PhD thesis (3 years)

Modelling the phenology of a species emblematic of climate change: the pine processionary moth.

Supervisors :

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Dates : 1st October 2018 – 30th September 2021
Main location: INRA, Orléans, France

ABSTRACT:

Context. The pine processionary moth (PPM), *Thaumetopoea pityocampa*, has become an international model of response to climate change (cited in the IPCC 4th Assessment Report in 2007, bio-indicator ONERC since 2006). The PPM is one of the few species for which the causal relationship with climate change has been clearly demonstrated [1,2]. Indeed, we have proved that its northward and upward range expansions result from the removal of a climate barrier that enables winter survival in areas that were previously unfavorable [3-5]. Although the increase of winter temperatures is the actual driver of this range expansion at the European scale, it cannot explain regional heterogeneities in the spread rate. Other factors associated with global changes could affect this rate, such as long-distance dispersal due to ornamental trade [6] and landscape changes [7]. Local adaptation of differentiated populations and their phenological variability resulting from climate constraints (large phenology variability among regions and recent occurrence of atypical phenologies) could also affect their establishment success in new habitats and lead to the observed heterogeneity [8]. Beyond the interest of this question for Ecology, the understanding of PPM phenology is crucial to enhance current control methods and is at stake due to the public health concern that urticating late instar larvae represent.

Thesis. The core hypothesis of the thesis is the interrelation between species distribution and their phenology [9,10]. In ectotherms, phenological shifts can result from the relationship between development rate and temperature as well as from adaptive processes. Phenological responses are nevertheless constrained by trade-offs along the biological cycle since life stages often have different thermal needs and vulnerabilities [9]. A phenology shift in a given life stage affects not only the climate conditions experienced by this stage but also triggers cascading effects on subsequent stages with possible contrasting effects. The overall response is thus constrained by climate forcing which excludes some maladaptive phenologies although they could appear favorable for a given stage. **The aim will be to develop a mathematical model based on experimental and observational data to understand the PPM´s phenological response to climate variability in different bioclimatic regions**.

***Working plan*.** Three approaches will be combined.

- Experiments in controlled and semi-natural conditions will be conducted to determine the degree-day needs and thermal tolerance of each stage. Incubators, a room dedicated to

manipulation of the PPM, a nursery of host trees and the assistance of an experienced technical staff will be available to the student.
- Field observations: two key stages indicating the beginning and the end of the larval development will be monitored in priority: adult flight and pupation processions. The student will study the time occurrence of these stages in contrasting climate regions in France and Europe. He/she will take advantage of a collaboration with a SME (Cap2020) developing innovative tools to automatically detect these stages.
- Modeling: a degree-day model constrained by thermal tolerance of each stage will be developed based on experimental data on development times and then it will be validated on observational data. Then, the effectiveness of control measures will be tested.
The student will benefit from the experience of IRBI in thermal ecology and he/she will learn will learn from the URZF savoir-faire about experiments and field observations of the pine processionary moth.
***Valorisation*.** The student will be able to promote the thesis results in the academic domain on a proven model and an issue tackled by a large scientific community as well as in the applied domain.

DESIRED PROFILE :
This PhD thesis fits to Master 2 students with initial training in biology, with a great interest in both experimentation and modelling. A previous experience in modelling and/or programming (in R) would be appreciated but not required. Driving license required. Maximum age : 30 years old on 01/01/2018.

APPLICATION :
Send your CV, letter of motivation and transcript of records of your Master (M1 and M2) to the two supervisors **before April 15th** the latest. A first selection will be based on these documents. Chosen candidates will be interviewed by the supervisors at the end of April 2018 at Orléans. Then, 3 selected candidates will be interviewed by the Doctoral School in May 2018 at Tours.

References:

[1] Parmesan C (2006) Ecological and evolutionary responses to recent climate change. *Annu. Rev. Eco. Evol. Syst*., 37:637-669.
[2] Roques A (2015) "Processionary moths and climate change: an update", A. Roques (Ed.). Springer/Quae.
[3] Battisti A, Stastny M, Netherer S, Robinet C, Schopf A, Roques A, Larsson S (2005) Expansion of geographic range in the pine processionary moth caused by increased winter temperatures. *Ecological Applications*, 15:2084-2096.
[4] Robinet C, Baier P, Pennerstorfer J, Schopf J, Roques A (2007) Modelling the effects of climate change on the pine processionary moth expansion in France. *Global Ecology and Biogeography*, 16:460-471.
[5] Robinet C, Rousselet J, Roques A (2014) Potential spread of the pine processionary moth in France: preliminary results from a simulation model and future challenges. *Annals of Forest Science*, 71: 149-160
[6] Robinet C, Imbert C-E, Rousselet J, Sauvard D, Garcia J, Goussard F, Roques A (2012) Human-mediated long-distance jumps of the pine processionary moth in Europe. *Biological Invasions* 14:1557-1569
[7] Rossi J-P, Garcia J, Roques A, Rousselet J (2016) Trees outside forests in agricultural landscapes: spatial distribution and impact on habitat connectivity for forest organisms. *Landscape Ecology*, 31: 243-254.
[8] Robinet C, Laparie M, Rousselet J (2015) Looking beyond the large scale effects of global change: local phenologies can result in critical heterogeneity in the Pine Processionary Moth. *Frontiers in Physiology*, 6:334.
[9] Briscoe NJ, Porter WP, Sunnucks P, Kearney MR (2012) Stage-dependent physiological responses in a butterfly cause non-additive effects on phenology. *Oikos*, 121:1464-1472.
[10] Chuine I (2010) Why does phenology drive species distribution? *Phil. Trans. R. Soc. B*, 365: 3149-3160.