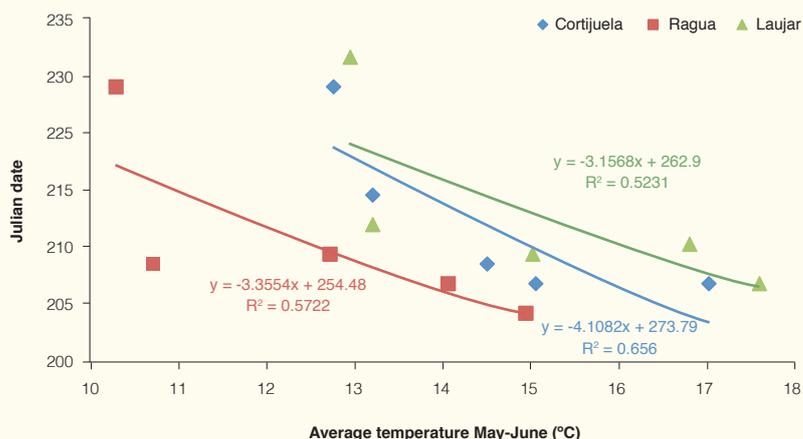
Thus, it is not clear that climate is the only factor explaining the population dynamics of this pest. Overall, a working hypothesis may be that a negative winter NAO (North Atlantic Oscillation), which in our region corresponds to mild, wet winters, triggers a population explosion of this insect, which wreaks maximum defoliation one or two winters later. After the peak, owing to the combined effect of colder winters, previously defoliated pines, and increased natural populations of parasitoids, the pest population returns to chronic levels.

Several predators can be postulated as being potential controllers of the processionary. In Sierra Nevada, the most common predators of the egg masses are bush crickets, which in some years and areas can consume more than half of the eggs. With respect to the parasitoids that attack the eggs, there is a clear pattern in the intensity of the parasitism: at higher altitudes, less parasitism. The percentage can vary from 50% of the parasitized eggs at low elevation to zero above 2000 m. a.s.l. (Figure 2). Apparently, while the processionary has managed to establish itself well at the highest elevations (finding a better relation between climatic variables and defoliation there [13]), this does not occur with its parasites, their control thus being limited at these elevations, where their activity is precisely most necessary.



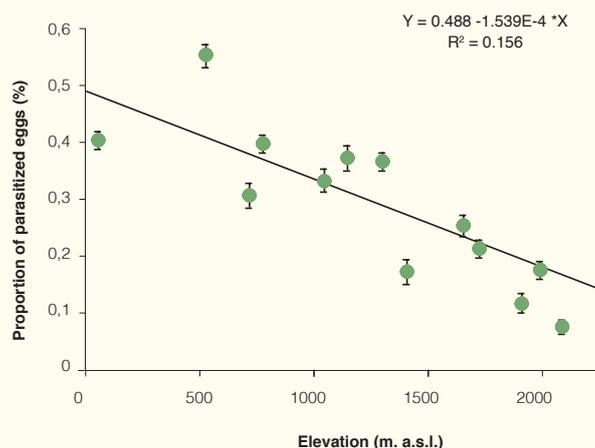
View of Trevenque and Trevenquillo climbing up to Collado Matasverdes, after the defoliation of 2010 (above) and 5 years afterwards (below). In the latter, although a new peak defoliation begins to be appreciated, the pines defoliated 5 years earlier clearly recuperate without problems.

Figure 1



Relationship between the median date of capture of the moths in pheromone traps in the study locations and the average temperature in the two months prior to the same spring, for the three locations monitored for the years 2009 to 2013.

Figure 2



Variation in the parasitism rate in egg masses of the processionary over an elevational gradient in the province of Granada. Each point (mean \pm 1 standard error) represents the average rate of the plots at the same altitude and for four study years (2008-2011), totalling 1727 egg masses.

> Discussion and conclusions

The main difficulty in identifying population trends in an organism such as the pine processionary moth is its cyclic dynamic. This species shows infestation episodes alternating with latency periods in which it is hardly detectable, a cycle that is completed in five or six years. The existence of other studies in the region with a longer series [12-13] help in the interpretation of the data from Sierra Nevada in a broader context. The analyses made indicate that the processionary clearly benefits from rising temperatures in the medium-high elevations of Sierra Nevada, since there the climate was until now the most limiting factor for this pest, natural predators are scarce at these altitudes, and it is also the area where most of the pines are found, natural or reforested. The management method used in Sierra Nevada is not focused on suppressing the pest outbreaks; treatments

have only been applied in certain areas for public health reasons, either by tank or areal sprayers, or by manual control of the nests, with limited effectiveness, as confirmed in the studies made [14].

In the specific case of the processionary, it is known that mixing the pines with other species not susceptible to this pest (broadleaf species, for example) diminishes the intensity of the attack [15]. Diversifying the forest by adding other plant species also offers alternative resources (food and other hosts) to the parasitoids of the processionary, and introduces inappropriate habitats for the pupation of the larvae, reducing its populations. Also, other predators such as birds can be favoured by a suitable mosaic of habitats. It should be noted that clearings opening implies a more conducive setting for

the processionary, which prefers the edges of stands to develop. However, if the clearings are not bare but covered with thicket, the area becomes unsuitable for pupation and can make the processionary egg masses more vulnerable to predation by bush crickets.

In this sense, the lower density and diversification of the reforested pines are the general recommendations for future management of these forests. In forestry terms, this implies carrying out the necessary tasks to diversify the stands, promoting the mixture of the tree and shrub species as well as the spatial heterogeneity of the forest structure.