Session 9A

Invasive Alien Species Risk Analysis 2

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Assessing and managing the distribution of risks posed by invasive alien species

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Introduction

It is challenging to estimate the overall level of risks from invasive alien species because of diverse values held by both ecologists and the public about the natural environment and inevitable uncertainties associated with the establishment, spread and physical effects caused by exotic organisms. Priorities and responses can only be managed efficiently for known risk distributions and risk attitudes. Some financial responses, such as insurance, environmental bonds and cost recovery based on levies depend on such assessments to set appropriate payment mechanisms. Pest risk analyses try to estimate economic consequences of exotic pests according to time, location, and commercial and non-commercial values. They also seek to transform the various qualitative and quantitative estimates into a common dimension, present monetary value, which may not be in accord with the way many people perceive the problem. While this achieves an aggregate risk estimate, it does not address distribution, which may be particularly significant for invasive alien species in the natural environment.

Discussion

The Great Britain Non-Native Species Risk Analysis Panel (NNRAP) is attempting to assess the risks posed by non-native species through an analytical process developed for Defra (Defra, 2005; Baker *et al*., 2007; and see www.nonnativespecies.org), in which a template of questions on entry, establishment, spread and impact is answered and reviewed by a series of taxon-focused and generalist experts. This follows a process broadly outlined in the International Plant Protection Convention standard on plant pest risk analysis (IPPC, 2004). In addition to two rigorous and parallel scoring systems there is also a subjective overall score for the seriousness of the risk.

In assessing impacts the scheme does not attempt to cover the distribution of risks within or across sectors – so for instance a pest causing homogenous loss would be treated in the same way as one causing heterogeneous losses to the same total value. The IPPC standard, ISPM 11, includes reference to situations in which losses vary over time and place, but mainly in the context of an actively spreading pest. Pests that remain localized add to the variance of impact as well as contributing to the overall mean of impact, and may therefore need additional consideration. Variance of impacts is an important factor in deciding the need for insurance, for instance, and could influence public perception and attitude towards invasive species risks. Amongst other issues, management policy may be more complex if only particular defined locations require treatment. The situation would be even worse if locally diverse outbreaks were dynamic rather than stable. General schemes to compensate affected parties or to share responsibility or costs for monitoring or controls could be far more difficult to establish and maintain than for more widely distributed invasions. Fewer people may be motivated to be involved and it could be more difficult to establish common values for the risks faced.

The NNRAP reviews, which began in early 2007, have now covered around a dozen species, including some freshwater crustacea, aquatic weeds and vertebrate pests. The scoring systems apply equal weight to all relevant questions answered by the taxon experts. However, an inferred weighting can be seen in comparison of overall subjective scores to the calculated equal weighted scores. The questions with the greatest correlation to the overall subjective sense of how serious a problem will be are: likelihood of surviving transport; similarity of new and existing habitats (hosts and climate); rapid natural spread; and the importance of environmental damage. The least correlated questions included: volume of movement in the entry pathway; whether management differences between existing and new areas would aid establishment; difficulty in containing spread once established; and monetary impacts on producer profits, loss of export markets or reduced consumer demand. On the basis of this, so far small sample, it appears that assessments for these species are most affected by consideration of ecological factors: survival, habitat quality, natural spread, and environmental value and less by aspects of management or human involvement, such as the volume of trade, control efforts, or monetary values. Scores for the more ecological factors (entry, establishment and spread) were higher (worse) than for the predominantly economic factor of impact.

If this trend in the non-native species risk analyses continues it has implications for the way in which invasive alien species are managed. Policy measures aimed at regulating trade and imposing control measures may not be very effective. Financial mechanisms based on the monetary value of impacts and control costs may also be ineffective, where impacts are intangible and many controls are considered impractical.

Conclusions

The way in which invasive alien species risk assessments are designed pushes management options into particular paths. The inclusion or not of particular temporal or spatial components of impact can affect the options for management or for financial mechanisms to encourage prevention or control. Also, at a technical level the respective emphases on ecological and economic factors in pest risk analyses conducted on environmental and agricultural pests may lead to very different management policies.

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Development of a Pest Risk Analysis for *Tilletia indica*, the cause of Karnal bunt of wheat

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Tilletia indica, the fungus which causes Karnal bunt of wheat, is listed as a I/AI quarantine pest for the European Union (EU). This listing was supported by a UK Pest Risk Analysis (PRA) that considered the potential for the pathogen to enter, establish and cause unacceptable impacts in the UK/EU. This followed the first reports of *T. indica* in the USA in 1996 which provided a significant new origin on an existing trade pathway for entry into Europe. Since 1996, there have been several reported or suspected interceptions of *T. indica* on wheat imported from India into Poland and the UK, from Mexico into Italy and from the USA into Greece.

A recently-completed four year, nine partner institute research project (European Commission (EC) Fifth Framework Project QLK5-1999-01554: 'Risks associated with *Tilletia indica*, the newly-listed EU quarantine pathogen, the cause of Karnal bunt of wheat' produced a revised PRA (http://karnalpublic.pestrisk.net/) for the EU. This new PRA strongly supports the view that *T. indica* has the potential to enter, establish and cause unacceptable economic impacts throughout much of the wheat-growing area of the EU.

T. indica is a damaging, floret-infecting smut pathogen of wheat (*Triticum aestivum* and *Triticum durum*) and triticale (×*Triticosecale*) causing the disease Karnal or partial bunt. Records on triticale are rare and the pathogen has not been reported in Europe. Control is difficult because the pathogen is not truly systemic and therefore cannot be controlled through seed treatments. Cultivar resistance is the main mechanism for control in currently affected countries (parts of Asia, Mexico, South Africa, Brazil and the USA).

The full life cycle of the pathogen has been described in many publications and in the EU PRA. In order to understand the work of the EU Project it is necessary to grasp the key aspects of the life cycle in the countries where it currently occurs:

The pathogen survives in the soil for up to five years as teliospores. Fresh teliospores are reported to have a period of dormancy before they will germinate; only those on or very near to the soil surface break dormancy. Germination of teliospores ultimately leads to the production of infective sporidia which can multiply on plant or other surfaces. If the infective sporidia are deposited onto the flag leaf of wheat and washed into the boot cavity, or deposited directly on the emerging ear of wheat plants at the susceptible stage for infection (broadly defined as at the '*heading*' stage for simplicity) under suitable climatic conditions, the pathogen can infect the developing grain through the glumes. Low temperatures and high humidity are necessary at flowering time for infection to occur, while dry weather, high temperatures and bright sunshine are unfavourable. Successful infection of wheat leads to production of teliospores which are restricted to the pericarp by the highly lignified external seed coat. Infected seeds are usually only partially colonised and within a wheat ear not all grains necessarily become infected. Harvesting disseminates the teliospores.

Because data were not available on the behaviour of the pathogen in the UK/ EU, such as teliospore survival, dormancy, germination and host susceptibility, the earlier UK PRAs formulated conclusions from the existing biological information in the available literature. Subsequently, there has been much international debate as to whether *T. indica* poses a risk to wheat production and whether it should be listed as a quarantine organism by any country. Some contend that *T. indica* does not have significant effects on yield or quality and that its main effect is in the loss of export markets for countries where it occurs. In addition, it has been surmised by some scientists that the pathogen will not be able to complete its life cycle on wheat under European conditions.

The EU Project aimed to produce a more accurate analysis of risk to the EU based upon experimentation. The likelihood of the pathogen completing its life cycle and establishing in wheat crops in the EU depends on:

a) A suitable pathway between origin and destination; b) the presence of susceptible host crops at the destination; c) the ability of the pathogen to survive between crops; and d) the ability of the over-wintering phase of the pathogen (the teliospores) to produce infective sporidia at the vulnerable growth stages for infection and under appropriate conditions to infect and cause disease, thus perpetuating the pathogen.

In developing a new PRA for the EU for *T. indica* the EU Project investigated stages b), c), and d) by experimental work and a review of the literature, with stage a) being completed by an analysis of imports from countries where *T. indica* occurs along with documented evidence of interceptions of *T. indica* over the past 10 years.

A key component of the risk of establishment of *T. indica* in the wheat-growing areas of the EU has been mapped by combining crop phenology models for bread and durum wheat with a disease model, the Humid Thermal Index, interpreting the results in the light of the experimental findings of the Project. The phenological stages at risk of infection for a range of EU bread and durum wheat cultivars was determined as well as their relative susceptibility to *T. indica*. The majority were susceptible as there is no bred resistance against *T. indica* in Europe. Teliospores were found to survive for at least three years under containment in field soils in Italy, Norway and the UK. A proportion of one year old teliospores subjected to soil moisture above field capacity and exposed to temperature regimes for Hungary, Italy, Norway and the UK from simulated planting to anthesis under European climatic conditions were found to remain viable and capable of germination during the critical window for infection of the wheat crop. The potential socio-economic impact of *T. indica* in the EU arising from a small and a large outbreak scenario in a wheat-growing area of the UK has been determined. Yield losses will be relatively small, whereas quality losses arising from downgrading of milling wheat to feed wheat under Quality Assurance schemes, as well as the potential for export losses arising from other countries import requirements are likely to be significant.

Acknowledgements

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Management of an invasive alien species, the Mexican rice borer (Lepidoptera: Crambidae) on sugarcane and rice

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Introduction and monitoring

The Mexican rice borer, *Eoreuma loftini* (Dyar), is the most seriously damaging stalk borer in sugarcane. It was first detected in the Lower Rio Grande Valley of Texas in 1980, most likely as an immigrant from the Sinaloa area on the west coast of Mexico (Reay-Jones *et al.*, 2007a). The devastation of the Texas sugarcane crop quickly exceeded 50% on many farms causing some fields not to be harvested. By the end of the 1980s, the range had extended well into the Gulf coast rice area causing substantial yield losses. The behavioural characteristics of *E. loftini* render the insect much less susceptible to parasitoids and insecticides than other stalk borers in sugarcane. Enhanced by plant stress, moth oviposition occurs in cryptic sites on dried leaves, and emerging larvae rapidly disperse to mine and bore into more succulent plant parts creating frass-packed tunnels. Our multi-agency, multi-state research and extension team was assembled to monitor and forecast *E. loftini* movement through Texas towards Louisiana, establish quarantines, and develop management strategies to mitigate losses with the eventual goal of reducing area-wide populations. Studies showed a continuous range expansion of 23km/yr from 1980 to 2005, but only 16.5km/yr from 2000 to 2005 (Reay-Jones *et al.*, 2007b). During this more recent period, *E. loftini* encountered substantial populations of another invader, *Solenopsis invicta* Buren, the red imported fire ant; however, the role of arthropod predators on *E. loftini* has not been studied.

Cultivar/plant stress/insecticide management

Studies in the greenhouse at Weslaco, Texas comparing resistant and susceptible sugarcane and rice cultivars showed that stressed plants were more than twice as attractive for *E. loftini* oviposition. This attraction was associated with the accumulation of several foliar free amino acids essential for insect growth and development (Reay-Jones *et al.*, 2007a). Field studies further showed that irrigation reduced injury by a factor of 2.5 in both susceptible (LCP 85-384) and resistant (HoCP 85-845) cultivars. Additionally, yield losses were reduced from 70% to less than 10% when a balanced combination of resistant cultivars, irrigation, and timely applications of biorational insecticides was used (Reay-Jones *et al.*, 2005). Plant resistance studies in rice and sugarcane have identified the presence of resistant germplasm (HoCP 85-845 and CP 70-321 in sugarcane; XL-7 and XL-8 in rice hybrid cultivars), both from a perspective of minimizing yield reduction as well as potentially reducing the build-up of area-wide pest populations (Reay-Jones *et al.*, 2005, Way *et al.*, 2006). However, none of the newer high yielding sugarcane cultivars have similar levels of resistance (Reay-Jones *et al.*, 2005).

Alternate hosts

Replicated non-crop host studies in 2006 indicated that, of five prominent weed hosts attractive to *E. loftini*, Johnson grass (*Sorghum halepense)*, Amazon sprangletop (*Leptochloa panicoides*), broadleaf signal grass (*Urochloa platyphylla*), Vasey grass (*Paspalum urvillei*), and barnyard grass (*Echinochloa crus-galli*), more than 80% of the plants showed either feeding signs or boring. However, all life stages were found only in *S. halepense*, *L. panicoides* and *P. urvillei*. Transects conducted in the main Texas rice area in the spring of 2007 showed that rice plants were still too small to host stem borers. *E. loftini* densities during May 22-27 in the lower (Jackson County), middle (Chambers County), and upper (Jefferson County) Texas rice area field margins were 1.17, 0.84, and 0.22 third instar or larger per m^2. *S. halepense* stems harboured 28.6%, 22.6% and 64.3% of *E. loftini* immatures recovered in upper, middle, and lower areas, respectively. *P. urvillei* harboured 57.1%, 61.3%, and 35.7% of *E. loftini* infestation for the three counties in their respective order. Preliminary information indicates that the relative importance of the non-crop hosts may change at different times of the year.

Forecasting

It is predicted that the impact of this invasive alien species in the semi-tropical sugarcane/rice management system of Louisiana can be reduced by (i) 29% with irrigation, (ii) 46% with up to four applications (in addition to the one currently in use) of biorational insecticides, and (iii) 24% with resistant cultivars. Combinations of management anticipate a 45% reduction with resistant cultivars and insecticides and a 59% reduction from all three. With a projected yield loss of up to $220 million in Louisiana, a balanced IPM approach from a proactive programme using resistant cultivars, minimizing plant stress with irrigation, and timely biorational insecticidal applications is forecasted to save $130 million per annum. In addition to these management strategies, the proportion of the different phenological stages of the graminaceous crop and non-cultivated hosts will also influence the success of IPM. An area-wide systems analysis component will help forecast pest reductions. This programme has received extensive funding from United States Department of Agriculture competitive grants and stakeholder support.

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The wheat curl mite, *Aceria tosichella* Keifer, and associated viruses, Wheat Streak Mosaic Virus and High Plain Virus - the risks posed to cereal crops in South America

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Aceria tosichella Keifer, an eriophyid mite known as the Wheat Curl Mite (WCM), was described from wheat in 1969. Yield losses in wheat and corn crops due to direct damage have been significant. Furthermore, the main damage caused by *A. tosichella* is indirect due to transmission of Wheat Streak Mosaic Virus (WSMV) and High Plain Virus (HPV), the causal agents of cereal diseases. WCM and WSMV are widespread and have been reported in wheat production areas around the world, while HPV is restricted to North America. The records of both WCM and WSMV in South America are recent. WSMV was first reported in 2002 infecting wheat fields in the Province of Córdoba, Argentina (Truol *et al.*, 2004). Shortly afterwards, the vector WCM was found for the first time in WSMV-infected wheat fields in the same country (Navia *et al.*, 2006). These recent reports have highlighted the potential risk posed by WCM, WSMV, and HPV to South America. It has also raised the need to conduct a Pest Risk Analysis (PRA) to identify pathways, define endangered areas and select management options to minimize the impact of these viruses in the PRA area. A PRA was conducted following FAO standards (ISPM 2 and 11). The potential for establishment was evaluated using CLIMEX and information on host availability.

The quarantine pest criteria were satisfied for WCM, WSMV, and HPV. For many years *A. tosichella* was misidentified as *Aceria tulipae* (Keifer), a pest of tulip bulbs. However, it has been showed that the eriophyid on Liliaceae was different from that on wheat and Keifer (1969) described the wheat species as *A. tosichella.*

Probability of introduction (entry and establishment) and spread

There are four main pathways: a) natural movement (wind is key for WCM; *A. tosichella* is present in Argentina, and plays the main role in WSMV and HPV spread); b) movement of vehicles and agricultural machines (winter cereal crop areas infested with WCM & WSMV in Argentine are contiguous with crop areas in Brazil and Uruguay and cross-border movement of vehicles and machines often occurs); c) trade in cereal seeds from countries where WCM, WSMV and HPV are present (this is increasing and these viruses can be transmitted through seeds at low rates (≅ 0.05%) and there are indications that the vectors of WCM can survive for short periods associated with seeds and may infest new fields) and d) trade in potted plants contaminated with grasses infested with the mites or viruses.

The probability of WCM, WSMV and HPV establishment in South America is high, considering the availability of hosts, climatic conditions and the vector's reproductive potential. The main host of WCM is wheat, but populations can also develop on sorghum, barley, corn, oat, rye, pearl millet and more than one hundred grass species. Winter cereals are widely cultivated in the southern part of South America. The Pampa biome occupies contiguous areas in South Brazil, Argentine and Uruguay and is characterized by open areas where grasses are predominant. Several of these grasses can act as alternate hosts to WCM and WSMV. Corn and grasses can be found throughout the PRA area. WCM can survive in a wide range of temperatures (-13ºC to 37ºC) similar to those in the USA where populations reach high levels (Harvey *et al.*, 2002). CLIMEX analysis has indicated suitable climatic conditions for the establishment of WCM in South America, with medium (50) to high (75) ecoclimatic indexes in the main winter cereal areas. WCM has a high reproductive potential under favorable conditions, with a short life cycle (≅ eight days) and a high oviposition rate (≅ 25 eggs/female) (Jeppson *et al.*, 1975).

Potential economic consequences

Yield losses in wheat crops due to WCM can reach 30% (Harvey *et al.*, 2002) and due to WCM and WSMV together have reached 100% in Poland (Jezewska, 2000). Yield losses from HPV can also be significant. Chemical control of the vector is unsatisfactory. Winter cereal crops have a high economic importance in the southern part of South America.

Conclusions

The PRA shows that WCM, WSMV and HPV have a high potential for introduction, spread and economic consequences in South America. The highest risk areas were defined as those of the southern part of South America, where WCM and WSMV have been recorded and where winter cereal crops are of major importance. Measures to minimize the risk posed by these viruses and their vectors to South America should be applied. For consignments, regulations to control the trade in cereal and grass seeds (post-entry quarantine or certification) are required as well as on the movement of vehicles/machines from infested to uninfested areas. For infested areas, reductions in infestations and spread to surrounding areas are needed. Host resistance is the most promising method to manage the viruses and their vectors. Cultural measures can help. Research should be directed to alternate hosts in the infested area and to evaluate the susceptibility of varieties to WCM, WSMV and HPV to define control strategies to prevent the spread of these viruses in the endangered areas.

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Bio-economic modeling for optimal pest risk management: an application to *Diabrotica virgifera virgifera* in England

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Introduction

Diabrotica virgifera virgifera (Dvv) is an important pest of maize whose larvae attack the roots leading to a decrease of nutrient intake and growth of the plant. Dvv was first detected in Europe near Belgrade, Yugoslavia in 1992. Since then, it has spread through Europe, reaching Paris, France in 2002. It was first detected in the south east of England in 2003 (MacLeod *et al*., 2003).

As a member of the EC, the UK must implement the measures listed in the EC legislation which aim to prevent the spread of *Diabrotica virgifera virgifera*. These measures include restrictions on maize production within defined buffer areas surrounding infested fields for two years. MacLeod *et al.* (2005) carried out a cost benefit analysis on the implementation of these measures. The results showed that EC measures were not economically justified since the impacts of the pest on maize growers without measures were lower than the costs of the measures themselves. The UK government is currently carrying out a consultation where stakeholders have been asked to provide a response to various questions and select one of three options for dealing with Dvv. This paper describes the use of bio-economic modelling to determine the optimum amount of effort to spend on detection and control of the pest to minimize costs and impacts for a given time horizon.

Methodology

Considerable progress has been made in recent years in modelling spread and impacts of invasive alien species (e.g. Waage *et al*., 2005; Heikkila & Peltola, 2004). However, the spatial spread of these species is not included explicitly in most of these frameworks. Alternatively, other bottom-up approaches such as Individual Based Models and Spatial Stochastic Simulation, which incorporate population dynamics and explicit spatial spread are being employed (e.g. Gilligan *et al*., 2004; Breukers *et al*., 2006). Although they allow for the inclusion of the biology of the invasive alien species and policy management details, optimization of the control and detection strategies is not performed.

A spatially explicit stochastic bio-economic risk model is proposed to explore the optimal risk minimizing policy when facing the invasion of Dvv in England. Risk is quantified as the net present value (NPV) of direct costs and impacts due to Dvv. Genetic algorithms are used to obtain an optimum set of detection and control efforts.

Model description

The model is composed of:

- A stochastic phenological sub-model, based on Julian date, which links population dynamics and spatial spread. The processes modelled are: maize phenology, egg mortality, adult emergence and mortality, mating, oviposition and dispersal.
- A sub-model that implements the management options and their effectiveness for the government and the farmers and calculates the costs and impacts derived: detection efforts (location and trap density), control efforts (radius of buffer zones, rotation practice and pesticide usage).
- A simulation-optimization module: Genetic algorithms are used to generate a population of sets of possible detection and control levels of effort for each year (chromosomes). The bio-economic model is simulated for each chromosome yielding a distribution of the NPV of costs and impacts. The chromosomes with lowest NPV mean and variance are selected, recombined and mutated to obtain a new population. After several iterations the best solution is chosen.

Conclusions

Plant health policy makers are in need of empirically applicable tools to identify the optimal policy that minimizes the risk posed by invasive species. A simulation-optimization module combined with stochastic spatial spread models might assist in the exploration of optimal solutions. However, there are some drawbacks to be accounted for: the models are difficult to interpret due to the large number of parameters, they are data hungry and there is no guarantee that the optimum reached is a global optimum. The drawbacks highlight the importance of performing sensitivity analysis for model interpretation and the need for available datasets on past invasions.

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