TOOLS FOR ENVIRONMENTAL RISK ASSESSMENT OF INVERTEBRATE BIOLOGICAL CONTROL AGENTS: A FULL AND QUICK SCAN METHOD

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ABSTRACT

The deliberate or accidental introduction of species from their native ranges to new environments is a major threat to biological diversity. Biological control is both an important management tool for controlling threats to agriculture an the environment as well as - in rare cases - a potential threat to the environment itself. The newly adopted International Standard for Phytosanitary Measures No. 3 (ISPM3) offers a framework for risk assessment and focuses specifically on the shipment, import, export and release of biological control agents. Guidelines for information requirements of exotic natural enemies and methods for risk assessments are currently in development. The major challenge in developing risk assessment methodologies is to develop protocols and guidelines that will prevent serious mistakes through import and release of potentially harmful exotics, while at the same time still allowing safe forms of biological control to proceed. We expect that a risk assessment methodology for biological control agents will integrate information on the potential of an agent to establish, its abilities to disperse, its host range, and its direct and indirect effects on non-targets. In this presentation, we first propose a comprehensive risk evaluation method (full scan) for new natural enemies and, second, a quick scan method for natural enemies already in use. The outcome of our evaluation of150 biological control agents, commercially available in northwest Europe, will be discussed.

INTRODUCTION

Measures to protect the environment, and people in it, have involved a wide variety of approaches and underlying principles (Calow 1998). Risks posed to human and animal health and to ecosystems from chemicals, genetically modified organisms and from biological introductions are widely assessed, based on scientific methods and procedures (Simberloff and Alexander 1998). Risk assessment is a tool that can be used to support exclusion of invasive species as well as to assess the potential impact of those that have become established. Risk assessment can be used in decision-making to help determine if action should be taken, and, if so, what kind (Wittenberg and Cock 2001). There is, however, still a great need for research on risk assessment procedures and methods to evaluate biological introductions. Although regulations for biological control agents of weeds have been more strict than those of pests, risk assessments have not always been accurate enough to prevent ecological side effects on nontarget hosts (Louda *et al.* 2003). Invertebrate biological control agents (IBCAs) are applied across the world to control pest species in agricultural, urban and natural ecosystems. In the past 100 years many exotic natural enemies have been imported, mass-reared and released as biological control agents for pest control in areas outside their origin. In few cases, negative effects of these releases have been reported, mostly of generalist predators, often vertebrates (Lynch and Thomas 2000; van Lenteren *et al.* 2005). The current popularity of biological control may, however, result in problems: an increasing number of projects will be executed by persons not trained in identification, evaluation and release of biological control agents, an increasing number of agents and products will become available for the control of pest organisms, and the internet increasingly lowers access, sales and demands for public use.

The International Plant Protection Convention (Rome 1951; IPPC 1997) and the Convention of Biological Diversity (CBD 1992) are the two conventions which are most relevant for biological introductions of economical and environmental concern. Obligations on contracting parties include development of scientifically based risk assessment procedures and methods. Whereas for plant pests there is a long history of such procedures and measures, for introductions of organisms of environmental concern these are relatively new (IPPC 2004). Since 1992 more and more countries have put legislation in place concerning biological introductions that threaten species habitats and biological diversity. This has increased the international interest in risk assessment as a legislative tool. The FAO Code of Conduct (FAO 1996) has brought about important changes in the regulation of IBCAs in developed (EPPO 1999; 2000; NAPPO 2001) and developing countries (Kairo *et al.* 2003), but these were still largely non-legislative instruments. The recently revised ISPM3 (IPPC 2005) includes assessment of environmental risks and offers contracting parties a minimal standard when putting regulation in place. In addition, its recognition by the WTO-SPS agreement, provides that ISPM3 will be an international binding instrument that offers a format for trade in and release of biological control agents (WTO 1994). Except that there is a need for generic risk assessment schemes for all types of biological introductions, there is a specific need for schemes tailored for biological control and other beneficial organisms. Here we summarize new tools for assessing environmental risks of biological control agents that have been developed recently (van Lenteren *et al.* 2005; van Lenteren and Loomans 2005), consisting of a full and a quick scan analysis.

ECOLOGICAL DETERMINANTS

Various qualitative methods are used to generate a cumulative risk index for potential quarantine pests by adding qualitative or quantitative scores, such as low, medium, high (APHIS 2000; NRC 2002), assign numerical scores in a questionnaire (EPPO 1997; MacLeod and Baker 2003) or using successive matrices (Biosecurity Australia 2001; Murray 2003). Similarly quantitative risk assessment models have been developed for weed introductions (Pheloung *et al.* 1999; Williams and Newfield 2002) and their biological control agents (Wapshere 1974). Risk assessment procedures for inoculative and inundative biological pest control need to be more tailored to its specific requirements and needs, and support a well-balanced decision making process, properly weighting its principal beneficial and potential detrimental impact (Sheppard *et al.* 2005). Environmental risk assessment should preferably be placed in a general framework for regulation of import and release of biological control agents (OECD 2004), including

- characterization of the agent (taxonomic, biological characteristics),
- risks posed to human and animal health,
- efficacy, quality control and benefits of use, and
- environmental risks.

The latter category, assessment and analysis of environmental risks, demands integration of many aspects of their biology, as well as information on ecological interactions identified above. The risk posed by introduced species, whether invasive and of ecological or of economic concern, including biological control agents (Simberloff and Alexander 1998; van Lenteren *et al.* 2003), is determined by the following ecological factors:

- the potential of an agent to establish in its novel environment,
- its abilities to disperse,
- its host range, and
- its direct and indirect effects on nontarget species.

Any risk-assessment of IBCAs should include information on these factors. The first three factors mainly determine to what extent the intrinsic attributes of a species determine its environmental impact (direct and indirect effects). The intrinsic factors of successful invaders and of successful biological control agents partly have common denominators. It is a critical issue to develop risk assessment schemes that recognize these potential conflicts of interest and distinguish keystone values subsequently.

ENVIRONMENTAL RISK ASSESSMENT TOOLS

The following account is largely summarized from van Lenteren and Loomans (2005) and van Lenteren *et al.* (2005), with additional references. In contrast to most PRAs for pests of phytosanitary importance, pathway analysis for biological control agents is of secondary importance as they are mostly deliberately introduced. Performing an ecological risk assessment prior to first introduction is then essential as addressed in ISPM3, thus avoiding undesired establishment of an IBCA. Nevertheless, potential IBCAs also are entering a country by range expansion or by accident as stowaways on infested plants and hosts and are discovered when they already passed ports of entry. When there is no legal justification for eradication measures, as for most IBCAs which are not of phytosanitary importance, regulation of an exotic IBCA present but still contained in a country, can be covered indirectly by performing a risk assessment prior to its commercial release (IPPC 2005).

Depending on the stage of the regulatory process, either a comprehensive full scan can be used as a tool for risk assessment, or a quick scan, based on the same environmental determinants as indicated above. A quick scan is an initial screening of available information for known nontarget impact to exist or to expect, revealing any invalid, missing or incorrect information. It is supposedly fast, less costly than a full scan, but mostly indicative and qualitative in its results. A full scan, on the other hand, includes all these elements as well, but is more thorough, comprehensive, evaluating and extrapolating potential hazards, including the use of generated data and performing a complete risk-analysis.

FULL SCAN

Any comprehensive environmental risk assessment will first identify the hazards (intended as potential to cause harm), subsequently estimate the risk (intended as the likelihood of that potential being realized) of environmental importance (intended to refer to the routes of exposure for both humans and animals) (Calow 1998). Risk assessment includes a risk identification and evaluation procedure and should be closely tied to risk management, risk-cost-benefit analysis and risk communication. Van Lenteren *et al.* (2003) proposed a first general framework of the first step, a risk assessment methodology for import and release of inundative biological control agents. Their method integrates and indexes the five ecological determinants mentioned above. A numerical value (1-5) is assigned to the likelihood (L) and magnitude (M) of each of the five elements to quantify risks. The overall ecological risk index (ERI) was based on multiplying values for L and M for each element and adding the values of all five elements. The minimum score was thus 5 (5 * 1x1) and the maximum score 125 (5 * 5x5). Thirty-one cases of natural enemy introductions where thus analyzed in retrospect. Although a clear categorization was obtained with an ERI ranging from 7-105, we encountered some practical and intrinsic drawbacks: calculation and evaluation of such a cumulative ERI would require a substantial amount of information and experimentation before any evaluation can be made, and when these are not available (mis)interpretation could lead to manipulation in decision making. In addition, the ecological elements are not independent and not equal in importance, they should not be rated equally and cannot be indexed in a cumulative way as we previously did. To optimize the process and avoid unnecessary research efforts and costs, we suggest a more advanced, stepwise risk assessment procedure (van Lenteren and Loomans 2005).

In contrast to the procedure of the cumulative risk assessment method described above, the decision to release is based on a tiered approach of each of the ecological determinants, using successive individual matrices of L*M matrix as indicated before. Prevention of entry and establishment is the first and most cost-effective line of defense against biological introductions, such as plant pests or other invasive species (Baker *et al*. 2005; Wittenberg and Cock 2001). Establishment is therefore considered as the first factor in line. When establishment (survival, reproduction, over-wintering) in the novel environment is aimed at, like in classical biological control (CBC) programs, host specificity (and host range testing) is considered the most relevant element, etc. The step-wise procedure of environmental risk assessment is shown in Table 1. For some steps (3, 4 and 6) successive ERI levels (L*M) are calculated according to

Table 1. Generic key to procedures of environmental risk assessment of invertebrate biological control agents (after van Lenteren *et al*. 2005).

Step #	Topic/Condition	Go To
Step 1	**Origin**	
	native to area of release	Step 6
	exotic to area of release	Step 2
Step 2	**Biological Control Program**	
	import and release for permanent introduction (CBC)	Step 4
	establishment not intended (ABC)	Step 3
Step 3	**Establishment**	
	certain	Stop
	possible	Step 4
	not possible	Step 6
Step 4	**Host Range Includes**	
	attack of related and non-valued nontargets	Release
	attack of related + unrelated and/or valued species	Stop
Step 5	**Dispersal**	
	local, moderate	Step 6
	extensive	Stop
Step 6	**Ecological Impact (direct and indirect effects)**	
	likely - permanent	Stop
	unlikely - limited - transient	Release

the approach of van Lenteren *et al.* (2003) and depending on its outcome, the procedure stops or continues.

When we applied the proposed stepwise risk assessment procedure (Table 1) to biological control agents commercially available in Europe (EPPO 2002), obviously risky species were eliminated early in the process. Other species that scored - erroneously - a high cumulative index in the first quantitative risk assessment procedure (van Lenteren *et al.* 2003), such as *Trichogramma brassicae*, were not eliminated early in the new procedure. In concordance with recent experimental data these are recommended for further release. See van Lenteren and Loomans (2005) for a full report.

QUICK SCAN

Under certain conditions a more qualitative 'quick scan' method could be used to assess potential adverse environmental effects based on currently available information only:

1. For *newly introduced organisms* a quick scan can act as an initial screening step for governments to initiate the evaluation process and to assess the status and of the species or population. level of containment prior to first import of a new organism into their country for research or production. For the applicant it helps before first introduction of a natural enemy to quickly evaluate the biological and ecological characteristics and to determine the potential research effort he will have to make to get an approval after efficacy testing is resolved. When after a thorough evaluation on efficacy a release is still considered, a comprehensive risk analysis would apply.
2. In countries developing new regulations a quick scan would allow governments to assess the environmental risk for *natural enemies already in use* to distinguish IBCAs with minor effects from those with large effects, based on evidence of ecological impact. Species considered safe for continuation of release can thus be exempted from further regulatory measures.
3. A quick scan can be used to assess the environmental risk of mass-releasing natural enemies originating from areas within the same ecoregion, but not present in the area of release itself (initial step 1 and 6 in Table 1). Thus, the results of a quick scan could help to establish lists of species that can be used in certain, specified regions or (parts of) ecoregions of the world (*ecoregional "white lists"*). This would result in strongly reduced costs for regulation of the major part of biological control agents currently used and continuation of current biological control programs.

We applied the quick scan method, based on the information requirements and ecological determinants as outlined above, to 150 species of natural enemies currently commercially available in The Netherlands (EPPO 2002; Loomans and Sütterlin 2005). About 5 % of the species were considered too risky for (continuation of) release and 80 % of the species were considered safe. For the remaining 15% information initially was either still partly inadequate, inappropriate or lacking to complete the quick scan. However, when no evidence was available on any significant nontarget effects, or not foreseen, it was advised for most species to continue release. In 2005, 134 species were placed on a "white list", which will be exempted from further regulatory measures in The Netherlands. All other species, IBCAs and other beneficial organisms, will need authorization by derogation.

CONCLUSIONS

The intrinsic factors of successful invaders and of successful biological control agents partly have common denominators. An environmental risk assessment (ERA) can help to reveal, and where possible distinguish, potential conflicts of interest in the application for certain taxa, guilds, species or populations of biological control agents and to distinguish keystone values subsequently. Thus, we can increase efficacy and avoid direct and indirect nontarget effects. In order to be of practical use, the risk evaluation method in a full scan should preferably be 1. quantifiable, so that the environmental effects of different biological control agents can be compared and choices can be made, and 2. consist of a tiered or stepwise procedure so that the clearly safest agents or the unequivocally hazardous natural enemies will be identified quickly and with lowest possible costs involved. The applicant needs to provide sufficient and reliable information to issue a permit or derogation for import and release. For natural enemies already in use (~200 species worldwide), the quick scan risk evaluation method consists of steps and questions which are the same as in the advanced method, but will be based on available data only. The results of a quick scan could help to establish lists of species that can be used in certain, specified areas or (parts of) ecoregions of the world.

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