POPULATION DYNAMICS & INTEGRATED MANAGEMENT OF FOREST INSECTS

8th — 11th July, 2019 • Québec City, Canada

Canadian Forest Service • Ministère des Forêts, de la Faune et des Parcs, Québec
Université du Québec à Chicoutimi • Literary and Historical Society of Québec

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The conference program containing abstracts is prepared as a .pdf file, published on the website of the conference…and sent to participants before the conference for their own printing.

We hope you enjoy your stay in Quebec City

With our best wishes,

Organising Committee
Andrea Battisti / Manuela Branco / Deepa Pureswaran – Coordinators of IUFRO WP 7.03.06
Jean-Noel Candau / Lidia Sukovata / Natalia Kirichenko – Coordinators of IUFRO WP 7.03.07
Eckehard Brockerhoff / Sandy Liebhold – IUFRO Board Officers

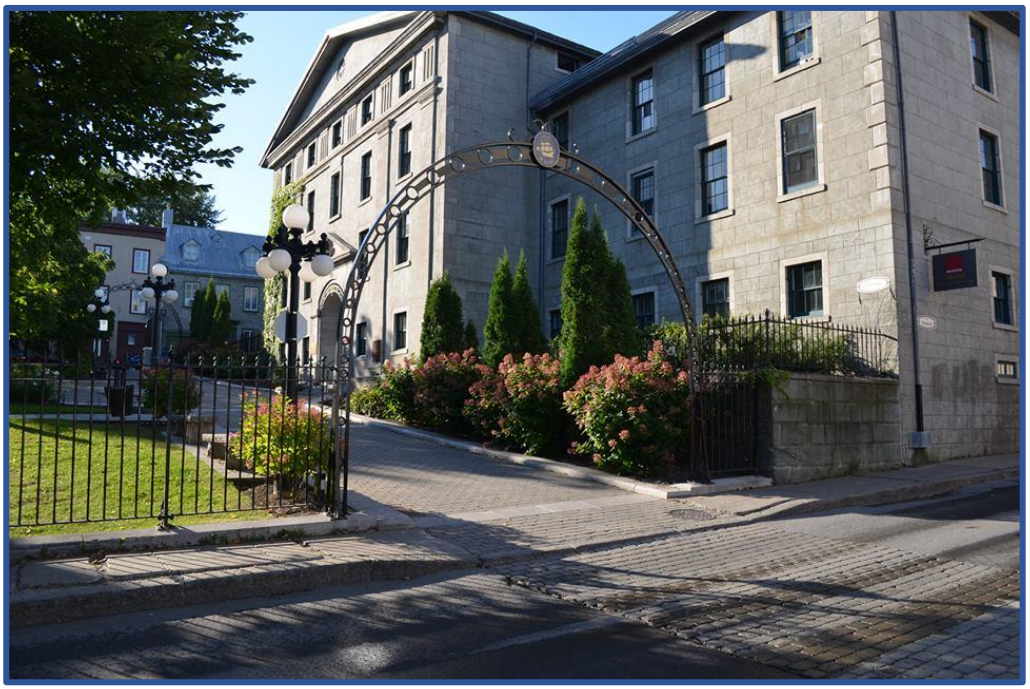
Local Arrangements
Deepa Pureswaran, Stephane Bourassa, Amanda Roe, Kerry Perrault

Cover design and logo
Amanda Roe

Population dynamics and integrated management of forest insects

8-11 July 2019, Quebec City, Canada

AGENDA



IMPORTANT NOTES – To be updated…

- The conference is at College Hall, The Morrin Centre
- Lunches, coffee breaks and the banquet will be served at College Hall in the Morrin Centre
- Welcome reception in the library followed by a tour of the building
- A ghost tour of Quebec City has been organised after the banquet
- Field trip details
- Sign up for dinner after the field trip

(Draft Schedule)

Monday, July 8, 2019

08:00 **Registration of participants (Registration Desk)**

09:00 – 10:00 **Welcome and Introduction (Moderator – Deepa Pureswaran)**

- Dominic St-Pierre, Director General, Canadian Forest Service, Laurentian Forestry Centre – Welcome address
- Barry McCullough, Executive Director, The Morrin Centre – The Literary and Historical Society of Quebec – Welcome address
- Andrea Battisti and Jean-Noel Candau, Co-ordinators of IUFRO WPs 7.03.06 – Integrated management of forest defoliating insects and 7.03.07 – Population dynamics of forest insects – Welcome address and overview of working group activities
- Deepa Pureswaran, Deputy Co-ordinator of WP 7.03.07 - Integrated management of forest defoliating insects, Local organiser, Organisational announcements

10:00 – 10:30 **Coffee Break**

10:30 – 12:10 **SCIENTIFIC SESSION 1. Ecology and population dynamics – Part I (Moderator – Louis De Grandpré)**

10:30 Carissa F. Aoki, Matthew P. Ayres, Ronald F. Billings
Predicting the irregular: Developing models to anticipate southern pine beetle outbreaks

10:50 Matt Garcia, Brian Sturtevant, Jacques Régnière, Yan Boulanger, Rémi St-Amant, Barry Cooke, G.L. Achtemeier, J.J. Charney, P.A. Townsend
Modeling aerial dispersal of eastern spruce budworm moths during summer migration

11:10 Eldon Eveleigh, Michael Stastny
Local determinants of adult moth dispersal in spruce budworm

11:30 Louis-Etienne Robert, Brian R. Sturtevant, Barry J. Cooke, Patrick M. A. James, Marie-Josée Fortin, Philip A. Townsend, Peter T. Wolter, Daniel Kneeshaw
Landscape host abundance and configuration regulate periodic outbreak behavior in spruce budworm and forest tent caterpillar

11:50 Jean-Noel Candau, Kala Studens
The role of mass migration in the population dynamics of the spruce budworm

12:10 – 13:40 Lunch – Poster installation

13:40 – 15:00 SCIENTIFIC SESSION 2. Ecology and population dynamics – Part II (Moderator Jean-Noel Candau)

13:40 Mathieu Bouchard, Clémentine Pernot
Balsam fir cones production and spruce budworm population dynamics

14:00 Louis De Grandpré, Deepa Pureswaran, Stéphane Bourassa, Maryse Marchand, Dan Kneeshaw
Potential positive feedback of spruce budworm defoliation on conifer needle nutritional status during an outbreak

14:20 Anne-Sophie Caron, Joshua Joseph Jarry, Benoit Lafleur, Emma Despland
Does predator- and parasitoid-caused mortality differ between defoliated and non-defoliated sites? A study of forest tent caterpillar in mixed-wood boreal and temperate forests of Quebec

14:40 Lorena Balducci, Hibat Allah Bouzidi, John Mackay, Annie Deslauriers
Interactive effects of defoliation and water deficit on water status, growth and mortality of black spruce saplings

15:00 – 15:30 Coffee break

15:30 – 16:30 SCIENTIFIC SESSION 3. Ecology and population dynamics – Part III (Moderator Jon Sweeney)

15:30 Kahraman Ipekdal, Christian Burban, Laure Saune, Andrea Battisti, Carole Kerdelhue
Pine processionary moth hybrid zone in a complex biogeographic context

15:50 Mizuki Uemura, Andrea Battisti, Myron Zalucki
Processionary caterpillars from opposite hemispheres: A comparative study

16:10 Emma Despland
Does leaf toughness define the window of opportunity for early spring feeders on conifers?

16:30 End of sessions

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8-11 July 2019, Quebec City, Canada

18:00 **Welcome Reception followed by Morrin Centre Tour – The Library, Morrin Centre**

Tuesday, July 9, 2019

9:00 – 10:20 **SCIENTIFIC SESSION 4. Climate impacts – Part I (Moderator – Kahraman Ipekdal)**

9:00 Stéphane Bourassa, Deepa Pureswaran, Louis De Grandpré
Temperature-Free Air Controlled Enhancement (T-FACE): A climate change research facility

9:20 Deepa S. Pureswaran, Stéphane Bourassa and Louis De Grandpré
Northern range shift of eastern spruce budworm

9:40 Manuela Branco, Carole Kerdelhué, Helena Santos, Susana Rocha, Christian Burban, Maria Rosa Paiva
Ecological consequences of shifts in phenology in Thaumetopoea pityocampa

10:00 Andrea Battisti, Michael Stastny, Stig Larsson
Pine processionary moth and climate change: an update

10:20 – 10:50 **Coffee Break**

10:50 – 11:50 **SCIENTIFIC SESSION 5. Climate impacts – Part II (Moderator – Kishan Sambaraju)**

10:50 Amanda Roe, Ashlyn Wardlaw, Kerry Perrault, Jean-Noel Candau
Geographic and environmental variation in spruce budworm developmental physiology

11:10 Sergio A. Estay, Nicolhole Atero F.
The role of temperature and landscape characteristics on the propagation and final size of Ormiscodes amphimone *outbreaks in Patagonian forests*

11:30 Salman Habibur Rahman, Mathieu Laparie, Philipp Lehmann, Andrea Battisti
*Diapause in the pine processionary moth (*Thaumetopoea pityocampa*): ecological and applied significance*

11:50 – 13:20 **Lunch Break**

13:20 – 15:20 **SCIENTIFIC SESSION 6. Invasive species (Moderator - Manuela Branco)**

13:20 Jennifer Anderson, Stephen B. Heard, Deepa Pureswaran, Jon Sweeney
The role of sexual blunders in the slow North American spread of the invasive brown spruce longhorn beetle

13:40 Jon Sweeney, Cory Hughes, Garrett Brodersen, Joel Goodwin, Kirk Hillier, Ed Czerwinski, Tarryn Goble, Rob Johns, Natalia Kirichenko, Marc Kenis, Michael Stastny
Mitigating the impact of the invasive beech leaf-mining weevil, Orchestes fagi*, in Nova Scotia*

14:00 Rylee Isitt, Steve Heard, Jon Sweeney, Paal Krokene, Bjørn Økland, Deepa Pureswaran
Potential for invasion of spruce bark beetles between North America and Europe

14:20 Ilesha Ileperuma Arachchi, Jon Sweeney, Steve Heard, Deepa Pureswaran
Invasion potential of xyleborine ambrosia beetles in Canada and Europe

14:40 Kishan Sambaraju, Kathryn Powell, Robert Lavallée, and André Beaudoin
A local-scale empirical model for the emerald ash borer

15:00 Kristopher Abell, Rafael B. de Andrade, Jian Duan, Daniel Gruner, Paula Shrewsbury
Do treated ash trees confer a protective "silhouette" from emerald ash borer for neighboring trees?

15:20 – 15:50 Coffee Break

15:50 – 17:00 Business Meeting

17:00 Free Evening – Dinner on your own

Wednesday, July 10, 2019

9:00 – 9:40 SCIENTIFIC SESSION 7. Poster Presentations – Flash talks (Moderator – Andrea Battisti)

9:00 Barry J. Cooke, Brian R. Sturtevant, Louis-Etienne Robert, Dan Kneeshaw
Forest defoliating insects in North America do not cycle synchronously

9:10 Horst Delb, Paula Halbig, Gregor Seitz, Eiko Wagenhoff
Oak processionary moth Thaumetopoea processionea *L. (Lep., Notodontidae): From a rarity to a climate change-induced permanent challenge in Southwest Germany*

9:20 Lionel Navarro, Miguel Montoro Girona, Hubert Morin, Emy Tremblay, Anne Elisabeth Harvey
A new paleoecological indicator for reconstructing insect outbreaks in forest ecosystems

9:30 David Williams, György Csóka and Boris Hrašovec
The oak lace bug, Corythucha arcuate (Heteroptera, Tingidae): Evaluation of the pest status in Europe and development of survey, control and management strategies

9:40 – 10:10 Coffee Break

10:10 – 11:30 SCIENTIFIC SESSION 8. Forest Insect Management – Part I (Moderator – Amanda Roe)

10:10 Sara Edwards, Rob Johns, Veronique Martel, Emily Owens, Deepa Pureswaran
Early Intervention Strategy for spruce budworm: Can we contain outbreak spread?

10:30 Vladimir Vujanovic
Are phytobiome studies useful for evaluating fungal effectiveness against insect pests?

10:50 David T. Williams, Alice Holt Lodge
*Optimizing the pheromone trapping for the oak processionary moth (*Thaumetopoea processionea *L.) to maximise efficiency*

11:10 Simon Fortier, Stéphane Tremblay
Spruce budworm in young stands - Effect of past pre-commercial thinning

11:30 – 13:00 Lunch Break

13:00 – 14:00 SCIENTIFIC SESSION 9. Forest Insect Management – Part II (Moderator – Deepa Pureswaran)

13:00 Luka Kasumović, Boris Hrašovec
*How important is long term monitoring with pheromone traps for better understanding in dynamics and phenology of eight-toothed spruce bark beetle (*Ips typographus *L.)?*

13:20 Päivi Lyytikäinen-Saarenmaa, Tuula Kantola, Maiju Kosunen and Markus Holopainen
*Assessing Risks of the Spruce Bark Beetle (*Ips typographus *L.) Infestation in Wind-Disturbed Boreal Forest*

13:40 Emily Owens, Ian DeMerchant, Rob C. Johns, Steve Heard
Comparing data quality and costs vs. benefits of conventional vs. community science moth monitoring programs: A case study using spruce budworm pheromone traps

14:00 – 14:30 Coffee Break – Poster take-down

14:30 – 16:00 SESSION 10. Concluding Session

Group Discussion – Forest pest management practices in different countries under current challenges of climate change and invasive species

(Introduction – Deepa Pureswaran. Moderator panel – Mathieu Bouchard, Andrea Battisti, Paivi Lyytikainan-Saarenmaa, Sergio Estay)

We have participants from 10 different countries. We expect to have an interesting discussion.

16:00 Concluding remarks

18:00 Banquet – MCs – Andrea Battisti, Jean-Noel Candau

21:30 – 23:00 Ghost Tour of Quebec City. Please gather outside the Morrin Centre after the Banquet

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ABSTRACTS

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THE ROLE OF SEXUAL BLUNDERS IN THE SLOW NORTH AMERICAN SPREAD OF THE INVASIVE BROWN SPRUCE LONGHORN BEETLE

Jennifer Anderson, Stephen B. Heard, Deepa Pureswaran, Jon Sweeney
jennifer.anderson@unb.ca

Tetropium fuscum is a European longhorn beetle, native to Western Europe and Northern Eurasia, that invaded Halifax, Nova Scotia, Canada circa 1990. *T. fuscum* has spread less than 100 km from its point of introduction. Contrasted with the invasive Emerald Ash Borer (EAB), the North American range expansion of *T. fuscum* is less than 10% that of EAB in the same time frame. *T. fuscum* is both morphologically and ecologically very similar to the North American species, *Tetropium cinnamopterum*, sharing similar emergence times, host plant choices and mating behaviours. Notably, the male-produced mating and aggregation pheromone blends in both species are nearly identical. We ask whether mate choice errors could be contributing to the slow North American spread of *T. fuscum*. Preliminary data show that both *T. fuscum* and *T. cinnamopterum* males will mate heterospecifically under no-choice mating conditions, but that they do so at a significantly lower rate than with conspecific females. Furthermore, in choice mating experiments, both species of male beetle attempt to mate with heterospecific females even in the presence of a conspecific female, suggesting that mating errors may take place in the field. The presence of a second female had no significant effect on duration of copulation in mating pairs, regardless of whether the female engaged in copula was heterospecific or conspecific to the male. Our results support mate choice error as a possible contributing factor to the slow North American spread of *T. fuscum.*

PREDICTING THE IRREGULAR: DEVELOPING MODELS TO ANTICIPATE SOUTHERN PINE BEETLE OUTBREAKS

Carissa F. Aoki, Dartmouth College, Ecology, Evolution, Ecosystems, and Society
Matthew P. Ayres, Dartmouth College, Dept. of Biological Sciences
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Of all the forest pest insects that cause widespread damage, the ones that exhibit non-cyclical outbreak dynamics are among the most challenging for forest resource managers. These dynamics can be theoretically complex, and models difficult to parameterize, but prediction models that can be of use for forest managers must be easily parameterized with available data. Southern pine beetle (SPB; *Dendroctonus frontalis* Zimmermann) is a native insect pest that has caused frequent widespread mortality across its range in the southern United States. One of the challenges produced by its outbreak data is that there may be many years and locations where the insect population is effectively zero. This produces an extreme case of statistical overdispersion. We utilized mixture models—which allow the simultaneous modeling of both zeros and count data such that overdispersion is no longer an issue—to test the effects of SPB and its clerid predator beetle (*Thanasimus dubius* Fabricius) on the occurrence of SPB infestations in locations across the south. Among several options, a zero-inflated Poisson model provided the best fit to the data. The independent variables providing the best fit in the final model included: SPB this year, predators last year, and number of infestations in the previous two years. Pest species with irregular outbreaks have disproportionate impacts on many natural and managed ecosystems. The application of zero-inflated mixture models provides a promising new tool for understanding the biology and improving our capacity to predict the irregular.

INTERACTIVE EFFECTS OF DEFOLIATION AND WATER DEFICIT ON WATER STATUS, GROWTH AND MORTALITY OF BLACK SPRUCE SAPLINGS

Lorena Balducci[1], Hibat Allah Bouzidi[1], John Mackay[2-3-4], Annie Deslauriers[1]

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Tree vitality is influenced by multiple factors such as insect damage, water deficit, and the timing of these stresses. Under drought, positive feedback via the reduction of leaf area may improve the water status of defoliated trees. However, the effect on tree mortality remains largely unknown. We investigated the effects of defoliation followed by a water deficit on tree growth, plant water status, and mortality in black spruce (*Picea mariana* (Mill.) B.S.P.) saplings.

In a controlled greenhouse setting, saplings were submitted to combined treatments of defoliation and water stress. To assess the impact of these stresses and their interaction, we measured water potential, secondary growth of the stem and mortality of the saplings. Both defoliation and water deficits reduced growth. During active defoliation, we observed a higher evaporative demand and a lower midday leaf water potential Ψ_{md}. We observed an opposite pattern of response post-stress. Drought alone increased sapling mortality immediately after the stress period, but after c.a. 20 days, mortality rates remained similar following combined drought and defoliation. Our results highlight two key periods during which defoliation affects plant water relations either negatively (during active defoliation) or positively (after defoliation). Mortality in defoliated saplings was reduced immediately following drought because available internal water increased in the stem.

DO TREATED ASH TREES CONFER A PROTECTIVE "SILHOUETTE" FROM EMERALD ASH BORER FOR NEIGHBORING TREES?

Kristopher Abell[1], Rafael B. de Andrade[1]*, Jian Duan[2], Daniel Gruner[1], Paula Shrewsbury[1]
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The emerald ash borer (*Agrilus planipennis*) (EAB) is a fast spreading invasive species in North America, accidentally introduced from northeastern Asia in the 1990s. Its burrowing larvae feed on ash (*Fraxinus spp*.) phloem, creating galleries, damaging and eventually killing the tree. In the United States, EAB has spread into 35 states, causing hundreds of millions of dollars in ecological damage and management costs. In Maryland, the Department of Agriculture injects select ash trees on public lands with emamectin benzoate, combined with releasing egg and larval parasitoids. Our study aims to assess the silhouette effect, i.e. whether non-treated ash trees are protected by nearby injected trees. 512 non-treated ash trees were sampled in 5 sites across the state of Maryland. At increasing distances up to 25m from treated trees, we estimated crown condition, adult EAB exit holes, wood pecks, epicormic growth, and bark splits in treated and non-treated trees. Data was analyzed through zero-inflated generalized linear mixed models. Preliminary results indicate considerable increase in infestation signs in non-treated tress (mainly exit holes and crown condition) with distance from treated tree. This information can be useful for the spatial planning of pesticide treatment and parasitoid release, increasing cost-efficiency in managing EAB infestations.

PINE PROCESSIONARY MOTH AND CLIMATE CHANGE: AN UPDATE

Andrea Battisti, University of Padova Italy
Michael Stastny, CFS Fredericton, Canada
Stig Larsson, SLU Uppsala, Sweden
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Twenty years after the first report on the link between climate change and range expansion of the pine processionary moth, the system has become a recognized model for temperature-mediated shifts in the distribution of forest insects. The effects of climate change on the life history traits of this species are important for understanding, and expecting, patterns in the distribution shift and perhaps in the population dynamics. Temperature affects the performance of this insect in multiple ways, acting on all stages of development through different mechanisms. Egg clutches, laid in the summer, are structured to optimize adsorption of solar radiation, although extreme heat events may kill the embryos. First instar larvae can also be negatively affected by heat waves but have evolved adaptations to circumvent this problem, including night feeding. Older larvae also feed at night but during the winter months, and only if temperature is above 0°C and is preceded by daytime warming of the interior of their silk nest above 9°C. Gregarious nesting and silk production thus facilitate winter feeding by absorbing solar radiation. Pupae are formed rather deep in the soil and temperature predicts the duration of both normal and extended (multi-year) pupal diapause. Finally, adult moths are active at night and their flight is positively correlated with night temperatures above a precise threshold. Research over the last two decades on all these relationships between insect performance and temperature has revealed complex, stage-dependent responses to changing climatic conditions that can translate to positive or negative population growth. Four decades of data on moth abundance in the southern Alps offer a unique opportunity to assess the impacts of climate change on its population dynamics and distributional shifts.

BALSAM FIR CONES PRODUCTION AND SPRUCE BUDWORM POPULATION DYNAMICS

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There are still many unknowns regarding the dynamics of low-density spruce budworm populations. One of the factors that have been proposed to be important in these populations is pollen (male) cone production in host tree species, particularly balsam fir (*Abies balsamea*). Even if the budworm is mainly a defoliator, it has often been observed to feed on these plant structures in early spring. Over the years, many foresters have hypothesized that variations in pollen cone abundance might play a key role in outbreak triggering. In this study, we used direct measurements balsam fir male cone abundance across the province of Québec over a ca. 30-year period. We examined if these variations were likely to explain changes in spruce budworm abundance. Our results suggest that pollen cone abundance could play role in overall population dynamics of this insect in some circumstances but is unlikely to be responsible for outbreak triggering on its own.

T-FACE: A CLIMATE CHANGE RESEARCH FACILITY

Stéphane Bourassa, Deepa Pureswaran, Louis De Grandpré

In 2014, we started the construction of a climate change research facility called T-FACE (temperature free-air enhancement experiment) to look at the effect of increased temperature on bud burst and insect development. This outside facility uses infrared heaters mounted on metal frame to increase the surface temperature of tree saplings in real time by 2 degree from the environment. Since 2016, twelve plots planted with black spruce and balsam fir sapling were heated throughout the growing season. In this presentation, I will explain the operation of this system and present resul from the past 3 years.

ECOLOGICAL CONSEQUENCES OF SHIFTS IN PHENOLOGY IN *THAUMETOPOEA PITYOCAMPA*

Manuela Branco[1], Carole Kerdelhué[2], Helena Santos[1,4], Susana Rocha[1], Christian Burban[3], Maria Rosa Paiva[4]

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[2] CBGP, INRA Montpellier, France
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Forest defoliators of temperate regions have evolutionarily adjusted their phenology to cope with food resources availability and seasonal climate fluctuations. It is critical in such environments that reproductive and developments stages coincide with suitable environmental conditions. In the pine processionary moth *Thaumetopoea pityocampa*, changes in phenology can occur gradually, such as in the course of adaptation to climate with latitude and altitude, or abruptly, when mutations occur in one or more genes regulating life cycle events. Abrupt changes can either cause an eco-evolutionary dead-end, or on the contrary bring ecological opportunities, such as escape from predators, or adaptations to climate changes. Here, we report the ecological consequences of a phenological shift in a particular population of the pine processionary moth. In typical populations of this species, the adult emergence and oviposition occur in the summer, while the larval stages develop in the winter. In the shifted population, the adults mate in the spring and the larvae develop through summer. Our observations demonstrated ecological implications of the shifted life cycle and ongoing adaptations. Changes in the thermal biology, phenotypic morphological traits, fecundity and egg mortality are evidenced. Feeding constraints imposed by season and host plant physiology are also observed. Finally, competition between sympatric typical and "shifted" populations may lead to competitive exclusion. Altogether our results show a comprehensive understanding of the implications of phenology in the ecology of this pine defoliator.

THE ROLE OF MASS MIGRATION IN THE POPULATION DYNAMICS OF THE SPRUCE BUDWORM

Jean-Noel Candau and Kala Studens

While mass migration of adult moths during spruce budworm population outbreaks has been commonly observed since monitoring programs were established in the 1940's, its role in the population dynamics of this species is still being debated. The current development of a new budworm outbreak in Eastern Canada has given a new impetus to this question. In this presentation we will review the role of migration in competing theories of budworm's population dynamics. Arguments and counter-arguments for the role of mass migration in the dynamics of spruce budworm populations will be assessed against population dynamics data and observations of mass migration events acquired during the current outbreak.

DOES PREDATOR- AND PARASITOID-CAUSED MORTALITY DIFFER BETWEEN DEFOLIATED AND NON-DEFOLIATED SITES? A STUDY OF FOREST TENT CATERPILLAR IN MIXEDWOOD BOREAL AND TEMPERATE FORESTS OF QUEBEC

Anne-Sophie Caron[1,2], Joshua Joseph Jarry[2], Benoit Lafleur[2], Emma Despland[1]

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Forest Tent Caterpillars (*Malacosoma disstria*) are early-spring defoliators attacking hardwood tree species, in the temperate and boreal mixedwood forests of Canada. The pest is present in ON, SK, MN, and AL. Outbreaks vary depending on the geographical location. In southern Quebec, outbreaks tend to be shorter and closer together, while in the north, they tend to be longer and at longer time intervals. With climate change, it is becoming increasingly difficult to predict winter temperature, which plays an important role in the survival of FTC colonies.

This difficulty also comes from the challenges in conducting studies on low-density, pre-outbreak populations. At that stage populations are not present in sufficient numbers to be sampled efficiently and are less visible. While outbreaking population vary dramatically in mortality rates, endemic populations are less understood.

In this study, we present results that aim to understand population dynamics of FTC at low density, especially interactions with predators and parasitoids. We compare survival rates of FTC colonies in sites that were both previously defoliated and not defoliated in two forest types, temperate and boreal mixedwood. We observed differences in community assemblages of arthropod predators at the same sites. We focus on taxonomic groups that have been shown to predate on FTC such as ants, spiders and beetles and on possible parasitoid wasps and flies.

By gaining a better understanding of the predator-prey interactions in those types of forests, we can gain some insight into the FTC population cycles and thus be equipped to face its threat.

FOREST DEFOLIATING INSECTS IN NORTH AMERICA DO NOT CYCLE SYNCHRONOUSLY (POSTER)

Barry J. Cooke[1], Brian R. Sturtevant[2], Louis-Etienne Robert[1], Dan Kneeshaw[3]

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The spruce budworm and forest tent caterpillar are defoliators of spruce/fir and aspen/maple trees, each exhibiting roughly periodic outbreaks. We studied the landscape ecology of each by conducting tree-ring studies of long-term dynamics of outbreaks in a common mixedwood landscape. We detected the expected pattern of dynamical variability, outbreaks of each species being more synchronous and more impactful in landscapes filled with their respective host plants. The fact that the pattern is occurring in two independent, but co-located systems strengthens support for the hypothesis that cyclic predator-prey interactions are strongly mediated by host-plant interactions at the landscape scale. But we also discovered that both systems were highly resistant to synchronization, with significant patterns of negative spatial cross-correlation persisting through time. Also, populations did not cycle with constant amplitude. Cycle peaks were either light, moderate, or severe in impact – indicating a high-dimension trophic interaction as the ultimate cause of cycling behaviour. Forest Lepidoptera in North America are thus neither strictly periodic in their cycling behaviour, nor are these periodic eruptions synchronized. Rather, it appears that pulse eruptions are only partially synchronized into area-wide cycles. This has profound implications for pest risk forecasting because it implies that the past is not just a poor predictor of the future, but is actually likely to mislead as to both when a major outbreak will occur, and where it will attain its heaviest impact.

POTENTIAL POSITIVE FEEDBACK OF SPRUCE BUDWORM DEFOLIATION ON CONIFERS NEEDLE NUTRITIONAL STATUS DURING AN OUTBREAK

De Grandpré, L, Pureswaran, D. S., Bourassa, S., Marchand, M. and Kneeshaw, D.D.

Spruce budworm outbreaks are causing severe damage to forest landscape in eastern North America. Although much attention has been put on the effect of defoliation on tree vigor and eventually mortality, not much is known on how the defoliation process is affecting the needles nutritional quality over the course of an outbreak. We monitored throughout the course of an outbreak the nutritional quality of *Abies balsamea* and *Picea mariana* needles in different stand composition in northeastern Québec. The results are showing that for both species but more strongly for balsam fir, we observe a linear increase in nitrogen, phosphorus and calcium concentration in needles as the outbreak progresses. We also observe a decrease in the C:N ration, suggesting that needle palatability is increasing as outbreak progresses. These results suggest that the spruce budworm may exert a positive feedback on the nutritional quality of its food throughout the course of an outbreak.

OAK PROCESSIONARY MOTH *THAUMETOPOEA PROCESSIONEA* L. (LEP., NOTODONTIDAE): FROM A RARITY TO A CLIMATE CHANGE-INDUCED PERMANENT CHALLENGE IN SOUTHWEST GERMANY (POSTER)

Horst Delb[1], Paula Halbig[1], Gregor Seitz[1], Eiko Wagenhoff[1]

[1]Forest Research Institute of Baden-Württemberg
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After successive years of dry and warm weather Oak processionary moth (OPM) became more abundant in the 1990s. Since then it occurs prominently with varying densities. The biology and population dynamics of OPM will be described considering climate change. The risk potential for forest health due to defoliation as well as for human health due to contamination with its urticating hairs will be pointed out. Different management approaches and attempts for control include mechanical and spraying methods. The concept of a currently developing early warning system for hazard assessment based on the temperature sum-driven OPM phenology will be demonstrated to provide the public and pest exterminators with appropriate information.

DOES LEAF TOUGHNESS DEFINE THE WINDOW OF OPPORTUNITY FOR EARLY SPRING FEEDERS ON CONIFERS?

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Leaf expansion in the spring provides a window of opportunity for early-spring feeders: these folivores, in many cases, require access to this young foliage for development. We examine the role of leaf toughness within the suite of defensive traits that define this window of opportunity in conifers, focussing on the spruce budworm (*Choristoneura fumiferana*) system.

Leaf toughness is an important defence mechanism of plants as it can prevent the initiation of feeding by herbivores. Toughness is lower in expanding foliage as lignin and cellulose fibers can only be laid down when growth is completed. We present the time course of leaf toughness in white spruce over the growing season and show how the feeding establishment of second-instar budworm emerging from diapause correlates negatively with needle toughness.

EARLY INTERVENTION STRATEGY FOR SPRUCE BUDWORM: CAN WE CONTAIN OUTBREAK SPREAD?

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Spruce budworm (*Choristoneura fumiferana* Clemens) (Lepidoptera: Tortricidae) is the major defoliating pest of spruce (*Picea* sp.) and balsam fir (*Abies balsamea* (L.) Mill) in northeastern North America. The recent resurgence of a budworm outbreak in northeastern North America has rekindled interest and discussion around how best to manage its potential impact across the region.

Early Intervention Strategy (EIS) is an area-wide management program aimed at containing the spread of spruce budworm in Atlantic Canada. In brief, intensive regional monitoring is used to help identify emerging 'hot spots' along the leading edge of outbreak, which are then treated with relatively narrow-spectrum insecticides (i.e., Btk or tebufenozide) to slow or prevent further population expansion. Our research represents a large-scale test of the efficacy of the EIS approach and has many key features, including work on population and community ecology, pest monitoring, public outreach, and citizen science (i.e., Budworm Tracker). Results from the first 5 years of this program indicate that under the right conditions the EIS approach has strong potential for containing budworm outbreaks with minimal impacts on non-target species.

THE ROLE OF TEMPERATURE AND LANDSCAPE CHARACTERISTICS ON THE PROPAGATION AND FINAL SIZE OF ORMISCODES AMPHIMONE OUTBREAKS IN PATAGONIAN FORESTS

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Outbreaks of the moth *Ormiscodes amphimone* cover large areas of temperate forests, raising great concem among local inhabitants. The region of Aysén in southern Chile is the more affected area with spots of defoliation with a size over 10,000 ha during several years in different localities. These outbreaks have occurred at an increasing rate in the last two decades, probably associated to the drastic warming in the southern cone of South America. Here we evaluate the role of temperature and landscape in defining the magnitude (ha) and propagation (ha/day) of several outbreaks of *O. amphimone*. Using remote sensing imagery we reconstructed the propagation of several outbreaks occurred between 2001-2017 in four localities in the Aysén region. Our analyses showed a strong relationship between the defoliated area and the accumulated degree days (ADD) in all localities. However, propagation was faster and the final size of the outbreak was larger in localities in the south of the region, where temperatures and ADD are significantly lower than localities in the north of the region. This counterintuitive result suggested that other landscape characteristics could be played an important role in determining the spread and size of outbreaks. For instance, southern localities show a lower elevations (~500 m.a.s.l.) than the northern localities (~1,100 m.a.s.l.), and there are marked differences in temperature seasonality. Our results showed that the occurrence, magnitude and propagation of *O. amphimone* outbreaks is a complex phenomenon that demands more efforts in the quest for predicting them.

SPRUCE BUDWORM IN YOUNG STANDS, EFFECT OF PAST PRECOMMERCIAL THINNING

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Despite the importance of precommercialy thinned (PCT) areas, there is little information about spruce budworm (TBE) outbreak compared to control stands. To explore this issue, since 2012, the Forest Protection branch of Quebec has monitored a network of plots located in 3 forest regions. This network is used to document defoliation and larval populations in balsam fir and black spruce stands, based on the time elapsed since the completion of the PCT and the beginning of the epidemic. The results will improve our understanding of the interactions of TBE on young managed stands. Therefore, they should useful in guiding decision-making with about the adequate protection measures to use depending on the epidemic context.

MODELING AERIAL DISPERSAL OF EASTERN SPRUCE BUDWORM MOTHS DURING SUMMER MIGRATION

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Passive aerial transport depends only on wind speed and direction, but the aerial dispersal of insects is an interactive process in which the individual expresses agency, both acting on and driven by its environment. We have developed an individual-based model of dispersal behavior, refined from decades of empirical research and coupled with the BioSIM phenological model. We use high-resolution wind and temperature fields from the Weather Research and Forecasting (WRF v4) model to drive high-density agent-based simulations of nocturnal dispersal activity for the adult eastern spruce budworm (*Choristoneura fumiferana* [Clem.]; SBW). We applied this approach to SBW moth migration events during the current outbreak period in Québec during an active three-week period in July 2013 along the lower St. Lawrence River with concurrent weather radar observations at Val d'Irène. Our model accurately represented flight/no-flight nights in the radar observations, suggesting general accuracy in our model triggers for moth lift-off (temperature range, minimum wind speed). On individual nights, modeled SBW migratory flights closely follow development of the nocturnal boundary layer inversion, which can support long-range migration events along and across the St. Lawrence River. Our simulated trajectories aligned closely with radar observations of both moth concentration and flight direction and allowed us to reduce the uncertainty in several biophysical flight model parameters. Our migratory flight modeling results are also consistent with observed regional patterns of SBW dispersal from defoliated areas with known spring feeding activity and will be useful for exploring emergent population dynamics of mass aerial migration across a landscape.

PINE PROCESSIONARY MOTH HYBRID ZONE IN A COMPLEX BIOGEOGRAPHIC CONTEXT

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Aim: The study of hybridization and hybrid zones is of particular interest in biogeography. Contact zones occur at the crossroad between specific dispersal routes, and are favoured by biogeographic discontinuities. Here we focused on two Lepidoptera sister species that come in contact near the Turkish Straits System (TSS). We aimed to infer their phylogeographic histories in the Eastern Mediterranean and finely analyse their co-occurrence and hybridization patterns in this complex biogeographical context.

Location Aegean region, Middle East

Taxon: Lepidoptera: Notodontidae: *Thaumetopoea*

Methods: We used molecular mitochondrial and nuclear markers to study 224 individuals from 42 localities. We used discordances between markers and complementary assignment methods to identify and map hybrids and parental individuals.

Results: We confirmed the parapatric distribution of *T. pityocampa* in the west and *T. wilkinsoni* in the east. We identified several glacial refugia of *T. wilkinsoni* in southern Turkey with a strong east-west differentiation in this species. Unexpectedly, *T. pityocampa* crossed the TSS and now occur in northern Aegean Turkey and some eastern Greek islands. We found robust evidence of introgression between the two species in a delimited zone in northwestern Turkey, but we did not identify any F_1 individuals.

Main conclusions: The distributions and genetic patterns of the studied species were strongly influenced both by the Quaternary climatic oscillations and the complex geological history of the Aegean region. *Thaumetopoea pityocampa* and *T. wilkinsoni* survived the last glacial maximum in disjoint refugia and met in western Turkey during the interglacial period. Expanding population of *T. wilkinsoni* constrained *T. pityocampa* to the western Turkish shore, following a total replacement in İzmir. Additionally, we found evidence of recurrent introgression by *T. wilkinsoni* males in several *T. pityocampa* populations. Our results suggest that some prezygotic isolation mechanism, such as phenological discordance, is a main driver of the isolation between the sister species.

INVASION POTENTIAL OF XYLEBORINE AMBROSIA BEETLES IN CANADA AND EUROPE (COLEOPTERA: CURCULIONIDAE, SCOLYTINAE)

Ileperuma-Arachchi, et al.

Species invasions have become more prolific over the past few decades due to increase in international trade. Introduction of species into habitats out of their native range has resulted invasions in those non-native habitats. Why some species show such behaviour while others remain promiscuous in their non-native habitats has been a persisting question in invasion ecology. Investigating the factors that cause variations in invasion potential is essential in understanding and predicting the extent of invasibility of non-native species. Among the phytophagous invasive insect groups, ambrosia and bark beetles in the sub family Scolytinae are successfully established and rapidly spreading group of coleoptera in non-native biogeographic regions. Being well established in introduced habitats in North America and Europe, ambrosia beetles have conquered the various challenges in the context of introductions through having symbiotic relationship with ambrosia fungi. However, the factors that cause differences in invasion potential of successful insect invaders like ambrosia beetles are poorly known. In the current proposed study, I will address the variations in invasion potential of selected ambrosia beetles in tribe Xyleborini as a function of climate (temperature), biogeography (Canada vs. Europe) and trophic interactions. I will test the extent to which non-native species become invasive using life history traits, interactions with the novel community and phylogenetic relationships between native and invaded communities. The main objective of the study is to test whether trophic interactions (insect-host tree, insect-fungus, fungus-host tree) and climate affect colonization and invasiveness of the candidate ambrosia beetle species in Canada and Europe.

Key words: invasion ecology, beetle-fungi mutualism, Xyleborini, trophic interactions, climate

POTENTIAL FOR INVASION OF SPRUCE BARK BEETLES BETWEEN NORTH AMERICA AND EUROPE

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The concept of a tri-trophic niche – the trophic interactions between a herbivore, its host, and predators – can be a useful framework for discussing the invasion potential of bark beetles. We have used this concept to guide field experiments investigating novel host utilization and predator avoidance by the spruce bark beetles *Dendroctonus rufipennis* and *Ips typographus* under hypothetical invasion scenarios. Host utilization experiments taking advantage of prior introductions of exotic spruce species allow us to determine if the bark beetles will feed on and reproduce within host species available in a potentially invasive range. By using synthetic pheromone lures, we can also test for attraction of predatory insects to the aggregation pheromones of bark beetles within a potentially invasive range. Our results to date suggest that both of our study species pose some risks of invasion: *Ips typographus* will utilize and reproduce within North American spruce, while *Dendroctonus rufipennis* avoids direct detection (via semiochemicals) by predatory insects in Europe.

HOW IMPORTANT IS LONG TERM MONITORING WITH PHEROMONE TRAPS FOR BETTER UNDERSTANDING IN DYNAMICS AND PHENOLOGY OF EIGHT TOOTHED SPRUCE BARK BEETLE (*IPS TYPOGRAPHUS* L.)??

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Conifer bark beetles and phloem-feeding insects belong to group of important disturbance agents in forest ecosystems. Eight toothed spruce bark beetle (*Ips typographus* L.) is capable to respond to changes quickly by increasing its population density if there is suitable material in stands which happened in the mountain region of Croatia after the ice storm in the late winter of 2014. During the period from 1990 to 2001 more than 31 million m^3 of spruce wood in Europe was killed. Better understanding of long term monitoring with pheromone traps in *Ips typographus* L. is crucial in planning of sanitation felling as hot spots recovery measure.

In youngest national park Northern Velebit network of pheromone traps had been assembled in forests since 2003 when the last long drought period occurred. For better understanding of pheromone catches monitoring of phenology within the species had been recorded for 5 year with trap trees on different elevations within conifer cultures (artificially raised stands) and natural uneven aged common spruce (*Picea abies* L.) stands. Observed development had been compared with provided phenology within PHENIPS model based on air and bark temperature.

Based on this research PHENIPS model and defined temperature treshold for pre-adult stages and callow beetles provide quite accurate development of *I. typographus*. Integrating population dynamics observed with traps and observed or predicted phenology will result with better understanding of caught number of bark beetles in traps.

Like understanding of overwintering strategy, this fact is crucial in planning of sanitation felling, especially for mountains picks where this operation could be difficult to provide because of shortage in time and manpower.

Ecological consequences of phenological variability in the PPM, and new methods and automated tools that are being developed to monitor the phenology over a large geographical scale.

Mathieu Laparie and Jerome Rousslet
INRA Orleans

ASSESSING RISKS OF THE SPRUCE BARK BEETLE (*IPS TYPOGRAPHUS* L.) INFESTATION IN WIND-DISTURBED BOREAL FOREST

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The survival of coniferous forests in northern latitudes is at risk with the advance of climate change. Hotter climate is favoring reproduction of their main enemies – bark beetles. There is an urgent need to focus on adding information on risk and severity of bark beetle infestations linked with stand suitability, heavy winds, and cumulative climatic risks. Our main goal was to produce tools for risk assessment of bark beetle infestations and for seasonal forecasts. We outline an approach to predict population density of a pest and risks of forthcoming mortality of Norway spruce (*Picea abies* (L.) Karst.), caused by the spruce bark beetle (*Ips typographus* L.). To develop a methodology, pheromone traps, infestation symptoms of trees, annual dynamics of damage spots, and remote sensing tools were applied in Ruokolahti, SE Finland over seven years. The study area met a massive wind disturbance in 2010 leading to eruptive populations of the bark beetle. Altogether 187 traps were baited with aggregation pheromone of *I. typographus*, close to mature Norway spruce stands. Our risk assessment was based on population level estimates, environmental and stand parameters, and climatic data. Crown symptoms were visually assessed, and classified into four infestation classes. Low-cost hyperspectral imaging technology was tested by small unmanned aerial vehicle (UAV) platform. Population, environmental and climatic data can be incorporated into forest health monitoring systems, producing risk maps and models for target areas. Furthermore, a methodology based on a high-resolution hyperspectral imaging will be of high practical value for forest health surveys.

A NEW PALEOECOLOGICAL INDICATOR FOR RECONSTRUCTING INSECT OUTBREAKS IN FOREST ECOSYSTEMS

POSTER

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At a multi-millennial scale, natural disturbances regimes determine the dynamics, structure, and composition of forest ecosystems. Insect outbreaks and wildfire shape boreal forest stand mosaics and the distribution of species. Despite the importance of such disturbances, there is a lack of studies focused on the long-term dynamics of spruce budworm (*Choristoneura fumiferana* (Clem.)) (SBW) outbreaks and the interaction of insect outbreaks and fire. Here, we combine macrocharcoal and plant macrofossils with a new proxy—lepidopteran scales—to describe the Holocene ecology around a boreal lake. Lepidopteran scales turned out to be a more robust proxy of insect outbreaks than the traditional proxies such as cephalic head capsules and feces. We identified 87 significant peaks in scale abundance over the last 10 000 years. These results indicate that SBW outbreaks were more frequent over the Holocene than suggested by previous studies. Charcoal accumulation rates match the established fire history in eastern Canada: a more fire-prone early and late Holocene and reduced fire frequency during the mid-Holocene. Although on occasion, both fire and insect outbreaks were coeval, our results show a generally inverse relationship between fire frequency and insect outbreaks over the Holocene. Therefore, we introduce the needs, potential and applications of this paleoindicator in forest ecology, and the main directions for the future research.

COMPARING DATA QUALITY AND COSTS VS. BENEFITS OF CONVENTIONAL VS. COMMUNITY SCIENCE MOTH MONITORING PROGRAMS: A CASE STUDY USING SPRUCE BUDWORM PHEROMONE TRAPS

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The province of New Brunswick (NB) has two spruce budworm (SBW) pheromone trapping programs: 1. the Budworm Tracker program (BTP) and 2. the provincial government's traditional program. The BTP is a community science program that was implemented to help researchers monitor SBW moth dispersal by having 150+ volunteers in NB check their traps at least once per week. This is different from the province of NB's program, which deploys nearly 300 pheromone traps across the province, but checks them only once, in the fall. Each trapping program has different priorities. The province's main priority is to get one annual total trap catch, which helps provincial managers determine relative SBW densities. The BTP's main priority is to get weekly trap catch data to detect dispersers that may be arriving throughout the season, which otherwise would not be detected in the province of NB's traps. Each program has a suite of costs, benefits and trade-offs from both financial and scientific perspectives. The two styles of monitoring has yet to be compared in terms of economic costs (i.e., trap deployment and labour hours) vs. the scientific merits (i.e., data quality relating to the ability to detect dispersers). In this talk, I will compare these trade-offs. This information will be of value because it will help managers better understand the costs of their programs and the associated data quality. Ultimately, the most suitable trapping program for managers will depend on what they deem to be a fair trade-off of the costs and benefits.

NORTHERN RANGE SHIFT OF EASTERN SPRUCE BUDWORM

Deepa S. Pureswaran, Stéphane Bourassa and Louis De Grandpré

We are sampling spruce budworm disturbance and ecosystem impacts in the northern limits of its range. We ar sampling a transect that runs 600 km north of Baie-Comeau, the northern most parts of which extend beyond provincial aerial survey routes. In 2018, moth captures averaged over 4500 at our northern-most site (km 568), however, there were no L2s nor L4s observed on sampled branches. Defoliation was estimated to be below 10% on both spruce and fir. The southern most sites (e.g. km 237) had medium defoliation on black spruce and high defoliation on balsam fir with an average of 20 L4 per branch and 3300 moths captured in pheromone traps. Moths are dispersing significantly north, but are not yet contributing significantly to population growth nor defoliation.

DIAPAUSE IN THE PINE PROCESSIONARY MOTH (*THAUMETOPOEA PITYOCAMPA*): ECOLOGICAL AND APPLIED SIGNIFICANCE

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Diapause has been rarely considered in the ecophysiology of the pine processionary moth (*Thaumetopoea pityocampa*) despite its acknowledged importance in pest establishment and dynamics. A review study indicated a U-shaped relationship between incidence of prolonged diapause and winter temperature, and a negative correlation between overall pupal survival and the proportion of diapausing individuals. Based on observations of anatomical changes in diapausing pupae, it has been proposed in the literature that the mechanism of diapause termination occurs at a key period not only in univoltine (emerging the same year) individuals, but also in those that will eventually enter prolonged diapause . By using two separate and real-time measures of metabolic activity, body temperature and O_2 consumption, the existence of a transient restoration of activity (termination) has been confirmed in both univoltine and prolonged diapausing pupae. Both methods clearly detected simultaneous diapause termination through increased metabolic rate in both types of pupae before any morphological or behavioural changes could be observed, but univoltine individuals were characterized by a continuous increase until emergence while prolonged diapause individuals later returned to previous low activity levels. This finding is a starting point for the study of diapause development in the pine processionary moth from an ecological point of view. In addition to pupal diapause, there is evidence of a prepupal dormant stage implicated in synchronizing emergences. Through a weekly sampling spanning a two-month procession period, prepupae were found to differentially regulate their development time in such a way that adult emergences were concentrated and synchronized in less than one month. The new findings on diapause and their significance in synchronizing emergences may improve phenological models in a climate change perspective.

LANDSCAPE HOST ABUNDANCE AND CONFIGURATION REGULATE PERIODIC OUTBREAK BEHAVIOR IN SPRUCE BUDWORM AND FOREST TENT CATERPILLAR

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Landscape-level forest management has long been hypothesized to affect forest insect outbreak dynamics. We hypothesized that the combination of increased hardwood relative to host tree species, prevalence of younger forests, and fragmentation of those forests due to forest harvesting legacies would reduce outbreak intensity, increase outbreak frequency, and decrease spatial synchrony in spruce budworm outbreaks. Through cluster analyses of 76-year-long time-series we found that areas found within the same land management zone tended to be more similar than those in different zones. Spatial nonparametric covariance analysis indicated that the highest and lowest degree of spatial synchrony of spruce budworm outbreaks were found within unmanaged wilderness and lands managed at fine spatial scales in Minnesota, respectively. We repeated this study in the same landscape using forest tent caterpillar on aspen, and found a somewhat similar landscape response, which generated an opposing spatial pattern of outbreak cycle synchronization because of the way host tree species of the two herbivore species are distributed oppositely. Our study is the first quantitative evaluation of the long-standing "silvicultural hypothesis" of forest insect pest management by looking at two distinct pest species responses in a co-located system. Viewed separately, each of the two designs was spatially pseudoreplicated. However the paired comparison approach allowed us to rule out that any factor other than host tree species distributions was driving the resulting differences in outbreak patterning.

GEOGRAPHIC AND ENVIRONMENTAL VARIATION IN SPRUCE BUDWORM DEVELOPMENTAL PHYSIOLOGY

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Spruce budworm (*Choristoneura fumiferana* - SBW) is a wide spread insect that is responsible for extensive defoliation throughout the North American boreal forest. SBW experiences cyclical population outbreaks and predicting SBW population dynamics is crucial for effective management. Much of our knowledge of SBW biology is derived from laboratory colonies with a long history in captivity. There are concerns that these insects may not reflect the true range of variability expressed in wild populations. We now have four colonies established from wild populations from across the range of SBW. We reared these colonies at temperatures ranging from 5°C - 35°C to examine developmental rates. Surprisingly, many insects showed alternate developmental behaviour, returning to diapause after a short time of feeding. The incidence of second diapause varies among populations and by temperature and contradicts long held assumptions of SBW life history.

A LOCAL-SCALE EMPIRICAL MODEL FOR THE EMERALD ASH BORER

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The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) is an East Asian-origin beetle that continues to cause unprecedented mortality of ash trees in Canada and the United States and is currently damaging ash species in European Russia. From its initial discovery in the summer of 2002 near Detroit-Windsor area in North America, the EAB has rapidly expanded its invaded range and is presently found in five Canadian provinces and 35 U.S. states. This rapid range expansion was facilitated through 'passive' human-mediated transport of beetles via infested logs and 'active' short-range dispersal of beetles from infestation epicenters, as well as climates conducive for beetle survival and lack of natural enemies. With regard to predicting EAB distributions, previous modeling efforts have mainly researched two important aspects pertinent to EAB spread, i.e., dispersal and climate, separately. Very few studies have simultaneously considered multiple factors that are associated with, or directly contribute to, an increased risk of EAB infestation via empirical models at a scale relevant to managers of urban forests. Therefore, the objective of this ongoing work was to develop a predictive model based on the associations between the occurrences of EAB infestations in cities and towns in Canada and relevant predictors that account for active dispersal (spatio-temporal neighborhood terms), passive dispersal (e.g., road length, campgrounds, etc.), and survival potential of EAB (climate-based variables). In this talk, preliminary results of this study will be presented and future work will be outlined.

LOCAL DETERMINANTS OF ADULT MOTH DISPERSAL IN SPRUCE BUDWORM

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Adult moth dispersal is a key factor in the population dynamics and the spatial spread of outbreaks of spruce budworm (*Choristoneura fumifurana*), the iconic defoliator of mixed and boreal forests of eastern Canada. Field observations and models suggest that both meteorological conditions and density dependence may contribute to moth emigration from local stands, potentially leading to long-distance dispersal. However, detailed empirical data is necessary to elucidate the role of these factors. We present trap catch data collected across multiple years in forest plots at Acadia Research Centre during the last spruce budworm outbreak in Atlantic Canada (1980s). Numbers of male and female moths in flight were monitored daily in traps placed both above and within canopy, along with mortality of local (non-emigrating) moths in drop trays. Daily records of temperature and humidity were juxtaposed against the moth data. Our findings show that trap catches for both males and females were temperature-dependent and proportional to the number of adults eclosed locally, except during immigration events into the local area. Therefore, adult moths tend to leave their natal area every night that weather conditions permit, regardless of their local density. Temperature above a certain threshold appeared to determine moth dispersal, corroborating theoretical predictions for moth flight. This research advances our insights into and ongoing modelling of long-distance dispersal of spruce budworm.

MITIGATING THE IMPACT OF THE INVASIVE BEECH LEAF-MINING WEEVIL, *ORCHESTES FAGI*, IN NOVA SCOTIA

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The beech leaf mining weevil, *Orchestes fagi* (Coleoptera: Curculionidae) is a European species that was discovered infesting American beech, *Fagus grandifolia,* in Halifax, Nova Scotia, Canada in 2012. Earlier observations of typical signs of infestation on American beech suggest the weevil had established 5–7 years prior to its discovery. Data from permanent sample plots in natural forests monitored from 2014–2018 show that >90% of American beech trees died in heavily infested plots (i.e., 70% of leaves with larval mines). Open grown beech trees in urban areas have fared slightly better, with about 50% mortality as of 2018, and an average cost of about $2000 CAN per property for tree removal. Parasitism of *O. fagi* in Nova Scotia has been observed in <1% of leaf mines dissected. We are exploring two strategies to mitigate the impact of *O. fagi*: 1) protecting individual trees in urban forests with stem-injections of TreeAzin™; and 2) determining the feasibility of classical biological control for reducing weevil populations in natural forests. Stem injection of TreeAzin™ in the fall significantly reduced larval survival and damage to foliage the following spring and summer, and should be useful for protecting high-value beech in urban areas. Surveys conducted in 19 sites in France and Switzerland in 2018 collected >900 individuals and 18 species/morphospecies of parasitoids; three of the most abundant parasitoid species appear to have narrow host ranges, and will be further investigated in 2019 to determine if they would be suitable for potential release in Canada.

PROCESSIONARY CATERPILLARS FROM OPPOSITE HEMISPHERES: A COMPARATIVE STUDY

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Pest insects are an ongoing issue to human society. Containment of these pests can become problematic especially when the species are gregarious and are a health risk to humans and animals. A species of recent interest is the processionary caterpillar, *Ochrogaster lunifer* Herrich-Schäffer (Lepidoptera, Notodontidae), an urticating species found in Australia and associated with acacias and eucalypts. Setae (detachable urticating hairs) from the abdominal segments of *O. lunifer* larvae are responsible for foetal loss in pregnant mares and is now an important Lepidoptera species for pest management. A similar species to *O. lunifer* is the European species, pine processionary moth, *Thaumetopoea pityocampa* Dennis & Schiffermüller (Lepidoptera, Notodontidae). A great deal of research has been done on this species because they are destructive defoliators of pine and cedar trees in the Mediterranean Basin and Southern Europe. Although geographically isolated, the two species have a univoltine lifecycle with similar periods of developmental stages throughout the year but in completely opposite seasons. Both species have a pre-pupation travel period on the ground, where they leave their nest in a procession to find a pupation site. The knowledge of the larval behaviour in this phase is crucial to predict the risk of humans and animals being exposed to these setae. The anatomy of the larval eyes is studied, and electrophysiology experiments are conducted to determine what visual cues larvae use to orientate to a suitable pupation site.

ARE PHYTOBIOME STUDIES USEFUL FOR EVALUATING FUNGAL EFFECTIVENESS AGAINST INSECT PESTS?

Vladimir Vujanovic

System biology's evergrowing interest is to picturing the Interactions between plants/trees - microbiomes and insects. However, there are identified deficiencies in our understanding of the ecology of insect-fungus-host interactions and the way they have been investigated at the phytobiome level. The aim of this phytobiome based next-generation-sequencing/omics study was to test the fungal SMCD 2210 strain-multiple host interactions in controlling insect pests in forestry, agriculture and horticulture sectors. A phytobiome approach at controlling forest insects also reveals particular benefit for the development of universal insect pests (including exotic insects) management strategy. In this regard, the fungal SMCD 2210 strain has opened new avenues for plant/tree protection by inducing beneficial changes in microbiome communities among host plants and associated metabolomes to harness the host's defense system and reduce the negative effects of insects.

OPTIMIZING THE PHEROMONE TRAPPING FOR THE OAK PROCESSIONARY MOTH (*THAUMETOPOEA PROCESSIONEA* L.) TO MAXIMISE EFFICIENCY

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Maximising the efficiency of trapping systems for detecting and monitoring invasive insects as they expand their range following introduction into new locations is a key objective within integrated pest management systems. The accidental introduction of a serious oak defoliating insect, the oak processionary moth (OPM) (*T. processionea*) into the most heavily populated and urbanised city in the UK (London), has led to the need to develop an effective detection system to facilitate the monitoring of the spread of this pest into new areas so that control measures can be implemented in as timely a manner as possible.

Here we describe the studies that have currently been conducted to optimize the pheromone trapping for adult OPM. Initial trials investigated how trap type, source of pheromone lure, and where the trap was positioned in the tree canopy influenced trap catches, with results leading to the development of an initial pheromone trapping protocol. Subsequent studies have investigated whether positioning the pheromone traps on the edges of oak woodlands improved trap capture rates, and whether positioning traps in different tree species, including non-host tree species, influenced trap catches. The latter study has revealed that pheromone trap catches of OPM are significantly influenced depending on the tree species that they are positioned in, which has led to the hypothesis that plant host volatiles may play a key role in adult oak processionary moth orientation. Future studies will investigate whether volatile constituents from the foliage of OPM's preferred host (*Q. robur*), and from a non-preferred host (*Q. palustris*) may have synergistic or antagonistic effects on pheromone trap catches.

Population dynamics and integrated management of forest insects
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THE OAK LACE BUG, *CORYTHUCHA ARCUATA* (HETEROPTERA, TINGIDAE): EVALUATION OF THE PEST STATUS IN EUROPE AND DEVELOPMENT OF SURVEY, CONTROL AND MANAGEMENT STRATEGIES - POSTER

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The initiation of a new Euphresco project 'OLBIE' (Oak Lace Bug in Europe) will focus on the oak lace bug (OLB), *Corythucha arcuata*, an invasive Hemipteran insect introduced from its native range in North America into Europe, and which was first detected in Europe in Italy in 2000[1]. Since its accidental introduction it has spread rapidly over a wide geographical area and is now found in over a dozen other European countries. In some countries, such as Hungary and Croatia its population has reached substantial levels where there is now serious concern that the pest may have significant impacts on oak health, as well as potentially increasing the susceptibility of oaks to other pests and diseases.

There is limited published information on this particular insect species. Within its natural range in N. America it is generally regarded as a nuisance pest, causing only incidental damage, although dense populations can cause premature leaf fall[2]. Within Europe there is considerable variation in its reported impacts, hence there is a real need to understand what factors are influential in the development of this insect species and how it can become a damaging factor to oak. The OLBIE project will address key questions and gaps in the knowledge of *Corythucha arcuata*, particularly in relation to the biology, dispersal, control and management options and the wider environmental impacts.

The project is co-ordinated through Euphresco, which facilitates the collaboration and networking of organisations to undertake national research in the phytosanitary area. See https://www.euphresco.net/ for specific details.