Population genetics of core and front populations of Thaumetopoea pityocampa in France

Jérôme Rousselet, Carole Kerdelhue, Ruixing Zhao, Emmanuelle Magnoux, Francis Goussard, Alain Roques, . European Commission

UE RTD Project - **Quality of Life and Management of Living Resources**

Global change and pine processionary moth:
a new challenge for integrated pest management

Acronym: PROMOTH

QLK5-CT-2002-00852

Key Action 5.3.1 Multifunctional management of forests

Belgodère, Calvi, Corsica, France, 23-27 September 2005

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J. Rousselet, C. Kerdelhué, R. Zhao, E. Magnoux, F. Goussard and A. Roques
INRA, Orléans, France

Abstract
A pre-requisite for the study of expanding populations of pine processionnary moth (PPM) was to characterize the genetic structure of the PPM populations in the historic range. For this purpose, a total of 6 highly-variable nuclear markers, microsatellites, were developed of which five were largely used for genotyping. Allelic diversity ranges from 8 to 21 according to locus).
Larvae were sampled in more than 50 sites throughout the historical and expanding areas in France, 30 nests having been collected on different trees at each site to minimize consanguinity. Microsatellite analysis did not show any isolation by distance in the historical area when the flight-of-bird distances are considered. However, when the values of Fixation index (Fst) were plotted against distances circumventing Massif Central, isolation by distance was verified (Mantel test). We therefore considered the existence of two expanding historical corridors, northwestern and northeastern respectively, from the Mediterranean native area. The Massif Central thus acted as a strong barrier even if its relief is moderate. However, this barrier seems no more tight, probably in direct relation with global warming. Genetic studies proved that the well-differentiated populations from East and West nowadays communicate through the Allier valley at least, the apparently western populations from Allier belonging to the eastern system.
Studies at a larger scale using a mitochondrial marker (COI, maternally-inherited and more conserved) proved that the Pyrénées chain also constituted a key barrier for PPM expansion, clearly separating the Iberian and French populations. By contrast, the western Alps did not constitute a similar barrier. Expanding populations from Italian Piémont and French Briançonnais showed only a very weak genetic differentiation although there are high mountains separating them. Recent trappings of males during 2004 and 2005 at the Col of Montgenèvre (1850m altitude), which separates the two areas, confirmed that gene flow actually exists between these alpine valleys. However, the situation may be different in other valleys of Northern French Alps (Tarentaise) due to higher relief. In the expansion area of Paris Basin, the populations of the northern front appeared slightly but significantly divergent from these of the core area and from these of the Eastern Front, suggesting two routes for PPM expansion in that area.
In the near future, genotyping of males trapped beyond the front as well as of isolated colonies far beyond may allow to precise the origin of the funders and the preferred routes of expansion. An important challenge remains to integrate these genetic data into models in order to improve the forecast of PPM expansion.

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FINAL MEETING
SCIENTIFIC PROGRAMME AND ABSTRACTS

Assembled by Patrizia Dall'Ara & Fernanda Colombari
Illustrated by Marco Guido

Conference1

Climate change and forest insects: the case of the pine processionary moth

Introductory lecture

9.00 – 9.45 Matt Ayres, Dartmouth University USA. Relationships between global change and forest insects.

10.00 – 10.30 Coffee break and posters.

Presentations on the pine processionary moth

10.30 – 11.00 Andrea Battisti et al., University of Padova Italy. Expansion of geographic range in the pine processionary moth caused by increased winter temperatures.

11.00 – 11.30 Michael Stastny et al., Cornell University USA. Range expansion of the pine processionary moth in the southern Alps: the role of the record warm summer of 2003.

11.30 – 12.00 Axel Schopf et al., BOKU University Vienna Austria. Cold tolerance in *T. pityocampa* – significance of the threshold activating winter feeding.

12.00 – 14.00 Lunch and posters.

Introductory lecture

14.00 – 14.45 Aldina Franco & Jane Hill, University of York UK. Analysing and modelling impacts of climate warming at species' southern range boundaries

Presentations on the pine processionary moth

15.00 – 15.30 Jérôme Rousselet, Carole Kerdelhué, Emmanuelle Magnoux & Alain Roques, INRA France. Population genetics of core and front populations of *Thaumetopoea pityocampa* in France.

15.30 – 16.00 Fredrik Schlyter et al., SLU Sweden. Host plant use in the expansion range of the pine processionary moth *Thaumetopoea pityocampa*.

16.00 – 16.30 Coffee break and posters.

16.30 – 17.00 Zvi Mendel et al., ARO Israel. The egg parasitoids in the expansion area of the pine processionary moth.

17.00 – 17.30 José A. Hódar, Universidad de Granada, Spain. The pine processionary moth in Sierra Nevada (SE Spain): host selection, host damage and range expansion as a consequence of climatic warming.

17.30 – 18.00 Paola Gatto et al., Univ. Padova, Italy. Cost-benefit analysis of insect outbreaks in relation to climate change scenarios: the pine processionary moth in the Venosta/Vinschgau valley (N Italy).

Posters for conference 1

E. Buffo, E. Petrucco Toffolo, D. Zovi, M. Stastny, S. Larsson, Andrea Battisti. Adaptation of *Thaumetopoea pityocampa* larvae to leaf toughness in *Pinus*.
J. Pennerstorfer, P. Baier, C. Robinet, A. Aimi, A. Battisti, A. Roques, A. Schopf. Modelling the range expansion of the Pine Processionary Moth *(Thaumetopoea pityocampa)* in complex alpine terrain.
C. Robinet et al.. Modelling the range expansion in the Paris Basin and French Alps.
M. Zamoum, G. Demolin, A. Bensidi. Particularities related to the egg hatching pattern of *Thaumetopoea pityocampa* (Lepidoptera: Thaumetopoeidae) in the south of its distribution area.
A. Zocca, A. Aimi, S. Minerbi. The outbreak in the expansion area of Venosta/Vinschgau: the role of extended diapause.

Conference 2

Ecology and management of the pine processionary moth

The situation in other Mediterranean countries

8.30 – 8.50 Mustafa Avci & Oguzhan Sarikaya, Univ. Isparta Turkey. Expansion, damage and natural enemies of Pine Processionary Moth in Turkey.

8.50 – 9.10 Mohamed Zamoum, INRF Alger Algeria, Pine processionary moth expansion and natural enemies in Algeria.

9.10 – 9.30 Mohamed L. Ben Jamaa, INRGREF Ariana Tunisia, Pine processionary moth in Tunisia: present situation and future prospects of research.

9.30 – 9.50 Nabil Nemer, American University Lebanon. Expansion, damage and natural enemies of Pine Processionary Moth in Lebanon.

9.50 – 10.10 Daniela Pilarska, Academy of Sciences Sofia Bulgaria. Distribution, damage and natural enemies of Pine Processionary Moth in Bulgaria.

10.10 – 10.30: Coffee break

Integrated Pest Management

10.30 – 11.00 Stig Larsson, SLU Sweden. An ongoing outbreak of *Thaumetopoea pinivora* in Sweden.

11.00 – 11.30 H. Jactel et al. INRA, France. Monitoring Pine Processionary Moth (Lepidoptera: Thaumetopoeidae) Populations with Pheromone-baited Traps.

11.30 – 12.00 Amos Navon, Zvi Mendel et al., ARO Israel. Btk management and *T. pityocampa/wilkinsoni* susceptibility in core and expansion areas.

12.00 – 14.00: Lunch and posters.

Population structure and genetics

14.00 – 14.30 Andrea Battisti & Carole Kerdelhué et al., Univ. Padova Italy & INRA, France. Phylogeography of *Thaumetopoea pityocampa/wilkinsoni* in the Mediterranean basin.

14.30 – 14.50 Helena Santos et al., ISA Lisbon, Portugal Genetic structure of a desynchronized population of *Thaumetopoea pityocampa* in Portugal.

14.50 – 15.10 Brigitte Frerot et al., INRA Versailles France. Update of the research on the pheromone system of the pine processionary moth on different host plants.

15.10 – 15.30 Christelle Robinet et al., INRA Orléans France. Mathematical evidence of an outbreak cycle in pine processionary moth

15.30 – 16.30 Coffee break and posters.

Population dynamics

16.30 – 16.50 Fina Lombardero, University of Santiago, Spain. Effects of site quality on tree response after *Thaumetopoea pityocampa* defoliation.

16.50 – 17.10 M. R. Paiva, E. Mateus, H. Santos, M.J. Barrento, M. Branco, Portugal. Preference/performance of T*haumetopoea pityocampa* on Mediterranean *Pinus* species.

17.10 – 17.30 M. Branco, M. S. Santos, G. Telfer, M. R. Paiva, Portugal. Biodiversity of arthropods sheltered in pine processionary moth nests.

17.30 – 18.00 Final discussion and priorities for future research.

Posters for conference 2

Y. Hillbur, S. Andersson, A. Battisti, G. Birgersson, M. Cappucci, M. Faccoli, F. Östrand, F. Schlyter. Host volatile release from *Pinus* spp and female and male response in pine processionary moth *Thaumetopoea pityocampa*: oviposition or habitat cues?

K. Ipekdal & S. Sualp Caglar. A Survey on PPM populations in Antalya (Southern Turkey).

M. Kalapanida, A. Zocca, A. Battisti, P. Gatto. Comparison of two areas attacked by *Thaumetopoea pityocampa* in Greece by cost-benefit analysis.

J-C. Martin et al. Effects of Btk applications on non-target insect species.

M. Simonato, P. Salvato, L. Zane, A. Battisti. Mitochondrial DNA phylogeny of *Thaumetopoea pityocampa* and *wilkinsoni* in the Mediterranean basin.

D. Zovi et al. Egg size affects the parasitism rate of a main egg parasitoid of *Thaumetopoea pityocampa*.

D. Zovi, E. Petrucco Toffolo, E. Buffo, D. De Gol, F. Schlyter, A. Battisti. Tree apparency and host selection by *Thaumetopoea pityocampa* on *Pinus nigra*.

Conference 1

Climate change and forest insects; the case of the pine processionary moth

Relationships between global change and forest insects

M. P. Ayres
Dartmouth College Hanover, NH USA

Abstract
Since the early 1990s, it has been hypothesized that the projected trajectory of climate change would have rapid consequential impacts on biotic disturbance in forests. The argument was mainly based on two points: (1) even in the absence of directional changes in climate, forests throughout the world are strongly influenced by episodic events of pestilence, and (2) insects are very responsive to climatic variation because of their short generation time, high reproductive potential, and physiological sensitivity to temperature and food quality. The most likely potential pathways of ecological change include: direct effects of temperature on insects; effects of temperature, soil moisture, or cloud cover on plant defenses, nutritional suitability, and compensatory growth; and effects of temperature on community interactions between herbivores and their predators, competitors, and mutualists. There are now numerous examples of insect populations whose distribution and abundance have changed in ways that are consistent with the expected effects of climate change. Some globally noteworthy examples of recent pestilence may be attributable to climate change during the last two decades. Presumably there have been some other impacts that are positive from the perspective of traditional forest management. Biological responses have been uneven across insect species and forest systems, and have not usually been predictable in their details. To my knowledge, we still lack well validated models for any forest system that can predict changes in biotic disturbance given specific scenarios of climate change. This is not a criticism of the scientific community, but merely reflects the difficulty of the challenge. I offer the following suggestions to facilitate progress: (1) develop, test, and refine general qualitative hypotheses that can predict when and where impacts will be large vs. small, and positive vs. negative; (2) develop programs of focused studies in systems with high importance and a high probability of consequential impacts; and (3) conduct multi-faceted tests (including meteorology, physiology, and population ecology at least) of explicit mechanisms by which climatic variation is theoretically transduced into biotic disturbance. Projects such as the PROMOTH are well advised because: (1) the problem is intrinsically multi-disciplinary and international; (2) there is potential for rapid progress because of increasingly sophisticated knowledge in the relevant subdisciplines; and (3) the products are likely to have high social value in anticipating, mitigating, and adapting to the unprecedented assaults on forests of climate change, fragmentation, biological invasions, and other forms of human disturbance.

Expansion of geographic range in the pine processionary moth caused by increased winter temperatures

A. Battisti [1], M.Stastny [2], S. Netherer [3], C. Robinet [4], A. Schopf [3], A. Roques [4], S. Larsson [5]
[1] University of Padova, Legnaro, Italy
[2] Cornell University, Ithaca, NY, USA
[3] BOKU University, Vienna, Austria
[4] INRA, Ardon Olivet, France
[5] SLU, Uppsala, Sweden

Abstract
Global warming is predicted to cause distributional changes in organisms whose geographic ranges are controlled by temperature. We report a recent latitudinal and altitudinal expansion of the pine processionary moth, *Thaumetopoea pityocampa*, whose larvae build silk nests and feed on pine foliage in the winter. In north-central France (Paris Basin), its range boundary has shifted by 87 km northwards between 1972 and 2004; in northern Italy (Alps), an altitudinal shift of 110-230 m upwards occurred between 1975 and 2004. By experimentally linking winter temperature, feeding activity, and survival of *T. pityocampa* larvae, we attribute the expansions to increased winter survival due to a warming trend over the past three decades. In the laboratory we determined the minimum nest and night air temperatures required for larval feeding, and developed a mechanistic model based on these temperature thresholds. We tested the model in a translocation experiment that employed natural temperature gradients as spatial analogues for global warming. In all transects we transferred colonies of *T. pityocampa* larvae to sites within zones of historical

distribution, recent distribution, and outside the present range. We monitored air and nest temperature, incoming solar radiation, larval phenology, feeding activity, and survival. Early-season temperature effects on phenology were evident, with delayed development of colonies in the more extreme (colder) sites. In the coldest months, our model was consistent with the observed patterns of feeding activity: feeding was progressively reduced with increasing latitude or elevation, as predicted by the lower number of hours when the feeding threshold was reached, and negatively affected final survival. Insolation raised nest temperature and increased feeding activity on the south but not the north aspect. Prolonged temperature drops below the feeding thresholds occurred at all sites, leading to starvation and partial mortality. Nonetheless, even the most extreme sites still allowed some feeding, and, consequently, up to 20% colony survival and successful pupation. Given that the present distribution of the oligophagous *T. pityocampa* is not constrained by the distribution of its actual or potential hosts, and that warmer winters will cause the number of hours of feeding to increase and the probability of the lower lethal temperature to decrease, we expect the trend of improved survival in previously prohibitive environments to continue, causing further latitudinal and altitudinal expansion. This work highlights the need to develop temperature-based predictive models for future range shifts of winter-limited species, with potential applications in management.

Range expansion of the pine processionary moth in the southern Alps: the role of the record warm summer of 2003

M. Stastny [1], A. Battisti [2], E. Buffo [2] and S. Larsson [3]
[1] Cornell University, Ithaca, NY, USA
[2] University of Padova, Legnaro, Italy
[3] SLU, Uppsala, Sweden

Abstract
Climatic anomalies may produce, or accelerate, geographic range expansions of species limited by temperature or other climatic variables. Most such expansions are only temporary, before the prevailing climatic conditions drive the founder populations extinct. In contrast, here we report a recent rapid shift of the range limit during the record hot summer of 2003 in southern Europe that has the potential to be both permanent, and to have important implications on species range dynamics in general. The winter pine processionary moth (*Thaumetopoea pityocampa*), an important pine defoliator whose larvae feed in colonies during the winter, is limited in its distribution by winter temperatures. In the last three decades, warmer winters have led to a gradual but substantial expansion of its range both latitudinally and altitudinally. In the summer of 2003, *T. pityocampa* underwent an extraordinary expansion to high elevation pine stands in the Italian Alps; its altitudinal range limit increased by one third of the total altitudinal expansion over the previous three decades. In an experiment, we found flight activity of newly emerged females to increase with temperature. By determining a threshold temperature for flight take-offs under controlled conditions, we calculated that the nights above the threshold temperature were over five times more frequent, and considerably warmer, at the range limit in 2003 than in an average year. We therefore attribute the colonization of extreme, high-elevation sites to increased nocturnal dispersal of females during the unusually warm night temperatures in June-August 2003. Importantly, the colonies established at extreme sites survived the winter and produced offspring in 2004, although the range did not expand further due to low night temperatures that year. We discuss several life history characteristics of *T. pityocampa* that maximize the likelihood of population persistence at the new range limit. As global warming continues and climatic anomalies are predicted to become more frequent, our results draw attention to the importance of extreme events in the range formation of phytophagous insects.

Cold tolerance in *Thaumetopoea pityocampa* – significance of the threshold activating winter feeding

S. Netherer, P. Baier, J. Pennerstorfer, G. Hoch, C. Schafellner, P. Kritsch & A. Schopf
BOKU University, Vienna, Austria

Abstract
We studied the cold tolerance and feeding activation of the pine processionary moth (PPM) from nests collected at different altitudes of its expansion range in the Venosta Valley (Italy). Most of the larvae were in their 4th instar during the main cold period, although 5th instars were already found in nests collected at the beginning of December 2002. The supercooling point (SCP) of 2nd to 5th instars varied to a high degree with a mean value of –8°C and a maximum SCP of –15°C. The majority of individuals already froze at temperatures above –8°C, however, freezing was lethal only at temperatures below this mean value. No

difference was recorded between the SCP of 4th instars collected from the various altitudes and we did not find any indications of accumulation of freeze avoiding compounds in the haemolmph of the larvae, neither by analysis of the of low molecular soluble carbohydrates nor by measurements of the haemolymph osmolality. Thus, PPM has to be classified as a moderately freezing tolerant species with a lower lethal temperature less than 10°C below its SCP, like it is common for insects which generally occur in relatively mild climates.
Studies on the threshold activating winter feeding showed that a day temperature of +9°C was necessary to trigger feeding during the following night. However, feeding occurred at night only, when the air temperature was above 0°C. In starvation/feeding experiments at different low temperature combinations we ascertained that larvae are able to survive two months without feeding when temperatures are above -5°C. Day-/night temperatures of +9°/0°C allowed feeding and digestion of already ingested food, however, feeding did not positively influence survival within the two months study period. Night temperatures of -10°C led to high mortality irrespective of the temperature during the light phase and day-/night temperatures below 0°C apparently did not allow digestion of already ingested food and caused increasing mortality in time, probably due to starvation. Thus, the function of the "feeding activating light temperature" of +9°C apparently is to allow digestion so that larvae are able to feed during the following nights when the temperature is above 0°C.

Analysing and modelling impacts of climate warming at species' range boundaries

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[1] University of York, York, United Kingdom

Abstract
Changes in species distributions have been associated with climate change. Southern distributed species are expanding northwards and this has been associated with availability of habitat and the capacity of the species to disperse. However, the effects of climate warming on Northern distributed species are less well know. The responses of species to recent climate warming at their warm and/or dry southern range margins are poorly understood compared with responses at northern margins. Thus, predictions of either general decreases or increases in future distribution sizes are equally credible because all published projections of future distributions are based largely or wholly on untested assumptions. We looked at existing long-term data sets and collect new field data for British butterflies to investigate impacts of climate on species distribution changes (data from mid-19th century onwards). We aimed to determine whether species are declining and contracting to cool/wet microhabitats at higher elevation, and whether spatial and temporal scales of recording affect estimated rates of distribution change. We developed statistical models relating species' distributions to local climate, tested models with historical distribution and climate data and then incorporated the output from future climate change scenarios to predict distribution changes in the future. We also investigated physiological mechanisms causing observed changes by studying species' thermal ecology (thermal thresholds for larval development and adult flight activity) and link these to landscape-level distributions of species. The main aim of this research is to provide a better understanding of the processes that determine the positions of range margins, as well as revealing general patterns of responses of species to recent warming.

Population genetics of core and front populations of *Thaumetopoea pityocampa* in France

J. Rousselet, C. Kerdelhué, R. Zhao, E. Magnoux, F. Goussard and A. Roques
INRA, Orléans, France

Abstract
A pre-requisite for the study of expanding populations of pine processionnary moth (PPM) was to characterize the genetic structure of the PPM populations in the historic range. For this purpose, a total of 6 highly-variable nuclear markers, microsatellites, were developed of which five were largely used for genotyping. Allelic diversity ranges from 8 to 21 according to locus).
Larvae were sampled in more than 50 sites throughout the historical and expanding areas in France, 30 nests having been collected on different trees at each site to minimize consanguinity. Microsatellite analysis did not show any isolation by distance in the historical area when the flight-of-bird distances are considered. However, when the values of Fixation index (Fst) were plotted against distances circumventing Massif Central, isolation by distance was verified (Mantel test). We therefore considered the existence of two expanding historical corridors, northwestern and northeastern respectively, from the Mediterranean native area. The Massif Central thus acted as a strong barrier even if its relief is moderate. However, this barrier seems no more tight, probably in direct relation with global warming. Genetic studies proved that the well-

differentiated populations from East and West nowadays communicate through the Allier valley at least, the apparently western populations from Allier belonging to the eastern system.
Studies at a larger scale using a mitochondrial marker (COI, maternally-inherited and more conserved) proved that the Pyrénées chain also constituted a key barrier for PPM expansion, clearly separating the Iberian and French populations. By contrast, the western Alps did not constitute a similar barrier. Expanding populations from Italian Piémont and French Briançonnais showed only a very weak genetic differentiation although there are high mountains separating them. Recent trappings of males during 2004 and 2005 at the Col of Montgenèvre (1850m altitude), which separates the two areas, confirmed that gene flow actually exists between these alpine valleys. However, the situation may be different in other valleys of Northern French Alps (Tarentaise) due to higher relief. In the expansion area of Paris Basin, the populations of the northern front appeared slightly but significantly divergent from these of the core area and from these of the Eastern Front, suggesting two routes for PPM expansion in that area.
In the near future, genotyping of males trapped beyond the front as well as of isolated colonies far beyond may allow to precise the origin of the funders and the preferred routes of expansion. An important challenge remains to integrate these genetic data into models in order to improve the forecast of PPM expansion.

Host plant use in the expansion range of the pine processionary moth *Thaumetopoea pityocampa*

F. Schlyter et al.
SLU, Alnarp, Sweden

Abstract
We hypothesised that during range expansion a secondary host (*P. sylvestris*) or a novel host (*P. mugo*) would act as sinks. The source would be the primary host in core areas, *P. nigra*, present in mixed stands in the new range. To test this hypothesis we observed field colonisation patterns, tested female oviposition on small trees in large cages and tested larval performance of neonates in lab and colonies in the field. *P. nigra* had more trees attacked and higher nest densities at two field sites surveyed. In a choice experiment, *P. nigra* and *P. mugo* was clearly preferred over *P. sylvestris*, but populations from expansion areas seemed less selective. The corresponding no-choice experiment showed a similar low preference for egg-laying on *P. sylvestris*. Neonate mortality did not differ among tree species or moth population origin. Needle toughness did not differ among hosts, but *P. nigra* had lower nitrogen content. Outdoor experiments on potted trees showed no difference on mortality and relative growth rate (RGR). Nests transplanted in the field to the different hosts showed little differences in mortality or RGR due to host species or moth origin.
Female moths show a preference for egg-laying on the original host and on the new host but not for the secondary host, while larval performance did not differ among hosts. Thus, there is a discrepancy between female preference and larval performance. Our results reject our hypothesis and in expansion areas where *P. nigra* is absent *P. sylvestris* and *P. mugo* could act as sources, rather than sinks, for the expanding populations.

The relationships between the pine processionary moths and their egg parasitoids: the ecological significance of the egg mortality rates, seasonal history of the parasitoids and their host adaptation

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[2] Instituto Superior de Agronomia DEF, Lisboa, Portugal
[3] BOKU University, Vienna, Austria
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Abstract
T. *pityocampa* and *Thaumetopoea wilkinsoni* (=PPMs) (Thaumetopoeinae*:* N*o*todontidae) continue to extend their geographical boundaries. *T. pityocampa* spreads because of the effects of global warming; it has invaded pine forests at high elevations and in northern zones which were never previously infested by it. *T. wilkinsoni* also spread into new territories which are mainly afforestation and reforestation.
Across their natural range, two egg parasitoids, *Ooencyrtus pityocampae* (Merc.) (Encyrtidae) and *Baryscapus servadeii* (Dom.) (Eulophidae) are their most common natural enemies.
Several objectives were addressed: (i) To study the effects of the egg parasitoids on PPMs, as related to the time of colonization of the studied forests, with particular attention to egg mortality in the core and divergent PPM populations; (ii) To examine the asynchrony between the emergence of the parasitoids and the occurrence of viable egg batches of PPMs in Portuguese and Israeli Forests; (iii) To determine if the

parasitoids are active in the spring and mid-summer, by monitoring their attraction to traps baited with eggs and with PPM sex pheromone; (iv) To examine the occurrence of the parasitoids on two potential alternative hosts whose eggs occur during the summer; and (v) To examine hypotheses regarding the ecological logic behind the emergence of the egg parasitoids, that displays a clear asynchrony with the seasonal history of their host.
Data collected in the three study areas, Israel, Portugal and Northern Italy (Vinschgau/Venosta) did not reveal significant differences between the egg loads in the various studied areas and habitats; no correlation was found between the size of the egg masses and the length of time the population had spent on the site.
The assembly of the principal egg parasitoid species did not vary much between study areas and, as shown in many previous studies, *O. pityocampae* and *B. servadeii* were the most abundant species. Partial correlation between the ratio of % egg mortality and % of eggs from which wasps emerged was found ($r = 0.63$). No significant correlation was found between the percentage of hatching eggs and the length of time the population had spent on the site ($r = 0.41$). Our data suggests that the spread of the parasitoids – *O. pityocampae* in the case of the Israeli forest – is fast. The present results show that the emergence of the wasps in the laboratory actually reflects their activity in the forest: most of the wasps emerge between spring and early summer (May-June), implying that the wasps may become active several months before the next egg batches are available. Furthermore, the extent of egg parasitism seems to be too high to be achieved only by the very last and very few wasps that emerge from diapause.
The information generated by egg traps set up in forests that were colonized or not colonized by the moth suggests that *O. pityocampae* is attracted to the pheromone only during the flight period of PPM.
The uniform pattern of emergence of the two egg parasitoids throughout their entire range supports the hypothesis that they exploit alternative hosts to bridge the long gap between their emergence and the appearance of new egg masses. In Portugal it is possible that *O. pityocampae* switches to the PPM summer population in order to reach the next generation of the winter population. Although the summer population (currently under study) is considered a rather new phenomenon and limited in Portugal to a single area, it may represent a more widespread phenomenon. In Israel the variegated caper bug *Stenozygum coloratum* (Petatomidae) seems to play a role in bridging the summer gap for *O. pityocampae*. Based on this, and earlier studies, we suggest that the summer *O. pityocampae* may be lured by the aggregation pheromone of various Heteroptera species. It is also suggested that the alternative hosts play a role in the survival of at least *O. pityocampae*, and therefore, preserving biodiversity may benefit the management of PPM.

The pine processionary moth in Sierra Nevada (SE Spain): host selection, host damage and range expansion as a consequence of climatic warming

J. A. Hódar

Universidad de Granada, Granada, Spain

Abstract
The pine processionary moth (*Thaumetopoea pityocampa*) is one of the main plagues both natural and afforested pine woodlands of SE Spain. Since 1997 we study the population dynamics of the pine processionary caterpillar in the National Park of Sierra Nevada (SE Spain), as well as the negative impact of the plague on the growth and reproduction of affected pines. The study area includes autochthonous woodlands of Scots, Black and Cluster pines (*Pinus sylvestris nevadensis*, *P. nigra salzmannii* and *P. pinaster*), although these grow intermingled with afforested tracts. The attack is heavier upon Scots and Black pines, while Cluster pines appear relatively free of attack. This is due to the high mortality of young larvae feeding on Cluster pine, since caterpillars of late instars are able to thrive on it. Young larvae also show lower viability when feeding on pines previously defoliated. The damage inflicted by the processionary slows down growth in juvenile pines and weakens reproductive capacity in adult ones, and even causes mortality when defoliation occurs during two consecutive winters or more. Our results reveal that the eruptive phase of the plague coincides with mild winters, which are increasing its frequency as a consequence of global warming. This is especially dangerous for the populations of *Pinus sylvestris nevadensis*, a relict variety of Scots pine living in SE Spain. We propose that damage by pine processionary moth plagues can be tempered by the appropriate management of the forest structure.

Cost-benefit analysis of a new Integrated Pest Management. A case-study in Val Venosta (BZ), Italy

P. Gatto, A. Zocca, A. Battisti
University of Padova, Legnaro, Italy

Abstract
The Val Venosta is an Alpine valley located in the Northern part of the Province of Bolzano, just at the border with Switzerland and Austria. The case-study area is represented by 880 hectares of Pine forest, of which 575 is pure Black Pine and 305 is Scotch Pine. These artificial pine forests are all located on the Southward mountain sides, at an altitude ranging from 700 and 1.500 m. Forests in Val Venosta are important for other reasons that timber production. Indeed, they produce the following recreational and environmental benefits. The Forest Authority (Servizi Forestali-Forest Service) of the Val Venosta is very active in the Pine Moth Pest Management. Three different phases can be single out in time: in the period 1958 (the first year for which we have records of attacks) to 1995, control had been carried out only through mechanical means.
Pine Moth nests were collected from tree using shears, then burned. When nests were too high on the tree, they were destroyed with lead shots. From 1995 to 1998 no interventions were carried out, until a strong attack took place, due to a wet and warm Summer when all the pines were attacked and defoliated – a very bad impact on landscape and therefore recreational use. Since 1999 up to date, the Forest Service has regularly carried out IPM using Btk sprayed by an helicopter. The analysis carried out so far shows that, given the availability of data, IPM to pine moth in Val Venosta is profitable even if only financial benefits and costs are taken into account. However, it must be clear that this is only a comparative value, the absolute values of cash flows being negative in both situation due to the lack of profitability of selling pine timber.
In this case, however, what makes the difference is the conservation of the estate (land plus growing stock) which is expressed by the *annual land rent* included in the cash flows. When passing from the financial to the economic approach, here profitability assumes positive values also in absolute terms, since the positive benefits of performing IPM are accounted for also from the society point of view. In this case, however, although we have generally established IPM profitability, further research is advocated in order to fine-tune the recreational and landscape use non-use values, which have proven to be the most important benefits for pine woods in Val Venosta.

Poster session - conference 1

Adaptation of *Thaumetopoea pityocampa* larvae to leaf toughness in *Pinus*.

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Abstract
In the southeastern Alps, *Thaumetopoea pityocampa* utilizes two *Pinus* hosts - *P. nigra* and *P. sylvestris* - but shows a strong preference for *P. nigra*. The native range of *P. nigra* coincides with that of a much more widespread *P. sylvestris*. However, *P. nigra* has been used widely in reafforestation within the range of *P.sylvestris* since1920.
The populations of *T. pityocampa* of Friuli and Venosta are causing outbreaks in expansion areas mainly on *Pinus nigra*. The needles of *Pinus nigra* are significantly tougher in Friuli than in Venosta, and the eggs and neonate larvae of Friuli are significantly bigger, and the larvae heavier, than those of Venosta.
We hypothesize that the Friuli population is adapted to tough needles of native host *P. nigra* as the larvae are bigger and perform better on any host, and the Venosta population is adapted to soft needles of native host *P. sylvestris* and introduced host *P. nigra*, as the larvae are smaller and perform poorly on tough needles.
We set up a reciprocal transplant experiment, with one egg batch from each population caged on each of 20 randomly selected trees in both areas. We followed larval development until the third instar (L3), and measured needle toughness, foliar nitrogen, larval survival, and relative growth rate (RGR). The Venosta pop showed high mortality and lower RGR on Friuli needles. The Friuli pop survived well on both Friuli and Venosta needles, but RGR was 31% higher on Venosta needles, likely because Venosta needles had higher

nitrogen content than Friuli needles (0.98% vs. 0.73%). Leaf toughness, influenced by environmental conditions in Friuli, drives the adaptation of the larvae on the local host through enhanced survival of larger larval genotypes on tough needles.

Modelling the range expansion of the Pine Processionary Moth *(Thaumetopoea pityocampa)* in complex alpine terrain

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Abstract
The winter pine processionary moth, *Thaumetopoea pityocampa*, has a geographic range in southern Europe, northern Africa and Middle East but in the last three decades a substantial expansion of the outbreak area has taken place, both northward and upward in elevation. Modelling and mapping of the range of PPM using GIS is therefore a useful tool for estimating the actual and future impact of the range of PPM on forest management and their socio-economic implications. The influence of weather conditions on nest temperatures and on the feeding activity of the nocturnally active larvae was studied in laboratory and outdoor experiments. Feeding activity was estimated under different temperature regimes. Activity was induced only when day-temperatures were above 9°C and night-temperatures above 0°C. Lower lethal temperatures were estimated by freezing experiments and supercooling point measurements. For a precise estimation of the relation between nest temperature, air temperature and solar radiation, garden settings for simultaneous measurements were done. Minimum temperatures of the nest correspond well with air temperature minimum; nest maximum can be predicted by air temperature maximum and daily sum of solar irradiation. Climatic conditions, actual position of extreme nests and survival of larvae/colonies transplanted outside the actual range were observed in two alpine valleys (Durance Valley; Venosta Valley). Specific alpine conditions for the occurrence of PPM were studied on a local scale model at Venosta Valley, based on fine scale field surveys (air and nest temperatures, solar radiation) on north and south exposed slopes. Differences in feeding activity between the northern and southern slope can mainly be explained by low potential radiation due to shading of the northern slope during midwinter. Regional models were developed to evaluate the potential range of PPM for the alpine regions Trentino–Alto Adige-Tyrol (Italy-Austria) and Durance Valley (France) using modelling procedures similar to those applied on local scale, but with data from meteorological recording stations. Due to limited availability of solar irradiation data, a sub-model for estimation of global solar irradiation was developed using MeteoSat 7 image-analysis and potential solar irradiation derived from a digital elevation model (DEM). In order to reduce model errors caused by macroclimatic effects and climate zones, the modelling area was divided into adjacent sub-regions.
Daily multiple regressions were calculated for modelling daily air temperature maxima and minima.
Validation of the estimated bioclimatic variables was done with independent sampled data (translocation experiments in 2002/03 and 2003/04). Instead of sharp temperature thresholds of nest temperature for feeding induction (>9°C) and night feeding (>0°C), fuzzy functions were used to calculate the relative potential feeding activity during the winter period. The spatial distribution of the relative potential feeding activity was compared with the geographic range of PPM in Southern Tyrol. The class limit for “very likely occurrence” of PPM was defined as the minimum of the relative potential feeding activity for locations at the edge of the range during the “normal” winter 2003/2004. The spatial analysis of potential occurrence of PPM showed a high inter-annual variability. Due to the influence of mediterranean climate, the range limit of PPM is much higher in elevation in Central Trentino and Val Durançe than in Southern Tyrol, Dolomiti and Western Trentino. The climatic conditions for feeding activity would also permit the occurrence of PPM in the northern alpine range, but compared with the Southern Alps the higher frequency of extreme frost events are limiting the occurrence of PPM. Concerning French Alps, the actual range of PPM is for some areas far behind the limit of potential occurrence. Therefore, a further range expansion into these areas near Briançon and Pelvoux can be expected. Scenarios for climate warming and range expansion at Venosta Valley are based on the climatic conditions during the winter 2003/2004 (deviation of the mean winter temperature from the long-term mean winter at Schlanders: +0.27°C). The relative potential feeding activity of the winter 2003/2004 was estimated using a function with the mean winter minimum temperature as predictor. The classification of the occurrence of PPM was intersected with the areas of black pine and conifer stands for each scenario. The scenarios of climate change predict that every increase of 1°C in winter minimum could

induce an altitudinal range expansion of ~200 m. A deviation of only +1°C dramatically increases the proportion of infested black pine stands at Venosta Valley. Almost all conifer stands in this area could be affected by PPM-infestations under +4°C-conditions.

Modelling the Pine Processionary Moth range expansion in the Paris Basin

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Abstract
The edge of the PPM distribution has shifted by 86.7 km between 1972 and 2004 with a significant acceleration during the last 10 years. This shift was coupled with an increase of minimum temperatures of about +1°C between 1972-1990 and 1994-2003. Climatic conditions affect indirectly the PPM survival, controlling the feeding activity. Indeed larvae effectively feed during the night when the air temperature is above 0°C only if the nest temperature during the preceding day was above 9°C (Battisti *et al*. 2005).
We used the maximum air temperature (°C) and the solar radiation (Wh/m²) to estimate the maximum nest temperature.
Based on these weather requirements, the feeding capacity was evaluated through the number of feeding days and the duration of the longest period of starvation from October to March in the range expansion area and in the still non-colonized area of the southern Paris Basin. During the period 1992-1996, an unfavourable zone split the area where PPM feeding is potentially allowed into two disconnected parts: the historical core area and the South of Paris where the PPM was still absent. But during the period 2000-2004, this in-between zone turned quite entirely favourable so that it does not constitute any more a barrier for the PPM progression towards Paris. Despite this significant change between the two periods, we could not exclude a natural oscillation of the climate. So, we looked for a climatic indicator which may account for the feeding ability in order to detect the effect of global warming. The mean of minimum temperature from October to March, explaining 77% of the feeding variance, was selected. The analysis of its fluctuation on a representative climatic period (~30 years) revealed a sudden warming at the end of the 1980s. This rupture is characterized in Orléans by a mean temperature of 2.46°C +/- 0.86°C before 1988 and 3.55°C+/-0.68°C after 1988. In this second period, temperature in Orléans (colonized in 1992) and Melun (beyond the current PPM front) became significantly not different from temperature in the historical core area before 1988.
Presently the PPM encounters favourable feeding conditions nearly everywhere in the study area in the South of the Paris Basin. The effective shift will depend on the dispersal capacity of the population, notably the reduced flying capacity of females and the presence of host tree in the potential expansion area. In this respect, pine plantations along motorways are probably providing noticeable relays for PPM progression.

Particularites related to the determinisme of *Thaumetopoea pityocampa* (Lepidoptera: Thaumetopoeidae) egg eclosion in the south of its distribution area.

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Abstract
The egg eclosion degree-day accumulation of the pine processionary caterpillar (Lep., Thaumetopoeidae) was carried out in the subsaharian reforestation pine area. The annual average number of the degree-day accumulation necessary to initial hatched caterpillar was situated between 1033 and 912 °C. In the south of Europe it was unregistered only 780 °C. It appears that the deceleration of the embryonic development which was observed in the subsaharian region is caused by the higher temperature exceeding 30 °C whereas, in southern Europe it was the minimal temperature which control the embryonic development speed.
The increase of the degree-day accumulation generated a physiological mortality of more than 19 % of eggs. The egg parasitoïds effectiveness was more higher.
The females moths flight which was reconstituted with the egg eclosion chronology and the degree-day accumulation average number show that there is a high possibility of the reproductive success between the two partners and can explain the egg masses abundance which was noted in the majority of the experimental plots.

The outbreak in the expansion area of Venosta/Vinschgau: the role of extended diapause

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Abstract
Venosta/Vinschgau Valley is an historical site for the study of the expansion of *Thaumetopoea pityocampa* in the Alps. The moth, endemic in the area, started the first outbreak in 1998 when it defoliated completely several hundred hectares of plantations of *P. nigra* placed on the southern slope, between 750 m and 1150 m. On that occasion, the Forest Service started to collect data about: 1) the moth emergence in 3 large cages (2 x 2 x 2 m) built in the field and where approximately 5,000 mature larvae were allowed to pupate in spring 1999; 2) the male catch by pheromone traps; 3) the areas attacked and treated (Btk) each year. The results show that the stock of diapausing pupae in the soil was substantial and one cohort could produce moths over at least 6 years. The emergence pattern of the 1999 cohort was related to the extent of the attack in the valley, and the contribution of the following cohorts to the diapausing stock was limited due to Btk treatments. No correlation was observed between the attacked area and the catch of males in pheromone traps.

Conference 2

Ecology and management of the pine processionary moth

Expansion, Damage And Natural Enemies Of Pine Processionary Moth In Türkiye

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Abstract
The pine processionary moths, *Thaumetopoea pityocampa* and *Thaumetopoea wilkinsoni* are widely spread in pine forests of Türkiye and the most important defoliators of the pine trees. *Pinus nigra* and *P. brutia* seems to be the main host plants. Mediterranean, Aegean and Marmara region are annually defoliated, especially along the Mediterranean and Aegean coasts. Both species have significant influence on stand dynamics by reducing tree growth. Insect damage undoubtedly the most important biotic factor affecting and threatening the very existence of forest resources in Türkiye. Trees damaged by PPM provide suitable feeding areas for secondary harmful insects, especially bark beetles. Cost control methods against these species have a share of 63 percent in the total expenses of control methods against all forest pests.
The larvae of PPM feed on the pine needles. Sometimes heavily damage is occurred on assimilation organs in some regions. Depending on the density of these caterpillars, the degree of defoliation varies not only from place to place, but also from year to year. In Türkiye, both defoliator species are found up to altitudes of 1800 m. Host phenology is to a large extent influenced by climatic factors. Temperature primarily determines moth exclosion, which lasts from July to October, depending on the latitude and longitude of the site.
Several natural enemies of the pests have been determined. The egg parasitoids are the most active natural enemies of *T. pityocampa* and *T. wilkinsoni* in Türkiye. Six parasitoid species were reared from eggs.
Its most frequent chalcidoid egg parasitoids are *Baryscapus servadei* (Dom.) and *Ooencyrtus pityocampae* (Mercet). Additionally *Anastatus bifasciatus* (Fonscolombe), *Trichogramma embryophagum* (Htg.), *Pediobius bruchicida* (Rond.), *Conomorium* sp. are recorded. Generally parasitism rate is 25 percent. Larva and pupae parasitoids are known in Türkiye as *Compsilura concinnata* Meig, *Phryxe caudata* Rond., *Exorista segregata* Rond., *Scambus* sp., *Erigorgus femorator* Aub., *Cryptus* sp., *Hockeria singularis* Boucek, *Meteorus versicolor* Ruth., *Villa brunea* Beck. Predator insects which are effective on these pests are *Calosoma sycophanta* (L.), *Carabus graecus* Dejean, *Dermestes undulatus* Brahm., *Forficula auricularia* L., *Staphylinus mus* Müll. A lot of bird species are also caterpillar predators. These are *Pyrrhocorax pyrrhocorax* (L.), *Upupa epops* (L.), *Parus major* L., *Parus ater* L., *Cuculus canorus* L., *Caprimulgus europaeus, Oriolus oriolus,*

Lanius nubicus Lich. During the fall and winter, birds of the genus *Parus* seem to be important predators of the young caterpillars. In Türkiye, different control methods were applied to reduce the populations of *T. pityocampa* and *T. wilkinsoni*. Among them, the most common method consisted in destroying the winter nests by cutting. Besides, chemical and biological control methods

Pine processionary moth expansion and natural enemies in Algeria

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Abstract
The absence of climatic constraints, such as solar radiation below the threshold of 1800 hours per year, allows the survival of *Thaumetopoea pityocampa* in *Pinus* and *Cedrus* forests from the littoral until the sub-Sahara in Algeria. Compared to the other insect pest species, the frequency of the damage is high especially in the afforestations; more than 100 000 hectares/ year are programmed for treatments.
The specific composition of the complex of the natural enemies of the pine processionary moth varies according to the ecological conditions and to the nature of the forest. This variation is the result of the different pressures, in particular climatic factors, plots characteristics, structure and nature of the forest, food quality and finally a certain genetic variability inter and intra population.
The inventory of the entomophagous species was carried out for different development stage (egg, larva, and pupa) of the insect pest in natural and artificial forest situated at the sub-Saharan locality of Djelfa. The "key" species parasitoids were found but the specific composition of the complex is poor compared to that of North Africa and the south of Europe. In fact, several mainly polyphagous parasitoïds were not found, such as: *Trichogramma sp*. (Hym., Trichogrammatidae), *Compsilura concinnata* (Dip., Tachinidae), *Apanteles vestalis* (Hym., Braconidae), *Xanthandrus comtus* (Dip., Syrphidae) and finally *Coelichneumon rudis* (Hym., Ichneumonidae). The last species accounted more than 10% of pupal parasitism during its peak periods in the south of France and Italy.

Pine processionary moth in Tunisia: present situation and future prospects of research

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Abstract
The Tunisian forests of pines are affected by various phenomena. Most important are human activities and climatic conditions (drought). Among pine défoliators, *T. pityocampa* is undoubtebly the most hurmful species because of the damage caused during its periodic outbreaks. The pest is present in all pine forests in Tunisia. It is also the most important defoliator of both native (*Pinus halepensis*, *Pinus pinaster*) and introduced (*Pinus pinea*, *Pinus brutia*) pines; and is especially damaging in young plantations and on ornamontal trees. In Tunisia, the studies on processionary moth are few and fragmented. There are only 6 publications on the subject: 3 were done in the Sixties and 3 in the Nineties. In the present paper, *i-* we present the main results of research obtained in Tunisia ; *ii-* we identify new orientations of research.
The biology of *Thaumetopoea pityocampa* in Tunisia is similar to that of many Mediterranean countries: one generation per year. But moth population in the region where the altitude is above 1000-1200m, can sometimes have one generation every two years. In Tunisia we use currently the mechanical method for control. This manual method consists in removing winter nests and incinerating them in December/January. This method present a lot of problems. First, it is difficult to practice it especially in adult plantations.
Second, the urticating hairs of larvae may cause serious health problem to workers. The first treatment trial using *Bacillus thuringiensis* has been done in Tuinisia in 1967. A second treatment trial against the pine processionary moth by *Bacillus thuringiensis* Kurstaki was conducted in 1994. Only two egg parasitoids (*Ooencyrctus pityocampae* Mercet and *Tetrastichus servadeii* Dom.) and two larval parasitoids (*Phryxe caudata* Rond. and *Erigorgus femorator* Aub.) were collected in 1996.
At Jebel Korbous, 30 tunisian and exotic provenances were compared, in order to examined if there were differences between Aleppo pine provenances to resist of this insect's attacks. This study demonstrated that at equal heights, different Aleppo pine provenances presented on average close rates of attacks by this insect. This suggests that the observed significant differences in attacks between provenances are not attributed to their intrinsic genetic resistance, but rather to their tree height differences. In the future, other studies of natural enemies to complete their list will be necessary. In addition, we aim to test other product

(growth regulator), and find out whether essential oils from various plants might be used as insecticides for the larvae of *T. pityocampa*. Finally, we are open to collaboration with other countries in research project.

Expansion, Damage and Natural Enemies of Pine Processionary Moth in Lebanon

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Abstract
The pine processionery moth, *Thaumetopoea wilkinsoni*, is the most damaging pest of pine trees in the Mediterranean region. It spreads in Lebanon on *Pinus halepensis*, *P. brutia*, *P.canariensis* which areas constitute 20% of the forested area of Lebanon. In 2003, it was estimated that around 10,000 ha of pine forests were infested by this pest with more damages on the solitary trees. Management programs include the use of *Bacillus thuringiensis* and the insect growth regulator Diflubenzuron. Studies conducted on the natural enemies of the pine processionery moth in 1999-2001 showed the presence of three egg parasitoids and two larval parasitoids. The two species of larval and pupal parasitoids present are *Compsilura concinnata* and *Phryxe caudate* (Diptera: tachnidae) and giving approximately between 16 % and 23 % parasitism. The egg parasitoids were identified as *Baryscatus servadeii* (Hym., eulophidae), *Ooencyrtus pityocampae* (Hym., Encyrtidae) and *Anastatus bifasciatus* (Hym., Eupelmidae). The percent parasitism by these egg parasitoids ranged from 10 % to 16 % depending on the location and altitude of the areas studied.

Distribution, damage and natural enemies of the Pine Processionary moth *Thaumetopoea pityocampa* (Lep.: Thaumetopoeidae) in Bulgaria

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Abstract
The pine processionary moth *Thaumetopoea pityocampa* (Den. & Schiff.) (Lep.: Thaumetopoeidae) is the most widely distributed needle-damaging pest of *Pinus sylvestris* and *P. nigra* in Bulgaria. Occasionally, it can also be found on *P. leucodermis.* An overview of the distribution, damage and natural enemies of this pest in Bulgaria are presented based on what is known and published in the scientific literature.
Thaumetopoea pityocampa was recorded for the first time in in 1907 in Southwest Bulgaria and the first mass infestation was observed also in the same area in 1924. The pest is distributed in the Southern portion of West and Central Bulgaria and recently has expanded its range considerably. The area of infestation has increased significantly during the last three decades and this increase is apparently correlated with an increase in the distribution and abundance of its preferred hosts. Data in the Bulgarian literature suggests that there are two subspecies of the processionary moth in Bulgaria, based on differences in the time of hatching of the larvae and their location for diapause. The first subspecies is typical Mediterranean and is distributed in the Southern area near the border with Greece. The caterpillars diapause in the nests and pupate in the spring. The second subspecies was found initially in the village of Banya by Tsankov et al. (1996) who described it as *Thaumatopoea pityocampa bulgarica.* It is distributed in the sub-Balkan region, which is Central Bulgaria. Caterpillars of this subspecies develop very rapidly and processions of 5^{th} instar larvae can be observed as early as the middle of October when they go into the soil for pupation.
Pupation takes place in March-April of the following year. The most important natural enemies of *T. pityocampa* in Bulgaria are the egg parasitoids. Studies indicate that seven species of egg parasitoids have been recorded from this pest. The most abundant species is *Ooencyrtus pityocampae*, followed by *Anastatus bifasciatus*, *Baryscapus servadeii, Trichogramma embryophagum, Macroneura vesicularis, Baryscapus transversalis* and *Pediobius* sp*.* A nucleopolyedrosis virus occurs in Bulgarian *T. pityocampa* populations and predators such as the long-horned grasshoppers *Ephippiger ephippiger*, *Rhacocleis germanica*, and the bird *Parus major* are reported to feed upon or destroy the egg clusters of the pine processionary moth.

An outbreak of *Thaumetopoea pinivora* in south Sweden

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Abstract
At present *Thaumetopoea pinivora* occurs at outbreak densities on the southern tip of the Swedish island of Gotland in the Baltic Sea. The population has been known from the area for many decades, but has never before occurred in such high densities. The Gotland population has a two-year development, with high larval densities only in even years. Larvae can be found also in odd years, but then in much lower numbers.
High larval numbers are expected to occur in 2006; recent surveys show very high densities of eggs.
In my talk I will report details on *T. pinivora* life history, the distribution of egg masses within and between trees, and hypothesize about reasons why *T. pinivora* in Sweden has its main distribution restricted to south Gotland and why it presently occurs there at outbreak numbers.

Monitoring pine processionary moth (Lepidoptera: Thaumetopoeidae) populations with pheromone-baited traps

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Abstract
A series of studies were carried out to design pheromone-based monitoring of the Pine processionary moth (PPM), *Thaumetopoea pityocampa*. In a dose–response field test the number of male captures significantly increased with the dosage of pityolure to a plateau around 10 mg. The activity of pheromone dispensers lasted at least 9 weeks, enough to cover the whole flight period of *T. pityocampa.* In a comparison of several saturating and non saturating trap designs, plate sticky traps always showed the best trapping efficiency. Captures were significantly higher in regularly cleaned traps and at tree canopy height but catches of males PPM were positively correlated with those obtained in non cleaned traps at human height. The relationship between the number of male PPM captured in pheromone plate sticky traps per day and the total number of winter nests per stand was then investigated. Ten traps baited with 0.5 mg of pityolure were located along transects that extended from the border to the centre of fourteen maritime pine stands. Mean trap captures calculated from ten to three traps were significantly correlated with nest density. Similar results were obtained with traps baited with 0.2 mg indicating that four plate sticky traps baited with 0.2 mg of pityolure would provide a cost effective tool for monitoring densities of PPM population. The reliability of this method was tested across three countries, France, Italy and Portugal and in two distinct epidemic conditions, in the core and in the expansion area of the pine pest. Four pheromone traps baited with 0.2 mg were activated in the centre of four plots of twenty trees in a total of 33 pine stands of different age and species. Results were remarkably consistent showing significant and positive correlations between mean male captures per trap per day and total number of winter nests per hectare irrespective to the areas. The slope of the regression curves were also similar. The relationship between mean trap captures and subsequent level of infestation (next PPM generation) was also tested in 2003. Positive although less significant correlations were observed for all regions within the core area of *T. pityocampa* but not in the expansion range. This latter observation originates in the heat wave recorded in summer 2003 in France which resulted in high larvae mortality within PPM populations situated at the fringe of the natural range.

Differential susceptibility of *Thaumetopoea wilkinsoni* and *T. pityocampae* from several geographical locations to *Bacillus thuringiensis* formulations and environmental persistence of three products tested under natural conditions

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Abstract
The susceptibilities of PPM larvae to Bt formulations were screened in 2003 and 2004. Eggs and larvae were collected from pine forests in 11 different geographical locations in Israel. Larval mortality bioassays were

conducted with formulations of Delfin, Dipel DF and Foray 48B at concentrations ranging from 0.001 to 0.1%, with 1% condensed milk used as a spray adjuvant. Significant differences in susceptibility to Bt were recorded among populations that were regularly treated, often treated, or never treated with Bt. The mortality bioassay was optimized with regard to the patterns of larval hatching and age. The mortality recorded in a population that was never treated with Bt was twice that found in a regularly Bt-treated population.
The experiments conducted in Italy in 2002 showed that the mortality was significantly higher in Divergent populations, suggesting development of some resistance in the core areas. The results that were obtained in France in 2003 suggested that the mortality in "long-time infested forest area" was higher in treated than in the non-treated plots suggesting development of some resistance in routinely treated plots.
Knowledge of persistence of Bt is needed to improve the microbial pest management programs against *T. wilkinsoni*. Therefore, we evaluated the persistence of the microbe under natural conditions of rain and sunlight. Pine saplings were sprayed with three above mentioned products, in formulation as mentioned earlier. The experiments were conducted in November and December 2004. The saplings were either exposed to rain and sunlight or were sheltered to avoid the impact of the environmental factors. Needles of the treated saplings and their controls were sampled after 0, 1, 5 and 8 days, and were fed to 1st or 2nd instar larvae. Dipel DF persisted better than Delfin and still retained its initial activity of 80-100% mortality on day 8. Dripping of Bt from upper to lower branches was quantified with the larval bioassays. Dipel DF persisted better than Delfin and the milk formulation proved to be an effective rain fasting adjuvant. The experiments conducted with T. pityocampa in Italy showed that the ability to resume feeding of the larvae surviving the Bt treatment increased significantly with the time after application but did not differ between treated and untreated needles. Furthermore, Bt (Foray 48B) was found effective up to 4 days, which is not enough to suppress the L2 of the core populations tested.

Phylogeography of the winter pine processionary moth *Thaumetopoea pityocampa/wilkinsoni* in the Mediterranean basin

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Abstract
Mitochondrial gene sequence was used to discriminate among 60 populations (Portugal: 4, Spain: 2, France: 5, Italy: 10, Albania: 1, continental Greece: 3, Greek islands: 12, Turkey: 8, Cyprus: 3, Lebanon: 2, Israel: 5, Libya: 2; Tunisia: 3), while nuclear DNA markers (microsatellite and AFLP) were available for 18 populations of *T. wilkinsoni* (Turkey: 8, Cyprus: 3, Lebanon: 2, Israel: 5). A hybridization experiment between the two species was carried out by using populations from Italy and Israel. The results showed that the two species are well separated species from a long time, but we observed reproductive compatibility under controlled conditions (F1 and F2 available). The lineages from north Africa and Crete are clearly separated from those of *T. pityocampa* and *T. wilkinsoni*. We also defined a hypothetical contact zone between *T. pityocampa* and *T. wilkinsoni*, where natural hybrids may possibly occur. The comparison of mitochondrial and nuclear data of *T. wilkinsoni* allowed to find a substantial population structure, with gene flow supported mainly by male dispersal, even on a long distance. The Israeli populations do not appear to be introduced from Cyprus but rather result from contiguous range expansion from south-west Turkey.

Genetic structure of a desynchronized population of *Thaumetopoea pityocampa* in Portugal

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Abstract
Pine processionary moth is a ravaging insect known from all Mediterranean basin causing economic damage and health problems. Several species of processionary moths are known to attack pines and oaks (*e.g.*), although only one species is described in Portugal, *Thaumetopoea pityocampa*. In 1997 a population in which the larvae develop in the summer instead of the winter was discovered in Mata Nacional de Leiria, and remain until today a unique case in Portugal. Other processionary moth species known to develop in the summer do not occur in Portugal. Genetic markers were used to assess the genetic position of this population in relation to other populations of normal cycle in Portugal and of other countries, as well as to other species of processionary moths. The flight periods of the Leiria Summer and winter populations were

monitored with funnel trap captures. Results indicate that this population belongs to *T. pityocampa* although there was a shift in the life cycle. Genetic distance between this and the normal populations suggests that the summer population is differentiated from the winter one, and there is little genetic flow between them. The adult's flight period of the two populations does not overlap in the field, which leads us to say there is no reproduction among the two populations. This might be the beginning of an evolutive event, which might lead to speciation, thus being of great scientific interest to continue studies on biological and ecological aspects of this population.

Update of the research on the pheromone system of the pine processionary moth on different host plants

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Abstract
Sex pheromone in Lepidoptera populations is an important factor in reproductive isolation between species but also within species. Previous works demonstrate that within a species different pheromone populations exist. These populations cannot anymore interbreed due to the pheromone composition. Some examples showed that the pheromone populations are related with the specialisation to a host plant or a host tree.
The aim of the study was to determine if the colonising populations differ from the established population from the point of view of the reproductive strategies based on pheromone communication.
Sex pheromone of processionary moth was investigated using SPME collection and GC and GC-MS.
Results showed that a polymorphisme existed. In 2004, comparing populations originating from different location and different species of pine trees, the isomer E of the main component (yne11,Z13 16:AC) was for the first time identified in a processionary pheromone and was only detected in Douglas fir population females. In the experimemt conducted in 2005, populations from front and core areas (respectively, Fontainebleau and Alps) were studied, leading to confirm the polymorphism in sex pheromone composition. Moreover, the main component of the sex pheromone of an individual female was identified as the E isomer. However, no relation between the sex pheromone composition and the colonising populations can be evidenced.

Mathematical evidence of an outbreak cycle in pine processionary moth

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Abstract
Foliage feeding insects commonly exhibit periodical outbreaks. In the case of the Pine Processionary Moth (PPM), *Thaumetopoea pityocampa* L., a roughly 6-year periodicity was observed but it has never been proved. We intended to demonstrate this periodicity and to understand the general mechanism of regulation. An extensive monitoring of nests began in 1981 (presently managed by the French Forest Health Department, DSF) and provided a remarkable database to analyse the population dynamics over a long-term period. We considered 31 plots continuously observed and never been treated with pesticides against the PPM. The study also focused on 4 regional dynamics covering the historical core and expansion areas and we investigated the effect of climatic conditions on the population fluctuation. We analysed the fluctuation of the nest density but we need to prove that the nest density is really representative of the population level.
The autocorrelation function (ACF) enabled to detect a significant periodicity of 6 to 12 years among the 31 individual plots and a periodicity of 8-9 years in the regional dynamics. When another method based on the spectral analysis was used, periods of 9 years were also dominant, even if few time series showed a significant periodicity. To detect the effect of each generation on the following generation level, we used the partial autocorrelation function (PACF). Negative feedback of time lag 2 reveals a delayed density dependence. To understand this mechanism, we re-analysed biological indicators reported by Abgrall (2001) on 9 time series from 1970 to 1980. The number of moth captures has a significant negative effect on the following generation fecundity and fecundity is clearly associated with the following population level (in terms of nest density). We proposed two models to describe the PPM population fluctuation: a statistical model (second order auto-regressive model) and a delayed Ricker model. The second model fitted better the PPM dynamics for the 31 individual plots and the aggregated plots in the historical core area.
Since the delayed Ricker model generates cycles of 6-year periodicity when the growth parameter is equal to 1 and the mean of the highly significant growth parameters was equal to 1.05, we concluded that the PPM

dynamics is likely to exhibit such periodicity. As the delayed Ricker model has a very low fitted success in the expansion area, we wondered if this could be attributed to disturbance caused by unfavourable climatic conditions at the edge of the PPM distribution. We selected climatic variables closely correlated with the density independent component of the population fluctuation (i.e. the residuals of the delayed Ricker model). Then we introduced these explaining variables into the delayed Ricker model using a survival function. This modified model accounted up to 95% of the population fluctuation in the expansion area but did not improve the fitted success for the populations in the core area. We concluded that PPM has an underlying outbreak cycle of 6-year periodicity but climate may disturb the population dynamics mainly at the edge of the PPM distribution.

Effects of site quality on tree response after *Thaumetopoea pityocampa* defoliation

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Abstract
Site quality is a determinant factor for trees. Tree growth rate is the result of its genetics background as well as the environment in which it grows. But also the ability of a tree to respond after an herbivore attack may vary depending on site quality, because tree defenses are energetic dependant and plants compete for limiting resources. I this study we explore both, the effect of site quality on tree growth and tree defenses, for two pines species: *Pinus pinaster,* a native species with moderate growth and *Pinus radiata,* an introduced fast growing species. Results from this study will help us 1. To improve growth models for these tree species for the Norwest of Spain and therefore get more accurate predictions of stand productivity for forest managers and 2. A better understanding of how native and exotic trees respond to defoliation by a native insect species and how this may be affected by site quality.

Preference / performance of *Thaumetopoea pityocampa* on Mediterranean *Pinus* species

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Abstract
Host selection preferences regarding oviposition of *T. pityocampa* females were investigated under field insectary conditions. Synthetic christmas “trees”, baited with extracts from four pine species, *P. pinaster, P pinea, P. brutia* and *P. halepensis*, plus an unbaited “tree” (control), all having the same size and shape, were offered to recently emerged females, in an experiment lasting for the whole flight periode. The number of egg batches oviposited varied significantly among pine species (X^2 = 25.8, p< 0.001), *P. brutia* being the prefered species, followed by *P. pinaster, P.pinea* and *P. halepensis*. No eggs were laid on the unbaited “tree”, thus showing that ovipositing females use olfactory stimuli to select their hosts. In parallel, the survivorship and development of *T. pityocampa* larvae was assessed, in two separate laboratory experiments, one covering instars 2 to 5, and another one for the 2nd instar only. The larvae were fed with needles from the same trees, and pine species, taken to prepare the extracts used for the female host selection experiment.
Several parameters related to larval performance were quantified, ranging from survival rates, to efficiency of digested food (ECD). The relative toughness of the pine needles was measured using a penetrometer. Phytochemical analyses were performed, regarding both primary components: dry matter, C, N, amino acids, carbohydrates, and some secondary metabolites: resinic acids. A significantly lower survival and growth rate was observed for the group fed with *P. halepensis*. Results indicate that, in general, primary compounds neither influenced larval performance, nor survival. However, a lower digestibility was observed for *P. pinaster* needles, which had the lowest N and aminoacid contents. Thus, the differences in larval survival and performance observed may, in part, be explained by variations of the secondary metabolites contents, particularly resinic acids. All insects used in the experiments originated from a population distributed along the Atlantic coast of Portugal, where *P. pinaster* is the main host. The results obtained regarding larval performance on different pine species; do not agree with studies by other authors, conducted in other geographical regions. It should be taken into account that both within pine species variations, and the origin of the *T. pityocampa* populations, are important factors reflecting on the outcome of the performance and impact of this defoliator. Our findings are in accordance with field observations for Portugal, where *P. halepensis* is very rarely attacked by *T. pityocampa*.

Biodiversity of arthropods sheltered in Pine Processionary moth nests

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Abstract
The arthropod fauna associated with the communal tents of the pine processionary moth *Thaumetopoea pityocampa*, in maritime pine stands in Portugal, was investigated aiming to identify their possible trophic relationship. Sixty species were associated with the nests, representing more than ten foraging guilds. Throughout winter, the nests increase in size and accumulate debris, attracting many different kinds of foraging arthropods such as scavengers, decomposers and fungi feeders. Spiders represented 10% of the total number of individuals collected and up to 50% of the total species richness. There is evidence that spiders use these shelters for both over-wintering and reproduction. The foraging guilds associated with the majority of the spiders were specialized jumpers, nocturnal ground hunters and cryptic hunters.
An interaction between the communities of spiders found in the coppice of the pine forest and the communities of the ground surface, or ground vegetation layer is suggested. The larval parasitoid *Phryxe caudata* was the most abundant species. The percent parasitism caused by *P. caudata* was dependent of host density on a spatial scale, suggesting a possible regulating effect. The diversity of arthropods and, in particular of the spider fauna collected, was influenced both by stand age and landscape complexity.

Poster session conference 2

Host Volatile Release From *Pinus* Spp And Female And Male Response In Pine Processionary Moth *Thaumetopoea Pityocampa*: Oviposition Or Habitat Cues?

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Abstract
We hypothesised that volatiles from host pines would be cues for host selection in female pine processionary moth adults. We predict that: 1) There should be an in-flight orientation to preferred pines based on volatiles. 2) These cues should vary among more or less preferred pines and sensitivity to single molecules should differ but correspond to host species preferences. 3) Male and female overall sensitivity may differ, due to use of these cues in long or short-range behaviours, respectively. Preference test in outdoor flight cages with potted *Pinus* trees showed some differences among species, with *P. nigra* having the most egg batches. Netted trees – including dummy trees (plastic Christmas trees of suitable structure) – with sticky traps did not show any difference in landings in males or females, which is contrary to prediction. Host volatiles, mainly monoterpene hydrocarbons, were collected *in situ* from *Pinus* trees from three spp of different exposure and age foliage appearance. Sampling was done at ecologically relevant time, i.e. during night in the flight period of local females/population. Overall volatiles, both hydrocarbons and oxygenated monoterpenes and sesquiterpenes, varied considerably both between species and among trees within species.
Contrary to our prediction, there was not a chemical distinction among species when analysing multivariate the major quantifiable compounds. GC-EAD analysis of volatile collections showed a qualitative similarity among the sexes, but generally a much stronger response in male antenna. Biological activity did not differ strongly among extracts of different spp, but showed activity in a low number of compounds / peaks.
Activity was highest in (trace) compounds of oxygenated type; mainly those that can be loosely termed limonene oxides. The sex specific biological response agrees with our third prediction. The results led us to suggest that the bioactive host compounds will have different biological activity as cues for egg-laying acceptance and suitable habitat cues, for females and males, respectively.

A Survey on PPM populations in Antalya (Southern Turkey)

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Abstract
This study evaluates the differences between local populations of the PPM located in Asar, Ciglik and Dagbeli situated at different altitudes in Antalya. The differences were evaluated by means of life-cycle, egg-batch orientation and morphology, egg number, egg hatch and parasitioid ratio, larval nest orientation and number and rate of damage to trees. In addition, food preferences of larvae were determined by laboratory experiments. Reasons of the observed differences in local populations between the years 2004 and 2005 were interpreted by using results obtained from food preference experiments. Results showed that local populations at higher altitudes reached the egg, larval and adult stage earlier than populations at lower altitudes, while initiation of the pupal stage occurred at a later time in the populations at higher altitudes, when compared with the ones at lower altitudes. In addition, duration of the larval stage was longer for populations situated at higher altitudes. Orientation of both larval nest and egg clusters were biased significantly towards the south and this trend increased with altitude. Length of egg-batches and number of eggs were higher at higher altitudes, while egg hatch ratios decreased and the number of eggs containing parasitoids increased. When damage ratios were compared the lowest damage values were found at the highest altitude.
The number of nests and damage ratios decreased significantly in the second year of the study when compared to the first year. Results obtained from food preference experiment showed that the consumption rate of *Pinus nigra* was higher than *P. brutia* and no significant preference between damaged and undamaged trees were found. Food consumption increased with temperature.

Comparison of two areas attacked by *Thaumetopoea pityocampa* in Greece by Cost-Benefit Analysis

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Abstract
In this work we compared two different alternatives using Cost Benefit Analysis :
1) the situation with Integrated Pest Management (IPM),
2) the situation with no pest management.
The approach considers a life-cycle of the investment of fifteen years: a longer period would have implied too many assumptions on the future evolution of the pine forests and no large investments, with longer depreciation and obsolescence periods, are needed in the with-situation being nearly most of the work carried out through contractors. The following items of benefits and costs have been considered: i. market revenues; ii. market costs; iii. Off site market benefits; iv. Off-site market costs and v. Off-site non-market benefits. A 2% discount rate is chosen.
Two areas have been selected:
Thessaloniki – Greece. The area, surrounding the city of Thessaloniki, includes the valley of Axios and Gallikos rivers located in Central Macedonia. The case-study area is not of importance from the economic viewpoint but for protection of soils from erosion, recreation and landscape
Volvi-Koronia – Greece. The valley of lakes Volvi and Koronia is located in Central Macedonia, North-East of Thessaloniki. Here the pine forest area is smaller, less important as a recreational resort being located in a more rural inland area and mainly managed for timber production.
Results show that management costs heavily influence the economic performances in CBA, which gives positive results only when the high recreational value of the forest is considered. The high number of visitors emphasises the importance of the potential damages to visitors, which should deserve careful estimations. Results for Volvi Koronia show no profitability of carrying out IPM even in the EEA1, where social benefits like protection of erosion and hunting are considered.

Winter spray of Bt did not affect the performance of an endangered pine defoliator, the Isabel moth, *Graellsia isabellae*

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Abstract
The pine processionary moth expansion in the southern Alps results in entering pine biotopes of an endangered, red-listed moth, the Isabel moth which is feeding on pine foliage.
Some authors hypothesized that Bt sprays against PPM will seriously threaten the survival of populations of Isabel moth in these areas (Lerault, 2003). We tested this hypothesis by spraying Btk at the usual dose for winter treatment of PPM (FORAY 48ST, 3 l / ha). Fifteen trees were treated and 15 untreated controls from Scots pine clone 872 at INRA Orléans nursery. The spray was done on 4 December 03 (Isabel moths in pupal stage in the ground). After hatching (5 June 04), the larvae were reared in plastic boxes on treated/untreated needles (7 larvae per box in 15 boxes: 105 treated, 105 control) until pupation (20 July 04). Then the pupae were sexed and weighted individually. There were no significant differences in survival between treatments nor in pupal weight. We concluded that the potential residue of the Btk treatment of December did not affect significantly the performance of the *Graellsia* larvae in the following spring.

Mitochondrial DNA phylogeny of the winter pine processionary moth *Thaumetopoea pityocampa* / *wilkinsoni* in the Mediterranean basin

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Abstract
The pattern of genetic differentiation of the two sibling species (*Thaumetopoea pityocampa* and*T. wilkinsoni*), has been studied in sixty populations from the whole range using single strand conformation polymorphism sequence analysis (SSCP) of the mitochondrial cytochrome oxidase 1 (COI) and cytochrome oxydase 2 (COII). Results indicate the existence of strong genetic differentiation among four clades: the two corresponding to *T. pityocampa* and *T. wilkinsoni* and two other ones related to populations from north Africa and Crete island. This subdivision seems to be begun at the end of the Messinian salinity crisis of the Mediterranean sea.

Egg size affects the parasitism rate of a main egg parasitoid of *Thaumetopoea pityocampa*

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Abstract
The egg parasitoids have an important role in the regulation of *Thaumetopoea pityocampa* populations.
The main two egg parasitoids, *Ooencyrtus pityocampae* (polyphagous) and *Baryscapus servadeii* (monophagous), are present in both core and expansion areas. The parasitism rate and the relative abundance of these two species are not homogenous across the moth range. This variability could be explained by climate, density of egg batches and egg characteristics. We hypothesize that egg size affects the parasitism rate and the parasitoid performance, specifically the larger eggs are most suitable.
An experiment was set up with moth populations with large (Friuli) and small (Venosta) eggs, reared under controlled conditions until the eggs were laid on experimental trees. Egg batches were measured and those having the same length were selected for the experiment. Then the egg batches were exposed in a site with wild egg parasitoids (Padova, Calbarina) from 30 June to 20 July, before that the natural egg batches appear. The egg size of Calbarina pop is intermediate between Friuli and Venosta.
The eggs of Friuli (0.982 mm, SE 0.01) were larger than those of Venosta (0.908 mm, SE 0.01) (Anova, $p < 0.01$) and the number of eggs per batch was similar between the populations. The percentage of parasitism was higher in Friuli (24%) than in Venosta (16.3%) egg batches, in each of the three weeks tested (Anova, $p < 0.01$). *Ooencyrtus pityocampae* (> 80% of parsitized eggs) was more abundant than *Baryscapus servadeii* and it was the main responsible for the difference in parasitism between the two populations of egg batches. In fact, the parasitism by *B. servadeii* did not differ between the moth populations, as this species accepted both large and small eggs. We conclude that the polyphagous *O. pityocampae* can be limited in exploiting the smaller host eggs. This is consistent with the lack of parasitism by this species in the expansion area of Venosta.

Tree apparency and host location by *Thaumetopoea pityocampa* on *Pinus nigra*

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Abstract
A pattern of higher density of larval nests on isolated trees and forest edges has been described by several authors. However there is no experimental evidence of a mechanism to explain this pattern. According to observations by Démolin (1969), visual cues are responsible for female host location. His description of the female moth behaviour follows: 'The female walks helping herself with the wings, then she takes off.
She flies up for 2-3 m, then moves in a large spiral and always turns to the tree with the highest silhouette, i.e. the tree forming the widest angle in relation to the female's position. The female flies up on a straight line up to 30 m of height. When she is around the target tree, she flies down to the branches and lands.
Then a decision is taken whether to stay on the tree or move to another. A female can repeat the search sequence several times during the night'.
We hypothesize that #1.) Moths are flying randomly in a stand and the egg masses are distributed among trees intercepted during flight. Prediction: Oviposition will be proportional to tree size. #2). Moths are attracted to (or may more readily locate) the most 'apparent' trees, i.e. trees with the more visible silhouette (isolated from other objects). Prediction: More egg masses on large and isolated trees. 2. Moths are flying randomly in a stand and the egg batches are randomly distributed among trees.
Two assumptions are made:
1. Egg masses' distribution reflects the first moth choice as post-landing acceptance is very high on the optimal host *Pinus nigra*,
2. Sources of moths are evenly distributed in the experimental site.

In a cage experiment, 8 potted trees of different size offered simultaneously to emerging moths (males and females, n = 1100). The oviposition was proportional to tree size, which made us accept hypothesis #1.
In a field experiment, we measured the height and the mean distance of each focal tree from the 4 nearest neighbour trees, together with the number of egg masses laid on each tree. The relationships tree height – egg masses (r^2=0.18) and tree distance – egg masses (r^2 <0.36) are significant but weak, whereas the relationship between height X distance (apparency or silhouette) – egg masses is stronger (r^2=0.62).
We conclude that the distribution of the egg masses depend on the visual orientation of the female moths towards the trees which have highest 'apparency' or 'silhouette' by a combination of size and isolation. Different outcomes can be expected on less preferred hosts because assumptions are not valid. There is the possibility to combine visual and chemical cues (e.g. host – non host) during the host location process.

Field excursion

HISTORY OF PPM RESEARCH IN CORSICA

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Abstract
Based on Demolin's assumptions about PPM lifecycle, the first studies were developed by Claude Géri with the help of Francis Goussard n the forest of Valdo Niello. This forest covers ca. 4300 ha (part managed by the National Forestry Office), and it is almost exclusively constituted of Corsican pine, *Pinus nigra laricio*, a black pine subspecies native to the island. In the 80's, Geri and Goussard (1980) already estimated that the forest surface was susceptible to double through rapid colonization of agricultural and pastoral lands by Corsican pine, and by oak at low altitude. This particular biotope also includes relict stands of fir, *Abies alba*, and numerous animal and plant species endemic of Corsica (Corsican wild sheep- *Ovis amon*; Corsican nuthatch, *Sitta whiteheadi*; spine barberry of Etna *Berberis aetnensis*). The bearded vulture (*Gypaetus barbatus*) can also be observed there.
Scientific studies on PPM began in 1965. During the following years, mortality tables were built up for 7 plots of the valley. Then, an overall survey of PPM populations in Valdo Niello was carried out over 15 years using a random, stratified sampling design (10 zones, 34 under-zones and 1600 survey points). During this survey, the nests present at each survey point were systematically harvested in order to check their sanitary status (parasites and diseases) together with the level of prolonged diapause.
The main results can be roughly summarized as follows. In the Niolo valley, PPM population dynamics was under strong control by climate because of the insect phenology. The winter nest (L4) had to be built before

December. In heavily damaged areas, populations collapse was mostly due to starvation but sometimes an important larval mortality due to viruses (Smithiavirus) played a key role. Parasitism by parasitoids was important but rather constant. In this valley, PPM population exhibited a very constant biennial cycle. The parasitoids emerging in counter-cycle were mostly responsible for such a PPM cycle. Damage level, estimated by the number of nests per tree, was dependant on:

- the level of PPM population of the preceding cycle
- pine density
- stand slope and orientation, but no relationships apparently existed with altitude
- abundance of broadleaved trees mixed with pines
- pine height.

During the course of the PROMOTH project, new surveys were realized in the same area in order to check the changes having occurred in PPM distribution during the 30 past years under the effect of climate warming. The results have not been analyzed yet.

From 1974 on, the work was extended to the whole island. It showed that, due to prolonged diapause phenomena, the PPM larvae of the inner valleys usually develop in two years (at least but up to 4 years), and PPM populations can be classified into two main types with respect to adult emergence. Some exhibit adult emergence during the even years whilst the others emerge during the uneven years. A few mixed populations including both types also exist. By contrast, the costal populations of low altitude usually show a yearly emergence. These results finally allowed to classify the valleys according to the potential risks of attack. Later on, studies concentrated on Bt treatments (J.C. Martin).