

## MOVEMENT OF MATURE TREES BY MAN, AN UNEXPECTED PATHWAY FOR INVASION OF THE URTICATING PINE PROCESSIONARY MOTH

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### ABSTRACT

The pine processionary moth (PPM), *Thaumetopoea pityocampa*, is a forest insect of Mediterranean origin which is extending its distribution northwards and upwards in Europe in response to climate warming. Because the gregarious larvae develop during winter, a warming up, even limited, is significantly increasing their survival. Barriers for PPM range are thus delimited by thermal thresholds such as a lethal temperature of  $-16^{\circ}\text{C}$  and a nocturnal feeding needing a positive air temperature preceded by a day temperature higher than  $9^{\circ}\text{C}$  in the nest built by the larvae. Such conditions were rarely observed before the 1990s in most areas of Western Europe and in the mountainous regions. These thermal constraints were largely released from the mid-1990s on. Climate models showed that a large part of Western, Central and Eastern Europe then became favourable to PPM establishment. For example, PPM naturally progressed by more than 100 km in the Paris Basin between 1972 and 2012, with a significant acceleration during the last 10 years. This expansion led the moths to enter highly-populated semi-urban areas, impacting not only forest trees but also human and animal health because the mature larvae are highly urticating.

In order to be able of measuring precisely the speed of expansion in the future we mapped, with the help of a large number of European colleagues, the 2011-2012 front of natural expansion all over the European range from French Brittany to the West to Bulgaria to the East, using a 16km-cell grid. During this survey, a total of 9 pioneer colonies were detected in France far beyond the main range, especially in the vicinity of downtown Paris but also in Northern and Eastern (Obernai nr. Strasbourg) France. These colonies were located from 40 to 190km to the nearest point of the front, and some of them apparently existed since the early 2000s.

Our study therefore aimed at understanding the origin and possible pathways corresponding to these pioneer colonies. Flight mill experiments confirmed that female moths fly only a few kilometers on the average, even if some of the individuals, especially these originating from the newly-colonized areas, can fly up to 11km. These limited flight capabilities would not have allowed females to come from the nearest established colonies. In addition, DNA microsatellite analyses excluded that most colonies originated from the front populations but indicated for three of them at least a link with remote areas of Southern France. A parallel analysis of their parasitoid complex did not show any egg nor larval parasitoids but the presence of specific pupa parasitoids. Moreover, all the pioneer colonies were detected near human dwellings (highways, runabouts, urban buildings, swimming pools, university and factory parks, Disneyland Paris) which have been recently planted with pines.

Combining these results tends to indicate that most pioneer colonies correspond to long-distance jumps, the likely pathway being the trade of mature pine trees for ornament, the moth being moved as pupae with the accompanying soil. A similar pathway has been hypothesized for the introduction of oak processionary moth in England. Such transportations may have existed for a long time although they probably recently increased with the 'green' fashion. However, if PPM was transported before the late 1990s, it is likely that the moth offspring could not have survived the harsh winter conditions in northern areas. At present, once PPM is introduced in urban and semi-urban areas, the combination of global warming and urban microclimate is favoring its survival. A comparative survey of the colonies during two recent, severe cold periods having occurred in 2009 and 2010 in the Paris Basin revealed that the larvae survived significantly more in urban areas, which behave like heated islands, than in the main range.