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Future trends
Chapter 6

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Introduction

The data supplied in the preceding chapters clearly confirm that the ever-increasing rate of arthropod invasions can be attributed to the upward trend in international freight transport, to passenger travel and, more generally, to globalization. The role that humans play in pest introductions as well as their likely dispersion is obvious and consequently there are strong geographic associations between higher numbers of alien pest occurrences and urban areas as already been noted by Colunga- Garcia et al. (2010) and Pyšek et al. (2010). Another important source of introduced arthropods comes from intentional releases, especially of alien hymenopterans, for the purpose of biological control programs. Invasive alien species threaten forests, agriculture, human and animal health. While economic losses attributed to exotic plant pests are poorly estimated in Europe (but see Vilá et al. 2009), they have been estimated at US $37.1 billion per year in U.S. agricultural and forest ecosystems (Pimentel et al. 2005). Invasive species can also cause irreversible changes to ecosystems, but there is no estimate of the full economic costs of their effects on ecosystems and on the human population that is dependent on them.

There is little chance that biological exchanges over borders may decrease in the next decades. Rather, the number of arthropod invasions will continue to grow, threatening economy and ecosystems globally. More and more people or agricultural commodities will cross borders, increasing the likelihood that arthropods will be translocated from one area of the world to another (Liebhold et al. 2006). In Europe, monitoring, detection of arthropod invasion mostly relies on poorly connected structures hosted by different countries, using non-interoperable tools that imply months if not years to detect the data for characterizing and managing new aliens. Such delays are unacceptable in cases where immediate action has to be taken. Globalization of biological exchanges should be met by globalization of the tools used to predict, detect and manage future bio-invasions.

Until now, no integrated biosecurity tool has been developed for arthropods (this is also true for all other bioinvaders). An ideal web-based integrated tool would encompass different interlinked modules to:

1. Identify the most likely future arthropod invaders
2. Provide generic and accurate identification tools
3. Compile biological information on these species
4. Predict where such aliens might potentially thrive, and their future distributions in a warmer climate or under
5. Estimate the full costs of the most likely alien arthropods
6. Finally, quantify and map risks associated with these non-indigenous species and prioritize them

Identify the most likely future arthropod invaders

Determining which species to target for development of detection tools, distributional area and risk estimation is not an easy task. However, it is increasingly important to identify potential invasive species prior to their introduction and establishment. This may help to reduce the likelihood of alien invasions and better define management scenarios. Only few studies have been published that help to select the most likely future arthropod invaders to Europe within the many thousands of potential bioinvader arthropods.

Worner and Gevrey (2006) recently developed an original and efficient method to identify potential invasive insects that should be subject to more detailed risk assessments. They based their study on 1) the assumptions that geographical areas with similar pest assemblages share similar biotic and abiotic conditions, 2) a comprehensive database of the global presence or absence of pests. They used artificial neural network analysis to propose a list of species that are ranked according to the risks they pose. It is important to develop further methods of this kind, to implement databases and make them easily accessible through web interfaces. The development of integrated European projects such as PRATIQUE (Enhancements of Pest Risk Analysis Techniques) is a step towards this goal (Baker et al. 2009).

The search for taxa that are particularly invasive worldwide may also benefit from phylogenetic or hierarchical clustering studies. Recent work on the hierarchical patterns in biological invasions has produced results that show both clustering as well as overdispersion of certain life-history traits that are associated with invasion success (e.g. reproductive traits) (Lambdon 2008, Procheş et al. 2008). In some cases, traits associated with invasiveness observed in a set of taxa tend to be more similar in closely related taxa, a phenomenon supposed to be linked to the conservation of ecological niches in closely related species. This observation provides promise that analysing these traits in a strict phylogenetic framework may help to predict better the most likely potential invasive species. However, few phylogenetic analyses of invasiveness have been proposed for arthropods. Such analyses may benefit from the development of DNA barcoding applied to multiple genes (see below) that could help in particular to reconstruct phylogenies within species complexes.

Another approach, for phytophagous invaders at least, could be to identify and establish 'sentinel' host plants in not yet invaded regions, to evaluate the impact of indigenous potential invaders in source regions should they become introduced as exotics at a later date (Britton et al. 2009). This is currently carried out in China for potential pests of European tree species (Roques et al. 2009; Roques 2010).

Provide generic and accurate identification tools

In the last few years, the application of molecular diagnostic methods have greatly accelerated. At the same time, DNA barcoding based on the mtDNA COI gene as well as nuclear markers, have shown great potential to improve the detection of invasive species. DNA barcoding has been used to detect pests efficiently (Armstrong 2010) and may also enable the flagging of invasive species trapped during biodiversity surveys (deWaard et al. 2009). Consequently, DNA barcoding many provide an efficient new tool in the biosurveillance armoury for detection of alien species. Next generation sequencing technologies (e.g. pyro and single-molecule sequencing) may further help to reduce costs and to increase both speed and quantity of molecular detection of arthropod species. In the near future, it is likely that most identifications of arthropods will proceed through comparison of multiple gene sequences to an online global library whose quality is vastly enhanced by taxonomic knowledge. Consequently, developing a worldwide DNA library of barcodes of the most likely invasive species, including all pests and their natural enemies that could be used in biological control project, is of strategic importance to enhance our ability to detect and manage invasive populations. Such a comprehensive database coupled to real time analysis of trapping may help to detect species even at low densities, long before they become established. Developing such an integrated detection toolkit may clearly improve both biosurveillance and biosecurity in the future.

Compile biological information on these species

Any introduced arthropod has an area of origin where it could already be a pest and where it may already have been studied and its biology described. Available lists of invasive species (NISIC, DAISIE, NOBANIS, etc) do not always provide an up-to-date compilation of all available biological information and so may be of limited use for improving future management or predicting spread. To infer better the potential distribution, costs and risks associated with the most likely arthropod invaders, we need to compile all available information on their biology and life-history traits, both in their native and, when possible, in their invaded ranges (Broennimann and Guisan 2008).

Predict where such aliens might potentially thrive

Predicting which arthropods can invade where is critical for their management, and ultimately in limiting the negative impacts of bioinvaders. Niche-based models are widely used to predict potential distributions of invasive insects, mites or other arthropods. These methods use observations either from the invaded or the native range of an invasive species to predict the potential range in the area of introduction. However, despite its increasing use, environmental niche modelling is based on fundamental assumptions that are easily violated and lead to incorrect prediction of the full extent of biological invasions. For example, the alien species may not occupy all suitable habitats when its ecological requirements have changed during the invasion process. Furthermore, predictions are sensitive not only to occurrence and environmental data, but also to the methods used to calibrate the models. These approaches have also been criticised for their lack of consideration of species interactions (natural enemies), dispersal, availability and synchrony with the host plant or host. However, unless we can accurately parameterize the relationship between a species and its environment, no single model predicting the invasive range is likely to represent reality. This task may prove to be not feasible for most arthropods, for which knowledge of their distribution and interactions is as yet fragmentary if not rudimentary. Consequently, multiple modelling methods are required to provide better prediction and error estimates for arthropod distributional areas, especially when based on poor observation datasets.

Moreover, identification of consensus areas of distributional estimate consistency using these different methods may help to produce more reliable estimates of species' potential distributions (Roura-Pascual et al. 2009). A recent study also showed that using predictions based on both abiotic variables (usually climate) and biotic ones (for insect or host assemblage) may be more accurate than predictions based on climatic factors alone (Watts and Worner 2008). Consequently, in an effort to improve the management of invasive arthropods to Europe, we need to 1) develop a comprehenive database of life-history traits and worldwide occurrences of invasive arthropods; 2) build or implement a system providing the most accurate projections based on this database; 3) develop free access tools that implement all these methods; 4) allocate research investment to such a task that will strongly improve both predictive methodology and knowledge of the most likely invasive arthropods and their natural enemies.

Estimate the full costs of the most likely alien arthropods

Until now few general models of the economic costs of biological invasion have been developed. The goal of such models is to develop effective management programs, that seek both to estimate current or future impacts of alien invasive species, and to prevent, control, or mitigate their biological invasion. Estimates of the full costs of biological invasions (i.e., beyond direct damages or control costs) are still rare, since the costs of such complex problems are hard to calculate. Vilá et al. (2009) provided a first continent-wide assessment of impacts on ecosystem services by all major alien taxa, including invertebrates, in terrestrial, freshwater, and marine environments. They tried to compare how alien species from the different taxonomic groups affect "supporting", "provisioning", "regulating", and "cultural" services and interfere with human well-being. However, many of these components are difficult if not impossible to quantify, such as the impacts of alien invasive species on biodiversity, ecosystem functions, human health and other indirect costs, for instance the impacts themselves of control measures. Furthermore, estimating the costs of an invasive arthropod that threatens biodiversity rather than agricultural production is particularly challenging. Precise economic costs associated with the most ecologically damaging alien species are simply not available. Consequently, we need to develop analysis of the ecological impact of introduced arthropods, especially those that are intentionally introduced for biological control purposes (Kenis et al. 2009). This is particularly important if we want in the near future to decrease our intake of pesticides and promote biological control.

Economic applications are also essential to provide more accurate and comprehensive assessments of the benefits and costs of control alternatives that can increase the effectiveness and efficiency of publicly funded programs. There is also a need for the development of better databases and modelling approaches to estimate better damages from invasive species and their control costs. Further research should also be conducted to narrow the uncertainty of the estimates. Work in these areas should help improve invasive species policy and achieve a more effective use of resources. Future cost estimates should be computed, within a real-time estimation procedure, using updated infestation measuresand regional input-output economic data.

Quantify and map risks associated with these non-indigenous species

In the case of invasive species, risk can be defined as the probability that an invader will become established in an area along with some evaluation of the economic consequences of this event. Traditionally, quantifying risks associated with arthropod invasive species require studies on 1) the process of introduction, dispersion and the pathways used; and 2) the economic consequences of spread in recently contaminated areas (Yemshanov et al. 2009). However - as emphasized above - biology, life history and full costs of most potential invasive arthropods are still poorly known and most risk assessment studies rely on expert judgment or rudimentary analytical approaches.

Here again the need of integrated tools is overwhelming to produce efficient risk assessment for policy-makers.

Toward a global european tool

Already 1590 alien arthropod species have been introduced and established in Europe and increased efforts are needed to minimize the risk of introductions and spread of additional species in the future.

Europe is poorly structured to detect rapidly, efficiently manage and control invasive arthropod species. In face of this global problem, European countries mostly have responded through nation-specific strategies and disconnected or weakly integrated projects. This disappointing situation must be changed. Faced with increasing economic pressure and despite already large grants in the past, the European Community has to invest more on invasive species prevention, detection and management.

One of the key elements is the need to establish a European early warning system and rapid response framework (Genovesi 2009). In the present situation where ornamental trade is a dominant pathway for invasion by phytophagous arthropods, a more thorough survey of parks, gardens and nurseries may function as such an early warning system. This could also be accompanied by the installation of more sophisticated quarantine and control measures at invasion 'hubs' for the ornamental plant trade (e.g. in the Netherlands) (Roques 2010).

While there is also a clear need for further research to understand better the ecological and genetic processes that facilitate the introduction and subsequent dispersion of exotic arthropods in agricultural and forest ecosystems (Facon et al. 2006), additional challenges include the improvement of Europe-wide biosurveillance and prediction tools. Clearly, the management of arthropod invasions will be enhanced by the integration and future improvement of already existing but widely dispersed tools. Researchers have to develop prototype Internet based systems to detect and manage better new arthropod invasions, and these tools should be reinforced through international collaborations. We are dealing with an outstanding global problem.

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