NeoBiota 18: 1–7 (2013)
doi: 10.3897/neobiota.18.6108
www.pensoft.net/journals/neobiota

EDITORIAL

A peer-reviewed open-access journal
NeoBiota
Advancing research on alien species and biological invasions

Invasive alien species in the food chain: Advancing risk assessment models to address climate change, economics and uncertainty

Darren J. Kriticos[1], Robert C. Venette[2], Richard H.A. Baker[3], Sarah Brunel[4], Frank H. Koch[5], Trond Rafoss[6], Wopke van der Werf[7], Susan P. Worner[8]

1 *CSIRO Ecosystem Sciences and Biosecurity Flagship, GPO Box 1700, Canberra, ACT 2601, Australia* **2** *USDA Forest Service, Northern Research Station, St. Paul, MN 55108 USA* **3** *The Food and Environment Research Agency, Sand Hutton, York YO41 1LZ, UK* **4** *European and Mediterranean Plant Protection Organization (EPPO/OEPP), 21 boulevard Richard Lenoir 75011, Paris, France* **5** *USDA Forest Service, Southern Research Station, Eastern Forest Environmental Threat Assessment Center, 3041 Cornwallis Road, Research Triangle Park, NC 27709 USA* **6** *Bioforsk – Norwegian Institute for Environmental and Agricultural Research, Høgskoleveien 7, 1342 Ås, Norway* **7** *Wageningen University, Plant Sciences, Centre for Crop Systems Analysis, Crop & Weed Ecology Group, P.O. Box 430, 6700 AK Wageningen, The Netherlands* **8** *Bio-Protection Research Centre, PO Box 84, Lincoln University, Lincoln 7647 New Zealand.*

Corresponding author: *Darren Kriticos* (darren.kriticos@csiro.au)

Received 18 August 2013 | Accepted 21 August 2013 | Published 13 September 2013

Citation: Kriticos DJ, Venette RC, Baker RHA, Brunel S, Koch FH, Rafoss T, van der Werf W, Worner SP (2013) Invasive alien species in the food chain: Advancing risk assessment models to address climate change, economics and uncertainty. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 1–7. doi: 10.3897/neobiota.18.6108

Economic globalization depends on the movement of people and goods between countries. As these exchanges increase, so does the potential for translocation of harmful pests, weeds, and pathogens capable of impacting our crops, livestock and natural resources (Hulme 2009), with concomitant impacts on global food security (Cook et al. 2011).

Potential invasions by alien species create a dilemma for nations that engage in international trade. On one hand, free trade may provide new markets for producers, cheaper and more diverse goods for consumers, and increase overall gross domestic product. On the other hand, unfettered trade may allow new pests to arrive and jeopardize domestic agricultural industries. Pests may lower agricultural production, reduce the marketability of a crop, or trigger quarantine restrictions from other countries to prevent the continued spread of the pest. The challenge, then, is to identify the risks associated with particular organisms, commodities, or pathways and mitigate those risks to desirable levels. Pest risk assessment, the process by which scientific evidence is used to assess the likelihood that a pest might invade and the extent of harm should the invasion be successful, is commonly applied to decide whether to engage in agricultural trade with another nation and whether phytosanitary precautions might be required in order to manage the risks (Magarey et al. 2009, Schrader et al. 2010). When conducted properly, risk assessments can avert economic losses and preserve economic activity (Keller et al. 2007).

Pest risk maps illustrate where invasive alien arthropods, molluscs, pathogens, and weeds might become established, spread, and cause harm to natural and agricultural resources within a pest risk area. Such maps can be powerful tools to assist policymakers in matters of international trade, domestic quarantines, biosecurity surveillance, or pest-incursion responses. The International Pest Risk Mapping Workgroup (IPRMW) is a group of ecologists, economists, modellers, and practising risk analysts who are committed to improving the methods used to estimate risks posed by invasive alien species to agricultural and natural resources. The group also strives to improve communication about pest risks to biosecurity, production, and natural-resource-sector stakeholders so that risks can be better managed. The IPRMW previously identified ten activities to improve pest risk assessment procedures, among these were: "improve representations of uncertainty, … expand communications with decision-makers on the interpretation and use of risk maps, … increase international collaboration, … incorporate climate change, … [and] study how human and biological dimensions interact" (Venette et al. 2010).

The IPRMW met in Tromsø, Norway from 23–26 July, 2012 to address the specific challenges of incorporating climate change into long-term risk projections for invasive alien species, estimating the economic effects of species invasions, and incorporating uncertainty in risk models. A special symposium focused on the interface between pest risk science and policy. The meeting was attended by 30 ecologists, economists, risk analysts and policy advisors from Australia, New Zealand, Canada, the United Kingdom, Finland, Norway, the Netherlands, Hungary, France, Italy, and the United States. The conference succeeded in stimulating new ideas about how to incorporate climate change, invasion dynamics, economics, and uncertainty into pest risk models and maps for invasive alien species, and how to communicate these improved results to biosecurity policy advisors. This special issue of NeoBiota documents the proceedings of the meeting, and this overview summarizes major findings.

Pest risk science and policy. Effective management of biosecurity risks requires close interactions between pest risk assessors and risk managers. Risk assessors evaluate the probability and magnitude of harm from new species incursions and may evaluate options to mitigate those risks. Risk managers within national biosecurity agencies and regional plant protection organizations may draw upon scientific and modelling inputs as they develop standards and implementation plans for phytosanitary measures and other biosecurity procedures. Pest risk assessment methods being developed or enhanced by this workgroup frequently underpin decisions about which species to survey and regulate. For example, the European and Mediterranean Plant Protection Organisation (EPPO) has adopted the risk assessment framework developed under the IPRMW-affiliated PRATIQUE project (Brunel et al. 2013). Economics offers policy analysis tools that estimate the likely impacts an invasive species might have on an economy under a range of policy scenarios. They can analyse these threats from a range of social, environmental and economic perspectives to help guide policymakers to assess what, if anything, should be done to mitigate or ameliorate these threats. Practical constraints (e.g., information quality and quantity) and procedural constraints (e.g., public comment periods) can affect risk assessors' choices about which methods to use to develop pest risk maps. The challenge for pest risk modellers is to try to balance rigor and timeliness in their work to obtain degrees of accuracy and precision that are acceptable to policy advisors and to help policy advisors understand the meaning of their work. For policy advisors, the challenge is to articulate clearly what information is needed to support time-critical decision-making.

Pest risk and climate change. Climate change is expected to affect the distribution and phenology of pests and crops. Some invasive alien species may pose threats to more poleward and higher-altitude regions as cold-related range limits are relaxed. For example, the citrus longhorn beetle, *Anoplophora chinensis* (Forster), is present in southern Europe (Caremi and Ciampitti 2006), but is only reported as transient under eradication in Denmark and the United Kingdom (EPPO 2013). It appears that *A. chinensis* could cause significant damage in parks, gardens, and forests in some coastal areas of northern Europe if it is able to overwinter there in the future. Models have identified other, currently-damaging species situations that may become less problematic as future heat-stress increases. For migratory pests such as aphids, climate change may alter the spatio-temporal synchronization of the pest and crop, affecting the extent of damage such pests may cause. Furthermore, elevated levels of atmospheric carbon dioxide are likely to stimulate plant growth in many crops, perhaps offsetting some damage from invasive alien species. Studies are being conducted to quantify the rate at which natural selection drives adaptation to local conditions in an invading species (Morey et al. 2013). The outcomes of this work will provide a better understanding of the reliability of niche models for describing species' potential ranges in novel environments. The effects of projected climate changes on pest risk models are being investigated by applying global climate scenarios to species niche models (Venette 2013). Given significant uncertainties about climate change and subsequent biological responses, adaptive management methods, guided by models, seem prudent to address future risks from invasive alien species. An adaptive management method balances the desire to avoid unwarranted expenditure on preventing or ameliorating risks that may not arise, whilst identifying adaptive measures that may be necessary if evidence indicates that the risks are likely to emerge in the near future.

Pest risk and economics. Economic analysis tools such as benefit-cost analysis and break-even analysis are effective in condensing complex information into relatively simple metrics about the potential impacts from invasive alien species and the potential benefits of preventative or ameliorative actions. These tools are particularly useful when the impacts of invasive species are limited to agricultural commodities because of the relative ease with which impacts can be quantified. Economic pest impact models are increasingly taking discounting effects into account by considering the rate of spread of pests. Whilst spread models can inform where invasive species might occur (at least in the short-term) (Robinet et al. 2012; Parry et al. 2013), their most important contribution to economics may be to simply estimate the rate of spread of pests through time. Methods that integrate simple pest spread and climate suitability models with crop productivity models have been developed to estimate economic aspects of pest risk in terms that are compatible with the International Standards for Phytosanitary Measures (Cook et al. 2013; Kriticos et al. 2013).

Pest invasions, spread, and surveillance. Biosecurity policies and procedures are frequently intended to prevent the introduction, or slow the spread, of invasive alien species. A significant gap remains between what we know and what we need to know about invasion pathways, especially those related to human activities. Probabilistic pathway models that link the arrival of invasive organisms to existing international and domestic trade flows and transportation corridors are being developed to estimate rates of pest arrivals at specific locations (Colunga-Garcia et al. 2013).

Risk-scoring methods exist to help prioritize species, often only requiring coarse characterizations of species traits. These methods are popular amongst biosecurity agencies, although doubts remain about their subjectivity and accuracy (Caley et al. 2008). A new method analyses the geographical distribution of species assemblages objectively to estimate the relative potential of new species to become established should they be introduced to an area of concern (Worner et al. 2013). New geospatial data standards allow synthesis of diverse geographical data to improve pest detections in the field (Rafoss et al. 2013). New statistical treatments of survey data evaluate biosecurity strategies more rigorously, particularly when detection surveys fail to find a targeted pest.

Even under the best of circumstances, pest risk maps are often challenging to develop and difficult to interpret correctly. Decision support systems are being developed to address these issues, ensuring that pest risk maps are fit for purpose and contribute fully to plant health biosecurity (Baker et al. 2012; Baker et al. 2013).

Pest risk and uncertainty. Uncertainty in risk estimates arises from a number of sources. If policymakers fail to consider uncertainty, they may make unwise decisions. Uncertainty can arise from a fundamental lack of knowledge of risk elements. This epistemic uncertainty can impact decisions such as which species to target during biosecurity surveillance, or whether it is better to apply resources to preventative measures at the expense of surveillance. Another source of uncertainty is inherent variation in risk components. New analytical methods are being developed to provide formal quantitative treatments of parametric uncertainty (Makowski 2013) and to address the perceived risk aversion of some biosecurity decision-makers (Yemshanov et al. 2013). Initial investigations suggest that the incorporation of a policy maker's risk perceptions adds credibility to pest risk maps, and narrows the set of geographical locations that would need to be targeted by costly inspections and public outreach activities. Methods for representing the uncertainty in spatial invasion models were demonstrated using a case study involving human-mediated dispersal of invasive forest pests in camper-transported firewood (Koch et al. 2013). This analysis was then extended to include consideration of the relative risk-aversion of decision makers who rely on risk model outputs for guidance.

Since its first meeting in 2007, the IPRMW has made significant advances in pest risk modelling and mapping methods. The meeting in Tromsø continued this tradition, with significant advances in economic model integration, a new understanding of the irreducible uncertainties in climate change forecasts and the desirability of an adaptive management framework for dealing with these uncertainties, as well as new methods for dealing with other forms of uncertainty. Clearly, more work needs to be done in the area of risk communication and the improvement of niche modelling methods to produce timely and reliable models.

Acknowledgements

We would like to thank the Co-operative Research Programme on Biological Resource Management for Sustainable Agricultural Systems (CRP) of the Organisation for Economic Co-operation and Development for sponsoring the sixth meeting of the International Pest Risk Mapping Workgroup. We especially thank Janet Schofield for her assistance in organizing the meeting, and OECD-CRP representatives Carl-Christian Schmidt, Gary Fitt, and Wayne Martindale for their participation in the meeting. We thank Bioforsk – the Norwegian Institute for Agricultural and Environmental Research – for hosting the conference and Øystein Ballari, Kari Munthe, Arne Hermansen and Erling Fløistad for their assistance with local arrangements. We thank Manuel Colunga-Garcia, David Cook, Martin Damus, Elizabeth Daugharty, Paul De Barro, Mark Ducey, Bob Douma, Dominic Eyre, Jaakko Heikkilä, Arne Hermansen, Tom Kalaris, Christer Magnuson, Amy Morey, Hazel Parry, Daniel de Rigo, Leif Sundheim, Karl Suiter, Mark Szalai and Denys Yemshanov for engaging presentations and thoughtful conversations during the conference. Lastly, we thank Roger Magarey for serving as an academic editor during the production of these proceedings.

References

Baker RHA, Benninga J, Bremmer J, Brunel S, Dupin M, Eyre D, Ilieva Z, Jarošík V, Kehlenbeck H, Kriticos DJ, Makowski D, Pergl J, Reynaud P, Robinet C, Soliman T, Van der Werf W, Worner SP (2012) A decision support scheme for mapping endangered areas in pest risk analysis. EPPO Bulletin 42: 65–73.

Baker RHA, Eyre D, Brunel S (2013) Matching methods to produce maps for pest risk analysis to resources. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 25–40. doi: 10.3897/neobiota.18.4056

Brunel S, Suffert M, Petter F, Baker R (2013) Interface between pest risk science and policy: the EPPO perspective. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models of invasive alien species in the food chain. NeoBiota 18: 9–23. doi: 10.3897/neobiota.18.4049

Caley P, Groves RH, Barker R (2008) Estimating the invasion success of introduced plants. Diversity and Distributions 14: 196–203.

Caremi G, Ciampitti M (2006) Il coleottero *Anoplophora chinensis* in Lombardia: diffusione e strategie di controllo. Atti Giornate Fitopatologiche I: 205–210.

Colunga-Garcia M, Haack RA, Magarey RD, Borchert DM (2013) Understanding trade pathways to target biosecurity surveillance. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 103–118. doi: 10.3897/neobiota.18.4019

Cook DC, Fraser RW, Paini DR, Warden AC, Lonsdale WM, De Barro PJ (2011) Biosecurity and yield improvement technologies are strategic complements in the fight against food insecurity. PLoS One 6: e26084. doi: 10.1371/journal.pone.0026084

Cook DC, Liu S, Edwards J, Villalta ON, Aurambout J-P, Kriticos DJ, Drenth A, De Barro PJ (2013) An assessment of the benefits of yellow Sigatoka (*Mycosphaerella musicola*) control in the Queensland Northern Banana Pest Quarantine Area. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 67–81. doi: 10.3897/neobiota.18.3863

EPPO (2013) PQR - EPPO database on quarantine pests (available online). www.eppo.int/DATABASES/pqr/pqr.htm

Hulme PE (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. Journal of Applied Ecology 46: 10–18. doi: 10.1111/j.1365-2664.2008.01600.x

Keller RP, Lodge DM, Finnoff DC (2007) Risk assessment for invasive species produces net bioeconomic benefits. Proceedings of the National Academy of Sciences of the United States of America 104: 203–207. doi: 10.1073/pnas.0605787104

Koch FH, Yemshanov D, Haack RA (2013) Representing uncertainty in a spatial invasion model that incorporates human-mediated dispersal. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 173–191. doi: 10.3897/neobiota.18.4016

Kriticos DJ, Leriche A, Palmer D, Cook DC, Brockerhoff EG, Stephens AEA, Watt MS (2013) Linking climate suitability, spread rates and host-impact when estimating the potential costs of invasive pests. PLoS One 8: e54861. doi: 10.1371/journal.pone.0054861

Magarey RD, Colunga-Garcia M, Fieselmann DA (2009) Plant biosecurity in the United States: Roles, responsibilities, and information needs. Bioscience 59: 875–884.

Makowski D (2013) Uncertainty and sensitivity analysis in quantitative pest risk assessments; practical rules for risk assessors. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 157–171. doi: 10.3897/neobiota.18.3993

Morey AC, Venette RC, Hutchison WD (2013) Could natural selection change the geographic range limits of light brown apple moth (Lepidoptera, Tortricidae) in North America? In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 151–156. doi: 10.3897/neobiota.18.5288

Parry HR, Sadler RJ, Kriticos DJ (2013) Practical guidelines for modelling post-entry spread in invasion ecology. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 41–66. doi: 10.3897/neobiota.18.4305

Rafoss T, Skahjem J, Johansen JA, Johannessen S, Nagothu US, Fløistad IS, Sletten A (2013) Improving pest risk assessment and management through the aid of geospatial information technology standards. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 119–130. doi: 10.3897/neobiota.18.4017

Robinet C, Kehlenbeck H, Kriticos DJ, Baker RHA, Battisti A, Brunel S, Dupin M, Eyre D, Faccoli M, Ilieva Z, Kenis M, Knight J, Reynaud P, Yart A, van der Werf W (2012) A suite of models to support the quantitative assessment of spread in pest risk analysis. PLoS One 7: e43366. doi: 10.1371/journal.pone.0043366

Schrader G, MacLeod A, Mittinty M, Brunel S, Kaminski K, Kehlenbeck H, Petter F, Baker R (2010) Enhancements of pest risk analysis techniques. Bulletin OEPP/EPPO Bulletin 40: 107-120. doi: 10.1111/j.1365-2338.2009.02360.x

Venette RC (2013) Incorporating climate change into pest risk models for forest pathogens: a role for cold stress in an era of global warming? In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 131–150. doi: 10.3897/neobiota.18.4047

Venette RC, Kriticos DJ, Magarey R, Koch F, Baker RHA, Worner S, Gómez NN, McKenney D, Dobesberger E, Yemshanov D, De Barro P, Hutchison WD, Fowler G, Kalaris T, Pedlar J (2010) Pest risk maps for invasive alien species: a roadmap for improvement. Bioscience 80: 349–362.

Worner SP, Gevrey M, Eschen R, Kenis M, Paini D, Singh S, Suiter K, Watts MJ (2013) Prioritizing the risk of plant pests by clustering methods; self-organising maps, k-means and hierarchical clustering. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 83–102. doi: 10.3897/neobiota.18.4042

Yemshanov D, Frank FH, Ducey MJ, Haack RA, Siltanen M, Wilson K (2013) Quantifying uncertainty in pest risk maps and assessments: adopting a risk-averse decision maker's perspective. In: Kriticos DJ, Venette RC (Eds) Advancing risk assessment models to address climate change, economics and uncertainty. NeoBiota 18: 193–218. doi: 10.3897/neobiota.18.4002