MODELLING THE PINE PROCESSIONARY MOTH RANGE EXPANSION IN THE PARIS BASIN

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PPM expansion & climate warming

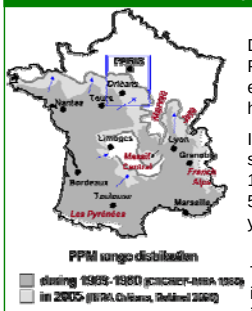


Fig.1. PPM range expansion

During the last 2-3 decades, PPM distribution in France has expanded northwards and at higher elevations (Fig.1).

In the Paris Basin, the front has shifted of 2.7km / year between 1972 and 2004 with a speed of 5.6 km / year during the last 10 years (Fig. 2).

This shift was coupled with an increase of minimum temperatures in winter of about 1°C.

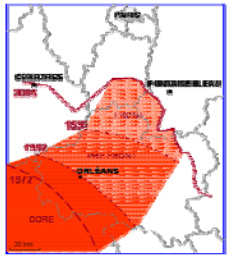


Fig.2. PPM expansion in the Paris Basin

PPM life cycle and models to describe the PPM dynamics

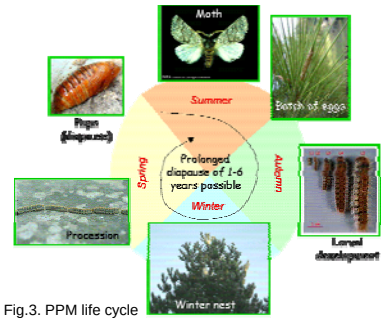
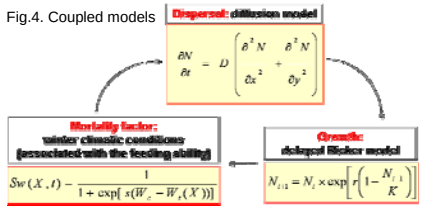


Fig.3. PPM life cycle

Fig.4. Coupled models



Based on the PPM life cycle (Fig.3), we modelled PPM dynamics using: a diffusion model (for dispersal), a delayed Ricker model (for population regulation) and a mortality function for the effects of climatic conditions on the PPM survival (Fig.4; Robinet 2006).

Feeding potential in the northward range expansion

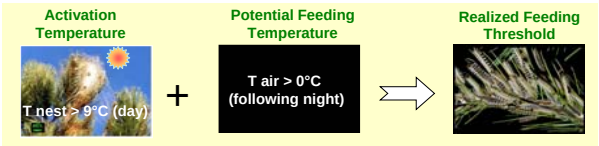


Fig.5. Climatic window for larval feeding

Based on the weather requirements for feeding (Fig. 5), we calculated the number of feeding days from October to March in a large area covering the historically-colonized area around Tours (core area), the expansion area (between the fronts in 1992 and 2004) near Orléans and beyond the current PPM front in the Paris Basin (Fig. 6). The mean values were taken over two unconnected periods: 1992-1996 (Fig. 6a) and 2000-2004 (Fig. 6b). Feeding conditions became more favourable at any location. During the first period, an unfavorable zone split the potential feeding area into two parts: the core area around Tours and the Paris Basin, where PPM was absent. But in the second period, this in-between zone turned favourable enough to enable PPM to progress towards the Paris Basin.

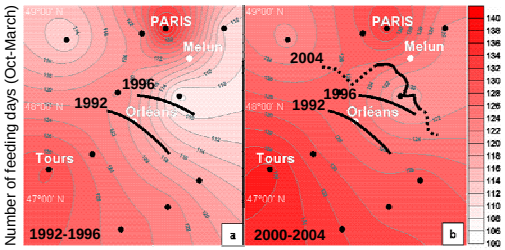


Fig.6. Modelling of the feeding ability

The mean of daily minimum temperature from October to March is a good indicator for estimating feeding conditions for PPM (R^2=0.77, P<0.001). Over a long period (~30 years), it revealed a temperature increase since the end of the 1980s, characterized in Orléans by a mean temperature of 2.46°C +/- 0.86°C (SD) before 1988 and 3.55°C+/-0.68 (SD) after. PPM colonized this area in 1992, just a few years after this warming.

(Robinet 2006, Robinet *et al.*, submitted)

Expansion dynamics and prediction

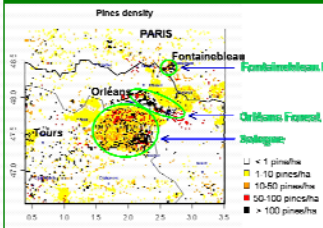


Fig.7. Pine density in the Paris Basin

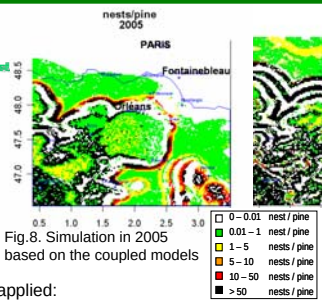


Fig.8. Simulation in 2005 based on the coupled models

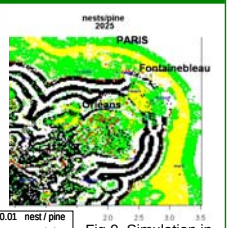


Fig.9. Simulation in 2025 using the climate scenario

Using the algorithm shown in figure 4, we applied:

- a growth model (parameters were estimated using field data from the French Forest Health department – DSF), taking account of the pines distribution in the carrying capacity (Fig. 7);
- a mortality function based on the feeding indicator (parameters were estimated using field data recorded during our experiment);
- a diffusion process: the dispersal capacity (closely linked to the diffusion coefficient) was determined *a posteriori* by the model: *rd* = 3-4 km. This value is far higher than the flying capacity previously known for PPM females (less than 2 km).

This model supplied a reconstruction of the past dynamics of PPM, e.g. the front retraction during cold winters, the activation of PPM expansion since the early 1990s, and the front position in 2005 (Fig. 8). This study confirmed the role of climate warming on the PPM shift and the importance of the spatial heterogeneity (large amplitude of heterogeneity in the density of pines accelerates the PPM expansion).

The climate scenario ARPEGE-Climat (Météo-France, scenario B2) was included in this model for the next years and simulations show that PPM will colonize Paris by 2025 if nothing is done to slow the spread (Fig. 9). This study is all the more important that PPM can release quite urticating hairs and cause severe allergies (which might become a serious problem in such urban areas). Moreover PPM attacks affect the pines growth and they could be responsible of great economic loss.

Consequently, PPM would encounter favorable conditions nearly everywhere in the Paris Basin. The effective shift will depend on its dispersal capacity, notably the females flying capacity. *Pinus nigra* plantations along motorways probably play also a key role, providing hosts ressources in expansion areas.

(Robinet, 2006)

References:

Battisti *et al.* (2005) Expansion of geographic range in the pine processionary moth caused by increased winter temperatures, *Ecol. Appl.* 15:2084-2096

Robinet (2006) Mathematical modelling of invasion processes in ecology: the pine processionary moth as a case study. PhD thesis, EHESS, Paris.

Robinet *et al.* (submitted) Modelling the effects of climate change on the potential feeding activity of *Thaumetopoea pityocampa* (Den.& Schiff.) (Lep., Notodontidae) in France.