11th Annual Meeting

International Pest Risk Research Group

29 August – 1 September, 2017

Ottawa, Canada

Hosted by

Canadian Food Inspection Agency

Agence canadienne d'inspection des aliments

Canada

Dear Attendee,

Welcome to the eleventh annual meeting of the International Pest Risk Research Group. We return to North America after a very successful program last year in Parma, Italy. The theme of our conference this year is "Predictability and Uncertainty in Pest Risk Analysis." We look forward to the opportunity to discuss efforts to improve and apply fundamental information, analytic methods, and uncertainty treatments for pest risk analysis. In that spirit, we are extremely pleased to feature a keynote address from Prof. Brian Leung, McGill University in Montreal, Quebec, to provide some perspectives on the challenges and approaches to predicting the outcome of pest invasions.

This meeting would not have been possible without the efforts of Martin Damus (CFIA) and Denys Yemshanov (Canadian Forest Service). They have been responsible for all local arrangements. Martin, in particular, has seen to numerous logistical details to ensure an engaging and productive gathering. We thank them both! We are also extremely grateful to the Canadian Food Inspection Agency / Agence canadienne d'inspection des aliment for their sponsorship of this meeting. CFIA is the lead agency in Canada responsible for "safeguarding food, animals and plants, which enhances the health and well-being of Canada's people, environment and economy."

Under the terms of our Constitution (ratified in 2015), this meeting will be the last to be organized by the inaugural, formal leadership team. We thank the IPRRG members for their confidence in our leadership.

We hope you have a thought-provoking time in Ottawa!

Kindly,

Richard Baker (Chair), DEFRA, UK
Robert Venette (Vice Chair), USDA-FS, USA
Darren Kriticos (Secretary-Treasurer), CSIRO, Australia
Frank Koch (Communications Officer), USDA-FS, USA
Amy Morey (Student Representative), University of Minnesota, USA

Day 1 – Tuesday, August 29, 2017

Introduction to the conference (Moderator: Robert Venette)

8:00 Welcome to IPRRG 11 – Richard Baker

8:05 Science in Plant Health at the CFIA– Pierre Bilodeau, Executive Director of the Plant Health Science Directorate at the Canadian Food Inspection Agency

8:15 History of IPRRG: Accomplishments and intentions – Richard Baker

8:35 Brief introductions from conference participants (*In 30 seconds or less, who are you, where are you from, for whom do you work, and why are you interested in this conference?*)

9:00 (1) Keynote address: Predictive ecology: modeling the risk of pest invasions - Prof. Brian Leung, Department of Biology, McGill University, Montreal

9:45 Break

International perspectives on PRA (Moderator: Darren Kriticos)

10:15 (2) Research needs in support of risk assessment and risk management at the CFIA – Brittany Day, Martin Damus & Cheryl Dollard

10:35 (3) The pest risk mapping and monitoring system in Taiwan – Yu-Bing Huang

10:55 (4) Uncertainty in qualitative and quantitative pest risk assessment at EFSA – Giuseppe Stancanelli, Olaf Mosbach Schulz, and others

11:15 (5) On the way: methods for quantitative risk assessment in China - Zhihong Li

11:35 Discussions of morning presentations

11:45 Lunch (Students-Please meet with Amy Morey for a small gathering and networking opportunity.)

Uncertainty - Conceptualization and treatment in PRA (Moderator: Richard Baker)

2:15 (6) Respecting critical assumptions of probability, statistics and inference during pest risk modelling how did the elephant in the room grow so big? - Darren Kriticos & Peter Caley

2:35 (7) Making sense of absence: a Bayesian framework – Andrew Robinson & James Camac

3:15 Break

3:30 (8) Testing model accuracy when predicting pest susceptibility using expert-driven spatially-explicit models - Justine Murray & Javier Garcia

3:50 (9) Coping with climate uncertainty in projected ranges of pests using hypervolumes - Frank Koch, Denys Yemshanov, Robert Venette, & Kevin Potter

4:10 Discussions of afternoon presentations

Workgroup activities

4:20 Introduction to Project Stinky – Robert Venette

4:40 Discussion of workgroup goals for conference

5:00 Adjourn for day

Day 2 – Wednesday, August 30, 2017

9:15 Welcome to the day

9:17 IPRRG12 & 13 - Potential venues - Presentations from Taiwan (Yu-Bing Huang) and Poland (Tomasz Kałuski)

Inspections and surveillance (Moderator: Robert Venette)

9:30 (10) Optimal strategies in surveillance programs for invasive pests: Detect early or delimit? - Denys Yemshanov, Robert Haight, Frank Koch, Robert Venette, Ronald Fournier, Tom Swystun, Yongguang Chen, Mireille Marcotte, & Jean Turgeon

9:50 (11) Early detection of forest invaders in New Zealand: optimising surveillance effort based on spatially-explicit modelling of high-risk pathways - Nicolas Meurisse, Steven Mascaro, John Kean, Paul Stevens, & Lindsay Bulman

10:10 (12) Inferential and geostatistical analysis to optimize sampling, monitoring, and decision making in the management of *Diaphorina citri* (Hemiptera: Liviidae) in Mexico – Gabriel Diaz Padilla, Rafael A. Guajardo Panes, Jose I. Lopez Arroyo, & Ignacio Sanchez Cohen

10:30 Discussion of morning presentations

10:40 Break

Climate change and pest risk (Moderator: Darren Kriticos)

11:10 (13) Predicting the potential distribution in China of *Euwallacea fornicatus* (Eichhoff) under current and future climate conditions - Xuezhen Ge, Chao Jiang, Linghong Chen, Shuang Qiu, Yuxiang Zhao, Tao Wang, & Shixiang Zong

11:30 (14) Estimating pest impacts under climate change: *Spodoptera litura* (F.) performance on brassica crops under elevated CO_2 - Tuan Pham Anh, Teawkul Papitchaya, & Hwang Shaw-Yhi

11:50 (15) Multi-species pest risk analysis of climate impacts on field crop pests in Canada – Ross Weiss & Owen Olfert

12:10 Discussion of climate change presentations

12:20 Working lunch; **lightning talks on posters** and interaction with poster presenters. Lightning talks provide an opportunity for poster presenters to say a few words about their work to the group. "Lightning talks" are meant to be less than 3 minutes. They are completely optional but are encouraged.

1:50 Group photo!! ☺

PRA praxis (Moderator: Amy Morey)

2:00 (16) Predicting the potential geographical distribution of *Tuta absoluta* in China based on CLIMEX and ArcGIS - Xiaoqing Xian, Wenjin Song, Guifen Zhang, & Fanghao Wan

2:20 (17) Exploring the limitations of degree day models in assessing the potential development of transient pests: *Bemisia tabaci* in the UK and France - Catherine Bradshaw, Debbie Hemming, Richard Baker, Matthew Everatt, Dominic Eyre, & Anastasia Korycinska

2:40 (18) A quantitative assessment of the likelihood of introduction of the Lewis mite, *Eotetranychus lewisi*, into the continental European Union - Maria Navajas Navarro, Filippo Bergeretti, Niklas Bjorklund, Gianni Gilioli, Josep Jaques Miret, Alan MacLeod, Gritta Schrader, Wopke van der Werf, & Sybren Vos

3:00 Break

3:30 (19) Effects of temperature transfers on development, survival and reproduction of *Hermetia Illucens* (Linnaeus) (Diptera: Stratiomyidae) - Ana Samayoa

3:50 (20) Swede midges and when they emerge: creating a predictive model of the *Contarinia nasturtii* life cycle - Jenny Liu, Boyd Mori, Owen Olfert, Jonathan Newman, & Rebecca Hallett

4:10 (21) Utility of simple mechanistic models of winter mortality for invasive alien species - Robert Venette, Amy Morey, Theresa Cira, Andrea Hefty, Lindsey Christianson, Derek Rosenberger, Amanda Stephens, Anthony Hanson, & Erica Nystrom Santacruz

4:30 Discussion

4:40 – 6:00 *Past, present, and future of IPRRG: getting down to business.* All are invited to attend this important meeting, which provides an opportunity for members to understand the operations of IPRRG, to inform IPRRG leaders of specific needs, and to help shape the direction of the organization. Complimentary snacks and beverages will be provided to those who attend the meeting. (Please consult the handout for critical information)

1. What will we accomplish in this meeting? (Chair)

2. It's supposed to be a living document: amendments to the IPRRG constitution (Chair) – 10 minutes
   a. What are the rules for proposing and ratifying an amendment?
   b. How do we vote? Review of online process (which closes at the end of the following day)
   c. Discussion of proposed amendments

3. Take me to your leader(s): Executive Committee officer elections for the 2017-2019 term (Secretary-Treasurer) – 5 minutes
   a. How does the IPRRG parliamentary election model work?
   b. How do we vote? Review of online process (which closes at the end of the following day)
   c. Who are the candidates for the primary Executive Committee offices?
   d. Who are the candidates for Student Representative?

4. Wait, we have how many members? IPRRG membership status report (Secretary-Treasurer) – 15 minutes

5. We're in the money (sort of): IPRRG finances / balance sheet (Secretary-Treasurer) – 10 minutes

6. Can you hear me now? Communications issues (Communications Officer) – 20 minutes
   a. Website, Facebook page, Twitter (?)

b. Are there other media / publication opportunities we should pursue?
c. What are the best ways to communicate both within and outside the Group?

7. I believe that "studying" is derived from the words "students dying": student issues (Student Representative) – 10 minutes

8. When and where is our next get-together? Future meetings (Chair / Vice Chair) – 5 minutes
   a. Host nominations and proposals (open to any IPRRG member)
   b. Discussion of host nominations / proposals
   c. Selection of host for 2018 IPRRG Meeting (Executive Committee)

9. Is there anything else we haven't covered? – 5 minutes

Day 3 – Thursday, August 31, 2017

Prioritization (Moderator: Frank Koch)

9:00 (22) Wading through rivers of information: a structured assessment process for emerging risks to plant health - Melanie Newfield

9:20 (23) Objective prioritization of exotic arthropods: development and validation of a new model - Godshen Pallipparambil, Leslie Newton, Jarrod Morrice, ByeongJoon Kim, Ernie Hain, & Alison Neeley

9:40 Brief discussion

Project Stinky

9:45 (24) Climate change impacts on the brown marmorated stink bug, *Halyomorpha halys* - Erica Kistner

10:05 Updates from Establishment team

10:25 Updates from Impact team

10:45 Project Stinky-Discussions

11:30 Break to prepare for technical excursion. Comfortable clothing, walking shoes, and an umbrella are recommended.

Technical excursion with lunch (all times are approximate)

~12:00 – Working lunch with Jason Pollard, City of Ottawa Chief Forester, Presentation: EAB and its consequences to the Ottawa area.

12:30 Bus to Brewer Park – 5 min. duration – 25 minutes visit and more discussion

1:00 Bus to Pleasant Park Woods – 10 min. duration – 25 minutes or less for visit and discussion

1:30 Depart for Gatineau hills and hike

4:35 Return to Ottawa.

5:30 Group Dinner - Ottawa Brew Pub (Mill Street Brewery): http://millstreetbrewery.com/ottawa-brew-pub/. Address: 555 Wellington Street. Ottawa, Ontario, K1R 1C5

Day 4 – Friday, September 1, 2017

Decision support analysis (Moderator: Frank Koch)

9:00 (25) A generic decision tool for assessing response options to tree pests in the UK – Glyn Jones, Adam Kleczkowski, Morag McPherson, Julia Touza, Stephen Parnell, Barbara Agstner, Vahid Mojtahed, & Piran White

9:20 (26) Facilitating trade by improving data quality in globally consulted pest information resources - Godshen Pallipparambil, Carol Hicks, Heather Hartzog, & Karl Suiter

9:40 Discussion

9:50 Break (brief)

10:00 The risk analyst, the entomologist and the economist - a North American road trip to inform UK plant health research programmes – Alan MacLeod, Neil Audsley, & Glyn Jones

11:00 Conference Wrap-up

-Announcement of election results

-Announcement of changes to the constitution

-Announcement of next year's meeting location

-Presentation of award winners

12:00 Adjourn

Posters

Monitoring of pathogenic fungi in air using spore traps and DNA based detection. Johanna Boberg, Anna Berlin, & Jon‡s Oliva

Plant health risk assessment at the CFIA. Martin Damus & Lindsay Vyvey

Modelling the expected entry rate of *Grapholita molesta* (oriental fruit moth) into Canada using @Risk. Martin Damus

Spatial risk and temporary severity of coffee rust (*Hemileia vastatrix*) in Mexico. Gabriel Diaz Padilla, Rafael A. Guajardo Panes, Jose I. Lopez Arroyo, & Ignacio Sanchez Cohen

Distancing and orientation of sitcky traps for the detection-monitoring of the Asian citrus psyllid in Colima State, Mexico. Gabriel Diaz Padilla, Rafael A. Guajardo Panes, Jose I. Lopez Arroyo, & Ignacio Sanchez Cohen

Exploring the cost-effectiveness of plant health surveys. Salla Hannunen

Evaluating the spatial transferability of a pest risk model. Amy Morey & Robert Venette

Modelling impacts using a participatory approach to encourage model adoption for best management practices in managing pests. Justine V. Murray, Javier N. Garcia, Carl Smith, & Rieks Van Klinken

The effect of temperature on the duration of the development of *Bactrocera dorsalis* (Diptera: Tephritidae). Ana C. Samayoa, Kyung-San Choi & Shaw-Yhi Hwang

The development and preferences of Oriental fruit fly (*Bactrocera dorsalis* Hendel) in various host plant in Taiwan. Amelia Sebayang & Shaw-Yi Hwang

Effect of elevated CO_2 and temperature on plant chemistry and their insect pest. Papitchaya Teawkul

Identification and introgression of tomato fruitworm (*Helicoverpa armigera*) resistance genes from wild tomato (*Solanum pimpinellifolium*) to cultivated tomato (*Solanum lycopersicum* L.). Pishayapa Thongmalai, Peter Hanson, Srinivasan Ramasamy, Mohamed Rakha, & Shaw-Yhi Hwang

Abstracts to Oral Presentations

(Arranged in order of presentation)

(1) Keynote address - Predictive ecology: modeling the risk of pest invassions

Brian Leung[1]*

1, Department of Biology and the McGill School of Environment, McGill University, Montreal, Quebec, Canada; *, presenting author.

For more information, contact Dr. Brian Leung, Department of Biology, McGill University, Stewart Biology Building, 1205 ave Docteur Penfield, Montreal, Quebec, CANADA H3A 1B1, brian.leung2@mcgill.ca.

Limited time, limited information and limited resources are ubiquitous challenges in invasive biology and most other conservation-oriented fields. It is in this context that risk assessment plays a critical role to allow decisions, even under substantial uncertainty. I will discuss risk assessment approaches, briefly starting with qualitative decision support tools and moving quickly to focus on quantitative approaches for both assessing risk and estimating uncertainty. Increasing amounts of publicly available databases are becoming available, and simultaneously the models for biological invasion have increased in sophistication over the last decade to take advantage of those data. I will discuss advances in predicting the different stages of invasions, the value of simple versus more complex models, and the integration of uncertainty.

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(2) Research needs in support of risk assessment and risk management at the CFIA

Brittany Day[1]*, Martin Damus[2] & Cheryl Dollard[3]

1-3, Canadian Food Inspection Agency, Ottawa, Ontario, Canada; *, presenting author.

For more information, contact martin.damus@inspection.gc.ca.

Risk assessment is often performed in a knowledge vacuum that ranges from moderate to severe. Questions arise that cannot be answered in a timely manner, and the assessment may suffer from unresolvable uncertainties. The identification and selection of risk management options must be supported by scientific knowledge, especially in the case where the management occurs on one's own territory, due to the risk -- the pest -- already being present and established. At the Canadian Food Inspection Agency, which is the National Plant Protection Organisation of Canada, research is done by in-house scientists in support of risk management activities such as survey tool development, genetic typing for pest identification, and integrated pest management. Often, the research to support risk assessment is attained through partnerships with scientists at Agriculture and Agri-Food Canada, or at the Canadian Forest Service. Collaboration with academia is also a means to obtaining specific information. The CFIA's Plant Research Program and how it supports risk assessment and risk management will be presented.

(3) The pest risk mapping and monitoring system in Taiwan

Yu-Bing Huang[1]*

1, Division of Applied Zoology, Agriculture Research Institute, Taichung, Taiwan; *, presenting author.

For more information, contact Huang Yu Bing, 189, Chung-Cheng Road, Wufeng District, Taichung City, 41362, Taiwan, ybhuang@tari.gov.tw.

Taiwan is developing a pest risk modelling platform to inform both pre- and post-border biosecurity. CLIMEX is used to estimate the potential distribution and relative abundance of invasive pests. The potential distribution of the pests is combined with information on the known distribution of crop hosts to estimate the potential impacts. For established pests, monitoring data are collected every ten days. Spatial data on land use, elevation, slope, aspect and other geographic information on the average temperature, maximum temperature were revised to a higher spatial resolution. An early warning system was developed to forecast pest abundance based on population fluctuation and climatic variables. This warning system helps to predict the risk of pest occurrence, so that the growers can take action to reduce pest outbreaks and hence to reduce economic losses. Newsletters advising farmers of the current status of pests are available at the website (http://www.tari.gov.tw/form). The platform will collect a large number of domestic climate data and the global climate scenarios, combined with pest distribution and degree day models to explore the effect of climate change on pests, food security impacts and risk assessment operations.

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(4) Uncertainty in qualitative and quantitative pest risk assessment at EFSA

Giuseppe Stancanelli[1]*, Olaf Mosbach Schulz, & others

1, European Food Safety Authority, Animal and Plant health unit; *, presenting author.

For more information, contact giuseppe.stancanelli@efsa.europa.eu.

To guarantee transparency of the risk assessment process and to support an informed science based decision making, all risk assessments must include consideration of uncertainties. Pest risk assessments at the European Food Safety Authority have been conducted applying qualitative ratings, mathematical models for specific risk assessment steps and more recently a quantitative mechanistic and population based method. The assessment and communication of uncertainties in qualitative and quantitative pest risk assessment is presented and discussed as well as the impact of uncertainty on the overall assessment conclusions.

(5) On the way: methods for quantitative risk assessment in China

Zhihong Li[1*]

1, College of Plant Protection, China Agricultural University, Beijing 100193, P. R. China; *, presenting author.

For more information, contact Prof. Zhihong Li, Yuanmingyuan West Road 2#, Haidian, Beijing 100193, P.R. China, lizh@cau.edu.cn.

Over the past four decades, China has embraced the challenge to develop and integrate advanced Pest Risk Analysis methods, and to apply them systematically. The greatest attention has been paid to developing quantitative risk assessment methods including potential geographical distribution, potential loss and invasion risk. Three methods have mostly been practiced for estimating the potential geographical distribution. The Bio-Climatic Analog Distance Database was established in the 1980s and was applied mostly from 1988 into the 1990s. The Bio-Model+GIS was applied from 1994, mostly based on biological experiments. Models such as CLIMEX, Maxent, DIVA-GIS and GARP were introduced into China from the 1990s, with CLIMEX and Maxent the more popular in the last 10 years. From the 2000 s deterministic multi-index models were developed to estimate the impacts of representative pests of agriculture and forestry. Subsequently, stochastic models of potential loss based on @RISK model were developed. The most popular method for estimating invasive risk in China is Multi-Index Integrated Assessment of Pests. It is a semi-quantitative method combining indices, standards and models, which has become widely-used at national and provincial scales in China. An international collaboration program during 2012-2013 introduced SOM+Matlab and Scenery models+@RISK into China. More recently, an integrated technical method of quantitative risk assessment has been practiced.

(6) Respecting critical assumptions of probability, statistics and inference during pest risk modelling: how did the elephant in the room grow so big?

Darren J. Kriticos[1]* & Peter Caley[2]

1-2, CSIRO, Canberra, ACT, Australia; *, presenting author.

For more information, contact Darren.Kriticos@csiro.au.

Pest risk analysis and modelling involves questions concerning probability, inference, causation and uncertainty. Statistics, probability and experimental design should therefore provide key foundations for many of the common analytical methods. However, statistical methods can be both seductive and intimidating, and we need to be mindful of the need for good underlying scientific method and associated strong inference. Here, we illustrate the need to adhere to the fundamental assumptions, tenets or principles of probability, statistics and inference when undertaking pest risk assessments. We demonstrate the potentially severe consequences arising from breaching these assumptions, and highlight the potential to consequently misguide biosecurity policy. We explore the factors that have shaped the evolution, promotion and adoption of popular methods, some of which we argue do not provide reliable inference. By acknowledging the elephant in the room, we hope that we can identify a pathway towards improved pest risk methods.

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(7) Making sense of absence: a Bayesian framework

Andrew Robinson[1]* & James Camac[2]

1-2, CEBRA, The University of Melbourne, Australia; *, presenting author.

For more information, contact apro@unimelb.edu.au.

Evidence of pest absence is critical for trading with World Trade Organisation member countries without the need for additional sanitary measures. In many cases, evidence of pest absence is derived from pests not being detected in internationally recognised surveillance programmes. However, if detection rates are imperfect, which is almost always the case, then an observed absence can arise from either the pest being truly absent or from the surveillance programme failing to detect it (i.e. a false negative). Therefore it is rarely, if ever, possible to be absolutely sure a pest is absent. Because of this, it is of critical importance that we quantify the degree to which we believe a pest is absent (i.e., the confidence) when determining pest-free status or when a pest has been successfully eradicated. Here we show how to use an under-utilised source of surveillance information, namely observed absences (i.e., negative records), to quantify our confidence that a pest is truly absent. In its simplest form, the model we propose requires information on only two processes: 1. the sensitivity of the surveillance system to detect the pest; and 2. the prior belief the pest is present. We will discuss the model and sketch an application with realistic data.

(8) Testing model accuracy when predicting pest susceptibility using expert-driven spatially-explicit models

Justine V. Murray[1]* & Javier N. Garcia[2]

1-2, CSIRO Health & Biosecurity, Brisbane, Qld. Australia; *, presenting author.

For more information, contact Dr Justine Murray, CSIRO Health & Biosecurity, GPO Box 2583, Brisbane, Qld, Australia. 4001, Justine.Murray@csiro.au.

Management of a pest or invasive species requires understanding of how it interacts within its environment, both directly and indirectly. We use expert-based probabilistic models in a spatially explicit framework to capture the species functional relationship within the environment. Expert knowledge is used to populate the models as invasive species and pests often have insufficient data for statistical modelling, especially new incursions. The resultant predictive risk maps can show where invasive species are likely to establish and persist within the landscape. Ensuring models give an accurate representation of the system being modelled is important. Identifying the uncertainties within the modelling process is also important. Predictive spatial models should be tested for their predictive accuracy as well as the accuracy of the baseline data. However, it is difficult to run traditional statistics on qualitative models based on expert knowledge. Validating the model with independent data is the best option but may not be feasible. Alternative solutions need to be considered, such as classification tree analysis and simulated bootstrapping. We present a case study of the predictive susceptibility of a pest and the solutions used to test model accuracy. Identifying and addressing model discrepancies can lead to improved model accuracy and performance and is a key final step in any predictive modelling exercise.

(9) Coping with climate uncertainty in projected ranges of pests using hypervolumes

Frank H. Koch[1]*, Denys Yemshanov[2], Robert C. Venette[3], & Kevin M. Potter[4]

1, USDA Forest Service, Southern Research Station, Research Triangle Park, NC USA; 2, Natural Resources Canada, Canadian Forest Service, Sault Ste. Marie, ON Canada; 3, USDA Forest Service, Northern Research Station, St. Paul, MN USA; 4, North Carolina State University, Department of Forestry and Environmental Resources, Research Triangle Park, NC USA; *, presenting author.

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Predictions about how pests will behave in the future are constrained by severe uncertainty in climate projections. More than a dozen regularly used global circulation models (GCMs), in combination with several CO_2 emission scenarios, yield a multitude of plausible outcomes. Such uncertainty places pressure on decision makers, who need analytical tools that can incorporate climate-related uncertainty directly into decision support products. We used CLIMEX to map the suitable range of a hypothetical forest pest in North America under different GCMs and emissions scenarios, and at different future time horizons. After compiling the results, each map location had a distribution of suitability values, one value for each CLIMEX realization. We then used hypervolumes to rank the locations based on these distributions. The hypervolume approach provides a continuous comparative measure that accounts for uncertainty in sets of input information. Because climate change will have non-linear and potentially hidden impacts on species ranges, overlooking uncertainty in range predictions could lead to erroneous decisions. Moreover, it is unknown which prediction will most resemble the eventual outcome. Our hypervolume approach allows decision makers to hedge their bets in this regard by including the uncertainty explicitly in the outputs.

(10) Optimal strategies in surveillance programs for invasive pests: detect early or delimit?

Denys Yemshanov[1]*, Robert G. Haight[2], Frank H. Koch[3], Robert Venette[4], Ronald Fournier[5], Tom Swystun[6], Yongguang Chen[7], Mireille Marcotte[8]*, & Jean J. Turgeon[9]

1, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON; 2, USDA Forest Service, Northern Research Station, St. Paul, MN; 3, USDA Forest Service, Southern Research Station, Eastern Forest Environmental Threat Assessment Center, Research Triangle Park, NC; 4, USDA Forest Service, Northern Research Station, St. Paul, MN; 5, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON; 6, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON; 7, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON; 8, Canadian Food Inspection Agency, Ottawa, ON; 9, Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON; *, presenting author.

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Early detection of invasive species populations has been long recognized as a strategy to reduce the costs of controlling and eradicating new outbreaks. Early detection surveys often operate at low survey densities and cover larger areas than surveys delimiting established populations. In broad terms, early detection and delimiting surveys have different objectives. In this study, we consider the case of an early detection survey program that aims to find the first presence of a harmful invasive species in an area of concern. We present a scenario-based optimization model of survey site selection that incorporates uncertainty about the pest's arrival and possible damage to a host resource and minimizes expected time to first detection in the area of concern. We compare the model behavior with a common delimiting survey strategy that minimizes damage from invasion in the area of concern. We then examine the spatial allocations of surveys for each strategy and their sensitivities to key model assumptions and parameters and decision-maker's perceptions of risk. Our problem setting reflects a trade-off faced by decision-makers who implement surveillance programs for invasive species: whether it is better to emphasize early detection of incursions prior to widespread establishment or management (i.e., delimiting surveys to target response actions in established areas). We examine the problem using the example of an ongoing surveillance program for Asian longhorned beetle (ALB) in the Greater Toronto Area (GTA), Ontario, Canada. Our approach is generalizable and can support survey programs for novel invasive pests and pathogens.

(11) Early detection of forest invaders in New Zealand: optimising surveillance effort based on spatially-explicit modelling of high-risk pathways

Nicolas Meurisse[1]*, Steven Mascaro[2], John Kean[3], Paul Stevens[4], & Lindsay Bulman[5]

1, Scion (New Zealand Forest Research Institute), Rotorua, New Zealand; 2, Bayesian Intelligence, Melbourne, Australia; 3, AgResearch, Hamilton, New Zealand; 4, Ministry for Primary Industries, Auckland, New Zealand; 5, Scion (New Zealand Forest Research Institute), Rotorua, New Zealand; *, presenting author.

For more information, contact Dr Nicolas Meurisse, Scion, 49 Sala Street, Private Bag 3020, 3046 Rotorua, New Zealand, nicolas.meurisse@scionresearch.com.

New Zealand is currently reviewing its system for early-detection of invasive forest pests and diseases. Probabilistic models have been developed to estimate the risk of unintentional introduction of potentially harmful organisms associated with seven import pathways (sea vessels, used vehicles, used machinery, sea containers, wood packaging, wooden furniture, live plants), international passengers (returning residents and visitors) and wind currents (natural introduction). The model estimates propagule pressure associated with each pathway, not only at the entry points (sea and airports) but also at each of 1912 area units covering any location in New Zealand. The modelling approach that was used, Bayesian networks, allows it to capture uncertainties in all model variables. Maps of expected propagule pressure have been produced for four potential insect invaders (Asian gypsy moth, pine shoot moth, Asian and citrus longhorn beetles) and two potential diseases (pine pitch canker and sudden oak death). These aim to represent invaders associated with different modes of introduction and biological characteristics. Specific propagule pressure maps have been weighted by climatic suitability and host-plant availability to produce establishment risk maps. An optimisation model then estimates what allocation of surveillance effort (type and intensity of survey within each area unit) maximises the overall probability of detection of an establishment for any defined budget. The model indicates that the probability of early establishment of forest invaders is particularly high in populated areas and around pathway specific facilities such as ports, car yards or container cleaning depots. These are priority areas to be surveyed.

(12) Inferential and geostatistical analysis to optimize sampling, monitoring, and decision making in the management of *Diaphorina citri* (Hemiptera: Liviidae) in Mexico

Gabriel Diaz Padilla[1]*, Rafael A. Guajardo Panes[2], Jose I. Lopez Arroyo[3], & Ignacio Sanchez Cohen[4]

1-4, National Institute for Forestry, Agriculture and Livestock Reseach of Mexico (INIFAP); *, presenting author.

For more information, contact Gabriel Diaz Padilla, KM. 3.5 Carretera Xalapa - Veracruz (EDIFICIO SAGARPA), Colonia Animas. Xalapa, Veracruz. Mexico. C.P. 91190., diaz.gabriel@inifap.gob.mx.

In this study a methodological tool was developed to establish practical, efficient and economic plans for the sampling and monitoring of *Diaphorina citri* (Hemiptera: Liviidae), the vector of the pathogen associated with Huanglongbing, a lethal disease of citrus. The first step was the development of a risk zones map for the presence/abundance of the vector in Mexico, followed by the exploratory, inferential and geostatistical analysis of data gathered weekly during 2015 from 86,334 sticky traps, located in the different Mexican citrus areas. Results from diverse analysis indicated that: 1) trap location should be in high risk zones for abundance of the vector in accordance with the generated risk map; 2) number of traps for monitoring of *D. citri* at a national level should be reduced by at least 40%; 3) due to the aggregated spatial distribution of the vector, sampling with at least 20 sticky traps, one trap per tree in alternated trees placed in the edge of the orchard is recommended; 4) the geographical orientation of the sticky traps in the orchard influences the amount of captured insects; therefore, each geographical area should follow a specific recommendation for placement of traps; 5) in some citrus areas, due to vector management, presence of *D. citri* has become scarce; thus, frequency of trap revision could be weekly or bi-weekly; 6) distance among orchards with monitoring traps should be analyzed by geostatistical techniques. The above information was implemented by the national campaign against Huanglongbing and the vector, achieving estimated savings in nearly 30% of the total cost in the execution of the monitoring campaign for the present year (2017).

(13) Predicting the potential distribution in China of *Euwallacea fornicatus* (Eichhoff) under current and future climate conditions

Xuezhen Ge[1]*, Chao Jiang[2], Linghong Chen[3], Shuang Qiu[4], Yuxiang Zhao[5], Tao Wang[6], & Shixiang Zong[7]

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Euwallacea fornicatus (Eichhoff) is an important forest pest that has caused serious damage in America and Vietnam. In 2014, it attacked forests of Acer trialatum in the Yunnan province of China, creating concern in China s Forestry Bureau. We used the CLIMEX model to predict and compare the potential distribution for E. fornicates in China under current (1981 - 2010) and projected climate conditions (2011 - 2040) using one scenario (RCP8.5) and one global climate model (GCM), CSIRO-Mk3-6-0. Under both current and future climate conditions, the model predicted E. fornicates to be mainly distributed in the south of China. Comparing distributions under both climate conditions showed that the area of potential distribution was projected to increase (mainly because of an increase in favourable habitat) and shift to the north. Our results help clarify the potential effect of climate change on the range of this forest pest and provide a reference and guide to facilitate its control in China.

(14) Estimating pest impacts under climate change: *Spodoptera litura* (f.) performance on brassica crops under elevated CO_2

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Spodoptera litura (F), recorded as global distribution, is an economically-important agricultural pest. Our understanding of the future pest risks posed by this insect is currently based on data of growth and development of *S. litura* in laboratory and greenhouse experiments where larvae are fed with intact-foliage under ideal conditions; the performance of the insect is being gauged under the effects of the host plant's "constitutive-resistance". In fact, plants suffer damage from multiple predators, they may boost their chemical-based defense capability via "induction-resistance"; producing secondary metabolites such as alkaloids, glucosinolates, phenolic & etc that reduce the growth and development of herbivores. We compare *S. litura* performance on both constitutive and induced-foliage under ambient [CO_2], finding a significant reduction of growth rate on induced-foliage. Under enhanced [CO_2], data showed a decline of *S. litura* performance under constitutive-resistance and an increase in larval growth rate when fed induction-resistant plant material. These findings suggest that patterns of future pest impacts may be affected by atmospheric chemical composition through changes in plants' ability to synthesis secondary chemicals for defense against herbivores. Plants whose growth has been promoted by exposure to elevated [CO_2] may be limited in their ability to synthesis nitrogen-derived defense compounds. Our results provide a caution to modellers attempting to estimate future pest risks under elevated [CO_2]: there is substantial uncertainty regarding the net outcome of altered insect herbivore population dynamics under elevated [CO_2]. In the absence of clear trends, perhaps an assumption of stationarity in pest impact functions is justified so long as the uncertainties are acknowledged.

(15) Multi-species pest risk analysis of climate impacts on field crop pests in Canada

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A number of biotic and abiotic factors affect crop production including crop management decisions based on the potential impact of multiple pest insect species. In the current study we investigated how multiple pest insect species interact, in terms of changes of relative abundance and potential distribution, in response to varying climate. An Agroecosystem model (AEM) has been designed to address issues associated with pest alert systems and global warning. The model produces output that can be used for decision support related to pest alert systems and adaptation strategies. The specific purpose of the study was to use the AEM to analyze how species overlap (between two and three species) would change for current and future climates. This study defined CLIMEX Ecoclimatic (EI) values that represented risk to host crops. Based on survey data and interpolation, species specific EI values were selected to represent a level indicative of pest risk to host crops. Mapped areas represented species specific EI values that were chosen to represent values indicative of pest risk to host crops. Climond (Kriticos et al. 2012) CSIRO Mark 3.0 climate data (A1B for 1975, 2030 and 2070) was used for climate data inputs into each of the models. Our results indicated that notable changes were predicted to occur across the Canadian prairies, particularly across the northern half of the prairies. The Peace River region of Alberta and British Columbia were predicted to be very vulnerable to climate change. Relative to 1975 values, the rate of increase was greater between 1975 and 2030 than 2030 to 2070.

(16) Predicting the potential geographical distribution of *Tuta absoluta* in China based on CLIMEX and ArcGIS

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The tomato leafminer, *Tuta absoluta*, a serious pest threatening the tomato industry in South America, Africa, Europe and Central-West Asia, now has recently invaded the neighboring countries of Northwest and Southwest China. In order to effectively prevent the introduction of *T. absoluta* and strengthen the alertness of plant quarantine staff and agricultural researchers against this pest in China, we used DYMEX 2.0 and ArcGIS 9.3 to predict the potential geographical distribution of *T. absoluta* in China. The predictive map suggested that the potential geographical distribution of *T. absoluta* in China covers most parts of Western, Central and Eastern China, while with few unsuitable areas in Xinjiang, Xizang and Qinghai. The optimal potential area (high risk area) is mainly distributed in Yunnan, Western and Southeastern Guangxi, Southwestern Guangdong, and partly Western Hainan. Others were scattered in Southeastern Gansu, Middle Sichuan, Middle Shaanxi, and the junction of Henan and Shanxi. Central and East China represent the moderate risk. This will assist Chinese policy-makers to improve current surveillance, phytosanitary measures and future management strategies for *T. absoluta*.

(17) Exploring the limitations of degree day models in assessing the potential development of transient pests: *Bemisia tabaci* in the UK and France

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Degree day phenology models of two tobacco whitefly (*Bemisia tabaci*) biotypes widespread in European glasshouses show that multiple summer generations could occur outdoors across the UK and France. However, despite ample opportunities, outdoor populations have only been found in southern France with a Mediterranean climate. To determine if other climatic factors could be limiting *B. tabaci* summer survival outdoors further north, we analysed 49 climatic indices for the period 1986-2015 using two daily European climate datasets: JRC-MARS and E-Obs (~25 km^2). Both datasets showed that, in addition to factors related to accumulated temperature, during the summer both the number of days and the number of consecutive days as cold as the coldest 10% of days and nights are significantly different in southern France where this pest occurs outdoors, and so may be limiting its development. Since a clear south-north gradient is demonstrated for these indices, linking any possible northwards spread of *B. tabaci* populations outdoors in France with changes in these indices should provide an important indicator of any change in the risks of outdoor populations of this species developing in the UK.

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(18) A quantitative assessment of the likelihood of introduction of the Lewis mite, *Eotetranychus lewisi*, into the continental European Union

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A quantitative plant pest risk assessment method is in development by the EFSA Plant Health Panel. Results will be presented from a pilot case study that used the novel method to assess the likelihood of the Lewis spider mite, *Eotetranychus lewisi* (McGregor), being introduced to the continental European Union. *Eotetranychus lewisi* is a quarantine pest for the EU and is currently regulated on *Citrus* but has emerged as a pest of strawberries in California in recent years and it is reported as having heavy outbreaks in peaches in Mexico. The assessment of introduction into the EU considered scenarios for four distinct pathways involving both plants for planting and fresh produce. Results from the baseline scenarios, which represent the current situation, will be compared to results from scenarios which have additional risk reduction measures in place. The benefits and challenges of implementing and communicating the results from the quantitative risk assessment method will be discussed.

(19) Effects of temperature transfers on development, survival and reproduction of *Hermetia illucens* (Linnaeus) (Diptera: Stratiomyidae)

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Newly-laid egg masses of *H. illucens* was exposed at 28 °C. Eight day old larvae (from eggs) were then transferred into treatment temperatures (10, 19, 28, 34, and 40 °C) for five days, then moved back to 28 °C (totally 13 days old) until insects reached adulthood. Adults were marked and released in a greenhouse set at 28 ◦C, survival and fecundity were recorded daily until the death of all individuals. Data were collected and analyzed based on an age-stage, two-sex life table. Population parameter (intrinsic rate of increase (r), finite rate of increase (ª), net reproduction rate (R0), and mean generation time (T)) were calculate to evaluate the temperature effect on adults after temperature exposure. Highest and lowest survival rate was at 34 and 10 °C respectively, the sex ratio was affected by temperature as well, at 10 °C only 2 individuals were females (n=12) and at 34°C 50 were females (n=84). Some females were able to lay eggs two times during its adult life span. We demonstrated that only a five days exposure to different temperature will influence *H. illucens* life history

(20) Swede midges and when they emerge: creating a predictive model of the *Contarinia nasturtii* life cycle

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The swede midge (*Contarinia nasturtii* (Kieffer)) is an exotic insect originating from Eurasia, whose feeding has caused a decline of over 60% of total canola acreage in Ontario, Canada since 2011. Management action must be undertaken to prevent impact to Canada's $26.7 billion canola industry, beginning with the development of a reliable forecasting model for swede midge emergence. The objectives of this project are to i) determine temperature-dependent development and mortality for Ontario swede midge populations; ii) use DYMEX modelling software to revise the current swede midge population dynamics model, entitled MidgEmerge, by incorporating this new information; and iii) use the model to determine environmental conditions for swede midge outbreak. Temperature-dependent rates of development, mortality, viability, and incubation of various swede midge life stages will be elicited using the thermal gradient plate facility at the Saskatoon Research & Development Centre, Agriculture and Agri-Food Canada. The regressions resulting from these data will be incorporated into the MidgEmerge model, which will then be used to compare environmental data between the site of a swede midge outbreak and a site with no outbreak. Inclusion of accurate developmental rates is expected to greatly improve model accuracy and aid in developing an effective integrated pest management strategy for the swede midge.

(21) Utility of simple mechanistic models of winter mortality for invasive alien species

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Cold stress remains one of the primary constraints to the distribution and activity of many tropical and temperate alien species, particularly insects. Stress reflects the physiological condition of an invading species at the time of exposure and the severity and duration of exposure to low temperatures. Considerable debate exists about the utility of relatively simple ecophysiological models derived from laboratory studies to forecast the potential extent of winter kill. We discuss relationships between the supercooling point (the temperature at which an individual spontaneously begins to freeze) and lower lethal temperature (a measure of the extent of mortality from acute exposure to a specified temperature) and how these relationships might be used to infer a cold tolerance strategy. We then discuss how such information might be used in simple models to describe spatial variation in overwintering potential. Strong trade offs exist between the level of ecological realism one hopes to capture in laboratory assays of cold tolerance and the time or cost involved. The challenge is to develop mechanistic models that are fit for predictive purpose with full awareness of remaining uncertainties.

(22) Wading through rivers of information: a structured assessment process for emerging risks to plant health

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MPI takes a systematic approach to assessing information about new and emerging risks to plant health through the Biosecurity Emerging Risk System. The first priority of the system is to identify changes in risk profile against which current interventions should be strengthened. Other priorities include identifying information that is useful for the general awareness of staff and communicating how current interventions are effectively managing the risk. A total of 7312 alerts have been received since the system was implemented in 2012. Of these, 262 alerts have been identfied as potentially not being managed by current measures, and were therefore sent for risk management evaluation. So far there have been changes to 7 IHSs, with 2 suspended. The specific requirements for dozens of different plant species have been changed as a result of this system. The process for moving from the alerts received through to risk management action involves a structured assessment process. It is currently manual and largely qualitative, but the structure and the improving sources of supporting data mean it is likely to be amenable to some degree of quantification or semi-automation. In the process of better documenting the assessment process, we have explored tools such as argument mapping. Such approaches have revealed hidden assumptions and uncertainties in our risk assessments. As a result, we better understand the challenges in producing reliable and consistent risk assessments.

(23) Objective prioritization of exotic arthropods: development and validation of a new model

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A primary goal of the USDA-APHIS's Plant Protection and Quarantine (PPQ) division is to protect agriculture and natural resources in the U.S. from the entry, establishment, and spread of exotic plant pests. To aid this mission, we have developed a statistically robust risk assessment tool, which categorizes exotic arthropods based on their likelihood of causing serious impacts to agricultural and natural resources. As part of the model development process, we compiled a list of 100 arthropods that have been introduced into the U.S., and prepared an initial list of predictor variables, or risk criteria, that may contribute to the impact potential of these species. The exotic pests in this training dataset were analyzed as though they were not yet introduced. We therefore relied only on information (behavior, impacts, and controls) from outside the U.S. We then developed an ordinal logistic regression model using mutual information from entropy based techniques to identify the most informative subset of predictor variables. Initial model assessment was conducted using K-fold cross validation for ROC. Further validation was conducted with an independent dataset of 75 additional introduced arthropods. Our model categorizes exotic pests as high, moderate, or low impact species, allowing PPQ decision-makers to more judiciously allocate agency resources towards regulatory activities such as early detection surveys.

(24) Climate change impacts on the brown marmorated stink bug, *Halyomorpha halys*

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The invasive brown marmorated stink bug, *Halyomorpha halys* Stål (Hemiptera: Pentatomidae), has recently emerged as a harmful pest of horticultural crops in North America and Europe. Native to East Asia, this highly polyphagous insect is spreading rapidly worldwide. Climate change will add further complications to managing this species in terms of both geographic distribution and population growth. This study used CLIMEX to compare potential *H. halys* distribution under recent and future climate models using one emission scenario (A2) with two different global circulation models, CSIRO Mk3.0 and MIROC-H. Simulated changes in seasonal phenology and voltinism were examined. On a global scale, potential *H. halys* range expanded polewards and contracted from its southern temperature range limits under possible future climates. All future climate scenarios explored here suggest that the invasion threat posed to Europe and Canada will greatly intensify. Prolonged periods of warm temperatures resulted in longer growing seasons. However, future climate scenarios indicated that rising summer temperatures decrease *H. halys* growth potential compared to recent climatic conditions, which in turn, may reduce mid-summer crop damage. Climate change may increase the number of *H. halys* generations produced annually, thereby enabling the invasive insect to become multivoltine in the northern latitudes of North America and Europe where it is currently reported to be univoltine. The results of this study can inform biosecurity planning and pest management by identifying regions of increasing as well as decreasing risk from *H. halys* in light of climate change.

(25) A generic decision tool for assessing response options to tree pests in the UK

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This presentation describes the output from a GB Forestry Commission project to develop a clear and replicable framework to inform decisions about possible responses to tree pests - namely whether to eradicate, contain, or live with it. The framework involved identifying critical factors in the spread and impact as well as involving direct users and indirect users of a decision tool that would be derived from the framework. The direct users in this case are government economists and the indirect users the relevant policy officers. Discussions with the latter group centred on the appropriate inclusion of values at risk as well as ways of expressing uncertainty and how they can discuss such issues with the direct users. The aim was to bridge the gap between the output of a complex model and the narrative that surrounds the policy discussions by the indirect users of the possible response options. The presentation includes the responses to the various stages of tool development and illustrates the near final tool with reference to some case studies undertaken as part of the project.

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(26) Facilitating trade by improving data quality in globally consulted pest information resources

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Pest information databases are widely consulted by the risk analysts of trading partners to determine the status or occurrence of pest species associated with the commodities considered for import. In some cases, inaccurate pest distribution data in these databases can delay trade negotiations. We facilitate trade between the United States and its trading partners by (1) proactively identifying pest candidates that have erroneous information in the global pest databases (2) prioritizing candidates that may have the most impact on trade (3) assessing the current status of the pest in the United States and (4) reporting and aiding to correct the pest data in the global database. With these activities, we aim to reduce the time and effort spent in negotiation to open export markets and prevent trading partners from imposing unwarranted phytosanitary measures that are based on inaccurate published information regarding pest status

Abstracts to Posters

(Arranged in alphabetical order by the first author's last name)

Monitoring of pathogenic fungi in air using spore traps and DNA based detection

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An efficient monitoring and detection system of plant pathogens can be achieved by targeting their main dispersal pathways. Many plant pathogenic fungi are dispersed by wind and can be captured using spore traps. The aim of this project was to evaluate the approach of combining spore traps and unspecific identification using DNA barcoding to monitor and detect native and invasive plant pathogens. Different spore traps (active ionic suction trap and the passive JB funnel trap) were used to capture fungal spores in the air from different plant production systems in Southern Sweden. Identification of the species captured were done using the ITS region sequenced using high through-put sequencing (Illumina MiSeq and PacBio RS II). The data obtained provides a basic understanding of the spatial and temporal patterns of fungal communities present in air in agricultural and forest landscapes throughout the vegetation period. Specifically, the combination of trap types, placement in the landscape and frequent sampling allowed us to study which seasons capture the highest variation and on what spatial scale spore traps will be able to provide information on pathogen presence. The results from this study can be used to develop disease monitoring systems which could be used for early warning, for disease forecasting and an important tool for disease risk management of plant disease in the future.

Plant health risk assessment at the CFIA

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The Plant Health Risk Assessment Unit is based in the Canadian Food Inspection Agency, Canada s National Plant Protection Organization, in Ottawa, Ontario, Canada. As an organization, the CFIA is responsible for food safety, commercial animal health and the safety and security of its plant resource base (agricultural and natural, import and export). This poster briefly outlines the roles and responsibilities of the PHRA Unit under the mandate of the CFIA.

Modelling the expected entry rate of *Grapholita molesta* (oriental fruit moth) into Canada using @Risk

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The Oriental fruit moth (*Grapholita molesta* (Busck)) is a regulated pest for Canada, present in Ontario and Quebec. There are many fruit commodities that could carry this moth either within Canada or from international sources, but the magnitude of risk posed by each commodity is unknown. This project attempted to model the likelihood of entry using @Risk. The results suggest that the current exclusion of apple fruit and its relatives from the regulated host list significantly negates the protective action of regulating the more common hosts (peaches and their relatives). Even so, the likelihood of entry leading to successful establishment on fruit is suggested to be very low.

Spatial risk and temporary severity of coffee rust (*Hemileia vastatrix*) in Mexico.

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In recent years, coffee rust (*Hemileia vastatrix* Berkeley & Broome) has become the most devastating disease in coffee plantations in Mexico. For its management, the generation of a map for coffee rust risk zones and the knowledge of its temporality are two basic tools to establish a strategy for disease monitoring, prevention and control. In order to generate this map, climatic information was analyzed (1961-2010) and processed for creating the following risk indexes: favorable days and potential disease period and a third index related to planted coffee area. The potential risk map was elaborated by using map algebra and spatial interpolation. Regarding temporal severity of coffee rust, its presence in plant and leaf was evaluated in seven coffee farms located in an altitudinal transect that goes from 545 to 1250 masl, during the period 2013 2016. The map of coffee rust risk in Mexico shows that higher values of potential disease were found in the followings states: Chiapas (.94), Guerrero (.67), Oaxaca (.61), Veracruz (.40), and Puebla (.38); these values ranged from 0: minimum risk to 1: maximum risk. In addition, periods of high rust occurrence were found in low-altitude coffee regions; in contrast, in high-altitude regions disease presence decreased. The results of disease severity showed that coffee rust damage was similar in all plant altitudinal sections (low, medium and high).Coffee rust risk areas and severity data will be presented to coffee growers and users in a digital application for easy access and use.

Distancing and orientation of sitcky traps for the detection-monitoring of the Asian citrus psyllid in Colima State, Mexico

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In 2010, the citrus area of Colima state, Mexico, was infected by *Candidatus Liberibacter asiaticus*, a pathogen associated with the lethal disease Huanglongbing, and vectored by the Asian citrus psyllid, *Diaphorina citri* (Hemiptera: Liviidae). In order to contribute to the vector management, a methodological process was proposed to map trapping-monitoring sites of *D. citri* in citrus orchards, as well as to define distancing among them and orientation for their location, according to the maps of *D. citri* abundance risk zones. The source data was provided by the national campaign against Huanglongbing and the Asian citrus psyllid in the Mexican citrus-industry for the monitoring period of 2015. A Poisson distribution analysis was performed to calculate probabilities of capturing 0, 1 and 2 psyllids/trap/week; such values were interpolated with Kriging model to estimate the spatial variation of probabilities to capture *D. citri* in the Colima citrus zone, selected as a study case due to the severe effects of Huanglongbing in the Mexican lime. The spherical Kriging model presented the smallest mean square of the standardized error (0.9656); this model was considered to perform the variogram analysis for different probabilities of psyllid capture (p = 0, 1, 2; ª = 1.87). It was observed that for the three scenarios of probability, there was fluctuation of variation explained by the spatial distance in 31-49%, with an anisotropy trend in the North-South direction. A new sampling scheme is proposed by placing in areas of highest risk of *D. citri* abundance groups of 20 sticky traps, each group separated by no less than 1,000 meters away and oriented to the south of the orchard centroid. This new sampling should reduce the number of traps required for the insect monitoring in 30-50% and it will reduce in nearly 30% the operation cost of the monitoring plan.

Exploring the cost-effectiveness of plant health surveys

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Plant health surveys serve several purposes one of which is to detect pest invasions at an early stage to enable eradication or containment. However, the value of the surveys for early detection is uncertain since the area to be surveyed is often very large compared to the resources available for the surveys. My aim is to explore the cost-benefit ratio of the plant health surveys carried out in Finland. For each survey I estimate the value of the target crop, the cost of the survey, and the probability of detecting invasions early enough in the survey. The latter two are estimated assuming a range of survey intensities attainable with the available resources. The probability of detecting invasions in time is estimated with Monte Carlo simulation of invasions and inspections. By exploring a range of probabilities of invasion and crop loss percentages I find the combinations of these two parameters for which the expected gain from the survey would be higher than its costs. The results are strongly affected by the assumptions made when estimating the probability of early enough detection of invasion, namely the efficacy of a single inspection, spread potential of the pest, and the definition of early enough detection. However, by using an overly optimistic probability of early detection I will test if the surveys have any change of being cost-effective in early detection. Also, by using the same parameter values for the different surveys I will compare the cost-effectiveness potential of the surveys on the different crops.

Evaluating the spatial transferability of a pest risk model

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Forecasting the spread and potential impacts of biological invasions is vital to management and policy decision-making. A key assumption of models used to calculate risk is that invasive species conserve their climatic niche through space and time. However, this assumption may not adequately reflect the phenotypic plasticity and rapid evolutionary potential often associated with invading populations. Using a correlative species distribution model, we explore the extent to which the native range of the invasive gypsy moth, *Lymantria dispar*, can inform the current invaded range, both in geographic and environmental space.

Modelling impacts using a participatory approach to encourage model adoption for best management practices in managing pests

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Engaging stakeholders and encouraging community engagement is fundamental for adoption of model results. Engagement benefits from starting from model development and continuing through to model completion and roll-out. This is especially the case when managing pests, where a coordinated management strategy between stakeholders works best. We use a participatory approach that combines expert knowledge and spatial information to develop risk maps of potential threats. Of particular relevance is the inclusion of scenarios that can be manipulated to determine the effects of different management strategies and combinations of coordinated strategies. Scenarios are built on expert opinion, guided from years of experience in research and management of the pests under field conditions. We capture their knowledge and understanding of the study system allowing us to independently validate how the model and scenarios replicate reality. Model results are presented as maps that visualise risk after applying different management scenarios. Maps facilitate interpretation of model results in a spatial context relevant to local communities. Capturing impacts of species invasions by running scenarios specific to targeted community groups, such as land managers, allow for increased adoption when economic incentives are introduced. Model results show a distribution of costs for each modelled commodity scenario, giving end-users a range of costs unique to each agricultural region. Using ecological knowledge to understand the species interaction within the environment, and economic and environmental drivers to capture impact, our scenario modelling allows for immediate relevance to community users and ease of adoption with its participatory approach.

The effect of temperature on the duration of the development of *Bactrocera dorsalis* (Diptera: Tephritidae)

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The phenological traits of *B. dorsalis* (Hendel) has been evaluated in the past, however nonlinear models have not been applied to *B. dorsalis* (The Lactin 2 model and the Sharpe-Schoolfield (SSI)). Nevertheless, validated, our aim was to modeling the phenological responses of *B. dorsalis*. The results will be useful for predicting that fly population dynamics and help develop better-approaches in *B. dorsalis* management. Both of nonlinear models appear to be well fitted to our observations. The SSI model has a better fit statistically but graphically at egg stage the optimal temperature were higher than the observed value. Experimental data for egg, maggot, puparium, and preadult stages indicate that development rate decline after approximately 30 °C and sharply decline at 34.8 °C. The data showed that the highest development rate is presented at 31.8 °C for egg, maggot, and pre-adult stage. Interestingly, for puparium the highest development rate was at 34.8 °C. Our model, indicated good realism and accuracy to our observations. However that was important to mention that because the wide plasticity of dipterans, there might be some differences on *B. dorsalis* development among different hosts and strains specially during maggot stage, contrary with puparia, were at this stage will have less variation and show similar developmental times even when reared at different conditions.

The development and preferences of Oriental fruit fly (*Bactrocera dorsalis* Hendel) in various host plant in Taiwan

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The aim of this research is to use the development rate of *Bactrocera dorsalis* under different host to adjust the developmental distribution models and use as a forecasting tool in pest management. Five fruits will be used as host of *B. dorsalis*: Eggplant (*Solanum melongena* L.), lemon (*C. limon* (L.) Burm.f.), banana (*Musa paradisiaca* L.), tangerine (*Citrus reticulata* Blanco), star-fruit (*Averrhoa carambola* L.), and artificial diet will be utilized as control. This experiment use two methods, choice and non-choice test. For non-choice test, cut every species of fruit into small and placed in individual 5-ml plastic cups, each containing fruit and one neonates larva. Each cup was set in a shallow pan with sand to allow pupation. Because temperature greatly affects tephritid larval development, all experiments were carried out in environmental chambers at a constant temperature of 25 °C. The observation of *B. dorsalis* will perform everyday days until the adult emerged. In this research, pupa weight, mortality of fruit fly, pupation time, adult emerged time, and sex ratio will be recorded. For choice test, Five kinds of fruits (eggplant, lemon, banana, tangerine, and star-fruit) in the middle of the cage (50x50x50 cm) release 20 female and male oriental fruit fly adults (2-3 weeks old). After 24 hours, fruits will be separate in individual cages and record the pupa weight, mortality of fruit fly, pupation time, adult emerged time, and sex ratio. This experiment will use Larval survival will be analysed using a general linear model (GLM) with a binomial error as a function of plant species, and interaction with oriental fruit fly. Developmental time and pupal weight will be analysed by analysis of variance (ANOVA) as a function of plant species, and interaction with oriental fruit fly. For forecasting pest management, collection and analysis of crop production data are very important.

Effect of elevated CO_2 and temperature on plant chemistry and their insect pest

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The climate change and extreme weather events affect plants and animals have been documented extensively over the past years. In tropical and subtropical regions shown only limited understanding of how climate change effect on plant chemistry and their insect pest interactions. The purpose of this research is to address the consequences of elevated CO_2 and temperature concentrations in sub-tropical regions by using greenhouse system. The experiment was set up, ambient CO_2 (500 ppm) and elevated CO_2 (1000 ppm), at ambient temperature 24/19 °C (day/night) and elevated temperature 29/26 °C (day/night). Broccoli was grown for six weeks; after that, short and long term *Spodoptera litura* performance were conducted under the same condition. The results show that the CO_2 elevation led to change in plant performance and chemistry; leaf area, fresh-dry weight and organic available protein, nitrogen, and carbohydrate content. Besides, the elevated temperature seems to shorten *S. litura* duration, and an increase the relative growth rate of larval, the present results indicate that temperature and CO_2 are direct and indirect influencing the population growth of *S. litura* and pest incidence may possibly be higher in the future. The effects measured here, along with other effects of global change on plant-insect interactions suggest that biological control will decline over the coming decades.

Identification and introgression of tomato fruitworm (*Helicoverpa armigera*) resistance genes from wild tomato (*Solanum pimpinellifolium*) to cultivated tomato (*Solanum lycopersicum* L.)

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Tomato cultivated line, *Solanum lycopersicum* L., is a host for many insect pests including tomato fruitworm, *Helicoverpa armigera*. However, there are wild tomato species that display a great variety of phenotype that can be crossed with cultivated tomato. We choose *S. pimpinellifolium* VI030462 that produce a red fruit and it is closed to the cultivated tomato. This wild tomato also abundance with glandular types IV and VI trichome which being resistant to whitefly (*Bemisia tabaci*) experiments have been executed at the AVRDC- World vegetable Center Taiwan. Our purpose it to investigate the role of trichrome types and total acylsugars in *H. armigera* resistance in the second filial generation (F2). We screened 200 F2 population (WorldVeg breeding line *S. lycopersicum* L.CLN3682C crossed to *S. pimpinellifolium* VI030462) and compared to their parent, susceptible check line, and F1 using a no-choice test during 7 weeks and 13 weeks after sowing. The result showed that the mortality rate of F2 populations in 10 days positively correlated with density of type IV, type VI trichrome, and acylsugar content in both 7 and 13 weeks test. The parent resistant *S. pimpinellifolium* presented density of type IV trichrome significantly higher than *S. lycopersicum* L., susceptible check line, F1, and F2. We selected the resistant F2 plants crossed with WorldVeg tomato line CLN3682C to produce the F1BC1. In Spring 2017, 12 plants of F1BC1 will be sib-mated to produce at least 1000 F2BC1 seeds to validate identified QTLs from F2 population.