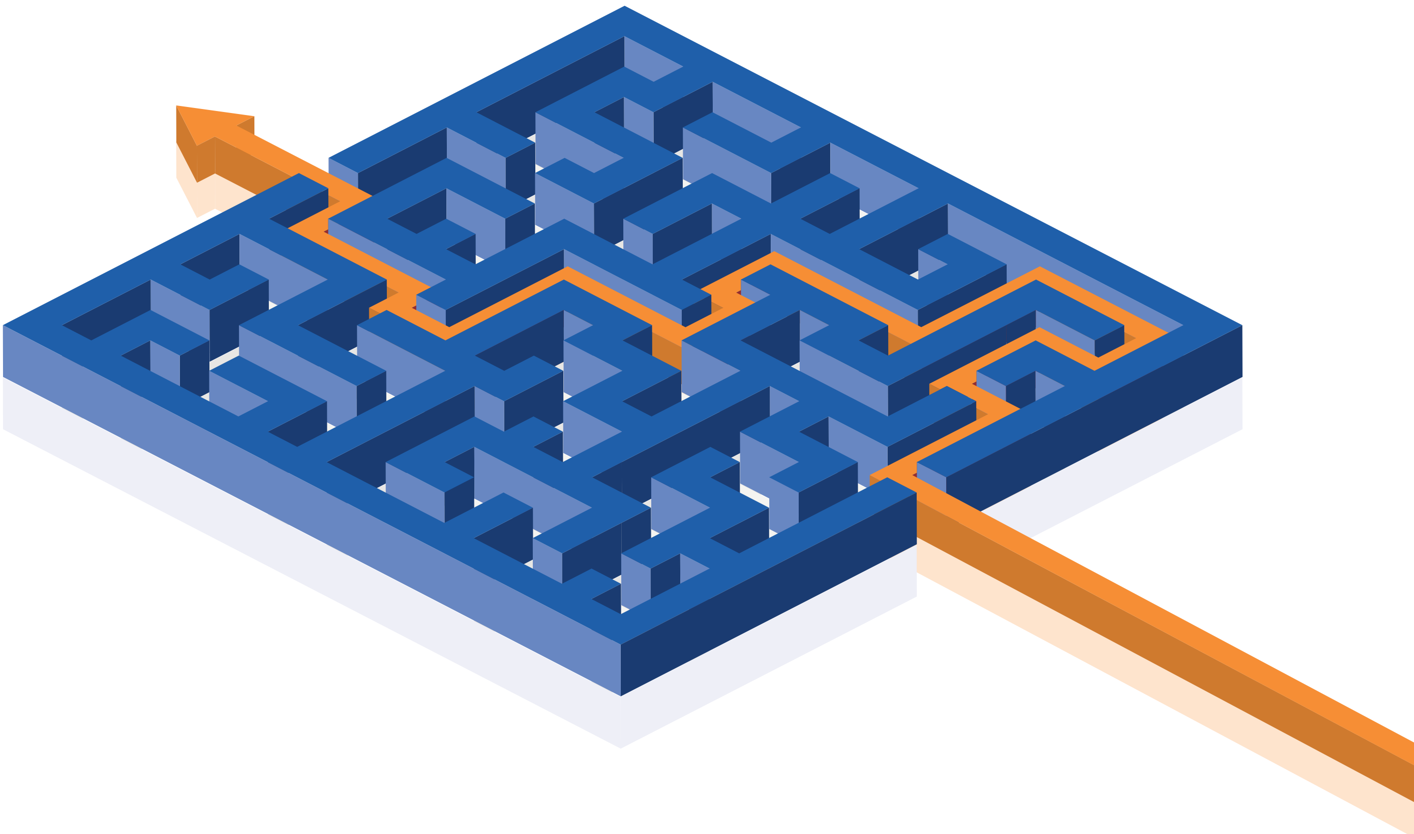
Guidance of the PLH Panel

Scientific Opinion of the EFSA Panel on Plant Health (PLH)

Guidance on the environmental risk assessment of plant pests

[December 2011]



European Food Safety Authority

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SCIENTIFIC OPINION

Guidance on the environmental risk assessment of plant pests[1]

EFSA Panel on Plant Health (PLH)[2, 3]

European Food Safety Authority (EFSA), Parma, Italy

ABSTRACT

The European Food Safety Authority (EFSA) requested the Panel on Plant Health to develop a methodology for assessing the environmental risks posed by harmful organisms that may enter, establish and spread in the European Union. To do so, the Panel first reviewed the methods for assessing the environmental risks of plant pests that have previously been used in pest risk assessment. The limitations identified by the review led the Panel to define the new methodology for environmental risk assessment which is described in this guidance document. The guidance is primarily addressed to the EFSA PLH Panel and has been conceived as an enhancement of the relevant parts of the "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA". Emphasizing the importance of assessing the consequences on both the structural (biodiversity) and the functional (ecosystem services) aspects of the environment, this new approach includes methods for assessing both aspects for the first time in a pest risk assessment scheme. A list of questions has been developed for the assessor to evaluate the consequences for structural biodiversity and for ecosystem services in the current area of invasion and in the risk assessment area. To ensure the consistency and transparency of the assessment, a rating system has also been developed based on a probabilistic approach with an evaluation of the degree of uncertainty. Finally, an overview of the available risk reduction options for pests in natural environments is presented, minimum data requirements are described, and a glossary to support the common understanding of the principles of this opinion is provided.

KEY WORDS

Biodiversity, ecosystem functioning, ecosystem services, environmental impact, environmental risk assessment, global change.

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1 On request from EFSA, Question No EFSA-Q-2010-00794, adopted on 23 November 2011.

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SUMMARY

The European Food Safety Authority (EFSA) asked the Panel on Plant Health to develop a guidance document on the environmental risk assessment of plant pests. The purpose of this document is to develop a methodology for assessing the environmental risks posed by non-endemic living organisms harmful to plants and/or plant products that are associated with the movement of plants and plant products, and that may enter into, establish and spread in the European Union. The range of the organisms of concern includes phytophagous invertebrates, plant pathogens, parasitic plants and invasive alien plant species.

The document is primarily addressed to the EFSA PLH Panel and has been conceived as an extension of the relevant parts of the "Guidance on a harmonised framework for pest risk assessments and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010). It also forms part of an EFSA initiative across all areas of its remit covering guidance for environmental risk assessment.

In this document, the available methodologies for assessing environmental risks of plant pests within the framework of pest risk assessment are reviewed, a new procedure for environmental risk assessment is defined, and its scientific principles are outlined. Therefore, the main scope of this document is the delivery of a sound tool for the evaluation of the environmental risks, including the identification of risk reduction options that may reduce the impact of a pest on the environment. The document is to be applied by the EFSA PLH Panel and will extend the "Guidance on a harmonised framework for pest risk assessments and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010).

By the development of this environmental risk assessment guidance document the PLH Panel aims at harmonising its outputs and implementing a common and explicit methodology for the evaluation of the environmental risks in PLH outputs when relevant, and to contribute to the overall EFSA effort in environmental risk assessment.

Based on its work, the Panel came to the conclusions presented below:

Although every pest risk assessment scheme based on ISPM No 11 includes an assessment of the environmental consequences of pest introduction, schemes focus primarily on the effects on biodiversity, without defining this clearly, and do not provide an explicit standardised methodology for assessing the consequences on ecosystem services. Therefore, the EFSA PLH Panel has developed a scheme that provides guiding principles on assessment practices and enhanced approaches for assessing the environmental risks caused by plant pests. The scheme takes into account the consequences for both biodiversity and ecosystem services.

<u>Review of current approaches</u>

The Panel first reviewed the current approaches and methodologies that assess environmental risks related to pests. In its previous scientific opinions, the Panel assessed environmental risks on an *ad hoc* basis, without following a clear approach and consistent methodology. In most cases, environmental consequences have been interpreted in terms of biodiversity loss. The existing pest risk analysis schemes (e.g. from EPPO, Canadian Food Inspection Agency, USDA and Biosecurity Australia) that are based on the text of ISPM No 11, mostly provide only general guidance to the assessor to help the assessor decide what elements of the "environment" need to be considered and what risk rating is appropriate. These also primarily assess risk according to biodiversity loss (direct effects according to ISPM No 11) and there is little guidance on assessing the consequences on ecosystem processes and services (included in the list of indirect effects according to ISPM No 11). Although risk ratings still have to be justified by written text, the lack of specific guidance can lead to considerable inconsistencies. However, where

applied, the principle of assessing consequences in the current area of invasion and extrapolating to the risk assessment area was considered to be a useful approach. The activities of the PRATIQUE and Prima phacie projects have focussed on the enhancement of the structural biodiversity component of environmental risk, and their approach has been reviewed and considered during the development of the current document, although we have provided a more comprehensive evaluation and adopted a different risk rating system. A serious shortcoming of all the considered schemes is the lack of an explicit evaluation of the consequences on ecosystem services and this provides a major focus of this document.

Methodology to prepare an environmental risk assessment

Next, the Panel developed a new methodology for environmental risk assessment. There are two basic reasons to be concerned about environmental consequences. The first one is the international obligation to protect biodiversity, particularly because biodiversity is essential for the normal functioning of ecosystems. The second one is that the outcomes of several ecological processes – the ecosystem services – are useful and indispensable for humans, and their continued functioning is important. This approach emphasizes the importance of assessing consequences on both the structural (biodiversity) and the functional (ecosystem services) levels of the environment. The document presents an approach which considers for the first time the inclusion of both biodiversity and ecosystem services perspectives in a pest risk assessment scheme is presented.

Biodiversity. The assessment of the potential effects of a pest on biodiversity starts with concerns emerging from legal/administrative constraints (e.g. protected/red-list species), and gradually moves towards a more ecological perspective, preparing the ground for the second stage of evaluation, the assessment of the consequences on ecosystem services. The biodiversity at the different organisational levels, from infra-individual to landscape/ecosystem levels is considered, and the potential consequences on genetic, species and landscape diversity are assessed and scored separately. There is a consistent distinction between elements of structural biodiversity that are legally protected, and elements of native biodiversity, and the consequences for these are scored separately.

Ecosystem services. For an environmental risk assessment of pests based on ecosystem services, it is necessary: (1) to identify the environmental components or units responsible for the genesis and regulation of the ecosystem services, the so-called "service providing units"; they are regarded as functional units in which the components (individuals, species or communities) are characterized by functional traits defining their ecological role; (2) to assess the impact of the pest on the components of the structural biodiversity at the genetic, species, habitat, community, and ecosystem levels; (3) to establish a procedure for the evaluation of the effects of pests on ecosystem services. The objective of an environmental risk assessment based on ecosystem services is to understand the consequences of invasion in terms of the modification of the functional traits that are components of the service providing units. Changes in functional traits are associated with the variation in ecosystem services provision levels by means of the consideration of trait-service clusters. The modification of functional traits by the action of pests influences ecosystem processes at the individual (e.g. survival), population (e.g. population structure), as well as community level (importance of functional groups). From the analysis of the traits, a table is derived listing: i) the target elements of the service providing units affected by the pest, ii) the functional traits affected by the pest, iii) whether the induced modification is positive or negative and iv) if necessary, relevant comments clarifying the interpretation of the analysis performed. This guidance document proposes the use of explorative scenarios related to the environmental risk associated with pests. Explorative scenarios are attempts to explore what future developments may be triggered by a driving force, in this case an exogenous driving force, i.e. a driving force that cannot or can only partially be influenced by decision makers.

For the list of the ecosystem services to be considered in environmental risk assessment, the Panel adopted the list originally proposed by the Millennium Ecosystem Assessment (MA, 2005). Concerning provisioning services, the complete list has been considered in this document. This choice raises the issue of a possible double accounting, since some of the items in the list have already been, at least partially, considered in the impact session of the pest risk assessment. However, the consideration of all the provisioning services allows for a comprehensive impact evaluation that is not limited to market value, but considers also other components of the value of the ecosystem services. The consideration of the impact on the provisioning services is therefore useful for a more comprehensive environmental impact assessment even for those components of ecosystems more directly computable in terms of market value (e.g., crops).

Questions for assessors. The environmental risk assessment questions for the assessors address the following topics:

1. The definition of the background and assumptions to the ecosystem services approach (e.g. identification of the service providing units and elements of biodiversity ecologically linked to the service providing units) as well as the temporal and spatial scale, to estimate the resistance and the resilience of the affected service providing units, to identify the trait-service clusters and to list the risk reduction options.

2. The evaluation of the consequences for structural biodiversity caused by the pest in the current area of invasion: what is the magnitude of change on genetic diversity, are protected, rare or vulnerable species affected, is there a decline in native species, is there an impact on objects or habitats of high conservation value, are there changes in the composition and structure of native habitats, communities and/or ecosystems?

3. The evaluation of the consequences for structural biodiversity caused by the pest in the risk assessment area: similar questions as under point 2.

4. The evaluation of the consequences for ecosystem services caused by the pest within its current area of invasion, to determine how great the magnitude of reduction is in the provisioning, regulating and supporting services affected in the current area of invasion.

5. The evaluation of the consequences for ecosystem services caused by the pest within the risk assessment area: similar questions as under point 4.

Rating system. A rating system has been developed based on a probabilistic approach which ensures consistency and transparency of the assessment. The rating system includes an evaluation of the degree of uncertainty. The rating system makes it possible to evaluate the level of risk and the associated uncertainty for every sub-question and then the overall risk and uncertainty for every question. At the end of the assessment process, the level of overall risk related to questions on biodiversity is categorized as either *Minor, Moderate* or *Major,* while for questions on ecosystem services, the categorisation is either *Minimal, Minor, Moderate, Major* or *Massive*. The degree of uncertainty is categorised as *Low*, *Medium* or *High*.

Finally, an overview of the available risk reduction options for pests in natural environments is presented, minimum data requirements are described, and a glossary to support the common understanding of the principles of this opinion is provided.

The Panel recognises that assessing environmental impacts on the basis of the ecosystem services concept is a developing area, and expects methodological developments and more precise and articulate schemes and quantification methods to emerge as experience accumulates. Attention has to be devoted to the evaluation of the provisioning services in order to avoid the possible problem of double accounting, and before evaluating them in the environmental risk assessment, it should be assessed whether these are not already satisfactorily covered in other parts of the pest risk assessment.

The Panel recommends revising and updating the present guidance document in three years, based upon:

- outcome and experience gained from the usage of the proposed environmental risk assessment approach in future pest risk assessments;
- results of horizontal harmonisation activities within EFSA;
- any relevant new information which may have an impact on the current opinion, e.g. further developments in the ecosystem services concept and its application.

Further work is recommended by the Panel, e.g.

- testing the scheme using species with a wide range of environmental impacts;
- comparing this approach with that used in other schemes from the perspective of the risk assessor, risk manager and risk modeller;
- exploring the possibility to use quantitative assessment (percentages) to describe levels of impact in other parts of the pest risk assessment;
- exploring the potentiality of the scenario exercise (leading to a set of assumptions guiding the assessment procedure) for the entire pest risk assessment.

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BACKGROUND AS PROVIDED BY EFSA

The Scientific Panel on Plant Health provides independent scientific advice on the risks posed by organisms which can cause harm to plants, plant products or plant biodiversity in the European Community. The Panel reviews and assesses those risks with regard to the safety and security of the food chain to assist risk managers in taking effective and timely decisions on protective measures against the introduction and spread of harmful organisms in the European Community.

On request, the Panel prepares pest risk assessments and identifies and evaluates the effectiveness of risk management options to provide scientific advice to the European Commission in support of protective measures within the European Community to prevent the introduction and further spread of organisms considered harmful to plants or plants products under the Council Directive 2000/29/EC[4].

In order to help its scientific work, the Panel has developed Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA[5]. During the development of this guidance document, the Panel identified the need of further, detailed guidance on how to assess the environmental aspect of risk assessment linked to plant health issues, in line with the scope of Council Directive 2000/29/EC.

Though every pest risk assessment procedure includes the assessment of environmental risk and consequences of pests, currently there are neither guidelines, nor standardised methodology supporting this procedure. Since there is limited knowledge on the causal mechanisms leading to environmental consequences, the most widely used method for assessing them is an *ad hoc* application of expert judgement. Therefore, the Panel considers it necessary to develop a document that provides guiding principles on assessment practices and approaches when assessing environmental risk of plant pests (invertebrates, diseases and plants). Furthermore, the analysis of environmental risks of management options also needs consideration.

Deliverables of the on-going EU FP7 project PRATIQUE and the EFSA Art. 36 project Prima phacie should be carefully considered by the working group. Based on the analysis of these deliverables and on the needs of additional data and documentation identified by the working group, the PLH Unit may launch a tender/grant in order to investigate and review approaches to assess environmental risks related to plant pests.

Upon completion of this guidance document, findings could be incorporated into the "Guidance on a harmonised framework for pest risk assessments and the identification and evaluation of pest risk management options by EFSA".

TERMS OF REFERENCE AS PROVIDED BY EFSA

The Panel on Plant Health is requested to produce a guidance document on the environmental risk assessment of plant pests (invertebrates, diseases and plants).

In fulfilling the mandate the Panel should make the best use of the relevant deliverables of the EFSA mandate Q-2008-704 on Guidance document on a harmonised framework for pest risk assessments and the identification and evaluation of pest risk management options by EFSA, as well as the results produced by the on-going EU FP7 project PRATIQUE. Specifically, the Panel is requested to:

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[4] Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. Official Journal of the European Communities L 169/1, 10.7.2000, p. 1–112.

[5] EFSA Panel on Plant Health (PLH), 2010. Guidance on a harmonised framework for pest risk assessments and the identification and evaluation of pest risk management options by EFSA. EFSA Journal, 8(2):1495, 66 pp.

a) Review the current approaches and methodologies that assess environmental risks related to pests, including their strength and shortcomings within the EFSA context;

b) Recommend methodology to prepare an environmental risk assessment of pests as well as management options in order to support the Guidance Document on Harmonised Framework and in so doing prepare a list of the minimum data requirements.

Following the endorsement of the draft guidance document by the Panel, a public consultation will be launched in order to receive comments from the stakeholders and the scientific community. Comments will be evaluated and considered in order to enhance the scientific quality and understanding of the document.

The Panel expects to deliver the opinion in 15 months (12 months for completion of the outcome + 3 months for related public consultation).

ASSESSMENT

1. Introduction

1.1. Purpose and scope of the document

The purpose of this document is to develop a methodology for assessing the environmental risks posed by non-endemic living organisms harmful to plants and/or plant products that are associated with the movement of plants and plant products, and that may enter into, establish and spread in the European Union. The range of the organisms of concern includes phytophagous invertebrates, plant pathogens, parasitic plants and invasive alien plant species.

The document is primarily addressed to the EFSA PLH Panel and has been conceived as an extension of the relevant parts of the "Guidance on a harmonised framework for pest risk assessments and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010) (Section 3.2.2.). It also forms part of an EFSA initiative across all areas of its remit covering guidance for environmental risk assessment (Section 3.2.1.).

In this document, the available methodologies for assessing environmental risks of plant pests within the framework of pest risk assessment are reviewed, a new procedure for environmental risk assessment is defined, and its scientific principles are outlined. Therefore, the main scope of this document is the delivery of a sound tool for the evaluation of the environmental risks, including the identification of risk reduction options that may reduce the impact of a pest on the environment. The document is to be applied by the EFSA PLH Panel and will extend the "Guidance on a harmonised framework for pest risk assessments and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010).

By the development of this guidance document the PLH Panel aims at harmonising its outputs and implementing a common and explicit methodology for the evaluation of the environmental risks in PLH outputs when relevant, and to contribute to the overall EFSA effort in environmental risk assessment.

1.2. Context of environmental risk assessment in plant health

Council Directive 2000/29/EC[6] provides the legal basis for the European Union's activities in the plant health domain. Though it does not lay down specific requirements for an environmental risk assessment, the assessment of potential consequences on the environment of introduction and spread of harmful organisms is included in the internationally recognised standards for pest risk assessment (FAO, 2004). In the EU, the issue of environmental consequences of non-endemic plant pests and invasive plants are being discussed in the context of the revision of the plant health directive.

As stated in the "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010), and also outlined in the relevant international standards for phytosanitary measures (mainly ISPM No 11 from FAO, 2004) "*the Panel assesses potential direct and indirect consequences of entry, establishment and spread of pests on all affected plant species as well as environmental consequences*".

[6] Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. O.J., L.169/1, 10.7.2000, p. 1–112.

In its previous scientific opinions, the Panel assessed environmental risks on an *ad hoc* basis, without following a clear approach and consistent methodology (Appendix A). In most cases, environmental consequences have been interpreted in terms of biodiversity loss. Sometimes additional considerations were provided on the secondary effects of the use of pesticides and other measures taken against the pests. The alteration of ecosystem processes and conservation implications was very rarely considered. The concept of ecosystem services was mentioned in only four cases (Appendix A). This has been considered an inevitable effect of the lack of a harmonised guidance for rating the risk and scoring the uncertainties of the environmental consequences, as part of the pest risk assessment process.

The need for a more consistent and transparent approach was identified during the development of the "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010), where it is stated that "*Pests that principally have effects on crop yield or quality may also have environmental side effects. In accordance with current ecological concepts, two orders of considerations should be analysed: impacts on ecosystem services and impacts on biodiversity itself (Millennium Ecosystem Assessment, 2005). If the main effects are already large and unacceptable, detailed consideration of such side effects may not be necessary*."

1.3. Methodology

1.3.1. Literature review

As set out in the terms of reference, the aim of the literature review was to identify the current approaches and methodologies that are used to assess environmental risks in plant health. Thus, the focus of the search was on methodologies used within the framework of pest risk assessments, while environmental risk assessment methodologies used in a context other than plant health were not included in the review.

Upon receiving the mandate, an extensive search to identify relevant studies/papers was carried out through the following databases: Agricola, CABI, Current Content Connect, Food Science and Technology Abstracts, Google Scholar, Journal Citation Reports, PRASSIS, PubMed, Web of Science, using the following key words in different combinations: biodiversity, ecosystem functioning, ecosystem services, environmental damage, environmental impact assessment, environmental risk assessment, invasive alien species, invasive species, non-target effects, plant health, plant pest, pest, uncertainty.

This search yielded an excessively broad body of publications the majority of which was not directly related to the concepts on which this document has been developed. Therefore, these were not subjected to a systematic evaluation but certain key papers were identified from their titles and summaries as providing valuable background and useful concepts for application in this guidance document. However, the literature cited here emerged primarily from specific searches carried out by the Working Group members who have developed this opinion.

As indicated in the background and terms of reference of this mandate, the relevant parts of the methods applied by the EFSA-funded project Prima phacie (Pest risk assessment for the European Community plant health – a comparative approach with case studies) were also reviewed (Section 3.2.3.).

Finally, the environmental impact assessment methodologies as collected and presented in the "Review of impact assessment methods for pest risk analysis" (Bremmer et al., 2009) delivered by the EU FP7 project PRATIQUE (Enhancement of pest risk analysis techniques), were also reviewed by the PLH Panel (Section 3.3.1.).

1.3.2. Terminology

In order to support the common understanding of the principles presented in this opinion, a glossary was developed and made available at the end of the document. The definitions provided are to be considered in the context of the environmental risk assessment presented in this document. The sources of information linked to each definition were selected according to the experts' judgement and the adequacy to the specific EFSA PLH needs.

1.3.3. Rating system for risk and uncertainty

In order to address the need for harmonization in rating the risk and scoring the uncertainties of the environmental consequences, as highlighted during the revision of previous PLH outputs, and to guarantee the principle of transparency as mentioned under Section 3.1. of the "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010), the Plant Health Panel has developed for this guidance on the environmental risk assessment of plant pests a specific rating system based on a probabilistic approach which ensures consistency and transparency of the assessment. The rating system includes an evaluation of the degree of uncertainty. The rating system makes it possible to evaluate the level of risk and the associated uncertainty for every sub-question and then the overall risk and uncertainty for every question. At the end of the assessment process, the level of overall risk related to questions on biodiversity is categorized as either *Minor*, *Moderate* or *Major,* while for questions on ecosystem services, the categorisation is either *Minimal*, *Minor*, *Moderate*, *Major* or *Massive*. The degree of uncertainty is categorised as *Low, Medium* or *High*. Due to the complexity and extensiveness of the subject, a full section of this guidance document has been dedicated to the description of the rating system (see Section 4.3., and the related Appendix C).

2. General assumptions and guidance required when undertaking assessments of potential consequences in pest risk assessment

While developing the guidance document on the environmental risk assessment for plant pests, it became clear that certain key assumptions and guidance that need to be made are not only important for environmental impact assessments but are also just as relevant to the assessment of other impacts, e.g. on crop yield and quality.

These issues are highlighted here because of the need to make sure that they are taken into account in any future amendments to the "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010).

In the EFSA scheme (in an appendix to the above Guidance document), some of the assumptions that the EFSA PLH Panel needs to define when conducting a pest risk assessment are described:

(i) Time horizon:

"*The replies should take account of both short-term and long-term effects*".

(ii) The degree to which worst-case scenarios should be considered:

"*In any case, providing replies for all hosts (or all habitats) and all situations may be laborious, and it is desirable to focus the assessment as much as possible. The study of a single worst-case may be sufficient. Alternatively, it may be appropriate to consider all hosts/habitats together in answering the questions once. If a selection is made, it should be* *justified. Only in certain circumstances will it be necessary to answer the questions separately for specific hosts/habitats*".

In the development of this guidance document on the environmental risk assessment for plant pests, some important issues related to the assumptions guiding the pest risk assessment emerged. A further elaboration on this theme is required, e.g. to:

- Indicate how assessments should be based on the "*hypothetical situation where the pest is supposed to have been introduced and to be fully expressing its potential* [...] *consequences*" in the risk assessment area, as indicated by ISPM No 11 (FAO, 2004);
- Determine the time horizon that should be taken into account, e.g. should there be separate assessments for 5 years, 20 years and for when the species has spread throughout the area of potential establishment?
- Describe how climate and land use change should be taken into account;
- Decide whether an impact that occurs quickly should be rated higher than the same level of impact that occurs slowly;
- Set the spatial scale and resolution that should be used;
- Clarify how to assess impacts with and without management measures;
- Provide a clearer description of the appropriate level of detail required;
- Ensure consistency between pest risk assessments and pest risk assessors while allowing risk assessors some freedom to decide on the scenarios they use for impact assessment;
- Communicate to risk managers:
    - Uncertainty;
    - Impact assessments with different impact ratings according to time scale;
    - Any positive impacts that may arise;
    - Impacts that may be severe in the short term but reversible to a greater or lesser extent in the long term.

3. Review of current approaches and methodologies that assess the environmental risks related to pests

3.1. Environmental risk assessment in the international context

Pest risk assessment in plant health is based on standards (ISPM No 2 and 11) of the International Plant Protection Convention. The international standard for phytosanitary measures (ISPM) No 11 (FAO, 2004) describes in Annex 1 the scope of the IPPC (International Plant Protection Convention) in regard to environmental risks. Effects of the pest are divided into direct (paragraph 2.3.1.1.) and indirect (paragraph 2.3.1.2.) effects, both including environmental consequences. It is stated that direct effects should include an assessment of the:

- Reduction of keystone plant species;
- Reduction of plant species that are major components of ecosystems (in terms of abundance or size), and endangered native plant species (including effects below species level where there is evidence of such effects being significant);
- Significant reduction, displacement or elimination of other plant species.

The indirect effects to be considered should include:

- Significant effects on plant communities;
- Significant effects on designated environmentally sensitive or protected areas;
- Significant change in ecological processes and the structure, stability or processes of an ecosystem (including further effects on plant species, erosion, water table changes, increased fire hazard, nutrient cycling, etc.);
- Effects on human use (e.g. water quality, recreational uses, tourism, animal grazing, hunting, fishing);
- Costs of environmental restoration.

ISPM No 11 notes that appropriate non-market valuation methods such as consideration of "use" or "non-use" values can be applied. Nonetheless, it does not prescribe any particular analytical method and stresses that, although the assessment of consequences may be either quantitative or qualitative, in many cases, qualitative methods are sufficient.

ISPM No 11 also states that: "*Environmental effects and consequences considered should result from effects on plants. Such effects, however, on plants may be less significant than the effects and/or consequences on other organisms or systems. For example, a minor weed may be significantly allergenic for humans or a minor plant pathogen may produce toxins that seriously affect livestock. However, the regulation of plants solely on the basis of their effects on other organisms or systems (e.g. on human or animal health) is outside the scope of this standard. If the PRA process reveals evidence of a potential hazard to other organisms or systems, this should be communicated to the appropriate authorities which have the legal responsibility to deal with the issue*".

3.2. Environmental risk assessment in the EFSA context

3.2.1. EFSA Task Force on environmental risk assessment

In 2010 EFSA established an internal task force on environmental risk assessment, with the participation of several EFSA Units (Biological Hazards, Communications Channels, FEED, GMO, Legal and Regulatory Affairs, Plant Health, Pesticides, Scientific Assessment Support and Scientific Committee). The scope was to review the current practices of environmental risk assessment within the different Panels.

Specifically the assignment of the task force was to:

- Describe the regulatory basis for environmental risk assessment
- Evaluate approaches within the EFSA Panels and Units

- Identify commonalities and possible discrepancies

A draft technical report on environmental risk assessment and proposal for an action plan has been prepared by the task force by June 2011 and will be published after finalisation.

3.2.2. EFSA Plant Health harmonised framework

In 2009, EFSA PLH developed its "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010). In this guidance document, the Plant Health Panel proposed a pest risk assessment scheme adapted to its needs, hereafter referred to as "EFSA scheme". This scheme includes environmental consequences with an expanded note asking assessors to consider the effects on ecosystem services as well as on biodiversity (see Appendix B for Q2.4. and Q2.5. of the EFSA scheme). In this guidance document, the importance of assessing impacts on ecosystem services following the methods set out in the Millennium Ecosystem Assessment (MEA, 2003) is clearly stated. Nevertheless, detailed guidance is missing. The provision of such detailed guidance is the key objective of the current document. It is to be noted, though, that recent work on the concept of ecosystem services tends to combine the formerly separated categories of regulating and supporting ecosystem services (e.g. Carpenter et al., 2009). The notes (accompanying the above-mentioned two questions in Appendix B) mention some ecological mechanisms through which invasive organisms can cause changes in different ecosystem service categories, but this list is neither systematic nor exhaustive. The notes are explicit in suggesting that, in most cases, effects on selected important species can be identified and assessed. Nevertheless, in other cases, a change in an ecosystem function may be noticed first, or may be easier to measure than the change in the organisms contributing to that function. For example, soil-based functions, such as decomposition or detoxification, are easy to measure by assessing the result of the process, rather than identifying key players and evaluating changes in their densities that may be connected to the intensity of these processes. Note 2 on biodiversity explicitly calls for an assessment of effects on biodiversity at various levels (from genetic to ecosystem diversity) providing important assistance to the assessor.

3.2.3. Prima Phacie (EFSA Art. 36 project of the PLH Panel)

The EFSA Art. 36 project Prima phacie (MacLeod et al., 2010) started in 2010 and has compared five different risk assessment methods by applying them to 10 case studies (i.e. 10 different plant pests). These methods also include the assessment of environmental impacts, and are shortly presented below, highlighting their relevance for the EFSA plant health context. Two of the methods are based on the above mentioned "Guidance on a harmonised framework for pest risk assessments and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010).

3.2.3.1. Method 1: Question-level BBN (Bayesian Belief Network) (Based on the EPPO pest risk assessment decision support scheme adapted by the EFSA PLH Panel (EFSA Panel on Plant Health (PLH), 2010), further adapted by Prima phacie)

This scheme considers environmental effects in three modules: (1) effects on "native biodiversity" (a concept open to different interpretations by the assessor), (2) alterations of ecosystem function, and (3) conservation impacts. This scheme is an important advance in ecological sophistication, but also contains some conceptual confusion. Native biodiversity is considered as one category, and thus combines effects on rare or protected species (although the latter category is not mentioned) with the common and ecologically important species. Under the multi-part module 2, there is (in 2.1, 2.3 and 2.4) a consideration of some (but not all) ecological functions – here common species are re-evaluated again (if the invasive organism causes changes in their population level, and consequently, in an ecosystem function linked to that species), thus running the risk of double accounting. Modification of natural succession (2.3) in some cases is an important criterion and, if damaged, often leads to unwanted changes. However, ecologically sensitive management often aims to stop, reverse, or slow down natural ecological succession as part of the management of natural values (Pullin, 2003). This criterion therefore is not unequivocally linked to an environmental damage – in many cases, there is a desired "modification of natural succession", and thus including this as damage does not increase clarity in the scheme. Under 2.4., trophic and mutualistic interactions are mentioned, but these are not the only important ecosystem functions. It is debatable whether ecosystem engineering is rightly attributed to "physical modification of habitats" (the concept is not mentioned in the scheme). Many assessors will not do this, and even if assessors decide to consider ecosystem engineering as a physical modification of habitats, this is not necessarily justified. Keystone species (which are usually neither rare nor protected) are mentioned together with rare or vulnerable species, while it is expected that an effect on a keystone species will result in alteration of ecosystem functions (module 2).

Therefore, this evaluation system is selective in listing ecosystem functions, and carries the risk of double-counting the effects on some categories. Effects on structure and function are not clearly separated.

3.2.3.2. Method 2: Based on the EPPO pest risk assessment decision support scheme adapted by the EFSA Panel on Plant Health for pest risk assessment (EFSA Panel on Plant Health (PLH), 2010), further adapted using multiple risk matrices to combine risk elements

Method 2 was modified by deleting one question and adding more sub-questions to a second one (see details below). More questions provide the opportunity to further articulate the assessment, and may provide important assistance to the assessors. At the time of writing, the project Prima phacie has not yet delivered the final report, so we do not yet know the reasoning behind these changes.

The added questions 2.9.b and 2.9.c take over the partial list from the previous method, which only includes some selected ecological functions (see comments there). Question 2.9.d has the strength of specifically calling attention to ecologically sensitive habitats with orientation notes. The questions are general in the sense that they ask the assessor to determine the impacts on "conservation". It might also be misleading because it leaves to the assessor to decide what a "conservation effect" is. The confusing mention of "rare, vulnerable or keystone species" remains, and thus the comments made on method 1 are valid also here.

3.2.3.3. Method 3: Based on the Canadian Food Inspection Agency's pest specific guidelines for pest risk assessment, 2009

There are several environment-related questions in this scheme, apparently at a level of equal importance with the economic questions. The scheme, though, only mentions plants (and thus would need to be widened in case of adoption). The explanatory notes unearth the apparently EU-specific interpretation of a "keystone" species that is not explicitly defined, but from the context it seems that this is not the ecological "keystone species" category. The term "key components" leaves the possible interpretation of "important species" or "major species" to the assessor – when major species (but again without a definition) are mentioned in the next question. This is a less detailed version of the EPPO and modified EPPO scheme mentioned under method 1 and method 2. The separation of the direct and indirect effects and the separate assessment of indirect effects is an important advance in ecological sophistication of this evaluation scheme. Nevertheless, it is unclear why effects on ecological processes are considered "indirect". The repeated use of the word "significant" is ambiguous as it is not linked to any statistical test, assessment, or procedure.

3.2.3.4. Method 4: Based on USDA Guidelines for Pathway-Initiated pest risk assessment version 5.02 (USDA, 2000)

An important strength of the USDA scheme is that it explicitly considers environmental damage caused by the invasion of the pest, through environmentally damaging protection methods (e.g. increased use of pesticides) against it. Otherwise, the focus is on biological diversity impacts, probably because this focus conforms to US legislation. However, a detailed analysis of the ecological interactions is unlikely under this scheme. The combined impact rating is simple and is decided using clear criteria.

3.2.3.5. Method 5 (based on Guidelines for import risk analysis, (Biosecurity Australia, 2001)

The strength of the Australian method is the use of risk matrices and of a formalised decision method about combined risk. It is the only method (apart from EFSA PLH/EPPO) explicitly mentioning ecosystem services as well as biodiversity, but it leaves to the assessor to decide what is considered under these concepts, and provides neither guidance nor a more detailed evaluation scheme.

3.3. Environmental risk assessment outside the EFSA context

3.3.1. FP 7 project "PRATIQUE"

Existing pest risk analysis schemes usually include one (or two) general questions related to the consequences on the environment with or without a rating system and guidance on the factors to be considered.

The Panel considered the review of impact assessment methods for pest risk analysis produced by PRATIQUE (Bremmer et al., 2009). In this work, 15 existing methods for assessing the environmental impacts of invasive organisms, including seven pest risk analysis schemes (EPPO, UK, Canada, USA, Australia, New Zealand and Mexico), were surveyed. All rely on expert judgement, expressed with different scoring methods. Among the several conclusions and recommendations presented in the PRATIQUE review, two were considered by the Panel particularly relevant for the preparation of the EFSA PLH guidance document on the environmental risk assessment of plant pests:

(i) Assessing environmental impacts is one of the most challenging parts of the pest risk assessment process and new ideas and approaches from invasive alien species assessments should be studied to enhance the schemes;

(ii) While qualitative methods that elicit expert judgements are appropriate "in most schemes, the criteria and indicators to assess potential environmental impacts are too vague to be applied accurately and consistently. It is essential that the pest risk analyst knows what he/she should search for and how each objective criterion, e.g. minimal, minor, moderate, major or massive, corresponds to a particular impact score".

PRATIQUE mainly focussed on the second issue identified by the review. As noted above, PRATIQUE has modified the EPPO scheme principally by addressing the problem of inconsistency and the difficulty to answer the questions by: 1) providing detailed rating guidance; 2) making use of examples in a series of sub-questions; 3) developing an explicit method using a matrix model for combining ratings, and 4) taking uncertainty into account.

The modifications are primarily designed to assess the impacts on structural biodiversity and have been tested successfully by pest risk analysts and invasion ecologists with a wide range of species, mainly insects and plants. The key difference between the PRATIQUE and the EFSA approach is that PRATIQUE lacks an explicit assessment of the effects on ecosystem services.

3.3.2. EPPO

In questions 2.6 and 2.7 of the EPPO scheme for pest risk assessment (EPPO, 2009) the assessors are required to summarise and assess the importance of "environmental damage" in a pest's current area of distribution, as well as in the risk assessment area. The principle of assessing impacts in the current area of distribution and extrapolating to the risk assessment area is considered to be a very useful approach. The explanatory notes mention several important elements that can result in large changes in ecosystem function, and thus – directly or indirectly – in changes in the services the ecosystems provide to humans. The notes, however, combine biodiversity-related factors with situations where invasive organisms cause functional changes. In the EPPO scheme, several ecosystem services are mentioned, but they are referred to under the social impacts.

The list of effects on the environment is based on ISPM No 11 (FAO, 2004), but it is far from exhaustive and is not systematic. This approach recognises that certain species have a disproportionately large importance in their ecosystems, but only mentions a few ways in which this can happen. For example, the category of "keystone species" (Mills et al., 1993) is mentioned, but "ecosystem engineers" (Jones et al., 1994) are not. The notes mention biodiversity but do not differentiate between the different levels of biodiversity and it is left to the assessor to recognise that different types of biodiversity exist. The approach also refers to ecosystem "stability" – a commonly used but also much debated ecological concept (Loreau et al., 2001). The notes to the questions provide some relevant ecological guidance for the assessor, but leave some important concepts unmentioned and include concepts that are neither easy to grasp, nor to evaluate.

3.4. Summary on the comparison of the existing schemes

The Panel concluded that the existing schemes to score environmental impacts do not provide sufficient, specific guidance to the assessor to help her/him to decide what elements of the environment need to be considered and what risk rating is appropriate. Although risk ratings still have to be justified by written text, the lack of specific guidance can lead to considerable inconsistency. The PRATIQUE and Prima phacie projects suggest approaches to tackle this key issue for structural biodiversity and their approach was reviewed and considered in the current document. In addition, the lack of an explicit evaluation of the consequences on ecosystem services in current schemes led to the decision of the Panel to develop a new approach as presented in this guidance document.

3.5. The choice of a combined ecosystem services and biodiversity approach for environmental risk assessment

In this document, an approach which considers for the first time the inclusion of both biodiversity and ecosystem services perspectives in a pest risk assessment scheme is presented.

This need was first presented in the "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010), based on:

- The widely accepted principle that biodiversity is essential for the normal functioning of ecosystems (Hooper et al., 2005) and the EU commitment to its protection and to halting related the losses in the EU by 2020 (EC, COM(2011) 244[7]);

[7] Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions. Our life insurance, our natural capital: an EU biodiversity strategy to 2020. Brussels, 3.5.2011. COM(2011) 244 final, 16 pp.

- The more recent realisation that the outcomes of several ecological processes are useful and indispensable for humans (Daily, 1997). These are termed ecosystem services.

These two components emphasize the importance of assessing impacts on both the structural and the functional aspects of the environment. The structural component is captured by the concept of biodiversity, and the functional component by the concept of ecosystem services. The consideration of the structural component of biodiversity at different level (individuals, species, communities) as well as habitat and ecosystems, recognizes the intrinsic importance of biological diversity and its preservation. Several species of concern are protected, rare, threatened, or vulnerable, and they often do not have measurable impact on the ecosystems they live in. The impact of pests on these species, nevertheless, will have to be considered. These species/entities are often culturally important, and represent important perceived components of the environment (MEA, 2003). By assessing impacts on rare species and vulnerable habitats, this focus is also better articulated in the suggested evaluation scheme.

Biodiversity is recognized at the basis of ecosystem processes. Change in the structural biodiversity results into modification in the functional biodiversity, which in turn influences ecosystem processes. The evaluation of the impact of pests on the level of provision of ES provides a comprehensive level of analysis to account for changes in ecosystem processes.

Framing the assessment of environmental risk on the combined consideration of the impact on ecosystem services and biodiversity provides a consistent structure to evaluate the different aspects of environmental impact. It is recognized that although the effects on human use of the environment is included in ISPM No 11, the ecosystem services approach, with a separate assessment of the effects on provisioning, regulating, and supporting services, is novel in plant health and this document therefore sets out the concept in detail.

In the following sections, the rationale, scientific framework and the fundaments of the procedures for environmental risk assessment based on an ecosystem services approach are presented (Section 4). Based on these underlying principles, the application of environmental risk assessment is framed in a list of questions including guidelines for ratings (Section 5) and a list of minimum data/information requirements is provided (Section 6). A scheme to assess available risk reduction options for pest in natural environments is presented (Section 7).

4. The new PLH environmental risk assessment approach

4.1. Principles

4.1.1. Environmental risk assessment of plant pests and the advantages of an ecosystem services approach

4.1.1.1. Environmental risk assessment of plant pests

The objective for environmental risk assessment in the plant health context is the need to assess the possible environmental consequences of the entry, establishment and spread of a pest that has not formerly been present in the area of concern. This new species will now become a component of one or more receiving habitats and the task of the risk assessor is to determine the extent to which it will negatively modify/affect the environment.

In plant health, considerable efforts have been devoted to developing the assessment of economic impacts caused by pests, while the assessment of their environmental impacts has received less attention (Parker et al., 1999), primarily because most pests only damage cultivated plants. In addition, despite extensive research efforts by ecologists, there is no standard and easily applied method to assess the current and potential environmental effects of invasive alien species in a pest risk assessment, which is therefore likely to be based on expert judgements (Kenis et al., 2009).

Some basic issues related to environmental risk assessment for plant pests are:

A. The complexity and the variety of mechanisms involved in the environmental impact of pests require that each case is studied separately, usually through long-term field or laboratory studies. These long-term studies are usually not possible within the usual framework of a pest risk assessment (Kenis et al., 2009).

B. There is still no agreement on the type (e.g. experimental, theoretical) and level (e.g. individual, population, ecosystem) of analysis that should be relevant to environmental risk assessment. Having identified the taxonomic identity of the agent and the context (habitat, ecosystem, landscape, geographic area) of invasion, the following criteria for the analysis have been proposed:

   (i) Level of organization: genetic (hybridization with native population), individual, population, community, ecosystem;

   (ii) Level of resolution: spatial (local, landscape, regional) and temporal;

   (iii) Small trophic web and direct effect: genetic (hybridization), herbivory/predation, competition (for resources or by interference, e.g. allelopathy), apparent competition, disease transmission;

   (iv) Complex trophic web and indirect effects: effects on community structure and ecosystem mechanisms, cascading effects.

C. Many attempts to describe the impact of invasive pests on the environment are based on the evaluation of the effects on biodiversity. According to the level of organization, biodiversity embraces a host of structural features of ecosystems (e.g. genetic and genomic structure, species or ecosystems on landscape units) (Carpenter et al., 2009). However, there is often an unclear distinction between analyses considering only structural aspects of biodiversity and those related to the functional impacts of biological invasions.

The latter issue is of particular importance and represents the main reason for the approach that is introduced and presented in this document.

Understanding the causes of changes in ecosystems is essential in designing interventions that enhance positive effects and minimize negative ones. In the Millennium Ecosystem Assessment (MA, 2005), a driver is any factor that changes an aspect of an ecosystem (see also Tomich et al., 2010). A direct driver unequivocally influences ecosystem processes and can therefore be identified and measured to differing degrees of accuracy. An indirect driver operates more diffusely, often by altering one or more direct drivers, and its influence is established by understanding its effect on a direct driver. Both indirect and direct drivers often operate synergistically.

Invasions can be regarded as processes of ecological disturbance (Turner, 2010). Disturbance has been defined in various ways, but here the general definition by White and Pickett (1985) is followed: “any relatively discrete event that disrupts the structure of an ecosystem, community, or population, and changes resource availability or the physical environment”. Disturbances alter ecosystem state and trajectory, and are thus key drivers of spatial and temporal heterogeneity (Turner, 2010). The effects of well established invasive alien species in a new territory cannot simply be regarded as disturbance, because of the temporal persistence of the invasive alien species in the receiving environment. Instead, an invasive alien species can be considered as a driver of ecosystem change. The importance of invasive alien species is well known: they are recognized among the five most important direct or structural drivers of ecosystem change (Henrichs et al., 2010; Tomich et al., 2010).

Despite the importance of functional aspects involved in the action of a driver of ecosystem change, most of the analyses on the environmental effects of invasive pests are restricted to the evaluation of the modifications in the structural aspect of biodiversity. In fact, most of the research has concentrated on components of biodiversity, particularly at the species level (e.g., richness, relative abundance, composition, presence/absence of key species). Effects on genetic and functional diversity within species, interactions among species, and ecosystem diversity across landscapes are areas that deserve greater attention, in biodiversity study in general and in the context of biological invasion in particular (Hooper et al., 2005).

Figure 1: Scheme of causal linkages between the establishment of an invasive species (driver) and the effects on provision of ecosystem services.

To understand how changes in biodiversity (e.g. species richness and composition) influence ecosystem properties, it is important to consider the functional traits of the species. By definition, functional traits influence ecosystem properties or species responses to environmental conditions (Hooper et al., 2005). Traits that determine how a species responds to a disturbance or a change in the environment due to the action of a driver (functional response traits, see Hooper and Vitousek, 1997 and 1998; Tilman et al., 1997a, b, c; Emmerson et al., 2001) may differ from those that determine how that species affects ecosystem properties (functional effect traits, see Lavorel et al., 1997; Landsberg, 1999; Walker et al., 1999; Lavorel and Garnier, 2002). Understanding links among functional response and effect traits remains a substantial challenge, which is critical to assess the effects of invasive species on the dynamics of ecosystem functioning in a changing world (Hooper et al., 2002).

The scheme presented in Figure 1 summarizes the conceptual framework outlined here. In the scheme an additional and final level of the causal chain is added to take into account the numerous well-documented cases of how alteration of the biota in ecosystems via species invasions alters ecosystem goods and services (Hooper et al., 2005). Many of these changes are difficult, expensive, or impossible to reverse or solve with technological solutions, and the evaluation of the cost of these impacts is not a trivial exercise. In fact, ecosystems are complex and nonlinear systems and there is often no direct connection or linearity in the relationship between functional and structural components of an ecosystem, making it difficult to achieve a general understanding of the role of biodiversity in ecological functioning (Gallagher and Appenzeller, 1999; Perez and Batten, 2006).

In this section, a framework for the evaluation of the environmental risks of pests is proposed, based on the effects they have as direct drivers on provision of ecosystem services. To develop the framework, it is essential to:

A. point out differences and peculiarities of structural and functional components of biodiversity in the environmental risk assessment for a pest, and

B. create a conceptual tool emphasizing the importance of ecological processes in understanding the environmental impact of a pest, considering the extent to which a change in structural biodiversity results into a modification in functional biodiversity and, in turn, on the ecosystem processes (Tilman et al., 1997a, b, c).

The aim is to set the first steps toward an ecologically based assessment of the environmental risks of pests in which the meaning of environment includes not only structural and functional components of the ecosystems but also ecosystem properties relevant to human well being. However, assessing the effects on cultural ecosystem services falls out of the remit of EFSA.

4.1.1.2. Definitions and characteristics of ecosystem services

According to the Millennium Ecosystem Assessment (MA, 2005), ecosystem services are defined as "the benefits people obtain from ecosystems". These include "provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits" (MA, 2005).

The definition of ecosystem services is a debated issue. For Boyd and Banzhaf (2007) ecosystem services are not the benefits humans obtain from ecosystems but rather the ecological components directly consumed or enjoyed to produce human well-being. Fisher et al. (2008) separate more precisely the benefits and the ecological structure and processes as the bases of ecosystem services, and define ecosystem services as aspects of ecosystems utilized (actively or passively) to produce human well-being. Three important aspects in these definitions of ecosystem services are relevant for our purposes: a) ecosystem services must be ecological phenomena, b) they do not have to be directly utilized, c) they are natural structures/processes that are services only in relation to human interests. Ecosystem services emerge as the functioning of certain structures under certain environmental conditions. This underlines the importance of both organization and structure, as well as processes and/or functions if they are used. Functions or processes become services if they yield benefit for humans.

Because benefits are considered, ecosystem services are an anthropocentric concept and are innately linked to social systems and decisions (i.e. they are linked to management contexts) (Carpenter et al., 2009). The decision/management context (i.e. the broad spectrum of processes which leads to social choice) is also crucial to implement the ecosystem services concept. The concept of ecosystem services is related to both ecological and social systems, as well as to the individual and collective use of natural capital. Various frameworks conceptualising the links between human and natural systems have been developed. Two dominant conceptual models are the DPSIR (adopted by the European Environmental Agency; EEA, 2007) and social-ecological systems (MA, 2005). In the framework developed here, the broader system to refer to for the production and use of ecosystem services is the social-ecological system (Berkes and Folke, 1998; Folke et al., 2005; Walker and Salt, 2006). The ecosystem services concept evaluates the ecological setting from a particular human utilitarian perspective. In other words, nature is valuable because of its usefulness to humans (Scholes et al., 2010). This is a defensible argument from the perspective arguing that the concept of "value" can only be conceived from a human perspective (Carpenter et al., 2009). Even humans' aesthetic, spiritual, cultural, or ethical appreciation of nature is, in this sense, "utilitarian" (Scholes et al., 2010). However, almost all researchers working in this field would concede that, even if humans were not present, nature would still have a "value." This is its "intrinsic value," in the strictest sense. The acknowledgement of the existence of an intrinsic or non-utilitarian value justifies and strengthens the need for the protection of biodiversity, irrespective of its usefulness to humans. Hence, an approach such as the one adopted in the Millennium Ecosystem

Assessment (MA, 2005) does not dismiss the existence of intrinsic value; it simply states that it is (by definition) unable to quantify an intrinsic value and therefore cannot assess it. In this sense, utilitarian value is complementary to non-utilitarian value, and not a replacement for it (MA, 2005; Scholes et al., 2010). The framework proposed here for an environmental risk assessment for pests is based on the argumentation that it refers both to the non-utilitarian value of nature considering the human influences on biodiversity as structural component of ecosystems, and to the utilitarian perspective considering modification in functional traits relevant to ecosystem services provision.

Several ecosystem services classification schemes have been proposed starting from the one elaborated in the context of the Millennium Ecosystem Assessment (MA, 2005). Among others Wallace (2007) argued that the classification systems currently used for ecosystem services are inadequate because they mix ends and means. However, in this document it is preferred to rely on the scheme originally proposed by the Millennium Ecosystem Assessment (MA, 2005) in virtue of the appropriately broad content (Costanza, 2008) and because it is widely recognized and adopted. Following Carpenter et al. (2009) and de Bello et al. (2010), the regulating and supporting ecosystem service categories identified by the Millennium Ecosystem Assessment (MA, 2005) are combined, because a clear objective distinction between the two categories is not available (Brauman et al., 2007; Carpenter et al., 2009; de Bello et al., 2010). Particular attention has to be devoted to the evaluation of the provisioning services in order to avoid the problem of a double counting, and before evaluating them in the environmental risk assessment, it should be assessed whether these are not already satisfactorily covered in other parts of the pest risk assessment.

A list of the ecosystem services adopted for the environmental risk assessment of pests is given in Table 1. Many of the ecosystem services in Table 1 can be regarded more properly as ecosystem processes and not services (Wallace, 2007; Fisher et al., 2009), particularly for regulating and supporting services. However the analysis of environmental risk assessment is simplified and can be usefully conducted if considering both ecosystem services sensu stricto and ecosystem processes at the basis of ecosystem services instead of considering only “the benefits people obtain from ecosystems” (MA, 2005).

Note: In the list of regulating and supporting services the Natural Hazard Regulation has not been considered as a separate category. Since natural hazards affect different environmental matrices (water, soil, air, etc.), the regulation of these extreme events or disturbances has been taken into account as a component of the regulatory services concerning the specific environmental matrices (e.g. flood regulation is addressed under “Water regulation, cycling and purification services”).

Table 1: List of ecosystem services for the evaluation of the environmental risk associated to the introduction and establishment of pests.

TYPE OF SERVICE	SERVICE
Provisioning services	Food
	Fibre
	Genetic resources
	Biochemicals, natural medicines, etc
	Ornamental resources
	Fresh water

Regulating and supporting services	Air quality regulation
	Climate regulation
	Water regulation
	Water cycling
	Soil formation
	Erosion regulation
	Nutrient cycling
	Photosynthesis and primary production
	Pest regulation
	Disease regulation
	Pollination

Some basic assumptions are presented below for the development of an ecosystem services approach for a risk assessment of invasive pests:

(i) Invasive pests may be regarded as a process of ecological disturbance. Such invasions can produce environmental stress occurring over a relatively short period of time and causing potentially large changes in the affected ecosystems. When a pest is establishing in a new area, it can gradually change its role into an ecological driving factor (ecological driver) and result in important socio-ecological system modifications.

(ii) In the environmental risk assessment procedure it is of primary interest to consider environmental structures and processes taking into account their interaction into a systemic complex unit. The ecosystem concept represents the most appropriate level of analysis for the environmental risk assessment of invasive pest species. It does not sacrifice the components, but prevents to overlook the importance of systemic effects. The concept of ecosystem is defined here following Jørgensen (2002) as a highly complex functional system that sustains life and includes all biological and non-biological variables. In this definition, spatial and temporal scales of ecosystems are not specified a priori but are based on the objectives of the analysis.

(iii) Environmental risk assessment in pest risk assessment deals with the ecological sub-system in a socio-ecological system (Walker and Salt, 2006). However, ecological or environmental assessment (here considered as synonymous) of invasions normally cannot ignore how humans manage the environment. In most cases, the interest in biological invasions is restricted to the effects of the pest on human-modified ecosystems (Western, 2001).

(iv) If the most appropriate level of analysis for the environmental risk assessment of a pest is at the ecosystem level, and the system of interest for evaluation is in most cases a human managed ecosystem, the potential effect of this type of driver of ecological change can be effectively assessed in terms of modification of ecosystem services provision. This is justified by the consideration that the concept of ecosystem services summarizes ecosystem properties of the environment relevant to human well-being and interests. In other words, because human interests for the ecological component of socio-ecological systems are described by the dynamics and exploitation (production and consumption, or depletion) of ecosystem services, an environmental risk becomes relevant inasmuch as it changes the dynamics of ecosystem services creation and use.

To perform the environmental risk assessment of a pest based on ecosystem services, it is necessary:

(i) To identify the environmental components or units responsible for the genesis and regulation of the ecosystem services. These units are here defined as service providing units (Vanderwalle et al., 2008), and are regarded as functional units in which the components (individuals, species or communities) are characterized by functional traits defining their ecological role. Service providing units share with the ecosystem concept definitions of the spatial and temporal scales which are not specified a priori but are based on the objectives of the analysis. Not all the elements (individual, species or communities) belonging to a service providing unit are necessarily measured: depending on the objective of the assessment and the ecological knowledge available, only a limited set of elements are taken into account in an environmental risk assessment based on ecosystem services.

(ii) To consider the impact of the pest on the components of the structural biodiversity at the genetic, species, habitat, community, and ecosystem levels. The importance of evaluating changes in structural biodiversity is twofold. First, it allows considering the non-utilitarian value of nature, addressing conservation related issues and the effects of the pest on the components of the natural capital. Second, the consideration of the pest effects on the natural capital is also a premise for the evaluation of the expected contribution of biodiversity (functional biodiversity) in ensuring that systems have the capacity to cope with drivers of ecosystem change and maintain desirable ecosystem functions (and services) (Walker, 1992; Naeem, 1998; Fonseca and Ganade, 2001; Rosenfeld, 2002).

(iii) To establish a procedure for the evaluation of the effects of pests on ecosystem services (Figure 2). The components of a service providing unit are characterized by specific functional traits. The analysis of the ecological basis of ecosystem services translates into an analysis of the relationship between functional traits in the service providing unit and the related ecosystem services. Given the systemic nature of ecosystems, a linear relationship between ecosystem services and functional traits is not expected, but it is possible to identify clusters that link functional traits and ecosystem services. In the environmental risk assessment of pests based on ecosystem services, the effect of the pest, as driver of ecosystem change, can be regarded as the ability to change the functional traits in the service providing unit, which in turn affects the level of ecosystem services provision. A number of characteristics and properties of socio-ecological systems, including control operations managed by humans, can modify or mitigate the degree of change due to the pest in functional traits, and then in the ecosystem services level of provision. These features (e.g., management activities, ecosystem resistance and resilience) have to be considered in the construction of future scenarios when the environmental risk assessment of the pest is performed.

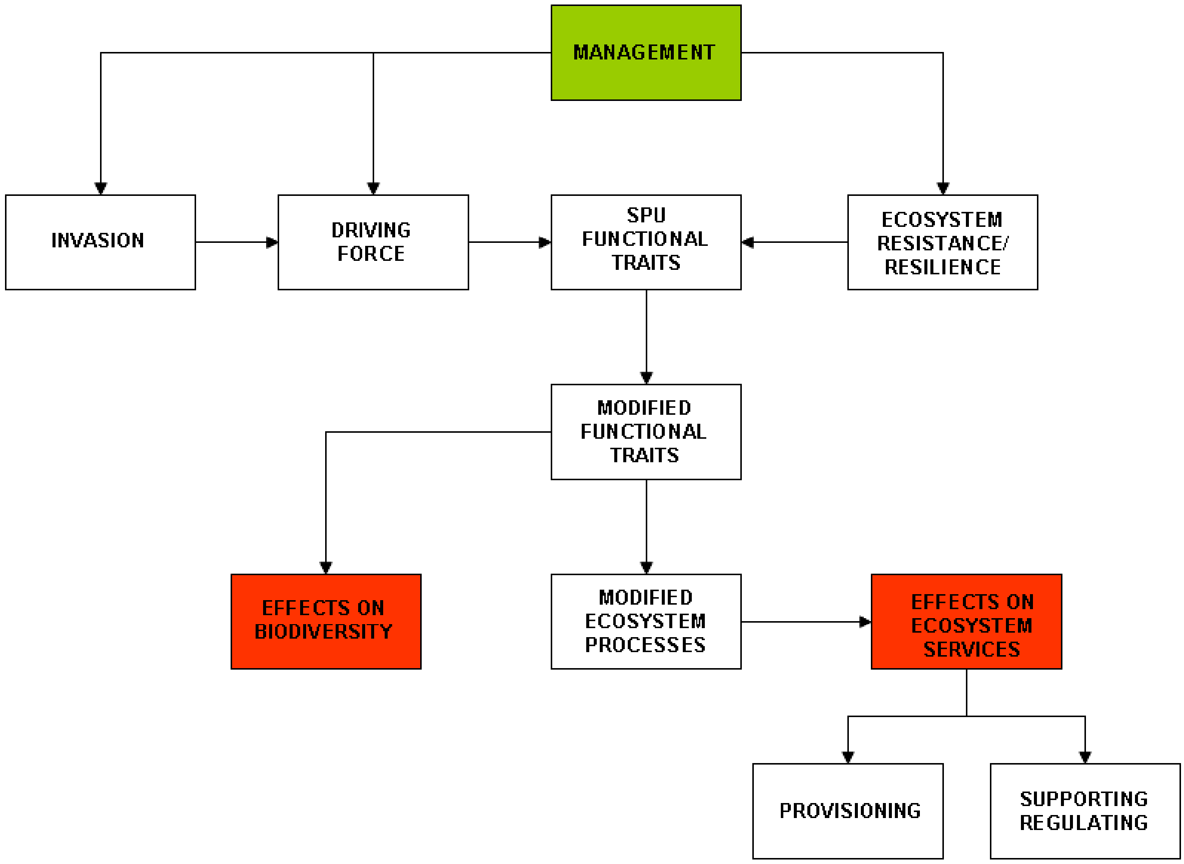


Figure 2: Flow diagram representing stages and pathways for an environmental risk assessment of invasive pests based on ecosystem services.

4.1.2. How to frame an environmental risk assessment for invasive pest species based on ecosystem services

4.1.2.1. Service providing units

Flows of ecosystem services per unit time are closely linked to changes in the levels (stocks) of resources (natural capital) needed to produce those flows. For example, there can be little cycling of soil nutrients, the flow of fertility, without the necessary populations of soil organisms, the stock of biological resources. Similarly, there can be a reduction in photosynthesis if plants have been defoliated by a pest. The MA conceptual framework emphasizes the flows of ecosystem services but rather disregards the stocks of resources that are essential to sustainability (Tomich et al., 2010).

Resource stocks are increasingly recognized as crucial variables, presumably because they can be used to determine how resources will persist under current or future patterns of use or pressure due to drivers of ecosystem change (Victor, 1991). Apart from the biophysical and the chemical components, resource stocks are made of biodiversity components (MA, 2005). The possibility to explain the origin and the maintenance of ecosystem services flows depends on an understanding of the link between biodiversity and ecosystem services (Haines-Young and Potschin, 2007a, b; Kremen et al., 2007).

While research on the contribution of biodiversity to ecosystem services is at an early stage, the biodiversity contribution to selected ecosystem processes is relatively well established (Vanderwalle et al., 2008). This line of research focused on the role species and functional diversity (particularly in plants) play in modulating ecosystem processes such as primary production, nitrogen retention, decomposition and stability (Huston, 1997; Schwartz et al., 2000; Díaz and Cabido, 2001; Loreau et al., 2001; Tilman et al., 2001; Duffy, 2002; Srivastava and Vellend, 2005; Tilman et al., 2006). Many authors highlighted the lack of a theoretical framework to link biodiversity with ecosystem services provision and human well-being (e.g. Balvanera et al., 2006; Carpenter et al., 2006; Díaz et al., 2006; Tilman et al., 2006). Approaches have been proposed that identify and quantify changes in ecosystem dynamics and their implications for ecosystem services (Luck et al., 2003; Kremen, 2005; Haines-Young and Potschin, 2007a, b; Kremen et al., 2007).

Kremen (2005) emphasised the importance of identifying key ecosystem services providers and determining how the dynamics of functional groups of species (e.g. population abundance and spatio-temporal variation in group membership) may influence ecosystem services provision. Luck et al. (2003) argued that species populations are the fundamental unit contributing to ecosystem services and there is an urgent need to understand the links between species population dynamics (e.g. changes in population density and distribution) and ecosystem services provision. To address this issue, Luck et al. (2003) introduced the concept of “service providing units” to link explicitly species populations, now extended to include communities of species, with the services they provide to humans. The crucial point of this approach is that changes in key characteristics of populations or other structural and functional units, such as functional groups and communities (that might for instance be caused by the effect of invasive species) have implications for service provision and such changes need to be quantified to fully understand these implications (Vanderwalle et al., 2008).

A service providing unit can be defined simply as the component of biodiversity necessary to deliver a given ecosystem service at the level required by service beneficiaries (Luck et al., 2003). This definition implies that the components of biodiversity providing the service can be identified and quantified, although their identification and the attribution of relative importance in most cases is necessarily limited to a restricted set of systematic and functional components (Vanderwalle et al., 2008). In the context of the environmental risk assessment for an invasive pest, the minimum set of biodiversity components providing a service is given by the plant community threatened by the invasive pest. The simplest case of service providing unit is represented by a single species of plant for a monophagous pest. According to the objective of the analysis and the available knowledge, the definition of the service providing unit can be expanded including other components of the ecosystem functionally related to the plant community (e.g. the community of herbivores associated to the plant).

The service providing units concept originally focused on species populations. A population can be defined using genetic, geographic or demographic criteria, but Luck et al. (2003) argued that defining a population based on its contribution to ecosystem services was essential when documenting the impact that changes in that population would have on human well-being. Recognising logistical difficulties (although not impossibilities) in applying the service providing units approach using species populations in real landscapes, Luck et al. (2003) suggested that the concept could be extended beyond the population level to include functional groups and ecological communities. In this sense, a service providing unit is a collection of individuals from one or more species that possess certain characteristics, or trait attributes, required for service provision (Vanderwalle et al., 2008). Thus extended, the service providing units approach is potentially freed from traditional organisational hierarchies by defining any collection of individuals or species as a service providing unit irrespective of their organisational level (Vanderwalle et al., 2008). Service providing units often comprise more than one species and there may be inter-specific differences in the contribution to a given service. Species or populations may also contribute to more than one service or be antagonistic to the supply of a different service.

A service providing unit can be regarded as a functional unit in which the components (individuals or species) are characterized by functional traits defining their ecological role (i.e. their contribution to ecosystem processes) and, in turn, their contribution to ecosystem services. Functional traits are morpho-physio-phenological traits which affect fitness via their effects on growth, reproduction and survival, the three components of individual performance (Violle et al., 2007). Functional traits are strictly related to variation in rate functions and depend on the pattern of functional connection within a community (Violle and Jiang, 2009).

4.1.2.2. Considerations about structural biodiversity

Invasive pests ubiquitously and profoundly influenced the shape of the world's biota over geological time. Invasive pests have caused drastic changes in the biota of islands like New Zealand or Hawaii (Pejchar and Mooney, 2009). Today, the pace of species introduction due to human activities has vastly increased. Invasions are recognized as an important component of human-induced global change and as a serious threat to biodiversity (Vitousek et al., 1997). Introduced species make up 26–40 % of all plant species in isolated regions, and even more on islands: for example, 82 % of Ascension Island's biota is composed of introduced species (Vitousek et al., 1997). Continental areas are no exception: in these regions, introduced species make a significant contribution both in terms of the number of species per unit area and as their relative share in the flora (Jeanmonod et al., 2011).

The long-term global effects of invasions are also substantial, because they decrease the distinctiveness of local floras and faunas. For example, New Zealand today has more vertebrate species than at the time of human colonization about 1,000 years ago (Tennyson, 2010). Although New Zealand has become more 'diverse', it has also become more similar to the rest of the world.

The concept of biological diversity, or biodiversity, denotes the variety of life forms. The definition of the Convention on Biological Diversity (CBD) states: "Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems. This includes diversity within species, between species and of ecosystems (Art. 2 of CBD, 1992). This definition recognises genetic, species and ecosystem diversity. While e.g. physiological and ontogenetical diversity also exist, in the interest of simplicity, it is useful to restrict the evaluation to genetic, specific and ecosystem diversity. Thus, diversity ranges from the infra-individual level (within individual level, genetic diversity) to the species level and above-individual diversity (ecosystem diversity). Of these layers, species diversity, characterised by sampling individuals, is the level of diversity most often mentioned, especially in a non-scientific context.

For the purposes of this guidance, the concept of biodiversity captures the structural aspects of ecosystem functioning (Naeem et al., 2002), e.g. "the players" in the "evolutionary play" (Hutchinson, 1965), i.e. the ecological processes subject to selection and other evolutionary forces. For the present evaluation, the ecological timescale (vs. the evolutionary one) is usually sufficient, as it encompasses the overall concern of the environmental risk assessment.

Spatial and temporal constraints of ecological events need to be considered, because by surveying biodiversity alone, the environmental risk assessment of a new, invasive organism is incomplete. The timescale, for example, of changes in species inventories, is linked to the lifespan of the constituting organisms. Adults of a certain species may still be present but unable to reproduce, and the loss of that species will not be obvious until most (or all) the adults die. This can take a considerable time (e.g. centuries for trees). Harmful effects are thus not necessarily manifested in species presence or absence. It may be possible to detect them only after changes in ecological function have appeared. Therefore, after a structural evaluation (i.e. effects on genetic, species and landscape diversity), a functional evaluation (i.e. effects on ecosystem services) is necessary.

Considering the spatial dimension of biodiversity, local (alpha-), medium-scale (beta-) and regional (gamma) diversities are recognised. A forest can be very species-rich, and thus will have high local (alpha) diversity. However, if all such forests have the same set of species, the higher-level (beta and gamma) diversities will be low. Invasions could result in an increase of the local (alpha) diversity, but at the same time the effect on higher level diversity is detrimental (beta- and gamma diversities decrease). In many cases, however, invasions cause a net loss of diversity at all spatial levels. This happens frequently enough so that the loss of diversity is a major concern when analysing the effects of invasions.

4.1.2.3. Why should biodiversity evaluation be restricted to species number-based characteristics?

Biodiversity is a complex and dynamic concept, and any assessment will simplify it. The two basic problems when trying to characterise diversity are caused by methodological constraints and the fact that diversity is not a static feature of a community or assemblage, but changes with time.

A taxonomy of diversity measures exists (e.g. Tóthmérész, 1995). The simplest diversity measures are based on the enumeration of species, while a second class considers both the number of species and their abundance. The advantage of the first approach is that it has an easy biological interpretation. The disadvantage is that this method neglects abundance, which can provide important information about the status and evenness of the community. Early work on diversity characterisation concentrated on the second class of measures, aiming to develop different indices that consider both species numbers and abundances. There is a large number of suggested indices (for a summary, see Magurran, 2003). Recent theoretical developments successfully synthesised the above two classes, and there is an emerging consensus that species-based statistics (called “number equivalent”) are useful and informative measures of changes in biodiversity (Jost, 2007). These indices still use quantitative information about abundance as well as the number of species, but express their result as number of expected or estimated species (or other suitable units of diversity). This makes their biological interpretation feasible and intuitive. Therefore, it is suggested only to use the approaches concerned with loss of entities: the decrease in the number of genes, species, or ecosystem/landscape types. Also to be noted is that changes in abundance and rearrangements of assemblage or community structure, as a consequence of invasion, will appear as changes in ecosystem function; these changes are also evaluated within this framework (Section 4.1.2.5.).

Biodiversity at one area is considered higher if the number of genes, species and ecosystems is higher than the number of the same entity at another area. This, however, is not a fixed number, and depends on the spatial and temporal scale of the assessment, as well as the sampling intensity. For example, the number of species in an area can be definitively assessed only if all individuals have been identified – and this is practically rarely possible. Care should be taken to compare the results of different censuses only if the conditions of the sampling are comparable.

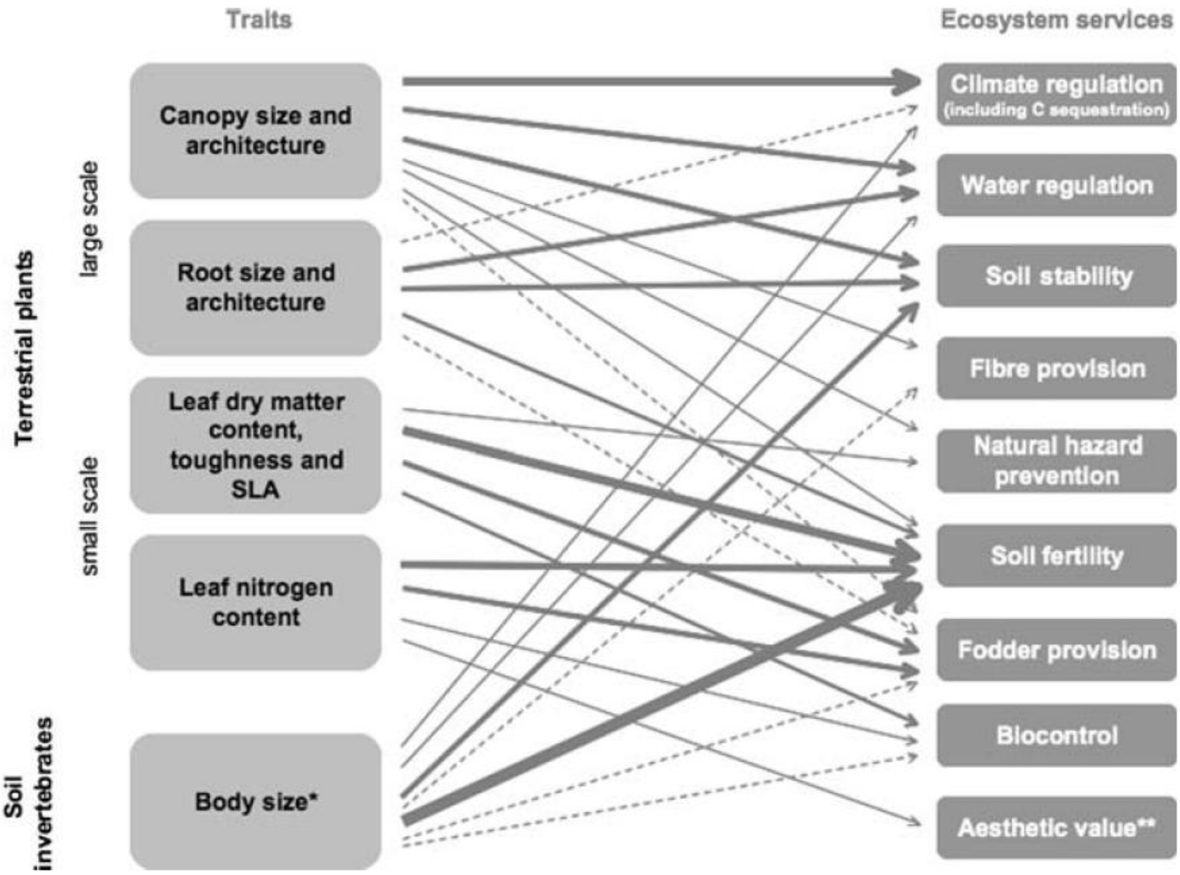
4.1.2.4. Service providing unit functional traits and ecosystem services

The ability of an ecosystem to provide multiple services can be gauged by:

(i) allocating relevant ecosystem properties to each service and identifying which organisms or groups of organisms in the service providing unit control these properties (Kremen, 2005);

(ii) identifying the key characteristics (functional traits) and mechanisms by which these organisms affect ecosystem properties (Luck et al., 2009).

Due to the systemic nature of ecosystems, there is the tendency to find clusters of traits and services (de Bello et al., 2010) (Figure 3). Each functional trait can participate in different ecosystem processes and may be linked to several ecosystem services. The connections or associations between a trait and the related services vary in amplitude and magnitude.



SLA: specific leaf area.
* Body size can be often related to difference in feeding habit.
** The aesthetic value refers to multiple cultural services linked to land stewardship

Figure 3: (from de Bello et al., 2010, with kind permission from Springer Science+Business Media B.V): Most commonly reported plant and invertebrate traits and their involvement in multiple ecosystem service delivery. Larger arrow thickness for a given trait–service relationship indicates associations with more entries in the database (i.e., more statistically significant associations found in the literature). The assessment within this framework of multiple trait–service association with field data is thought to reduce uncertainties in the management of multifunctional ecosystems.

The available knowledge on the functional traits underlying the delivery of ecosystem services across different trophic levels is still limited. Nonetheless, the recent increase in the amount of studies enables a more solid analysis of the relationship between biodiversity components and their role in ecosystem functioning (de Bello et al., 2008, 2010). The processes most often reported to underlie trait-service associations were rate of decomposition and mineralization, nutrient retention and sedimentation, net primary productivity, evapotranspiration and herbivory. Functional trait effects on ecosystem processes were most frequently reported at the levels of functional groups and dominant trait values in a community followed by those assessing traits of single species. Studies on the range of traits in a community and its effects on ecosystem services were less common and mostly referred to primary productivity, nutrient cycling, pollination and their maintenance through time. A clear directional relationship between functional traits and the delivery of services could be established in the majority of the cases analyzed in literature.

Within organism groups defining a service providing unit, combination of key traits are fundamental in controlling a range of ecosystem processes and services. Several individual traits simultaneously affect the provision of multiple services and the single services often depend on multiple traits, resulting in clusters of association between traits and services (de Bello et al., 2010). The idea of a simultaneous control from a combination of traits on a given process has been considered a common pattern in socio-ecological systems across trophic levels and ecosystem services (Diaz et al., 2007). The combination of functional traits across trophic levels controls the provision of multiple ecosystem services and can be used to identify trait-service clusters. The identification of these clusters is a complex methodological task. A method based on multivariate analysis has been proposed (de Bello et al., 2010), and examples showing a strong association between traits from different types of organisms in controlling a range of processes and services are accumulating (Kremen et al., 2007; de Bello et al., 2008), especially for traits of plants and soil organisms that underlie nutrient cycling, herbivory, fodder and fibre production.

Trait-service clusters underlie potential associations between services depending on the same functional traits. However, studies explicitly quantifying the relative influence of various traits on multiple ecosystem function and services are rare (Diaz et al., 2006). For example, the same trait configuration in plant communities could improve fodder production and reduce soil carbon sequestration. Trait-service analysis can be expanded across trophic levels. A synergistic effect could occur when ecosystem services are determined by the coupled action of two or more trophic levels (for example pollination is determined by the interaction of plant and insect traits). In multitrophic cascades, one trophic level alters the functional composition of an associated trophic level modifying the provision of a given service. Pathway analysis could be applied to provide estimates of the magnitude and significance of the hypothesised causal connections between trophic levels and ecosystem services.

Also the spatial dimension has to be considered in the analysis of trait-service clusters. For each ecological process it is necessary to consider the spatial scale over which biological effects are primarily acting. The strength of trait-service associations might depend on the spatial scale over which the effect traits operate and the scale over which services are delivered.

4.1.2.5. Impact of pests on ecosystem services

The ecological meaning or effect of an invasion depends on the interaction between traits of the invasive species and traits of the invaded community (Levine et al., 2003). The same interaction is at the basis of invasibility analysis.

In many traditional approaches to environmental risk assessment, invasive pests are considered for the modification they cause to components of the structure of invaded communities (e.g. genetic and genomic structure, species or ecosystem diversity, structural aspects in trophic webs, etc.). This is the main focus in most of the published reviews dealing with invading insects (Kenis et al., 2009), plants (Levine et al., 2003), and fungi (Desprez-Loustau et al., 2007). However, modification in structural aspects at individual, population and community levels, produced by the pests as a biological driving force, is the observable outcome of an underlying modification in the functional traits of the biotic component of ecosystems, due to the semantic process of interaction between a pest and the receiving community (Figure 2).

The objective of an environmental risk assessment based on ecosystem services is to understand the impact of invasion in terms of modification of functional traits of the components of the service providing unit. Then, changes in functional traits are associated with the variation in ecosystem services provision levels by means of the consideration of trait-service clusters. As stated above, the service providing units approach is potentially freed from traditional organisational hierarchies by defining any collection of individuals or species relevant to the provision of ecosystem services (Vanderwalle et al., 2008). The modification of the functional traits of the components of the service providing unit is the object of the environmental risk assessment of the pest.

Functional traits modification due to the action of pests influences ecosystem processes (Figure 3) at individual, population, as well as the community level (McGill et al., 2006).

A. *Individual level*. Many characteristics of an organism with demonstrable links to organism function can be modified during the interaction with invasive pests (e.g. morphological, biochemical or regeneration traits in plants; growth, reproduction and survival, or movement in animals). These features can be globally interpreted in terms of changes in rate processes characterizing the life history strategies. Easily measurable functional traits have been identified for plants, and standardized protocols for their assessment have been produced (Cornelissen et al., 2003). Such shortlists need to be further developed for other organisms and functional groups (e.g. pollinators).

B. *Population level*. Properties that characterize the population contribution to ecosystem processes can be modified by the direct or indirect interaction with an invasive species (e.g. demographic traits, competitive capacities). These effects finally result in a modification in population abundance, structure and dynamics.

C. *Community level*. Properties that characterize community contribution to ecosystem processes can be modified under the pressure of a biotic driving factor. These factors have effects on matter and energy fluxes, temporal and spatial dynamics and evolution of biocenosis, variation in stability and regulative properties. Trait effects on ecosystem processes are mediated by the type, range and relative abundance of functional attributes in a given community (a property also known as functional diversity, see Diaz and Cabido, 2001; Loreau et al., 2001; Diaz et al., 2007). Some examples of functional trait evaluation at community level are reported by de Bello et al. (2010). The functional traits identified by these authors represent important elements of possible interest for an evaluation of the impact of pests on service providing unit components at community levels. Such elements are:

   (i) The presence of functional groups, defined as collection of organisms with similar suites of co-occurring functional attributes (also referred as guild);

   (ii) The consideration of the dominant traits. The dominant species in a community are those which represent most of the biomass in each trophic level and control biomass fluxes in that level and exert a key effect on many ecosystem processes;

   (iii) The functional divergence (or trait range), the degree of functional dissimilarity in traits within the community (e.g. number of functional groups or functional richness). Functional divergence can be seen as linked to “niche complementary effects”, where ecological differences between species lead to more complete utilization of resources (Tilman et al., 1997a, b, c).

Ensuring continuation of service provision via service providing unit requires consideration of their resistance and resilience to changes and the maintenance of future options. The level of resilience in an ecosystem is defined by its capacity to cope with environmental change, through buffering, adaptation and re-organisation, and still maintain crucial ecosystem functions (Holling, 1973; Walker, 1995; Elmqvist et al., 2003). The degree of ecological change induced by a pest is mediated by resistance and resilience properties (including adaptability) of the invaded community.

Clearly, resilience is a relative term dependent on the interactions between ecosystems and the magnitude and types of environmental pressures produced by the driving force. Sensitivity to environmental change and the implications of service disruption is a potential approach to prioritising the protection of ecosystem services (and their service providers). System resistance (Bailey and Schweitzer, 2010) and resilience (Walker et al., 2010) to invasion also depend upon the scale of the impacts. The temporal and spatial dimensions are extremely important. An invasive species needs time to change its role from a driving force causing local disturbance to become a component that drives ecosystem change in determining the direction of the evolution of large communities over wide areas. Aspects of resistance and resilience have been studied experimentally mostly at individual levels, while at community and ecosystems levels the results are often inconclusive (Ives and Carpenter, 2007). There is some evidence, though, that more diverse ecosystems are more resistant to the invasion of pests and pathogens (Keesing et al., 2010).

The service providing units concept facilitates the identification and quantification of variation in functional traits related to the extent and importance of the functional relationship that the invasive species establishes with the resident community. Variations in both functional traits and relationships are at the origin of resistance and resilience properties and mediate the possible impact of a pest. Resilience is relevant within and across service providing units, but its management is dependent on the type of service providing unit. For example, if a service providing unit has been identified as the population of a key species, resilience may be maintained by ensuring that life history (e.g. reproductive success), population and genetic characteristics (e.g. variability) are appropriate to cope with likely changes in the environment due to the pest.

If service providing units are defined by functional groups, resilience at the local level is likely best maintained if there is a high degree of functional redundancy within a group, ensuring that the service is preserved even if some species are lost. This can be facilitated by maximising ecosystem diversity (Chapin et al. 2000), although the value of this approach appears to be context-dependent (Balvanera et al., 2006). If functional redundancy is low, it is necessary to focus on protecting populations of key species. At the ecosystem level, resilience is conferred by maintaining system diversity and appropriate spatio-temporal characteristics (e.g. area and seasonal fluxes) that enhance adaptability and by reorganising capacity (Elmqvist et al., 2003). Protection of whole ecosystems that provide services is crucial since their replacement is extremely difficult.

The value of the service providing units concept in relation to dynamics is further enhanced when the influence of external, anthropogenic processes such as climate change is considered. A permanent shift in conditions or an increase of stress can lead to changes in the balance between species, changes in species and/or functional composition and therefore to changes in the composition of service providing unit, with potentially important consequences for conservation and management.

4.2. Methodology

4.2.1. Scenario development

4.2.1.1. Meaning and importance of the scenario exercise

In the absence of complete information or models assessing the effects of pests on ecosystems, a useful contribution can still be made by describing the causal chain by which an effect can be estimated. Even a narrative description of the pathway of an effect is an advance over having no information at all

(Carpenter et al., 2009). In most cases of environmental risk assessment, evaluation criteria and qualitative/quantitative estimation cannot benefit from a deeper understanding of the ecological processes and their reaction to the driving force. In fact, only the use of a scenario can help to address complexity and uncertainty characterizing the environmental risk assessment of pests. Scenario exercises are seen as particularly useful to assess future developments within complex and uncertain systems, such as ecosystems. As a consequence, scenarios have been widely used in ecosystem assessment issues (IPCC, 2000; UNEP, 2002; EEA, 2005).

In MA (2005), scenarios are defined as "plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces and relationships". Many other definitions have been proposed, but nearly all definitions have in common that scenarios explore a range of plausible future changes and that scenarios are neither predictions nor forecasts; scenarios are also no attempts to show the most likely estimates of future trends (Zurek and Henrichs, 2007; Henrichs et al., 2010).

In this guidance document, there is an interest in producing explorative scenarios related to environmental risk associated to pests. Explorative scenarios are attempts to explore what future developments may be triggered by a driving force, in this case an exogenous driving force, i.e. a driving force that cannot or can only partially be influenced by decision makers (Henrichs et al., 2010). As in many recent international environmental assessments, the purpose of the present document is to develop and analyze scenarios that explicitly combine qualitative and quantitative information and estimates (EEA, 2001). Most of the work is based on qualitative evaluation that can be translated into quantitative assumptions on the final state of the system (Henrichs et al., 2010). In the probabilistic evaluation at the basis of scenario development, expert opinions and conjectures are fundamental (Hein et al., 2006).

4.2.1.2. Scenario assumptions

For the environmental risk assessment of pests on ecosystem services, a scenario of the expected modifications is produced. To develop scenarios, assumptions on the initial state of the systems and future trends need to be considered. The consideration of different configurations of assumptions leads to just as many scenarios to be developed. Also the consideration of critical uncertainties may require the development of additional scenarios (Henrichs et al., 2010). By providing a representation of the initial conditions of the system (e.g. current distribution of the invasive pest, distribution of the host plant(s) reported in other sections of the pest risk assessment), a scenario can be produced according to the following list of assumptions.

A. Temporal horizon

Defining a time horizon(s) is critical. The temporal horizon of a scenario should be based on what is a reasonable length of time for the main issue of concern to be explored or managed (Henrichs et al., 2010). This temporal frame is dependent on the expected trends in the time evolution of the environmental impact of the pest. There is a lack of clearly definable criteria to assist in delimiting a time horizon. Nonetheless, the following characteristics may be taken into account:

(i) The spread of the pest (assessed in the full pest risk assessment scheme, corresponding to questions 1.32-1.34 in the EFSA scheme). The time horizon should be shortened as the rate of spread increases. The rate of spread depends on the biology of the pest (e.g. number of generations per year), the patterns of diffusion (e.g. random, stratified, human assisted), the continuity of the suitable habitat, and the climatic factors.

(ii) The rate of appearance of the impact. The impact of an invasive pest becomes manifest only after some time: for this aspect, information on the appearance of the impact should be considered, because the faster the appearance of changes in affected ecosystems (low resistance) the shorter the time horizon could be. Besides the biology and ecology of the pest, the rate of appearance is strictly related to the system resistance (see below). In the case of a full pest risk assessment including the evaluation of effectiveness of risk reduction options, information can be extracted from parts of the pest risk assessment scheme where detection and eradication measures are described. The concept of lag phase is not considered as such in the current pest risk assessment scheme, but rather through the ease of detection of the species, manifestation and visibility of symptoms, time frame chosen, adaptability of the pest even if the time is not taken into account in this question. So it could be considered further in the pest risk assessment scheme.

(iii) Process uncertainties. Long term exploration and projections in ecosystem assessment are affected by high uncertainties, due to the future pattern of action of other drivers (endogenous and exogenous) of ecosystem change. Uncertainties tend to increase over time. High levels of uncertainties in mechanisms and effects involved in the interaction between the pest and the receiving environment suggest a reduction of the time horizon. In the pest risk assessment, uncertainties are considered for each question and the main uncertainties are summarised at the end of the risk assessment process.

There are three options for time horizon choice:

(i) Single time horizon;

(ii) Multiple time horizon;

(iii) The assessment is made on the worst case: by assuming that sufficient time has passed for the pest to invade the whole area of potential establishment.

In the case of multiple time horizons a scenario evaluation is required for each defined time horizon. While some pests may take a very long time to cause impacts, e.g. because the climate is not yet sufficiently warm to allow multiple generations to develop and reach very high population densities, it is recognised that pest risk managers still need an assessment of impacts under current conditions and the choice of a too long time horizon may make it difficult to justify phytosanitary measures.

B. Spatial scale: spread in the defined time frame

The spatial extent considers the area of potential establishment and corresponds to the total area potentially affected by the driving force (the pest) at the end of the selected time horizon.

The spatial extent is determined by means of the selected timeframe, the estimated area of potential establishment and the assessment of the dynamics of the spread in the risk assessment area provided elsewhere in the pest risk assessment.

The assessment is performed for the area assumed to be affected.

C. Spatial scale: resolution

Scale aspects related to the grain clarify whether the impact in the risk assessment area is expected to be spatially inhomogeneous, and give information on the possible spatial pattern of variation in the magnitude of the impact. A worst case scenario has to be considered to be the area of potential establishment (already identified in the pest risk assessment). According to the level of spatial resolution required in the assessment, for the cases ii) and iii) under point A, a specific comment reporting information on the spatial variation of the impact is added at the end of each sub-question in the list of questions.

D. Resistance

Resistance to an invaded pest is a new concept to be introduced to the pest risk assessment scheme, as it is not dealt with as such. The expected pattern of variation in the impact of an invasive pest depends on the capacity of the invaded ecosystem to oppose resistance to ecosystem change. Different patterns in the time evolution of the impact offer the possibility to consider three different options (Figure 4). If the impact is defined as the % of loss in ecosystem services provision level:

(i) Low resistance, the trend of the impact displays from the beginning a significant growth, with the possibility to rapidly reach a saturation level (Figure 4A);

(ii) Medium resistance, ecosystem services loss grows gradually over time (e.g. linearly), with no apparent sharp change in the impact rate of variation (Figure 4B);

(iii) High resistance, impact appears not to emerge until a certain point in time when a rapid variation may occur. The ability of the system to oppose to the driving force action could result into a long phase of low impact (Figure 4C).

For the assessment, a specific assumption on the resistance level of the invaded environment is required and the impact is evaluated accordingly. The selection of a level of resistance contributes to set an appropriate time horizon.

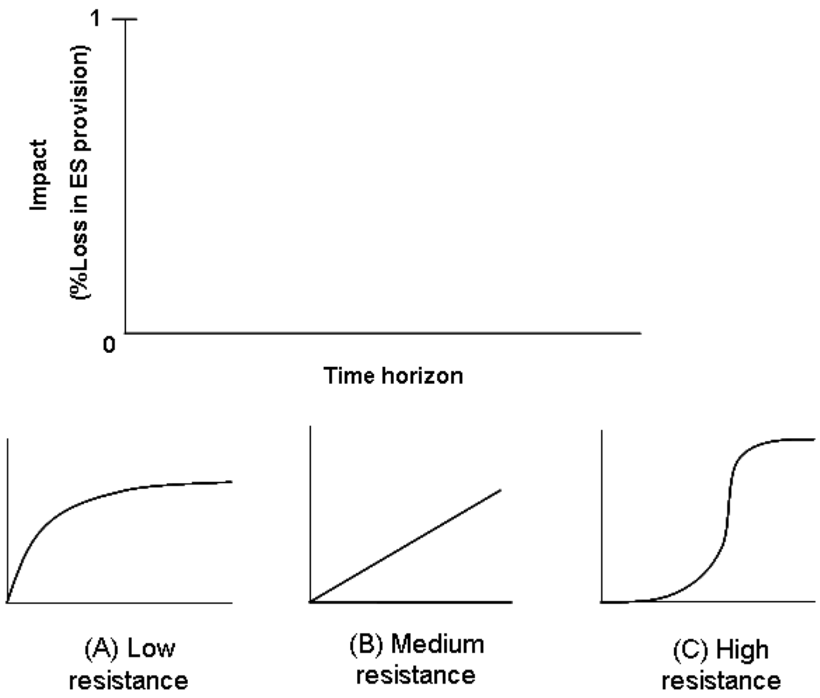


Figure 4: Three different resistance profiles expressing the expected rate of variation in the environmental impact over the temporal dimension.

E. Resilience

Resilience to an invaded pest (Neuenschwander et al., 1987) is a new concept to be introduced to the pest risk assessment scheme, as it is not dealt with as such. The risk variation with respect to the time dimension is also influenced by system resilience. Different types of resilience correspond to different profiles in environmental impact of the pest. At the two extremes, the trend in ecosystem modification may be almost completely reversible (high resilience) or irreversible (low or no resilience).

Different hypotheses on the extent to which ecosystem resilience can mitigate or revert the impact of the pest lead to the consideration of the following three options:

(i) Low resilience (Figure 5A);

(ii) Medium resilience (Figure 5B);

(iii) High resilience (Figure 5C).

For the assessment a specific assumption on the resilience level of the invaded environment is required and the impact is evaluated accordingly. Also the type of resilience characterizing the system contributes to set an appropriate time horizon.

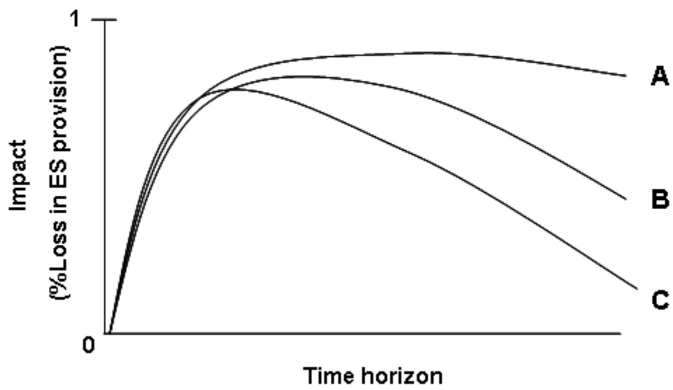


Figure 5: Schematic representation of three possible trends in the temporal development of the environmental impact of the invasive pest related to three resilience options. In low resilient systems, the impact increases up to a maximum after which only little or no change in the impact is observed (A). In medium resilient systems, a decrease of the impact is expected over time after the maximum impact has been reached (B). In highly resilient systems, a strong reduction on the impact is expected (C).

F. Management measures

Assumptions on the presence, type and efficacy of the existing management measures allow modifying possible trends of the impact of the pest.

There are two options:

(i) No management measures or actions that do not change the pattern of the impact;

(ii) Management measures capable to modify the pattern of the impact through a) containment and eradication, b) modification of the intensity of the driving force action, c) resistance and/or resilience of the invaded communities and ecosystems.

For the assessment, a specific assumption on management is required and the impact is evaluated accordingly.

4.2.2. A procedure for environmental risk assessment based on impacts on ecosystem services: preliminary information

A. Review of the available scientific literature and documents

A review of the type and intensity of the current environmental impact in other invaded regions (outside the risk assessment area) is required. From this information, the prevalent ecological role and the ecological interactions that the pest establishes (or is expected to establish) in the current area of invasion and in its different developmental stages, can be defined. If the species has not invaded any other area, or if the invasion is too recent and too little is known on its ecology in the invaded areas, the ecological role of the species as a driver of ecosystem change can be evaluated in the native distribution area. This information is not considered as a predictor for the potential impact on the risk assessment area, but helps identify elements and mechanisms of the potential impact.

The ecological role for a pest acting as a driver of ecosystem change is restricted to the following cases:

- Autotroph
- Heterotroph
    - Phytophage / herbivore
    - Predator
    - Parasite
    - Pathogen
    - Vector

B. Identification of the service providing units

The environmental risk assessment based on impacts on ecosystem services requires the identification of one or more target components in the service providing units. An impact on ecosystem services exists only if the pest interacts with target species or target functional groups (populations or other functional units) that have implications for service provision. The components of the affected service providing units are potentially countless. Necessarily, the evaluation has to focus on the main species (e.g. the host plant) or functional group in the community substantially affected by the invasive species. Based on available knowledge, we can start from a minimum set of elements that are affected by the invasive species, then expand – if feasible – the level of detail. Ecological mechanisms of such relationships are trophic interactions, including host-vector-pathogen relationships, and competitive or cooperative interactions. In plant health, only ecosystem services caused by effects on plant species (primary producers) that act as prey/host/competitor of the pest can be included.

C. Identification of the functional traits in the target service providing units components that could be affected by the pest and the sign of the modification

Modification of functional traits (also defined as functional response traits, see Hooper et al., 2005) is evaluated under the hypothesized intensity and scale of the driver pressure.

The following traits at individual level for the target service providing unit can be considered (Lessels, 1991; Begon et al., 2006):

(i) Survival

Components: maintenance, activity/resource acquisition, defence, reparation;

Effects: change in the mortality rate function;

(ii) Uses of the body

Components: storage (accumulation), shape and its change (modification in the organization of the body), uses of the body, dimension;

Effects: change in the growth rate function;

(iii) Development

Components: embryonic development, immature stages development, aging;

Effects: change in the development rate function;

(iv) Reproduction

Components: earliness/delay, semelparity/iteroparity, number of brood, clutch size, offspring dimension, reproductive allocation;

Effects: change in the fecundity rate function.

The following traits at population level for the target service providing unit can be considered (Begon et al., 2006; Smith and Smith, 2006):

(i) Population structure

Average population abundance

Spatial structure: (i) area of distribution, (ii) pattern of distribution defined in terms of continuity (continuous/fragmented=patchiness) and aggregation (regular, random, aggregated);

Demographic structure: (i) stage/age structure, (ii) sex-structure;

Strategic structure: structure in classes with respect of LHS;

(ii) Population dynamics

Spatial dynamics: (i) variation in the area of distribution (rate of spread), (ii) variation in the pattern of distribution (continuity and aggregation);

Temporal dynamics: (i) population rate of increase, (ii) variation in age/stage structure (ii) variation in sex structure;

(iii) Strategic dynamics: variation in LHS traits structure (rate of selection of traits).

Also traits at community levels can be considered (Luck et al., 2003; Vanderwalle et al., 2008). Changes in functional traits due to the driver may affect:

(i) relative abundance/importance of functional groups (guilds);

(ii) relative abundance/importance in dominant species (in different trophic nodes);

(iii) degree of functional dissimilarity in traits within the community (e.g. number of functional groups or functional richness, also called functional divergence).

From the analysis of the traits reported above a synthetic table is derived listing: i) the target elements of the service providing unit affected by the driving force (the invasive pest), ii) the functional traits affected by the pest, iii) an evaluation of the sign of the induced modification, iv) if necessary, relevant comments clarifying the interpretation of the analysis performed (Table 2).

Table 2: Example table to list elements of the service providing units, their affected functional traits, and the evaluation of the induced modification

Elements of the service providing units	Function traits	Effect +/-	Comment

4.2.3. A procedure for environmental risk assessment based on impacts on ecosystem services: impacts on biodiversity

4.2.3.1. Phases and steps of biodiversity assessment

The assessment of biodiversity starts with concerns emerging from legal/administrative constraints, and gradually moves towards a more ecological consideration, thus preparing the ground for the second stage of evaluation, concerning the impacts on ecosystem services. Biodiversity in general, articulated in different ways, is entitled to legal protection in Europe, and thus it is important to assess the impact of a pest on such protected entities. They are often protected not for their ecological role, but for their perceived value, cultural or historical importance. Often (but not always) these are also rare species, which have narrow tolerance limits (Gaston, 1993), and are thus valuable biological indicators to signal emerging changes in the status of ecosystems.

However, neither are all rare species protected, nor are all biological indicators rare. Therefore a general assessment of changes in overall diversity/community structure can lead to useful information on the impact of a pest. Additionally, these can provide a focus when assessing the environmental impact of a pest. This step is performed in the second part of the biodiversity impact assessment.

The general assessment can be divided into several phases which themselves can be subdivided into several steps:

<u>Phase 1</u>

Step 1 – identify the recognised nature values/protected units (species, landscape, object) in the area of concern, being aware that these can be at sub-species, species or above species level. Include domesticated species in the search. Protection can be extended to a special race (e.g. the Florida panther), subspecies, or species. There are different endangerment categories (Red Lists) at species level, but also protected landscapes, or groups of individuals (e.g. avenues formed by old trees).

If step 1 does not yield results, document the search for this information and its result, and skip to the next phase.

Step 2 – identify the special feature for the reason of protection for all those units identified in Step 1. This reason can be its global, regional or local uniqueness, rarity, vulnerability, or other perceived values. This feature can often be found in the document declaring or discussing its protected status.

Step 3 – search for information about the identified protected unit and the special feature. Use flexible relevant search criteria (i.e. searching for related species, similar features) to find information relevant to the pest invasion.

Step 4 – using the collected information and the questions of the environmental risk assessment scheme (Section 5), assess the expected effect (both direction and magnitude) of the pest on those identified units of protection, considering the feature that is the reason for their protected status.

Step 5 – assess if the impact/effect is reversible or irreversible, can or cannot be managed.

Phase 2

Step 6 – search for evidence that other components of biodiversity can be influenced by the pest.

At this step, there is no need to consider protected entities which were already evaluated above. This should be an assessment at the assemblage or community level. Concentrate on common as well as rare species, but consider only changes in presence/absence, population trends, changes in the range of distribution, changes in the dynamics of distribution, extinction of local populations, changes in the dynamics of local metapopulations. The ecological consequences of such changes may serve as pointers for further steps in the evaluation, but at this stage the focus of the assessment is biodiversity, characterised by the presence or abundance of a species (in rare cases, subspecies or race).

Biodiversity is a composite concept, including variability at different organisational levels, from below-individual (genetic diversity) to above-individual (landscape diversity). As a diversity characteristic, evaluate here only the number of entities: the number of genes, species, local populations, or identifiable habitats/communities at landscape level. Be aware that these are dynamic features, and also subject to bias in assessment. For example, the number of species in an ecosystem can only be precisely identified if all individuals that form the community have been inventoried and categorised. This is practically impossible, which is a limit of the census methodology. The reliability of the assessment of changes in species richness should therefore be cross-examined in the light of the applied methodology.

In addition, the number of species that constitute a community is not a static feature, with species present in one year, absent the next, and present again in the following one. Therefore, both the spatial and the temporal scale of the data should be considered: the more extensive any of these is, the more reliable the results.

If step 6 does not yield results, document the search for this information and its result,

Step 7 – using the information collected and the questions in the environmental risk assessment scheme (Section 5), assess the expected effect (both direction and magnitude) of the pest on other (non-protected) biodiversity. When reporting results, make it clear on what basis you reached the conclusion (quantitative data, qualitative data, extent of data, expert opinion).

Step 8 – assess if the impact/effect is reversible or irreversible, can or cannot be managed. Present evidence, if found.

4.2.4. A procedure for environmental risk assessment based on impacts on ecosystem services: change in ecosystem services provision levels

In Section 4.2.2., the target service providing unit has been identified and target components within the service providing unit at the basis of the evaluation have been selected. Then, changes in the functional traits of the service providing unit have been evaluated. The objective is now to derive case-specific trait-service clusters and to estimate the sign and the magnitude of the modification induced by the driver. The analysis is based on the following aspects.

A. Trait-service clusters

Given the systemic nature of social-ecological systems and the limited knowledge available on the ecological basis of ES, identification of trait-service clusters is a complex task. Therefore, exploring throughout the causal chain service providing unit → trait → service could result in an excessive complex pattern of connection, and it is appropriate to set limits to this exploration. The proposed heuristic approach is to derive the most parsimonious set of relationships defining the trait-service cluster.

B. Type of effect

The considered functional traits can be positively or negatively influenced by the effect of the driving force. In turn, variation in the traits can lead to a positive or negative ecosystem services modification (Figure 6). For each trait-service association an analysis of the types has to be conducted.

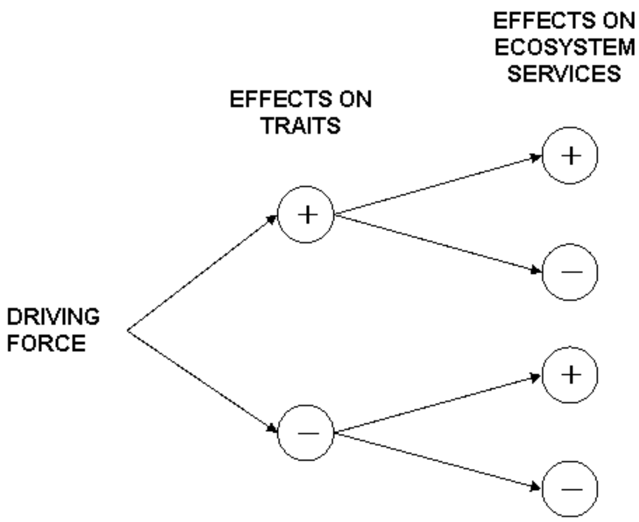


Figure 6: The pest (driving force) can positively or negatively influence the functional traits of the service providing unit, which will lead to a positive or negative modification in ecosystem services provision.

C. Evaluation of changes in ecosystem services provision level

For each trait-service association highlighted in point A, an index is proposed to evaluate the intensity of the impact of trait modification on ecosystem services provision, given the assumptions in Section 5.2. Variation in ecosystem services provision represents the resulting effect of the driving force direct impact on target elements of the service providing unit and the subsequent indirect impacts on other components of the service providing unit.

For the list of affected ecosystem services the relative magnitude of variation (expressed in percentage) in the ecosystem services provision level has to be estimated. Magnitude of the impact is categorized in 5 classes listed in Table 3. Positive variations are not considered.

Table 3: Classes of magnitude for the change in ecosystem services provision

Magnitude class	Reduction (%) in ecosystem services provision level
0	0 (or negligible) variation
1	0 < M=5 %
2	5 < M=20 %
3	20 < M=50 %
4	M>50 %

4.3. Rating system

To help the assessor in determining whether the introduction of the pest will or may have consequences on structural biodiversity and ecosystem services in the risk assessment area, a risk assessment method was developed in this guidance document based on i) a list of $k = 1, \ldots, K$ questions and $i = 1, \ldots, I$ sub-questions, and ii) a proper rating system which ensures consistency and transparency of the assessment. The proposed rating system includes: a) an evaluation of the level of risk for each sub-question; b) a calculation of an index of risk for each question; c) an evaluation of the degree of uncertainty related to the answers of each sub-question; d) the calculation of an index of the uncertainty associated to the answer of each question.

The basis for the proposed procedure for determining the risk is consistent with the definition of risk in the Regulation (EC) No 178/2002[8], as well as with the recent revision of the definition of risk by the International Organization for Standardization (ISO 31000, 2009). This revision shifts the emphasis from "the event" (something happens) to "the effect" and, in particular, the effect on objectives (Purdy et al., 2009). Despite principles and guidelines on risk management provided by ISO are usually addressed to industry, the aim of ISO 31000 is to be applicable for any public, private or community enterprise, association, group or individual.

According to the above definitions, risk is characterized and described in terms of both the consequences of what could happen and the likelihood of those consequences. Following this approach, the risk (R) associated to a recognized threat (or hazard, H) requires the assessment of: i) the magnitude L of the potential consequence, and ii) the probability that the consequence will occur, $P(L)$. The combination of consequences and their likelihoods define a level of risk.

Risk assessment procedures are separately provided for questions related to structural biodiversity (Section 4.3.1. and Appendix C) and ecosystem services (Section 4.3.2. and Appendix C), because in the latter case the magnitude L of the potential consequence is expressed in quantitative terms while in the former one it is only expressed in qualitative terms. Evaluation of uncertainty follows the same scheme for biodiversity and ecosystem services (Section 4.3.3. and Appendix C).

In case the use of the probabilistic method here described becomes not applicable, the assessor might decide to use a different rating system. This needs to be justified with explanatory notes.

[8] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. OJ L 31, 1.2.2002, p. 1-24.

4.3.1. Risk assessment for structural biodiversity

There are K = 2 questions (Q2 and Q3) on structural biodiversity, both with I = 5 sub-questions. The proposed method makes it possible to a) evaluate the level of risk for each sub-question and b) categorize the risk for each question (Section 5.3.), through a simple procedure with 4 steps:

Step 1: rate the magnitude L of consequences for each hazard or sub-question, H,

Step 2: define the probability distribution of the magnitude of consequences, *P(L)*, for each sub-question,

Step 3: assess the risk of each sub-question in categorical terms,

Step 4: assess the risk of the question from the risks of the sub-questions, in categorical terms.

At the end of this process, the risks assessed for the sub-questions are summarized by an index of risk, R', for the related question. The assessment of R' is based on the three categories Minor, Moderate, or Major. Different methods are proposed, which are based on: i) the modal rating (i.e., the rating with the highest frequency), ii) the highest rating assigned, or iii) the range of ratings. The assessor should select the most appropriate index/es case by case and carefully explain the reasons of his/her choice.

Details on the proposed method are provided in Appendix C.

4.3.2. Risk assessment for ecosystem services

The question on ecosystem services (Q4.1 and Q4.2) considers 14 hazards or sub-questions, i.e. K = 2 and I = 14. Sub-questions are rated in five categories denoted by $j = 1, \ldots, 5$ and based on a quantitative assessment of the potential impact (Minimal, Minor, Moderate, Major, Massive; from 1 to 5 respectively) (Section 5.4.). The risk, R, associated to any hazard H, i.e. to any sub-question, is determined by combining the magnitude L of the potential consequence and the probability that the consequence will occur, $P(L)$, by the simple product $L\,P(L)$.

If the assessor is absolutely certain that only one kind of consequence, $L_0 = l_0$, can happen, then $P(L_0 = l_0)$ = 100 % and the risk coincides with this consequence, that is $R(H) = l_0$. However, if the consequence L is uncertain, and two assessments about its magnitude can be made, say l_1 and l_2, but the assessor believes that l_1 is two times more likely than l_2, then $P(L = l_1)$ = 66.7 % (2/3) and $P(L = l_2)$ = 33.3 % (1/3). In the latter case, the risk is computed as the combination $R(H) = l_1 P(L = l_1) + l_2 P(L = l_2)$. Formally, if the magnitude of the consequence can be completely described by J different levels, l_j (j = 1, … , J), and the probability of each level is assessed, then the risk is computed by the following formula:

$$R(H) = \sum_{j=1}^{J} l_j P(l_j) \qquad [2]$$

The formula [2] defines the risk R associated to the hazard H whose consequences can be described by a number J of recognized levels of magnitude, as the weighted sum of the risk of each possible effect. This corresponds to the average (or expected) magnitude of the consequence.

By using formula [2], the proposed method makes it possible to a) evaluate the level of risk for each sub-question and b) calculate an index of risk for each question on ecosystem services (Section 5.4.), through a simple procedure with 7 steps:

Step 1: rate the magnitude L of consequences for each hazard or sub-question, H, Step 2: define the probability distribution of the magnitude of consequences, $P(L)$, for each sub-question,

Step 3: calculate the risk for each sub-question, by combining L and $P(L)$,

Step 4: scale the calculated risk for each sub-question in a percent value,

Step 5: categorize the risk of each sub-question,

Step 6: calculate the risk index for the question by combining the calculated risks of the sub-questions,

Step 7: categorize the risk of the question.

At the end of this process, the risks calculated for the sub-questions are summarized by an index of risk, *R'*, for the question, and this index is categorized as either Minimal, Minor, Moderate, Major, or Massive by using the five categories of Step 5. As in 4.3.1, different risk indexes are proposed.

Details on the proposed method are provided in Appendix C.

4.3.3. Assessment of the uncertainty

Regardless of how ratings are obtained (that is, regardless of the magnitude is a continuous variable as in the case of ecosystem services or a categorical variable as in the case of biodiversity), an assessment of the uncertainty U_i associated to the *i*-th sub-question is carried out and then combined to define an index of the uncertainty of the related question, *U'*.

Uncertainties are calculated based on the probabilities of occurrence assigned to each magnitude of consequences, $P(L_i = j)$, for each hazard, H_i. According to Information Theory (Wiener and Shannon, 1949; Aczél and Daróczy, 1975) the uncertainty we deal with arises from the difficulty in predicting the result of an experiment when we only know the probability of any possible result. A measure of the uncertainty should satisfy the following requirements:

(i) there is no uncertainty when one of the ratings has 100 % of probability of occurrence and, therefore, the probability of the other ratings is 0 %;

(ii) the uncertainty is maximum when all the ratings have the same probability of occurrence, i.e. $P(L= 1) = \ldots = P(L = J) = 100\ \% / J$;

(iii) when all the categories of the magnitude have the same probability, the uncertainty increases as far as the number of possible results increases. This means that the uncertainty associated to 5 equiprobable ratings is higher than the uncertainty associated to 3 equiprobable ratings.

The Shannon entropy (Shannon, 1948) is the first, and the most widely known, measure of uncertainty and is widely applied in ecology, e.g. as an index of species richness (Whittaker, 1972).

For the sub-question *i*-th of any question, the Shannon entropy, U_i, associated to the probability distribution of the magnitude of the consequences is computed as shown in Appendix C.

To summarize the uncertainty of each sub-question as measured by the Shannon entropy and obtain an evaluation of the uncertainty for the related question, *U'*, several indexes could be used, analogously to what introduced for risk.

Uncertainties must be clearly presented by the assessors in the environmental risk assessment of plant pests. In this rating system, the identification and the assessment of uncertainties for each sub-question support the assessor in combining the judgment for the final score of uncertainty for the question, and the reader in following the approach and logic behind the conclusion, having in front a transparent document.

5. The proposed new EFSA environmental risk assessment scheme

5.1. Process of the environmental risk assessment approach

The flowchart (Figure 7) describes the suggested workflow during the assessment of the environmental consequences. The process starts with the collection of the available evidence, followed by the scenario setting (Sections 4.2.1. and 5.2.). Work is suggested to continue on the evaluation of effects on structural biodiversity first (Section 5.3.) (note the branches: in some cases, the process can be simplified when, if appropriate, a question can be left unanswered and the next question considered). Once this part of the assessment is completed, the assessment moves onto the right part of the flowchart, evaluating impacts on ecosystem services (Section 5.4.) (note the optional branches also here), before finally summarising the evaluation and making a verbal summary or composite assessment.

The question and sub-question scheme, as well as the rating system, are flexible. It may be possible to do the assessment very simply, if sufficient evidence is already available or the risk presented by the pest is widely agreed. Before answering the questions, it should be decided whether it is relevant for the species to apply the environmental risk assessment. For some species, only a part of it may be necessary to be carried out, and it should be determined beforehand which questions and sub-questions are applicable.

Questions 1-6 including the sub-questions (represented in Sections 5.2-5.5 below) will eventually replace questions 2.4 and 2.5 in the EFSA Scheme.

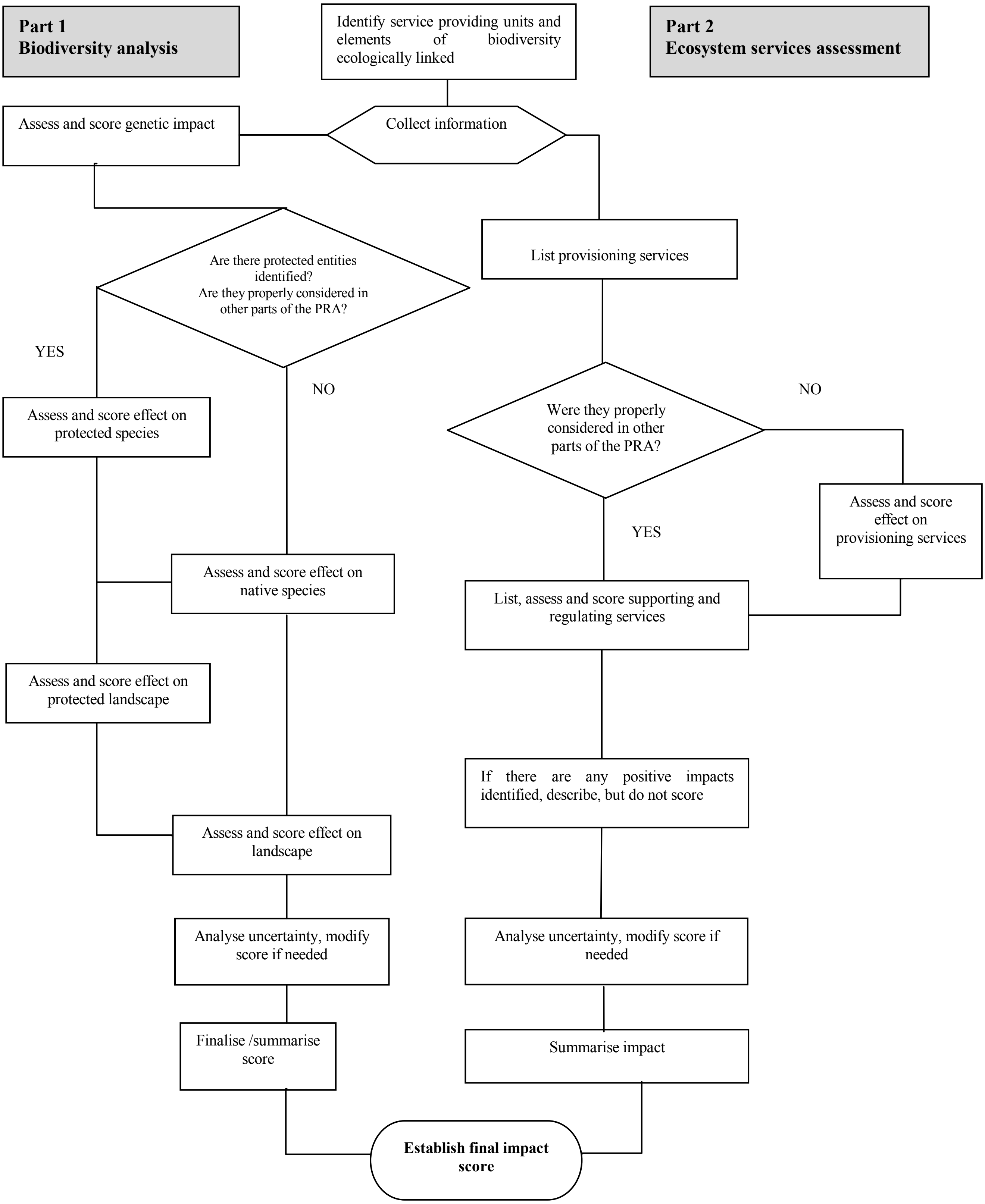


Figure 7: Flowchart describing the suggested workflow of environmental risk assessment of plant pests.

5.2. Assumptions

Q1. Define the background for the environmental risk assessment.

(i) Based on the hosts and/or habitats that the pest may threaten[9] identify the service providing units (Section 4.1.2.1.). Identify the relevant elements of biodiversity ecologically linked to the service providing units.

Note: To identify the service providing units, restrict consideration to the main host plants or the main functional groups in the community that are affected by the pest by means of ecological mechanisms such as trophic interactions, including host-vector-pathogen relationships, and competitive or cooperative interactions. Develop the assessment under the assumption that the composition of a service providing unit is fixed in terms of ecological components and their ecological role and relationships. Specify if there are strong indications that the structural and functional composition of the service providing unit may be modified.

Example: The service providing unit threatened by *Ophiostoma novo-ulmi* is non-Asian elm trees.

(ii) Define the temporal horizon.

Note: Decide whether a single or a multiple time horizon should be chosen or the time horizon is based on the worst case, when the pest has spread throughout the area of potential establishment. Consider in particular the spread rate of the organism[10] based on its biology and pattern of distribution and the rate at which impacts are likely to be observed, to define the temporal horizon. Refer also to the questions on eradication[11] and containment[12] in the EFSA scheme. For invasive alien plants, also consider that there may be a lag phase. The same temporal scale should be used for the evaluation of the consequences on biodiversity, on all the ecosystem services, and all other consequences in the pest risk assessment scheme.

Examples: Johnson et al. (1999) demonstrated that the impact of redberry juniper (*Juniperus pinchotii*) in Texas rangeland is strictly dependent on the time-horizon considered. Also the number and the type of ecosystem services taken into account modify the magnitude of the impact and the net benefit resulting from control. Charles and Dukes (2007) stated that the temporal scale for the evaluation of the impact has to take into account the scale of change of the considered services. Because of such differences in the scale of change, for a fixed time scale the impact on some ecosystem services could be more evident than the impact on others. For instance, the impact on climate and atmospheric composition needs a long period to become evident because changes occur over large temporal scale.

(iii) Define the spatial scale.

Note: Select the extent of the spatial scale on which to perform the evaluation. Two options can be considered. The first option considers a spatial extent defined by the area that is expected to be occupied at the end of the selected time horizon(s). The second option considers the worst case scenario, i.e. the entire area of potential establishment. Estimate how homogeneous the distribution of the pest within the suitable habitats is expected to be, and evaluate if the impact will follow gradients or other spatial patterns. The same spatial scale is used for the evaluation of the consequences on structural biodiversity and on all the ecosystem services.

[9] described in questions 1.16-1.18 of the EFSA scheme
[10] see questions 1.32-1.33 of the EFSA scheme
[11] see question 1.26 of the EFSA scheme
[12] see question 1.35 of the EFSA scheme

Example: Ehrenfeld (2003) showed that invasive plant impacts on nutrient cycling can vary in magnitude and direction (i.e. positive or negative) depending on the invader type but also on the location leading to a spatially heterogeneous pattern of the impact.

(iv) Estimate the resistance of the affected service providing units when the pest is present.

Note: To answer this question, consider the presence of natural enemies and competitors of the pest in the pest risk assessment area[13]. Consider also the status of the host plants or habitats or ecosystems that are affected (e.g. healthy versus weak plants, undisturbed versus disturbed habitats), including the possibility that they are already subject to management of some sort that may influence ecosystem resistance.

Example: The citrus longhorn beetle, *Anoplophora chinensis*, can attack healthy trees. It has no natural enemies in the pest risk assessment area (i.e. Europe). The resistance is considered to be very low.

(v) Estimate the resilience of the affected service providing units when the pest is present.

Note: see point 4.

Examples: The chestnut gall wasp, *Dryocosmus kuriphilus* (Hymenoptera: Cynipidae), in Europe has a large community of natural enemies that are only weakly able to control the pest population dynamics. Resilience can be considered low in the short term. However, in the medium-long term it is expected that this community of natural enemies can play a major role in modifying the resilience to medium.

(vi) List the main functional traits of the service providing units affected by the pest in the scenario developed above.

Note: The list of examples below is not exhaustive, but it provides an indication of what needs to be considered (refer to Section 4.1.2.1. for further details).

Functional traits at individual level: survival, uses of the body, development, growth, reproduction, etc.

Functional traits at population level: average population abundance, spatial population structure, demographic structure, strategic structure, pattern of population dynamics, etc.

Functional traits at community level: relative abundance/importance of functional groups (guilds), relative abundance/importance in dominant species (in different trophic nodes), degree of functional dissimilarity in traits within the community (e.g. number of functional groups or functional richness, also called functional divergence), etc.

(vii) Based on the list of functional traits of the service providing units affected by the pest provided above (see point 6.), identify the trait-service cluster that guide to the identification of the affected ecosystem services (for further explanation see Section 4.1.1.2.). The identified affected ecosystem services have to be listed in Table 1.

(viii) List the management measures that are assumed to be taken into account[14].

[13] see questions 1.23 and 1.24 of the EFSA scheme
[14] see questions 2.2 and 2.3 of the EFSA scheme

Note: For every management measure listed, explain whether it changes the pattern of impact or not. Take into account the feasibility of containment and/or eradication, the effect on the intensity of the impact of the pest, the effect on resistance and/or resilience of the invaded area.

5.3. Structural biodiversity

Q2.: How important are the consequences for structural biodiversity caused by the pest within its current area of invasion?

Minor, moderate, major

Uncertainty: low/medium/high

This question will be answered after answering the five sub-questions and with the help of the guidance provided below. For each of the sub-questions, a rating has to be given based on three choices: *Low, Medium* or *High*, following the guidelines provided in Section 4.3.1 and Appendix C. Information is provided for each indicator on the meaning of these ratings. The uncertainty should be evaluated at the level of the sub-questions, and then summarised for the question as explained in Section 4.3.3.

In this question the current consequences on structural biodiversity in already invaded regions are rated. The result can be used as an indicator for determining the potential consequences on structural biodiversity in the pest risk assessment area (Q3).

If the species has not invaded any area (i.e. is only present in its native range), or if the invasion is too recent and too little is known about its ecology in the invaded areas, this question cannot be answered properly (assuming that no additional investigations can be undertaken during the time available for producing the pest risk assessment). The assessor may choose to go directly to Q3. He/she may also choose to answer these questions based on well studied closely-related species or data for the target species from the region of origin. Although the concept of "environmental impact" of an indigenous species on native biodiversity and ecosystems is debatable, in some cases native species clearly have an environmental impact, usually resulting for example from climate change or change in management regimes. For example, the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Curculionidae) is presently causing serious outbreaks and extending its range in Canada, as a result of change in climate as well as forestry management. Nevertheless, the assessor should take into account the fact that the environmental impact of a pest in its region of origin is often a very poor predictor of potential impact in regions where it has been introduced. In particular, the absence of any obvious environmental impact in the region of origin should not be considered as a predictor for a low impact in a new area.

Examples of species for which Q2 may be difficult to answer include:

- The spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae) and the white pine weevil or Engelmann spruce weevil, *Pissodes strobi* (Coleoptera: Curculionidae): these North American species have never invaded any area.

- The Asian longhorn beetle, *Anoplophora glabripennis* and the citrus-root cerambycid, *A. chinensis* (Coleoptera: Curculionidae): Currently (2010) all outbreaks in invaded areas worldwide are still under eradication and the beetle has not yet been studied in natural areas or even semi-natural forests in invaded areas.

- The box tree pyralid, *Diaphania perspectalis* (Lepidoptera: Pyralidae) and the palm moth, *Paysandisia archon* (Lepidoptera: Castniidae): their invasion in Europe is too recent to accurately assess their current impacts, and they have not invaded any other region.

Q2.1. To what extent is genetic diversity likely to increase or decrease as a result of invasion?

Note: both direct and indirect effects should be considered here: gene flow disruption, introgression, hybridization (new genotypes, sterile hybrids, genetic pollution, outbreeding depression and extinction of native taxa)

- Hybridization between an alien and a native species or sub-species may affect the genetic identity of native species or sub-species. This could lead to "extinction by assimilation". For example, native populations of *Argyranthemum coronopifolium* (Asterales: Asteraceae) , an endemic plant on the island of Tenerife, are in various stages of hybridisation with the invasive weed, Paris daisy, *A. frutescens* (Levin, 2001 cit. Ellstrand, 2003). Extinction is also possible by outbreeding depression. In the British Isles, the hybrids of the common horsetail *Equisetum hyemale* (Equisetales: Equisetaceae) and the protected branched horsetail, *E. ramosissium* have reduced fitness (Stace, 1975), and there exist numerous other plant examples (Waser, 1993).

- Genetic drift: genetic drift is a consequence of reproduction of small populations, when neutral genes gradually disappear from the gene pool. This however can be counteracted even with a small amount of gene flow (Ellstrand, 2003).

- Bottleneck effect: Small populations suffer loss of genetic diversity through a number of mechanisms. The genetic diversity of a native species/population can be much reduced as the numbers decline due to the effect of the pest. Such an effect can be indirect: the pest occupies large areas, and fragments the population of a native species. The reduced number of individuals in the native species means much reduced genetic diversity, and even if the native species recovers afterwards due to successful management of the pest, the genetic diversity of the native species remains low – the population undergoes a "genetic bottleneck". This can reduce its fitness, causing malformations during development, weakened immune defense, decrease in seed/egg viability, etc. Most such examples are from larger animals, e.g. the elephant seal (*Mirounga angustirostris* and *M. leonina*, Carnivora: Phocidae), European bison (*Bison bonasus*, Artiodactyla: Bovinae), giant panda (*Ailuropoda melanoleuca*, Caniformia: Ursidae), but several insect examples exist, for example, from New Zealand (New, 2008).

Rating	**Explanation**
Minor	Changes in genetic diversity have not been appreciable. None of the above-mentioned population genetic effects have been observed. Alien species without taxonomically very closely related species (sub-species or congeneric) or with no record of cross-breeding with other species will fall into this category.
Moderate	Changes in genetic diversity (specify if - or +) have been appreciable One or two of the above-mentioned population genetic effects have been observed, but expression of the effect(s) is not strong. Examples: Hybridization between alien and native bumble bee, *Bombus* spp. (Hymenoptera: Apidae) is obtained in the laboratory, but their offspring is usually sterile. In Japan, fertile hybridization is obtained in the lab between the native parasitoid *Torymus beneficus* and the alien *T. sinensis* (Chalcidoidea: Torymidae), but studies showed that hybridization in the field was marginal.
Major	Changes in genetic diversity have been substantial (specify if – or +) Several of the above-mentioned population genetic effects have been observed, at

	least for one effect, the expression is strong. Introductions in North-Western Europe of two southern European sub-species of European honey bee, *Apis mellifera* (Hymenoptera: Apidae) caused large-scale gene-flow and introgression between these sub-species and the native sub-species, whose native populations are now threatened.

Q2.2. To what extent are there any rare or vulnerable species[15] among the native species expected to be affected as a result of invasion?

First, refer to the previously prepared list of conservation values (protected individuals, groups of individuals, landscapes, habitats, ecosystems) in the risk assessment area. If none was identified, skip the question and move to Q2.3.

Rating	**Explanation**
Minor	No or few rare or vulnerable native species have been involved. No sudden decline or extinction of a local population of any protected, rare, or vulnerable species has been recorded or observed. Examples: the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae) is restricted to ash, *Fraxinus* spp. (Lamiales: Oleaceae), but, so far, none of these species are considered to be rare or vulnerable in North America. The Western corn rootworm, *Diabrotica virgifera* (Coleoptera: Chrysomelidae) attacks mainly maize and some grasses in Central Europe, none of which are rare or vulnerable.
Moderate	Some rare or vulnerable native species have been involved. Sudden decline or extinction of few populations of any protected, rare, or vulnerable species has been recorded or observed. Examples: In North America, no major host of the gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae) is rare or vulnerable. However, the pest is so polyphagous that, during outbreaks, the chance that it will feed on rare woody species is high.
Major	Many rare or vulnerable native species have been involved. Sudden decline or extinction of several populations of protected, rare, or vulnerable species has been recorded or observed. Examples: In North America, one of the major hosts of the balsam woolly adelgids, *Adelges piceae* (Hemiptera: Adelgidae) is the fir tree, *Abies fraseri* (Pinales: Pinaceae), which is classified as a vulnerable species by the IUCN. In Florida, the cactus moth, *Cactoblastis cactorum* (Lepidoptera: Pyralidae) used as a biological control agent, attacks several endangered paddle cactus, *Opuntia* spp. (Cactaceae: Caryophyllales) and the cycad aulacaspis scale, *Aulacaspis yasumatsui* (Hemiptera: Diaspididae) threatens the survival of several rare and endangered cycad species.

[15] includes all species classified as rare, vulnerable or endangered in official national or regional lists within the risk assessment area

Q2.3.To what extent is there a possible decline in native species as a result of the invasion?

The word "native" in "native species" or "native biodiversity" should be interpreted in a broad sense. It should also include species that have been naturalised for centuries and that play an important role in the ecosystems or local cultural heritage, such as walnut (*Juglans* spp.) or chestnut (*Castanea* spp.) in Europe. The assessor may also include other, more recently introduced beneficial organisms (such as biological control agents) or exotic plants (e.g. plants used against erosion) that play a role in ecosystem services.

Rating	Explanation
Minor	Decline in native species has not been observed. Examples: The impact of alien gall wasps of the genus *Andricus* spp. (Hymenoptera: Cynipidae) on native gall wasps in Britain has been studied but no significant impact was found. *Phytophthora infestans* (Peronosporales: Pythiaceae), the causal agent of late blight on potato, mainly attacks cultivated crops in Europe and the effect on native species populations is low.
Moderate	Decline in native species has been appreciable. Sudden decline or extinction of few populations of any native species has been recorded or observed. There are higher numbers of events of local extinction than events of metapopulation recolonization. Examples: Severe outbreaks of *L. dispar* in North America cause local decline in host trees and their associated fauna (e.g. birds), but most studies suggest that the decline is temporary. *Cryphonectria parasitica* (Diaporthales: Cryphonectriaceae), the causal agent of chestnut blight, severely affected populations of European chestnut when it arrived in Europe, but chestnut forests have largely recovered since the pathogen introduction.
Major	Decline in native species has been substantial. Sudden decline or extinction of several populations of native species has been recorded or observed. There are much more events of local extinction than events of metapopulation recolonization. This is observed over 30 % of the risk assessment area / Range contraction is observed. Examples: *A. piceae* has decimated natural Fraser fir populations in Eastern North America. *Ophiostoma novo-ulmi* (Ascomycetes: Ophiostomataceae), the causal agent of the Dutch elm disease, has caused the general decline of elm species in Europe and North America. Although studies to accurately measure the impact of *A. planipennis* on populations of several ash species in North America are still lacking, the fact that the beetle has already killed over 40 million trees and the prediction that the damage is going to continue unabated for the foreseeable future strongly suggests that it has a severe effect on ash populations and the associated fauna.

Q2.4. To what extent is there an expected impact on objects or habitats of high conservation value[16] as a result of invasion?

[16] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. OJ L 206, 22.7.1992, 1–66.

First, refer to the previously prepared list of conservation values (protected individuals, groups of individuals, landscapes, habitats, ecosystems) in the risk assessment area. If none was identified, skip the question and move to Q2.5.

Rating	Explanation
Minor	Impact has not been observed/recorded. The pest occurs exclusively, or nearly exclusively outside habitats of high conservation value. Examples: In Central Europe, the horse chestnut leaf miner, *Cameraria ohridella* (Lepidoptera: Gracillariidae) attacks horse-chestnut nearly exclusively but this is an exotic ornamental tree that is rarely found in habitats of high conservation values. The Potato Spindle Tuber Viroid, PSTVd (Pospiviroidae) is found nearly exclusively in agricultural and horticultural habitat.
Moderate	Impact has been appreciable. The pest occurs only occasionally in habitats of high conservation value or, where it occurs more commonly, no major host is an important component of these habitats (e.g. dominant or keystone species, ecological engineers, etc.). Examples: the scarlet lily beetle, *Lilioceris lilii* (Coleptera: Chrysomelidae) in North America may be found in protected areas, but its hosts (*Lilium* spp., Liliales: Liliaceae) cannot be considered as important components of these protected habitats. *Phyllonorycter robiniella* (Lepidoptera: Gracillariidae) is restricted to black locust, *Robinia pseudoacacia* (Fabales: Fabaceae), which occurs occasionally in protected areas in Europe. However, the host is an alien species and, so, is not an important component of the protected habitats.
Major	Impact has been substantial. The pest occurs commonly in habitats of high conservation value and at least some major hosts are important ecological components of such habitats (e.g. dominant or keystone species, ecological engineers, etc.) Examples: the Hemlock woolly adelgid, *Adelges tsugae* (Hemiptera: Adelgidae) attacks hemlock species in nature reserves and national parks, where these trees are ecologically important species. *C. parasitica* has nearly eradicated American chestnut, an important tree species of several forest ecosystems in Eastern America, including in protected areas.

Q2.5. To what extent are changes likely in the composition and structure of native habitats, communities and/or ecosystems as a result of invasion?

Rating	Explanation
Minor	Changes in the composition and structure have not been appreciable. Changes in the landscape composition and structure have not been observed. Examples: Alien pests and pathogens attacking mainly or exclusively crop species will fall into this category, only if the crop hosting the pest remains a main component of the landscape. Species (e.g. *Lilioceris lilii*) that are specific to plants species that

	do not, or rarely dominate plant communities (e.g. lilies) will also score Low here.
Moderate	Changes in the composition and structure are appreciable. Changes in the landscape composition and structure have been observed but are limited. Examples: Defoliation by *Lymantria dispar* can cause a major shift in tree species in North America either through tree mortality or via seed failure or mortality of oak seedlings. Bird communities may also be modified. However, in general, defoliations by *L. dispar* only induce temporary changes.
Major	Changes in the composition and structure are substantial. Large or important changes in the landscape composition and structure have been observed and the impact is likely to be widespread within the habitats occupied by the species and persistent if no risk reduction option is taken. Examples: Mortality of Fraser fir caused by *Adelges piceae* in North America has totally altered plant communities in these forest ecosystems. *Cryphonectria parasitica* has had a same effect on plant communities associated to American walnut forests. The decline of eastern hemlock due to *A. tsugae* in North America strongly affects bird species composition.

The overall rating for Q2 is assigned based on Section 4.3.

Q3.: How important are the consequences for structural biodiversity caused by the pest likely to be in the risk assessment area?

See notes and examples in Q2

Minor, moderate, major

Uncertainty: low/medium/high

Assess whether, based on Q2, an environmental impact is also likely to occur in the risk assessment area, and, if yes, whether it is at a comparable level, using the following questions. For this, answers to the "likelihood of establishment" section of the pest risk assessment should be taken into account:

Q3.1. Taking into account the responses to the relevant questions (on hosts and habitats, climatic conditions, abiotic factors and management methods) in the establishment section, are the conditions in the risk assessment area sufficiently similar to those in the area of invasion to expect a similar level of impact?

If No: the situation regarding environmental impact may be different
If Yes: go to next question (3.2.)

Uncertainty: low/medium/high

Q3.2. Does the same native species or community, or the same threatened ecosystem services, occur in the risk assessment area and, if not, is it known whether the native species or communities, or ecosystem service in the risk assessment area are similarly susceptible?

If the species will encounter similar conditions (susceptible hosts and habitats, compatible climate, etc.) in the pest risk assessment area and in the areas where they are already invasive, it is likely to have a similar impact. Therefore, the rating of Q2 can be used for Q3 as the impact elsewhere is a strong predictor of impact in the risk assessment area.

In contrast, if the species could encounter a suitable climate but the main host plants do not occur naturally in the pest risk assessment area, or it will not encounter suitable native host plants or climatic conditions, the species should be assessed separately in Q3. If the conditions in the pest risk assessment area are different, the situation regarding environmental impact may also be different, and this has to be detailed in the assessment.

For example*:* the beetle *Anoplophora glabripennis*, the pine wood nematode, *Bursaphelenchus xylophilus* (Aphelenchida: Parasitaphelenchidae), or Potato spindle tuber viroid will most likely have a similar impact in the pest risk assessment area and in the areas where they are already invasive, because they would encounter susceptible hosts and habitats, as well as a compatible climate. Species such as the aphid *Adelges tsugae* could encounter a suitable climate but the main host plants do not occur naturally in Europe. Similarly, the aphid *Aulacaspis yasumatsui* will not encounter suitable native host plants in Europe and, nor will it encounter a very suitable climate outdoors.

Uncertainty: low/medium/high

Q3.2.1. To what extent is genetic diversity likely to increase or decrease as a result of invasion?

Rating	**Explanation**
Minor	Changes in genetic diversity (specify if - or +) are not appreciable
Moderate	Changes in genetic diversity (specify if - or +) are appreciable
Major	Changes in genetic diversity (specify if - or +) are substantial

Q3.2.2. To what extent are there any rare or vulnerable species among the native species expected to be affected as a result of invasion?

Rating	**Explanation**
Minor	No or few rare or vulnerable native species are involved. The host has no rare or vulnerable native species as hosts. Examples: In Europe, *Agrilus planipennis* will only attack three *Fraxinus* species, none of which is rare or vulnerable. *Adelges tsugae* will not attack any native species in Europe and, thus, no rare or vulnerable native species.

Moderate	Some rare or vulnerable native species are involved. The host has rare or vulnerable native species as minor hosts. Example: *Anoplophora glabripennis* and *A. chinensis* have such a broad host range that they will undoubtedly include rare or vulnerable species in their host range while spreading through Europe.
Major	Many rare or vulnerable native species are involved. The host has rare or vulnerable native species as major hosts. Examples: If introduced in the Rocky Mountains and the West coast of the USA, *Lilioceris lilii* will undoubtedly cause a threat to native, threatened *Lilium* spp. *Cactoblastis cactorum* will represent a threat to rare *Opuntia* spp. if introduced into Mexico.

Q3.2.3. To what extent is there a possible decline in native species as a result of the invasion?

Rating	Explanation
Minor	Decline in native species is not appreciable. The pest harms or will harm only exotic species. Examples: *Adelges tsugae*, feeds exclusively on *Tsuga* spp., a genus which does not occur in Europe. *Guignardia citricarpa* is a fungus that attacks only exotic plants, mainly *Citrus* spp., in Europe.
Moderate	Decline in native species is appreciable. The pest harms or will harm native species as minor hosts. “Minor hosts” means that, if they have already been in contact, severe damage has never been observed on these hosts. If they have never been in contact, there is an indication that development on these hosts is less favourable. Examples: *Diabrotica virgifera* and *Leptinotarsa decemlineata* have mainly exotic cultivated plants as major hosts in Europe, but both are able to feed occasionally on native plants as minor hosts.
Major	Decline in native species is substantial. The pest harms or will harm native species as major hosts. “Major hosts” include all hosts on which severe damage has been observed, i.e. damage for which the species has gained its pest status. If the pest and the host have never been in contact in the field, laboratory observations suggest that damage may be as high as on its recognised major hosts. Examples: *Phytophthora ramorum* has a wide host range and several native European woody plants are major hosts. Many major host trees of *Lymantria dispar* are native to the UK, e.g. *Quercus robur*.

Q3.2.4. To what extent is there an expected impact on objects or habitats of high conservation value as a result of invasion?

Rating	Explanation
Minor	Impact is not appreciable. The hosts occur exclusively outside habitats of high conservation value. Example: In Europe, *Aulacaspis yasumatsui* would only occur outside habitats of high conservation value because it only feeds on cycads, which are ornamental exotic species. In Europe, *Diabrotica virgifera* will be largely restricted to agricultural areas.
Moderate	Impact is appreciable. The hosts occur only occasionally in habitats of high conservation value. Example: *Rhagoletis completa* feeds on *Juglans regia* in Europe, which only occasionally occurs in habitats of high conservation value.
Major	Impact is substantial. The hosts occur frequently in habitats of high conservation value. Examples: *Bursaphelenchus xylophilus* and *Choristoneura fumiferana* may attack several conifer species in Europe, many of which frequently occur in nature reserves and other protected nature conservation areas.

Q3.2.5. To what extent are changes likely in the composition and structure of native habitats, communities and/or ecosystems as a result of invasion?

Rating	Explanation
Minor	Changes in the composition and structure are not appreciable. Host plants are not killed and reproduction potential is not altered. Examples: *Pissodes strobi* does not kill its host pine and spruce trees but rather reduces the value of timber by crooking stems. *Adelges tsugae* has no native host in Europe.
Moderate	Changes in the composition and structure are appreciable. Host plants are occasionally killed or reproduction potential is occasionally altered. Examples: *Lymantria dispar* only occasionally kills its host trees.

	Leptoglossus occidentalis does not kill pines, but feeds on seeds which may alter their reproduction potential.
Major	Changes in the composition and structure are substantial. The host plant is often killed or reproduction potential is seriously and frequently altered. Examples: *Bursaphelenchus xylophilus* or *Anoplophora glabripennis* usually kill host trees when these belong to the most susceptible tree species.

The overall rating for Q3. is based on Section 4.3.

5.4. Ecosystem services

Q4. How important are the consequences for ecosystem services caused by the pest within its current area of invasion?

In this question the current consequences on ecosystem services in already invaded regions are rated. The result can be used as an indicator for determining the potential consequences on ecosystem services in the pest risk assessment area (Q5.). Nevertheless, as in the case of consequences for biodiversity (see Section 5.2) the assessor should take into account the fact that the environmental impact of a pest in its region of origin is often a very poor predictor of potential impact in regions where it has been introduced. In particular, the absence of any obvious environmental impact in the region of origin should not be considered as a predictor for a low impact in a new area.

If the species has not invaded any area (i.e. is only present in its native range), or if the invasion is too recent and too little is known about its ecology in the invaded areas, this question cannot be answered properly (assuming that no additional investigations can be undertaken during the time available for producing the pest risk assessment). The assessor may choose to go directly to Q5. also in the case that the information provided in Q4. is considered of little importance for the evaluation of the impact on ecosystem services in the risk assessment area. The reasons for taking this option have to be explicitly stated (i.e. a declaration that "the available evidence was judged insufficient" is not enough). He/she may also choose to answer these questions based on well studied closely-related species or data for the target species from the region of origin.

Q4.1.: How great is the magnitude of reduction in the provisioning services affected in the current area of invasion?

Note: the provisioning services include the complete list provided in the Millennium Ecosystem Assessment (MA, 2005) document. This choice raises the issue of a possible double accounting, since some of the items in the list have already been, at least partially, considered in questions 2.1 and 2.2 of the EFSA scheme where the negative effects on crop yield, quality and control costs are assessed. However, the consideration of all the provisioning services allows for a comprehensive impact evaluation that is not limited to market value (or consumptive use value, see Charles and Dukes, 2007), but considers also other component of the value of the ecosystem services. The consideration of the impact on the provisioning services is therefore useful for a more comprehensive environmental impact assessment even for those components of ecosystems more directly computable in terms of market value (e.g., crops). The provisioning services include the following:

1. *Food*. This category includes crops, livestock, capture fisheries, aquaculture, forage, as well as plant and animal products collected from the wild. Note that the evaluation of this aspect should have already been assessed in the impact section. To avoid double counting, only assess factors that have

not been taken into account in questions 2.1 and 2.2 of the EFSA scheme, e.g. plants collected from the wild.

Examples: The impact of invasive plants such as the green spurge, *Euphorbia esula* (Malpighiales: Euphorbiaceae) and the yellow star-thistle, *Centaurea solstitialis* (Asterales: Asteraceae) results in lost livestock forage. The introduction of Water Hyacinth (*Eichornia crassipes*) into Lake Victoria in East Africa has reduced catches by fisheries and the quality of fish landed.

2. *Wood and fibre* (fuelwood, timber, natural fibres such as cotton, hemp and silk).

   Examples: The larvae of the citrus longhorned beetle (*Anoplophora chinensis*) bore tunnels in wood, thus decreasing the quality and the value of the timber. To avoid double counting, only assess factors that have not been taken into account in questions 2.1 and 2.2 of the EFSA scheme, e.g. wood collected from the wild for, e.g. fuel.

3. *Genetic resources* (crop species and crop breeding, livestock species and breeds).

   Example: The widespread plantation of Euro-Canadian poplar hybrids, together with their subsequent spread in the landscapes of Europe, resulted in the loss of genetic diversity by introgression in the endangered native poplar species *Populus nigra* (e.g. Ziegenhagen et al., 2009).

4. *Biochemicals, natural medicines and pharmaceuticals*. An estimated 30 % of the world's medicine still originates from wild-collected plants. Invasive pests probably deplete these medicinal resources by displacing native organisms or driving them to extinction. Little research appears to have specifically addressed the connection between invasive pests and the lost value of medicinal plants (Pejchar and Mooney, 2010).

   Example: The invasive weed *Parthenium hysterophorus* was reported to be causing the decline of various native medicinal plant species in the wastelands around the town of Islamabad (Pakistan) (Shabbir and Bajwa, 2006).

5. *Ornamental resources*. Frequently, ornamental plants are of exotic origin. While some of them may become invasive pests themselves, they are often subjected to attacks by invasive pests. Sometimes a herbivore, parasite or pathogen will "jump" to a new, taxonomically related host of an exotic ornamental plant. To avoid double counting, only assess factors that have not been taken into account in questions 2.1 and 2.2 of the EFSA scheme, e.g. ornamentals that are used for environmental purposes, e.g. *Lupinus* spp. to stabilise sand dunes.

   Examples: Ornamental resources, especially trees, are susceptible to attack, and even death from the cypress aphid, *Cinara cupressi* (Hemiptera: Aphididae) throughout Europe and Africa, and the beetle *A. chinensis*, as well as from pathogens such as *Phytophthora* spp. (Peronosporales: Pythiaceae).

6. Freshwater, both in term of quantity (e.g. level of reservoir in inland water systems, rate of flow in rivers) and quality (e.g. turbidity or pollution).

   Examples: The introduction of Water Hyacinth into Lake Victoria has damaged water supply intakes. Some invasive plants can fundamentally change the flow of water for drinking and irrigation if they have at least one of the following characteristics: (i) deep roots (several *Eucalyptus* species in California), (ii) high evapotranspiration rate (Water Hyacinth into Lake Victoria, Salt Cedar in Southwestern USA), (iii) large biomass.

For each item of the list, estimate the impact on ecosystem services provision in terms of relative (%) magnitude of reduction in the provision level of the affected ecosystem service. Estimate also the probability of occurrence of each class of impact.

Ecosystem services	Magnitude class	Reduction in ecosystem services provision level	Probability of occurrence
Q4.2.1. *Food*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.2.2. *Wood and fibre*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.2.3. *Genetic resources*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.2.4. *Biochemicals, natural medicines and pharmaceuticals*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.2.5. *Ornamental resources*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.2.6. Freshwater	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	

	5. Massive	M>50 %	

For each provisioning service, it is important to identify the elements not yet covered in questions 2.1. and 2.2. of the EFSA scheme (EFSA Panel on Plant Health (PLH), 2010), and only assess these.

Sections 4.2.1., 4.2.2., and 4.2.4., and Table 2. of the framework can help answer the question.

Minimal, minor, moderate, major, massive

Uncertainty: low/medium/high

Q4.2.: How great is the magnitude of the reduction in the regulating and supporting services affected in the current area of invasion? (The relevant regulating and supporting services are listed in Table 1)

Note: The regulating and supporting services include the following:

1. *Air quality regulation*. Ability of the plants and other components of the ecosystems to remove pollutants (particulates, NO_X, SO_2, CH_4, etc.). For instance, an increase in fire frequency and magnitude causes increased emission of pollutants to the atmosphere. The removal of vegetation could modify the capacity of the ecosystem to remove these pollutants.

   Examples: The drooping brome, *Bromus tectorum* (Poales: Poaceae) and other invasive plants can increase fire frequencies, releasing more particulates into the air. The emission in the atmosphere of isoprene and other volatile compounds by *Eucalyptus* spp. leads to the production of air pollutants (ozone).

2. *Climate regulation*. Regulation of source and sink of carbon dioxide, methane and sulphur dioxide and balanced heat transfer from solar radiation to the earth surface and from this to the troposphere. Changes in land use and cover as a consequence of invasion influence the amount and local/regional impact on temperature and precipitation. These changes alter surface heat balance not only by changing surface albedo, but also by altering evaporative heat transfer caused by evapotranspiration from vegetation (highest in closed canopy forest), and by changes in surface roughness, which alter heat transfer between the relatively stagnant layer of air near the earth's surface (the boundary layer) and the troposphere. An example of this is the warmer temperatures observed within urban areas versus rural areas (the urban heat island effect). A warming effect was also found where croplands or grasslands have replaced forests because croplands are less efficient than forests in evapotranspiration. Land cover changes can influence local precipitation, but not as markedly as land cover affects temperature (Ellis and Pontius, 2010).

   Examples: In the US Great Basin region, non-native annual grasses have largely replaced native sagebrush. This led to a net loss of carbon sequestration over a large land area with possible effect on climate regulation. Differences in carbon storage capacity (sink) characterize woody species in comparison to grassland. If single or groups of trees are lost as in the case of mortality induced by the citrus long-horned beetle, a decrease in carbon storage capacity in the service providing unit is expected.

3. *Water regulation, cycling and purification*. Ecosystem changes produced by invasive pests affect the timing and magnitude of water runoff, flooding, and aquifer recharge. The capacity of the

ecosystems to filter and purify chemical waste as well as pathogen and organic pollution can also be modified.

Examples: The introduction of Water Hyacinth into Lake Victoria has increased water loss through evapotranspiration and contributed to the spread of waterborne diseases (Opande et al., 2004). The spread of the introduced Golden Apple Snail, *Pomacea canaliculata* (Gastropoda: Ampullariidae) damaged Asia's wetlands that were important for water purification; they are now in a state dominated by algae, and the water is turbid (Carlsson et al., 2004). Invasive pests can increase flood-risk by narrowing stream channels and decreasing the holding capacity. Saltcedar (*Tamarix ramosissima*, Caryophyllales: Tamaricaceae) is the best illustration of this impact on flooding.

4. *Erosion regulation*. Change in land use and cover due to the action of invasive pests can exacerbate soil degradation and erosion. Vegetation removal leaves soils vulnerable to massive increases in soil erosion by wind and water, especially on steep terrain, and when accompanied by other stressors (e.g. fire).

   Example: The large-scale invasion of fire-tolerant giant cane, *Arundo donax* (Poales: Poaceae) in riparian areas in North America has serious negative consequences for native plant communities that are generally not fire-adapted. These play an important role in erosion control and water purification.

5. *Soil formation and nutrient cycling*. These services may be affected by changes in decomposition rates, soil carbon mineralization, geomorphologic disturbance process, as well as succession. Changes in ecosystems (e.g. modifications in land cover due to the introduction of invasive pests and the consequences change in net flux of biomass into the soil) may slow the rate of soil formation and degrade soil fertility over time, reducing the suitability of land for future agricultural use. Modification in the biological buffer limiting the transfer of nutrients from terrestrial to aquatic systems causes the release of huge quantities of phosphorus, nitrogen, and sediments to streams and other aquatic ecosystems, causing a variety of negative impacts (increased sedimentation, turbidity, eutrophication and coastal hypoxia). Changes in decomposition rate, such as might occur if an invasive pests altered the litter chemistry, can affect nutrient cycling. Nutrient cycling can also be altered by invasive plants that fix nitrogen, leach chemicals and inhibit nitrogen fixation by other species and release compounds that alter nutrient availability or retention, including nitrogen and phosphorous.

   Examples: The best studied of these mechanisms is the introduction of leguminous species with mutualistic nitrogen-fixing microorganisms, largely due to the dramatic effect of the fire tree, *Myrica faya* (Fagales: Myricaceae) in Hawaii, New Zealand and Australia, and black wattle, *Acacia mearnsii* (Fabales: Fabaceae) in South Africa.

6. *Photosynthesis and primary production*. Primary production increases or decreases if an invasion leads to a shift in the major vegetation type of an area. Modifications in the plant community may affect the assimilation or accumulation rate of energy and nutrients. Changes in the NPP (net primary production) can result in modification of terrestrial and aquatic food webs.

   Examples: In many cases, invasive plants increase the NPP, as in the case of the giant reed and the common reed (*Phragmites* spp., Poales: Poaceae) in marshes, but the buffelgrass (*Pennisetum ciliare*, Poales: Poaceae) causes an opposite effect in the Sonoran desert in Mexico (Charles and Dukes, 2007).

7. *Pest and disease regulation*. Ecosystem modifications due to the introduction of invasive pests can reduce the pest control services provided by natural enemies. This is due normally to direct competitive or predatory (intra-guild) interactions between the invaders and the natural pool of pest

regulators. Invasive pests can also introduce new pathogens or create more suitable habitats for the establishment of new vectors and pathogens in the new environments.

Examples: The predatory red imported fire ant (*Solenopsis invicta*, Hymenoptera: Formicidae) has negative impacts on native biological control agents in soybeans (Eubanks, 2001). The invasion of dense stands of Spanish flag, *Lantana camara* (Lamiales: Verbenaceae) in East Africa provided new habitat for tsetse flies (*Glossina* spp.) which carry trypanosomiasis (sleeping sickness) in animals and humans, leading to a higher disease prevalence. Invasive mosquitoes exacerbated the spread of yellow fever and dengue fever (Juliano and Lounibos, 2005). Invasive non-native bird species in Hawaii carried avian malaria, reducing the density and diversity of native birds.

8. *Pollination*. The introduction of invasive pests in new environments can modify the distribution, abundance and host range of native pollinators. The modification of the native vegetation due to an invasive plant can affect the native community of pollinators.

   Examples: Non-native European honeybees (*A. mellifera*) are widely used to pollinate crops, providing indispensable services for farmers. In some cases, however, honeybees act as invasive pests disrupting mutualism and displacing native bees which may be better pollinators (Pejchar and Mooney, 2010). Invasive plants can also recruit native pollinators (Pysek et al., 2011), and thus influence this service in the original ecosystem.

For each item of the list, estimate the impact on ecosystem services provision in terms of relative (%) magnitude of reduction in the provision level of the affected ecosystem service. Estimate also the probability of occurrence of each class of impact.

Ecosystem services	**Magnitude class**	**Reduction in ecosystem services provision level**	**Probability of occurrence**
Q4.3.1. *Air quality regulation*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.2. *Climate regulation*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.3. *Water regulation, cycling and purification*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.4.	1. Minimal	Zero or negligible	

Erosion regulation	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.5. *Soil formation and nutrient cycling*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.6. *Photosynthesis and primary production*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.7. *Pest and disease regulation*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.8. *Pollination*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	

Sections 4.2.1., 4.2.2., and 4.2.4., and Table 2. of the framework can help answer the question.

Q5. How important are the consequences for ecosystem services caused by the pest within the risk assessment area?

In this question the expected consequences on ecosystem services in the risk assessment area are assessed and rated according to the assumptions given in Q1.

Q5.1.: How great is the magnitude of reduction in the provisioning services affected in the risk assessment area?

Note: for the complete list of provisioning services, their definition and examples, refer to Q4.1.

For each item of the list, estimate the impact on ecosystem services provision in terms of relative (%) magnitude of reduction in the provision level of the affected ecosystem service. Estimate also the probability of occurrence of each class of impact.

Ecosystem services	Magnitude class	Reduction in ecosystem services provision level	Probability of occurrence
Q4.2.1. *Food*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.2.2. *Wood and fibre*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.2.3. *Genetic resources*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.2.4. *Biochemicals, natural medicines and pharmaceuticals*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.2.5. *Ornamental resources*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.2.6. *Freshwater*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	

	5. Massive	M>50 %	

For each provisioning service it is important to identify the elements not yet covered in questions 2.1. and 2.2. of the EFSA scheme (EFSA Panel on Plant Health (PLH), 2010), and only assess these.

Sections 4.2.1., 4.2.2., and 4.2.4., and Table 2. of the framework can help answer the question.

Minimal, minor, moderate, major, massive

Uncertainty: low/medium/high

Q5.2.: How great is the magnitude of the reduction in the regulating and supporting services affected in the risk assessment area? (The relevant regulating and supporting services are listed in Table 1)

Note: for the complete list of regulating and supporting services, their definition and examples refer to Q4.2.

For each item of the list, estimate the impact on ecosystem services provision in terms of relative (%) magnitude of reduction in the provision level of the affected ecosystem service. Estimate also the probability of occurrence of each class of impact.

Ecosystem services	Magnitude class	Reduction in ecosystem services provision level	Probability of occurrence
Q4.3.1. *Air quality regulation*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.2. *Climate regulation*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.3. *Water regulation, cycling and purification*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.4.	1. Minimal	Zero or negligible	

Erosion regulation	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.5. *Soil formation and nutrient cycling*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.6. *Photosynthesis and primary production*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.7. *Pest and disease regulation*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	
Q4.3.8. *Pollination*	1. Minimal	Zero or negligible	
	2. Minor	0<M=5 %	
	3. Moderate	5<M=20 %	
	4. Major	20<M=50 %	
	5. Massive	M>50 %	

Sections 4.2.1., 4.2.2., and 4.2.4., and Table 2. of the framework can help answer the question.

5.5. Positive effects

Q6. Are there any positive effects of the species? List any potential positive effects.

In addition to negative impacts, the invasion of new species may have a variety of positive effects (Schlaepfer et al., 2011). Some non-native species may be introduced specifically for the benefits they provide, e.g. soil stabilisation by the large-leaved lupine, *Lupinus polyphyllus* (Fabales: Fabaceae) (Fremstad, 2010). Some native species may gain, e.g. by the availability of a new food source (bees and

Impatiens glandulifera (Bartomeus et al., 2010)). In many cases a mixture of positive and negative impacts may occur.

In assessing environmental impacts, it is proposed that only negative impacts are taken into account when providing a risk rating. Any positive impacts that are likely to occur should be documented but no attempt should be made to reduce the risk rating based on positive impacts. This approach has been adopted because:

1. *A priori*, risk assessments are undertaken to determine the negative impacts that may result from invasion so that risk managers can determine what action, if any, is necessary;

2. Assessing positive impacts is extremely difficult and may also be inappropriate or cause a potential conflict of interest for risk assessors if introductions are intentional;

3. If risk assessors attempt to balance negative and positive impacts, serious impacts may be overlooked.

6. List of minimum data/information requirements

The environmental risk assessment of pest introductions, as presented in this document, can only be meaningfully undertaken as part of a pest risk assessment, as described in the EFSA "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010). The other components of the pest risk assessment will provide many of the key elements required to assess the environmental risk, such as the range of hosts/habitats affected, the area of potential establishment and the pest's spread potential. For many species, the pest risk assessment will also be supported by data/information extracted from specific databases and webpages (e.g. CABI Crop Protection, Invasive Species and Forestry compendia or EPPO datasheets), summarising the key information about the organism.

However, environmental risk assessments also have specific data requirements, e.g. to determine the potential for hybridisation with native species, the importance of the species in ecosystem functioning and the identification of protected objects and areas that could be affected by the pest. Guidance on the types of data required and some key sources are provided, as appropriate, for each question.

It is recognised that the environmental risk assessment is a particularly challenging part of the pest risk assessment process because there are often very few data and the assessments require considerable extrapolation from the locations where the pest is currently present. In such situations of often very high uncertainty, although some guidance can be given on what to do, e.g. to use expert judgement and refer to related species, it may be too difficult to answer the question and, following the recommendations in Section 2.1 on data quality and uncertainty (EFSA Panel on Plant Health (PLH), 2010), the assessor may then omit the question providing a written justification (see paragraph 3 in the introduction to Section B). However, because of the great variety of organisms and situations that may need to be assessed, it is not possible to specify the minimum data requirements required before questions can or cannot be answered. In this document, therefore, the types of data required to make the assessments are specified but no attempt is made to set minimum data requirements.

Data already collected for other parts of the risk assessment (as described in the "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA") include:

- taxonomy and biological characteristics of pests;
- occurrence, distribution and prevalence of pests in various geographical areas;
- characteristics of diagnostic techniques;
- environmental data (e.g. climate, soil, geography) that could affect establishment and spread;
- farming practices and crop characteristics;
- transport and storage conditions of commodities that can potentially carry pests;
- patterns of trade and other pathways relevant to the spread of pests (e.g. movements of tourists).

Data specific to the assessment of environmental impacts utilising the ecosystem services approach as described in this document:

(i) Additional ecological characteristics of the pest in its current area of invasion

- niche of the pest;
- population dynamics, population genetics;

(ii) Characteristics of the ecosystems affected in the pest's current area of invasion

- service providing units and specific functional traits;
- clusters linking functional traits and ecosystem services (de Bello, 2009);

(iii) Human interactions in the pest's current area of invasion

- management measures.

7. Risk reduction options for plant pests in natural environments

7.1. Introduction

As with all quarantine pests, a wide variety of measures, as described in the EFSA "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010), are available to prevent their entry into the pest risk assessment area. However, this section is concerned only with the risk reduction options that are available to eradicate, contain or control/ suppress pests following an incursion in the pest risk assessment area (see Q3.28 in the EFSA scheme) with particular reference to those which are available for use in "natural" environments.

Few truly "natural" environments occur in Europe because most habitats are directly managed in some way, e.g. to enhance nature conservation. In this context, therefore, we can include all habitats except urban areas and those areas where cultivated crops are grown. From the EU Corine classification (EEA, 1994), this means that the following habitats are excluded:

- Arable land;
- Protected agriculture (e.g. glasshouses);
- Permanent crops (e.g. vineyards, fruit tree and berry plantations, olive groves);
- Forest plantations;
- Road and rail networks and associated land;
- Urban areas, including parks, gardens, sport and leisure facilities.

From the EUNIS level 1 habitat classification (EUNIS, online), the following habitats are excluded:

- Regularly or recently cultivated agricultural, horticultural and domestic habitats;
- Constructed, industrial and other artificial habitats.

However, it is recognized that some cultivated habitats and urban areas are extremely important for nature conservation.

Although "natural" environments are important for biodiversity and ecosystem services and are not subject to the intensive pest management measures applied to cultivated crops, the same types of chemical, biological and physical pest management measures can still be considered. However, their application is generally much more restricted. These restrictions will be specified on the product label or listed in regulations. Thus, even in intensively cultivated habitats, the use of pesticides is strictly limited to protect the "natural" environment, e.g. by stating that spraying must not be undertaken within a certain distance of water courses.

The main difference in pest control between the "natural" and cultivated/urban environment is therefore in the method of application. Thus, the same herbicide may be used in cultivated crops and in a nature reserve. However, in the former, the application might be by using a tractor mounted sprayer to cover the whole area, whereas, in a nature reserve, the herbicide may be applied directly to stands of invasive alien plants using a back-pack sprayer or even by treating individual plants (as in the case of the Japanese knotweed, *Fallopia japonica*, in the UK, described by Ford, 2004).

Since chemical usage is generally very restricted in "natural" environments and few biological methods are available (and take a long time to develop), the emphasis is often on physical methods, e.g. the removal of invasive alien species by cutting, burning, etc. While these measures are rarely subject to regulation, if these occur over large areas, the environmental consequences also have to be considered.

Due to the severe limitations on the application of measures in "natural" environments, the emphasis is often placed on containing existing outbreaks and ensuring that no further pest movements are made into such environments. This is often best achieved by other measures, e.g. publicity and restrictions on sale.

7.2. Classification of risk reduction options

Most of the risk reduction options listed below is similar to the options used to manage a pest in a cultivated habitat. The choice of the options to be used will depend primarily on the pest, the extent of the outbreak, the availability of the risk reduction options and the type of environment where the pest is present.

The following classification has been developed from that provided by the EU PRATIQUE project in deliverable 5.3 (Sunley et al., under publication).

Four actions can be considered:

- No action: advisable if the risk reduction options available will result in a more negative effect on the environment than without action, when no effective risk reduction options are available, the pest is already too widespread for cost-effective action or the pest is not likely to cause damage or will die out without intervention, e.g. because it cannot reproduce. Surveillance and monitoring may still be advisable, even if no management measures are undertaken.
- Eradication
- Containment
- Suppression

The following control methods can be used for actions 2, 3 and 4 on their own or in combination (e.g. by using Integrated Pest Management (IPM) which integrates methods to minimize the disturbance to the ecosystem):

- Physical and mechanical control (e.g. temperature treatment of the soil to kill soil pests, diseases or weeds; cutting and burning of plants or infested plant parts)

- Biologically based control methods

    - Biological control (e.g. the release of natural enemies / antagonists of pests, diseases or weeds in the natural environment for permanent reduction of their populations);

    - Semiochemical control (e.g. arthropod control with attractants, repellants, antifeedants, pheromones, kairomones or hormones);

    - Genetic control (e.g. the use of sterile insects to prevent/reduce the reproduction of the pest);

- Chemical control

- Other methods primarily aimed at preventing the movement of pests, pathogens or plants from cultivated habitats to natural environments, e.g. by regulations, legislation, codes of conduct, restrictions on sale, restrictions on movement, prohibitions to release in unintended habitats, publicity and the obligation to report findings.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Although every pest risk assessment scheme based on ISPM No 11 includes an assessment of the environmental consequences of pest introduction, schemes focus primarily on the effects on biodiversity, without defining this clearly, and do not provide an explicit standardised methodology for assessing the consequences on ecosystem services. Therefore, the EFSA PLH Panel has developed a scheme that provides guiding principles on assessment practices and enhanced approaches for assessing the environmental risks caused by plant pests. The scheme takes into account the consequences for both biodiversity and ecosystem services.

Review of current approaches

The Panel first reviewed the current approaches and methodologies that assess environmental risks related to pests. In its previous scientific opinions, the Panel assessed environmental risks on an *ad hoc* basis, without following a clear approach and consistent methodology. In most cases, environmental consequences have been interpreted in terms of biodiversity loss. The existing pest risk analysis schemes (e.g. from EPPO, Canadian Food Inspection Agency, USDA and Biosecurity Australia) that are based on the text of ISPM No 11, mostly provide only general guidance to the assessor to help the assessor decide what elements of the "environment" need to be considered and what risk rating is appropriate. These also primarily assess risk according to biodiversity loss (included in the list of direct effects according to ISPM No 11) and there is little guidance on assessing the consequences on ecosystem processes and services (indirect effects according to ISPM No 11). Although risk ratings still have to be justified by written text, the lack of specific guidance can lead to considerable inconsistencies. However, where applied, the principle of assessing consequences in the current area of invasion and extrapolating to the risk assessment area was considered to be a useful approach. The activities of the PRATIQUE and Prima phacie projects have focussed on the enhancement of the structural biodiversity component of environmental risk, and their approach has been reviewed and considered during the development of the current document, although we have provided a more comprehensive evaluation and adopted a different risk rating system. A serious shortcoming of all the considered schemes is the lack of an explicit evaluation of the consequences on ecosystem services and this provides a major focus of this document.

Methodology to prepare an environmental risk assessment

Next, the Panel developed a new methodology for environmental risk assessment. There are two basic reasons to be concerned about environmental consequences. The first one is the international obligation to protect biodiversity, particularly because biodiversity is essential for the normal functioning of ecosystems. The second one is that the outcomes of several ecological processes – the ecosystem services – are useful and indispensable for humans, and their continued functioning is important. This approach emphasizes the importance of assessing consequences on both the structural (biodiversity) and the functional (ecosystem services) levels of the environment. In this document, an approach which considers for the first time the inclusion of both biodiversity and ecosystem services perspectives in a pest risk assessment scheme is presented.

Biodiversity. The assessment of the potential effects of a pest on biodiversity starts with concerns emerging from legal/administrative constraints (e.g. protected / red-list species), and gradually moves towards a more ecological perspective, preparing the ground for the second stage of evaluation, the assessment of the consequences on ecosystem services. The biodiversity at the different organisational levels, from infra-individual to landscape/ecosystem levels is considered, and the potential consequences on genetic, species and landscape diversity are assessed and scored separately. There is a consistent distinction between elements of structural biodiversity that are legally protected, and elements of native biodiversity, and the consequences for these are scored separately.

Ecosystem services. For an environmental risk assessment of pests based on ecosystem services, it is necessary: (1) to identify the environmental components or units responsible for the genesis and regulation of the ecosystem services, the so-called "service providing units"; they are regarded as functional units in which the components (individuals, species or communities) are characterized by functional traits defining their ecological role; (2) to assess the impact of the pest on the components of the structural biodiversity at the genetic, species, habitat, community, and ecosystem levels; (3) to establish a procedure for the evaluation of the effects of pests on ecosystem services. The objective of an environmental risk assessment based on ecosystem services is to understand the consequences of invasion in terms of the modification of the functional traits that are components of the service providing units. Changes in functional traits are associated with the variation in ecosystem services provision levels by means of the consideration of trait-service clusters. The modification of functional traits by the action of pests influences ecosystem processes at the individual (e.g. survival), population (e.g. population structure), as well as community level (importance of functional groups). From the analysis of the traits, a table is derived listing: i) the target elements of the service providing units affected by the pest, ii) the functional traits affected by the pest, iii) whether the induced modification is positive or negative and iv) if necessary, relevant comments clarifying the interpretation of the analysis performed. This guidance document proposes the use of explorative scenarios related to the environmental risk associated with pests. Explorative scenarios are attempts to explore what future developments may be triggered by a driving force, in this case an exogenous driving force, i.e. a driving force that cannot or can only partially be influenced by decision makers.
For the list of ecosystem services to be considered in environmental risk assessment, the Panel adopted the list originally proposed by the Millennium Ecosystem Assessment (MA, 2005). Concerning provisioning services, the complete list has been considered in this document. This choice raises the issue of a possible double accounting, since some of the items in the list have already been, at least partially, considered in the impact session of the pest risk assessment. However, the consideration of all the provisioning services allows for a comprehensive impact evaluation that is not limited to market value, but considers also other components of the value of the ecosystem services. The consideration of the impact on the provisioning services is therefore useful for a more comprehensive environmental impact assessment even for those components of ecosystems more directly computable in terms of market value (e.g., crops).

Questions for assessors. The environmental risk assessment questions for the assessors address the following topics:

1. The definition of the background and assumptions to the ecosystem services approach (e.g. identification of the service providing units and elements of biodiversity ecologically linked to the service providing units) as well as the temporal and spatial scale, to estimate the resistance and the resilience of the affected service providing units, to identify the trait-service clusters and to list the risk reduction options.

2. The evaluation of the consequences for structural biodiversity caused by the pest in the current area of invasion: what is the magnitude of change on genetic diversity, are protected, rare or vulnerable species affected, is there a decline in native species, is there an impact on objects or habitats of high conservation value, are there changes in the composition and structure of native habitats, communities and/or ecosystems?

3. The evaluation of the consequences for structural biodiversity caused by the pest in the risk assessment area: similar questions as under point 2.

4. The evaluation of the consequences for ecosystem services caused by the pest within its current area of invasion, to determine how great the magnitude of reduction is in the provisioning, regulating and supporting services affected in the current area of invasion.

5. The evaluation of the consequences for ecosystem services caused by the pest within the risk assessment area: similar questions as under point 4.

Rating system. A rating system has been developed based on a probabilistic approach which ensures consistency and transparency of the assessment. The rating system includes an evaluation of the degree of uncertainty. The rating system makes it possible to evaluate the level of risk and the associated uncertainty for every sub-question and then the overall risk and uncertainty for every question. At the end of the assessment process, the level of overall risk related to questions on biodiversity is categorized as either *Minor, Moderate* or *Major,* while for questions on ecosystem services, the categorisation is either *Minimal, Minor, Moderate, Major* or *Massive*. The degree of uncertainty is categorised as *Low, Medium* or *High*.

Finally, an overview of the available risk reduction options for pests in natural environments is presented, minimum data requirements are described, and a glossary to support the common understanding of the principles of this opinion is provided.

RECOMMENDATIONS

The Panel recognises that assessing environmental impacts on the basis of the ecosystem services concept is a developing area, and expects methodological developments and more precise and articulate schemes and quantification methods to emerge as experience accumulates. Attention has to be devoted to the evaluation of the provisioning services in order to avoid the possible problem of double accounting, and before evaluating them in the environmental risk assessment, it should be assessed whether these are not already satisfactorily covered in other parts of the pest risk assessment.

The Panel recommends revising and updating the present guidance document in three years, based upon:

- outcome and experience gained from the usage of the proposed environmental risk assessment approach in future pest risk assessments;
- results of horizontal harmonisation activities within EFSA;
- any relevant new information which may have an impact on the current opinion, e.g. further developments in the ecosystem services concept and its application.

Further work is recommended by the Panel, e.g.

- testing the scheme using species with a wide range of environmental impacts;
- comparing this approach with that used in other schemes from the perspective of the risk assessor, risk manager and risk modeller;
- exploring the possibility to use quantitative assessment (percentages) to describe levels of impact in other parts of the pest risk assessment;
- exploring the potentiality of the scenario exercise (leading to a set of assumptions guiding the assessment procedure) for the entire pest risk assessment.

DOCUMENTATION PROVIDED TO EFSA

1. Letter, dated 29 April 2010 with ref. RM/EBC/VK/ddr (2010)-out-4809462. Submitted by C. Geslain-Lanéelle to M. Jeger.

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APPENDICES

A. ENVIRONMENTAL RISK ASSESSMENT IN PLH OPINIONS

Title of the opinion	Page(s) number	Content	Aspects considered
Opinion of the Scientific Panel on Plant Health on an evaluation of asymptomatic citrus fruit as a pathway for the introduction of citrus canker disease (*Xanthomonas axonopodis* pv. *citri*) made by the US Animal and Plant Health Inspection Service (APHIS) **(Question N° EFSA-Q-2006-054)**	8	Graham *et al*. (2004b) mentioned the occurrence of copper resistance in xanthomonas populations and the negative environmental consequences of excessive copper use. Copper resistance was also noted by Canteros (2004) and by Schubert *et al*. (2001).	Impact of pest risk reduction options
Opinion of the Scientific Panel on Plant Health **on the Pest Risk Analysis made by Spain on *Bactrocera zonata*** **(Question N° EFSA-Q-2006-052)**	14-15	The pest risk assessment does not give a score for the environmental impact in the PRA area (Section B, question 2.13) and states that there are no data to allow predictions to be made. However, although native fruit flies may be displaced, attacking ripe fruit is unlikely to reduce the number of native species (see comments for question 2.2) so a low score is warranted. Following invasion, pesticide use may be very high, pollute the environment and have a negative effect on pollinator and natural enemy populations, particularly if there is illegal use. However, this may be limited because the EC has very strict regulations for pesticide use and many importers require residue testing.	Negative impact on native biodiversity Impact of pest risk reduction options
Opinion of the Scientific Panel on Plant Health on the pest risk assessment made by Lithuania on *Ambrosia* spp. **(Question No EFSA-Q-2006-055A)** **And** **Opinion of the Scientific Panel on**	10 for A and 9 for B	1.2.2. Ecological impact / impact on biodiversity Limited information is available about the occurrence of *Ambrosia* spp. in natural habitats in their alien range. The ecological impact in these habitats is not described. Information from ecological studies in Europe demonstrating the negative impact of *Ambrosia* spp. on biodiversity in their alien range is sparse. According to Pál (2004), *A. artemisiifolia* may have an effect on segetal weed associations. Further ecological studies are needed to judge whether *Ambrosia* spp. might become a problem in natural habitats in Europe (for example on riverbanks, in oligotrophic grassland communities or in open habitats). Large populations of *A. artemisiifolia* can be found on riverbanks particularly in the south of France. Very few plant species are able to survive in these areas (generally only other alien species such as	Negative impact on native biodiversity

Plant Health on the pest risk assessment made by Poland on *Ambrosia* spp.1 (Question No EFSA-Q-2006-055B)		*Amaranthus* spp. or *Xanthium* spp.). Seeds of *Ambrosia* spp. can be easily dispersed by water. Since control methods are more complex (the use of herbicides is not allowed) or more expensive (grazing with sheep or cattle – Riaille and Faton, 2004), the spread of *A. artemisiifolia* is very effective in riverbanks. However, no impacts on biodiversity have been documented in France. *A. artemisiifolia* is a pioneer herb which usually grows in open habitats, rarely occurring in dense vegetation or in forests. On the Transcarpathian plain, *A. artemisiifolia* grows in pastures with 10 - 20 specimens/m2 (Song and Prots, 1998). *A. artemisiifolia* is suppressed by perennial grasses in pastures in Ukraine (Maryushkina, 1991). Vermeire and Gillen (2000), studying the effect of *A. psilostachya* on the herbaceous standing crop in Great Plain grasslands of the USA, found that *A. psilostachya* did not appear to reduce the grass standing crop in mixed prairie and that its increase was more due to other stresses such as improper grazing. Some studies show that *A. artemisiifolia* has allelopathic abilities, which might have negative impacts on the germination of other species (Brückner *et al.*, 2003; Siniscalco and Barni, 1994; Siniscalco *et al.*, 1992).	
Opinion of the Scientific Panel on Plant Health on the pest risk analysis made by EPPO on *Hydrocotyle ranunculoides* L. f. (floating pennywort)1 (Question N° EFSA-Q-2006-053B)	9	2.5. Environmental and social impact The plant is listed as an endangered species in its native range in the USA (USDA, 2006), but has been recorded as damaging in some areas where it has been introduced. Claims of significant adverse environmental effects including impacts on biodiversity are stated in the pest risk assessment, but are not referenced. However, little or no impact has been reported in Denmark, France, Italy and Portugal, although the plant has been present for around 30 years. The pest risk assessment speculates about factors explaining these differences, but supporting scientific data are not available. The panel considered that the rating of "major" given in the pest risk assessment of the actual (but not potential) environmental damage as major is not supported by the evidence provided. However, the Panel agreed that negative effects on the environment are likely to be incurred as a result of chemical control of the plant.	Negative impact on native biodiversity Impact of pest risk reduction options
Opinion of the Scientific Panel on Plant Health on the pest risk analysis made by EPPO on *Lysichiton americanus* Hultén & St. John (American or yellow skunk cabbage) (Question N° EFSA-Q-2006-053A)	8	2.5. Environmental and social impact The panel concluded that the rating of environmental damage as "major to massive" is not supported by the evidence provided in the EPPO document. The EPPO risk assessor also acknowledges difficulties in ascribing a rating to the environmental impact, where effects are highly localised. The potential for serious environmental impacts is acknowledged by the Panel, as species displacement and local extinction of rare and endangered species is reported from the Taunus area of Germany (Alberternst and Nawrath, 2002; König and Nawrath, 1992). However, the plant is naturalised in a number of areas in Europe where it has been introduced, with no	Negative impact on native biodiversity Conservation impacts

		recorded impacts and thus is not considered invasive. The reasons for this difference cannot be deduced from the information presented in the document and without a clear definition of the endangered area, it is difficult to accurately assess the environmental impacts.	
Pest risk assessment made by France on *Erionota thrax* L. considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-096)**	16	2.3.2.3. Environmental consequences According to the French document, a presumed environmental risk is to ornamental and wild plants (bananas, Zingiberales, possibly palms). However, impacts are neither specified nor quantified, only a statement that wild populations of *Heliconia* in Guadeloupe and Martinique could be threatened. Concerning the risk for palms and host plants other than banana, it is not clear, how severe the damage for these would be or even if there would be any.	Negative impact on native biodiversity
Pest risk assessment made by France on *Ralstonia solanacearum* race 2 considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-099)**	20	2.3.2.3. Environmental consequences The document does not discuss potential environmental consequences. The Panel is of the opinion that environmental consequences may be associated with changes in land cover due to a reduced presence of *Musa* and *Heliconia* plants in commercial plantations, private gardens and in the wild.	Negative impact on native biodiversity
Pest risk assessment made by France on *Trachysphaera fructigena* considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-105)**	18	2.3.2.3. Environmental consequences The document does not discuss potential environmental consequences.	
Pest risk assessment made by France on *Odoiporus longicollis* considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-098)**	11	2.3.2.3. Environmental consequences The document does not discuss potential environmental consequences. Environmental consequences might result from changes in land cover due to a reduced presence of *Musa* spp. plants in commercial plantations, private gardens and in the wild. In the case of establishment, increased pesticide treatments would cause more environmental contamination (including spray drift, pesticide residues, and water pollution). Existing natural control processes of other crops and habitats could be damaged, and biodiversity could be reduced. Such damage could also lead to a reduction in beneficial ecosystem services (pollination, natural pest control, decomposition).	Negative impact on native biodiversity Impact of pest risk reduction options Ecosystem services

Pest risk assessment made by France on *Phyllosticta musarum* [Cooke] van der Aa considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-106)**	17	2.3.2.3. Environmental consequences The Panel considers that no additional environmental impacts are expected in the PRA area as a result of the introduction of the pathogen.	
Pest risk assessment made by France on Banana bract mosaic virus considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-108)**	18	2.3.2.3. Environmental consequences The document does not discuss in detail any potential environmental consequences. The Panel is of the opinion that environmental consequences that might be associated with the introduction of BBrMV would be limited, and may arise from a potential increase in insecticide applications to minimise the aphid vector population.	<u>Impact of pest risk reduction options</u>
Pest risk assessment made by France on *Xanthomonas campestris* pv. *musacearum*, considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-100)**	23	2.3.2.3. Environmental consequences Potential environmental consequences associated with changes in the landscape due to a reduced presence of banana plants within commercial plantations and private gardens have not been considered in the document. As an outcome of the socio-economic impact analysis, alternatives to banana cultivation could have been identified and assessed in the context of the ecological and economical services of banana production such as soil health, water management, use of agrochemical inputs and farmers income.	<u>Negative impact on native biodiversity</u> <u>Ecosystem services</u>
Pest risk assessment made by France on *Ralstonia* sp. pathogenic agent of banana blood disease considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-101)**	17	2.3.2.3. Environmental consequences The document does not discuss potential environmental consequences. The panel is of the opinion that environmental consequences may be associated with changes in land cover due to a reduced presence of *Musa* plants in commercial plantations and private gardens. Should BDB be proved to cause wilting on *Heliconia*, environmental consequences on biodiversity would need further investigations. [...] There are further uncertainties regarding the effects on *Heliconia* cut flower production and the potential environmental impact, such as soil erosion and biodiversity modifications, as a result of the death of host plants in the PRA area.	<u>Negative impact on native biodiversity</u> <u>Alteration of ecosystem processes and patterns</u>
Pest risk assessment made by France	18-19	2.3.2.3. Environmental consequences	<u>Impact of pest</u>

on Mycosphaerella fijiensis considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-102)**		Because a large number of fungicide applications are normally needed for the effective control of *M. fijiensis,* the environment in banana growing areas could be adversely affected (Bertrand and Bonacina, 2002). The Panel agrees on the pest risk assessment of non-commercial consequences. Due to the proximity of export banana plantations in Guadeloupe and Martinique to inhabited areas, the increase in fungicide aerial treatments may impact on human health through pollution of the air and surface water (Bertrand and Bonacina, 2002). It may also cause social alarm as the population would be aware of the impact of pesticides on human health and the environment (Bertrand and Bonacina, 2002). The banana industry in Guadeloupe and Martinique is currently experiencing problems controlling *M. musicola* because of a limited number of fungicides registered for use and restrictions on aerial spraying (de Lapeyre *et al*., in press). The introduction of *M. fijiensis* would compound these problems. There are uncertainties regarding the increase of pesticide residues in banana fruit should *M. fijiensis* establish in the PRA area.	risk reduction options
Pest risk assessment made by France on Banana mild mosaic virus (BanMMV) considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-110)**	17	2.3.2.3. Environmental consequences The document does not discuss potential environmental consequences. The Panel is of the opinion that there is a low likelihood of environmental consequences due to the limited impact of BanMMV on the plant.	
Pest risk assessment made by France on Banana streak virus (BSV) considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-109)**	18	2.3.2.3. Environmental consequences The document does not discuss potential environmental consequences. The Panel is of the opinion that environmental consequences may be associated with changes in land cover due to a reduced presence of banana plants in commercial plantations, small holdings and private gardens.	Negative impact on native biodiversity
Pest risk assessment made by France on *Mycosphaerella eumusae* considered by France as harmful in French overseas departments of Guadeloupe and Martinique **(Question No EFSA-Q-2006-103)**	15	2.3.2.3. Environmental consequences A presumed environmental risk mentioned in the French document is “use of phytosanitary products if other genetic and agricultural methods prove insufficient”. This statement is not supported with data. *M. eumusae* may possibly cause additional environmental risks (e.g. additional applications of phytosanitary products) if the pathogen does not respond to the chemical control methods currently used in Guadeloupe and Martinique for *M. musicola*.	Impact of pest risk reduction options

Pest risk assessment made by France on *Nacoleia octasema* considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-097)**	12	2.3.2.3. Environmental consequences The document does not discuss potential environmental consequences. The Panel considers that any environmental consequences are likely to be very small since damage is essentially cosmetic and confined to the skin of mature fruit.	
Pest risk assessment made by France on *Fusarium oxysporum*. f. sp. *cubense* considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-104)**	17	2.3.2.3. Environmental consequences Potential consequences associated with landscape changes due to a reduced presence of banana plants within commercial plantations and private gardens, after the establishment of Panama disease, have not been considered in the document. Alternatives to banana cultivation have not been identified and assessed.	<u>Negative impact on native biodiversity</u>
Pest risk assessment made by France on *Banana bunchy top virus* (BBTV) considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-107)**	16	2.3.2.3. Environmental consequences The document does not discuss potential environmental consequences. The Panel is of the opinion that environmental consequences may be associated with changes in land cover due to a reduced presence of banana plants in commercial plantations, small holdings and private gardens.	<u>Negative impact on native biodiversity</u>
Pest risk assessment made by France on *Aceria sheldoni* (Ewing) considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-081)**	11	2.3.2.2. Social and environmental consequences The French document does not address social and environmental consequences but notes that other potential impacts are not expected. Potential environmental impacts associated with additional pesticide applications were considered by the Panel. However, as this pest very seldom reaches pest status and lemons represent a small proportion of the total area of citrus grown, the Panel agrees that social and environmental consequences are not expected.	<u>Impact of pest risk reduction options</u>
Pest risk assessment made by France on *Sphaeropsis tumefaciens* Hedges considered by France as harmful in	13	2.3.2.3. Environmental consequences As *S. tumefaciens* has a broad host range, the introduction of the disease might affect the biodiversity in the PRA area. *S. tumefaciens* was reported to increase the mortality of a state-	<u>Negative impact on native biodiversity</u>

French overseas departments of French Guiana, Guadeloupe and Martinique **(Question No EFSA-Q-2006-090)**		endangered endemic shrub, *Hypericum edisonianum*, in Florida in 2000 (van de Kerckhove, 2002).	
Pest risk assessment made by France on *Citrus exocortis viroid* (CEVd) considered by France as harmful in French overseas department of Réunion **(Question No EFSA-Q-2006-093)**	13	2.3.2.2. Social and Environmental consequences No environmental consequences have been described as a result of CEVd infection. The Panel agrees with the French document stating that non-commercial and environmental consequences of CEVd in the PRA area would be of low importance.	
Pest risk assessment made by France on *Prays citri* considered by France as harmful in French overseas departments of French Guiana, Guadeloupe and Martinique **(Question No EFSA-Q-2006-086)**	17-18	2.3.2.2. Social and environmental consequences The document does not provide supporting evidence for any potential social or environmental consequences as a result of the establishment of *P. citri* in the PRA area. It suggests that environmental consequences for the PRA area are likely to be "important". The host range of the organism is reportedly restricted to citrus, some other Rutaceae and a few species of Sapotaceae and Oleaceae (CABI, 2001; 2007), but it is unclear which wild plant species may suffer damage should *P. citri* be introduced in the PRA area. It is also not clear if the statement made in the pest risk assessment regarding the fact that chemical treatments are carried out during flowering, refers to potential detrimental effects on pollinators or other flower-visiting organisms. Chemical treatments against the pest may be carried out just before, during or shortly after flowering, but the number of treatments needed to control the pest, and thus the degree of exposure suffered by non-target organisms, strongly varies among reports. Further, non-chemical management measures are available as alternative options to control the pest (e.g., *B. thuringiensis*, pheromonal control).	<u>Negative impact on native biodiversity</u> <u>Impact of pest risk reduction options</u>
Pest risk assessment made by France on *Xanthomonas axonopodis* pv. *citri* considered by France as harmful in French overseas departments of French Guiana, Guadeloupe and Martinique **(Question No EFSA-Q-2006-088)**	17	2.3.2.3. Environmental consequences In accordance with the document, the Panel considers that repeated applications of copper for controlling XCC could increase the risk of pollution of the soil and contamination of the crops. These effects have been reported for grapevines in Europe by Flores-Vélez *et al*. (1996) and by García-Esparza *et al.* (2006). The document estimates as "fairly important" the environmental damage in the PRA area because of loss of biodiversity following the eradication of infected "wild rutaceous plants". However, the document does not provide any information regarding the presence and distribution of species of the *Rutaceae* family in natural vegetations in the French Guiana, Guadeloupe and Martinique.	<u>Negative impact on native biodiversity</u> <u>Impact of pest risk reduction options</u>
Pest risk assessment made by France on *Mycosphaerella citri* considered	15	2.3.2.3. Environmental consequences Timmer and Gottwald (2000) note that *M. citri* is mainly controlled using copper fungicides	<u>Impact of pest risk reduction</u>

by France as harmful in French overseas department of Réunion **(Question No EFSA-Q-2006-089)**		and petroleum oils. Copper has been shown however to inhibit growth of citrus as a result of the accumulation of toxic levels of the element in acidic soils. It has also been shown to reduce the colonisation of citrus roots by the beneficial mycorrhizal fungus *Glomus intraradices* (McGovern *et al*., 2003).	options
Pest risk assessment made by France on *Ceratocystis fimbriata* considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-091)**	16	2.3.2.3. Environmental consequences The document does not provide any information regarding the presence and distribution of host species of *C. fimbriata* in natural vegetations in French Guiana, Guadeloupe, Martinique and Réunion. The Panel considers that, in areas where *C. fimbriata* has been introduced, the damage is primarily to planted species and not to native vegetation. However, recently, a species of the same genus, *C. platani*, which normally attacks amenity plane trees, has been reported to cause substantial mortality of native *P. orientalis* in Greece (Ocasio-Morales *et al.,* 2007).	Negative impact on native biodiversity
Pest risk assessment made by France on *Prays endocarpa* considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-087)**	13	2.3.2.2. Social and environmental consequences The document does not address any potential social or environmental consequences as a result of the establishment of *P. endocarpa* in the PRA area.	
Pest risk assessment made by France on *Metcalfa pruinosa* (Say) considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-083)**	13	2.3.2.4. Environmental consequences The document does not analyse potential environmental consequences, yet gives a high rating. The statement in the document that the species' polyphagous nature suggests that it may be able to harm ecosystems in the PRA area is speculative and conflicts with information provided under the final evaluation. As *M. pruinosa* feeds on many plant species, the impact on biodiversity is expected to be dispersed. The high rating is not substantiated with supporting evidence and in the absence of evidence the Panel notes that there is uncertainty relating to the potential environmental consequences.	Negative impact on native biodiversity
Pest risk assessment made by France on *Parlatoria ziziphi* (Lucas) considered by France as harmful in French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-085)**	13	2.3.2.3. Environmental consequences The document does not analyse potential environmental consequences, but indicates that they are "fairly important". As the pest risk assessment does not provide any information regarding this issue, the Panel cannot properly judge the estimate of "fairly important". However, the Panel considers this rating to be too high, as citrus is produced commercially on a limited area for home consumption and additional chemical treatments are unlikely to be justified for control specifically targeted at this pest.	Impact of pest risk reduction options
Pest risk assessment made by France	14	2.3.2.3. Environmental consequences	Impact of pest

on *Citrus chlorotic dwarf virus* considered by France as harmful in the French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-094)**		Potential environmental consequences associated with the introduction and establishment of CCD have not been considered in the French document. The introduction of the CCD agent in areas infested with *P. myricae* may result in an increase in the use of pesticides, aimed at reducing whitefly vector populations.	risk reduction options
Pest risk assessment made by France on *Citrus yellow mosaic virus* or *Citrus mosaic badnavirus* considered by France as harmful in the French overseas departments of French Guiana, Guadeloupe, Martinique and Réunion **(Question No EFSA-Q-2006-095)**	13	2.3.2.3. Environmental consequences Potential environmental consequences associated with the introduction and establishment of CMBV have not been considered in the French document. The Panel has not identified detrimental environmental consequences.	
Pest risk assessment made by France on *Hop stunt viroid* (HSVd) considered by France as harmful in the French overseas department of Réunion **(Question No EFSA-Q-2006-092)**	13	2.3.2.2. Non-commercial and environmental consequences No environmental consequences have ever been described as a result of HSVd infection. The Panel agrees with the French document, which states that non-commercial and environmental consequences of HSVd in the PRA area would be of low importance.	
Pest risk assessment made by France on *Panonychus citri* considered by France as harmful in French overseas departments of French Guiana and Martinique **(Question No EFSA-Q-2006-084)**	13-14	2.3.2.3. Environmental consequences The document does not discuss potential environmental consequences. In spite of being polyphagous, the pest has not been recorded to damage any host plant apart from citrus, so negative impacts to other hosts or wild plants are unlikely. Unwise pesticide applications may create environmental damage by disrupting natural pest control of this species (McMurtry, 1985) or that of others in citrus orchards. Environmental damage through disruption of ecosystem services, spray drift and contamination is possible but unlikely, because commercial citrus production is not extensive in the PRA area. It is not likely that backyard orchards will be sprayed with pesticides, because pest effects on the host plant or yield are not serious.	Negative impact on native biodiversity Impact of pest risk reduction options Ecosystem services
Pest risk assessment made by France on *Brevipalpus californicus, Brevipalpus phoenicis and Brevipalpus obovatus* (Acari:	19	2.3.2.3. Environmental consequences Apart from an increase in production costs in citriculture, application of pesticides for control of *B. californicus, B. phoenicis* and *B. obovatus* may lead to environmental risks, suppression of the mites' natural enemies or to high selection pressure of resistant populations of *B.*	Impact of pest risk reduction options

Tenuipalpidae) considered by France as harmful in the French overseas departments of Guadeloupe and Martinique **(Question No EFSA-Q-2006-082)**		*phoenicis* (Bassanezi and Laranjeira, 2007).	
Pest risk assessment and additional evidence provided by South Africa on *Guignardia citricarpa* Kiely, citrus black spot fungus – CBS **(Question No EFSA-Q-2008-299)**	90	4.3. Evaluation of the current EU measures [...] Moreover, side-effects of fungicide treatments need to be considered: copper fungicides may cause stippling of fruit tissue due to direct copper injury, (Schutte *et al*., 1997) and negative environmental effects, like high toxicity to aquatic organisms, and food safety effects i.e. residues in the fruit adding to the overall copper exposure in diet (EFSA, 2008). *G. citricarpa* may develop resistance to some fungicides (CAB International 2007; Herbert and Grech, 1985; Kotzé, 1981; Schutte, 2006; Schutte *et al.,* 2003).	Impact of pest risk reduction options
Mortality verification of pinewood nematode from high temperature treatment of shavings **(Question No EFSA-Q-2009-00447)**		N/A	
Evaluation of a pest risk analysis on *Thaumetopoea processionea* L., the oak processionary moth, prepared by the UK and extension of its scope to the EU territory **(Question No EFSA-Q-2008-711)**	16	2.3.3. Environmental consequences The UK document considers that environmental damage in the current range of *T. Processionea* is moderate, as the pest may be a contributing factor to the general syndrome of oak decline (Thomas *et al*., 2002). Oak decline is caused by a complex of biotic and abiotic factors and the Panel found that it has been frequently linked in the literature to defoliation of oak by lepidopteran larvae. The majority of the published literature refers to defoliation by lepidopteran species other than *T. processionea* – and particularly with *Lymantria. dispar*. A first review of the oak decline phenomenon has been made by Delatour (1983); more recent reviews include those of Siwecki and Ufnalski (1998) and Thomas *et al*. (2002). The role of defoliating insects as predisposing factors is stressed in all of these review papers, but the most in-depth analysis is to be found in Thomas *et al*. (2002), as cited in the UK document. From a review of several studies, Thomas *et al*. (2002) conclude that the combination of severe insect defoliation in at least two consecutive years with climatic extremes is the most significant complex of factors in the incidence of oak decline in north-western Germany, and that significant damage to oaks due to severe defoliation by lepidopteran larvae has also been reported from France, Russia, Romania and Hungary. Bréda and Badeau (2008) report on the effect of extreme events and noted that complete defoliation by *Lymantria dispar* for two consecutive years, and subsequent infection	Negative impact on native biodiversity Impact of pest risk reduction options

		of replacement shoots by mildew led toheavy and rapid mortality, and reduced growth rings in those trees that survived. Similarly, successive entomological and fungal defoliations have been observed to lead to plant death, especially if additional pests or diseases such as buprestid beetles and *Armillaria* spp. are also involved (Thomas *et al*., 2002; Marçais and Bréda, 2006; Möller, 2006). *Quercus robur* is usually more affected by oak decline episodes than *Q. Petraea* (Delatour 1983). Most often, a combination of water logging and repeated defoliation, or repeated defoliation and spring frosts, or repeated defoliation and severe spring or summer drought has been observed before a decline episode. Thomas *et al*. (2002) consider that insect defoliation is most important because of its overriding effect in reducing the trees' carbohydrate supply (and hence in subsequent frost resistance) and because it leads to reduced diameters of earlywood vessels and hence to impaired hydraulic conductance. Studies by N. Bréda in north-eastern France (Bréda, 2009, personal communication) focusing on dendrological and chemical analyses (carbohydrates) of artificially defoliated pedunculate oaks confirm the hypothesis that water and carbon relationships are severely affected by defoliation. Further studies are being undertaken which may provide further evidence of effects from defoliation by *T. processionea*. The Panel adds that control measures against *T. Processionea* using non selective chemical or biological control agents may cause negative effects on non target organisms, which may include endangered species of Lepidoptera occurring in the same habitat.	
Statement on the dossier for a derogation request of the US authorities concerning cold-treated strawberry plants intended for planting **(Question No EFSA-Q-2009-00937)**		N/A	
Statement on a study proposal prepared by the US to support a future derogation request from the EU import requirements for wood packaging material originating in the US and used to pack and transport military ammunition **(Question No EFSA-Q-2010-00056)**		N/A	
Scientific Opinion on the effect on public or animal health or on the	21-23	8. Effects of *Ambrosia artemisiifolia* on the environment *A. artemisiifolia* is classified as an epoecophyte. i.e. a xenophyte species established only in	

environment on the presence of seeds of *Ambrosia* spp. in animal feed **EFSA Panel on Contaminants in the Food Chain (CONTAM), EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA) and EFSA Panel on Plant Health (PLH)** **Question No EFSA-Q-2009-00655 adopted on 19 March 2010 by the CONTAM Panel, Question No EFSA-Q-2010-00890**		ruderal or segetal (arable) vegetation (Protopopova et al., 2006). In its current range, *A. artemisiifolia* occurs predominantly in disturbed and open habitats and its constant presence can be expected in locations where disturbance is repeated regularly, i.e. in arable fields, roadsides and generally in places where human activities cause disturbance (Bazzaz, 1974; Mihály and Botta-Dukát, 2004; Szigetvári and Benkö, 2008). Normally it decreases in the course of succession (Szigetvári and Benkö, 2008). According to Bonnot (1967) *A. artemisiifolia* grows wherever competition is low and also in ecosystems regularly disturbed by humans. Fumanal et al. (2008) found *A. artemisiifolia* with other non-native species and with species from early successional stages. They conclude therefore that *A. artemisiifolia* does not present a threat to the plant biodiversity of the different invaded areas, but is an alien generalist species occupying a free ecological niche. They refer with regard to *A. Artemisiifolia* to a “winner species” (as defined by McKinney and Lockwood, 1999) rather than a “transformer species” (according to Richardson et al., 2000). Some studies show that *A. artemisiifolia* has allelopathic abilities, which might have negative impacts on the germination of other species (Siniscalco et al., 1992; Siniscalco and Barni, 1994; Brückner et al., 2003). Allelopathic effects were also found by Hodişan et al. (2009) for *A. artemisiifolia* on wheat, rye, barley and rape (aqueous extracts from roots and leaves of mature plants had a significant inhibiting influence on the germination of these plants; stem extracts only inhibited germination of wheat and rye). Lucerne was not inhibited at all. These allelopathic effects may also inhibit germination of other plant species. General or indirect statements are made in literature regarding the environmental impact of *A. artemisiifolia*, particularly with regard to threat to biodiversity by competition with other species (Bohren et al., 2008; Chauvel et al., 2006; Delabays et al., 2008; van Vliet et al., 2009) but published evidence on this aspect is sparse. Brandes and Nitzsche (2006) did not find any evidence of a replacement of native species by *Ambrosia* spp. in Germany. They found *A. artemisiifolia* only scarcely at river banks in Germany and explain this with the assumption that the summer fluctuations of the water level may be the main reason for hampering the establishment in these habitats, because the species seems not to be tolerant to inundation. For torrential rivers with an extended period of summer drought this is different, as *A. artemisiifolia* often grows in dried up river beds. In one case cited in Alberternst et al. (2006), *A. artemisiifolia* had an environmental impact on a sand dune. In the vicinity of a nature conservation area near Daßfeld (lower Bavaria), 10 cm of soil contaminated with *A. artemisiifolia* seeds had been deposited illegally. Since 1993, around 20 mature specimens were found. In 2000 and the following years, the number of specimens suddenly increased to around 10000, growing on 200-300 m2 of an adjacent, so far undisturbed sand dune under nature conservation, threatening rare species like *Teesdalia nudicaulis*, *Veronica verna*, *Veronica dillenii* and others. Due to nature conservation measures	

		(mainly hand pulling), the population could be reduced by 75 % in 2005 and seems to be eliminated by now.17 According to Brandes and Nitzsche (2007), the increase of the population was caused by inappropriate management measures. They assume that *A. artemisiifolia* did not invade the sand dune actively but was introduced by substrates for soil amelioration. *A. artemisiifolia* is reported as invasive on river banks of South France (Doutriaux, 1997; Faton and Montchalin, 2007), particularly in new artificial embankments or in occasion of floods when the secondary river beds (usually dry) are flooded and then dried again (Doutriaux, 1997). Seeds of *A. artemisiifolia* can be easily dispersed by water but also human activities as movement of soil and gravel are very active pathways of dispersal. Use of herbicides being not allowed in river banks, in natural reserves *A. artemisiifolia* is controlled by sheep grazing with the objective to reduce pollen production (Faton and Montchalin, 2007). However, no impacts of *A. artemisiifolia* on biodiversity have been documented in France. In Austria, the majority of *A. artemisiifolia* populations is expected to grow on fields and associated habitats in the near future (Essl et al., 2009), no evidence is given for environmental impacts. In Hungary, *A. artemisiifolia* is also reported in forest, where the common ragweed prefers the disturbed and light rich habitats as cut road margins, ditches, fields for game and feed troughs (Hirka and Csoka, 2009). With respect to a similar study conducted in 1969-1970 (Ujvarosi, 1975, cited in Pál, 2004), Pál (2004) showed in southern Hungary a pauperization of the segetal (arable) weed flora in terms of number of species. For the 2001-2002 surveys, he reported a 90 % coverage by *A. artemisiifolia* of stubble fields and summer annual crops. However, from the data presented in this paper, it is not possible to distinguish whether the pauperization is due to a change in agriculture practice, to a transforming effect of the invasive weeds or to both. More details with regard to environmental impacts of *A. artemisiifolia* in Hungary are given by Pinke et al. (2008), who studied the weed vegetation on extensively managed fields in western Hungary. The surveyed vegetation contained 41 International Union for Conservation of Nature (IUCN) red list weed species (among which, two “critically endangered” (CR), four “endangered” (EN), seven “vulnerable” (VU), 22 “near threatened” (NT), and 6 “data deficient” species)18, showing that extensively managed fields represent refugia for threatened weed species. Furthermore, these species support the agro-ecosystem food chain. This indicates a high value for the conservation of biodiversity of these habitats, which are considered by the author threatened by the increasing spread of *A. artemisiifolia* in two ways: by invading these habitats, *A. artemisiifolia* could replace these species, and a total weed control as well as an early ploughing of stubbles to remove *A. artemisiifolia* would also remove these valuable red list species. Maryushkina (1991) has conducted studies to analyse the species strategy of *A. artemisiifolia*	

		in the steppe in Ukraine. A reduction in the number of species was observed when ragweed seedlings were not removed in an experiment on a freshly ploughed plot of an abandoned field. Also in the steppe zone in Ukraine, *A. artemisiifolia* demonstrated high invasiveness and wide ecological amplitude (it occurs in eight synanthropic and two natural floristic complexes) (Protopopova et al., 2006). *A. artemisiifolia* penetrated even into dense stands of *Festuca sulcata*, especially if the communities were overgrazed and trodden by cattle and other livestock (Solomakha et al., 1992 cited in Protopopova et al., 2006). On pastures, large stands of *A. artemisiifolia*, as well as of other invasive weeds, prevented the process of restoration of steppe communities, which were replaced by various synanthropic communities, especially under proceeding overgrazing pressure (Protopopova et al., 2002 and 2003, cited in Protopopova et al., 2006). During the processes of restoration of completely or partly transformed vegetation, alien species as *A. artemisiifolia* raised the level of competition for ecotopes and are stronger competitors than native plant species acting in the newly formed ruderal communities as dominants (Protopopova et al., 2006). Regarding other ragweeds, *A. trifida* is categorised in Japan as a Rank A species, i.e. one of the 16 most invasive species, having demonstrated strong adverse effects on biodiversity and ecosystems. Most of these 16 species dominate large areas of riparian habitats. Uraguchi et al. (2003) found allelopathic effects of *A. trifida* against an endemic floodplain plant in Japan. Kong et al. (2007) state that *A. trifida* could release allelochemicals into the soil to act as inhibiting the growth of wheat both in rhizosphere and non-rhizosphere soils in which *A. trifida* had been grown to different growth stages. In the *A. trifida* non-rhizosphere soil, however, the growth of wheat was considerably more reduced compared to that in the rhizosphere soil, implying that soil phytotoxicity did not result primarily from *A. trifida* root exudates, but from residues. As a result, there appear to be phytotoxins in the *A. Trifida* infested or amended soils. A possible beneficial effect of *A. trifida* is mentioned in a study by Liang et al. (2007) in China, where, investigating the temporal dynamics of soil nematode community structure under invasive *A. trifida* and native *Chenopodium serotinum*, the number of nematode genera was higher in soil under *A. trifida* than under *C. serotinum*. In Great Britain, *A. psilostachya* naturalised on sand dunes on the coast, but no environmental impacts were described (Rich, 1994). Yaacoby (2008) states that another ragweed *A. confertifolia* (generally considered as a synonym of *A. psilostachya* according to Szigetvári and Benkö, 2008) severely infests nature reserves and reduces biodiversity in Israel, but no details were provided. The Panel concludes that there is no direct evidence that *Ambrosia* spp. cause extinction of plant species. However, there are some indications that *A. artemisiifolia* could become highly	

		invasive in certain environmentally-valuable habitats and that under certain conditions, generally in habitats disturbed by human activities, *A. artemisiifolia* might be linked to an impoverishment of species richness, therefore further ecological studies are needed.	
Risk assessment of *Gibberella circinata* for the EU territory and identification and evaluation of risk management options **(Question No EFSA-Q-2009-00678)**	51	3.5.1.2. Indirect pest effects *G. circinata* directly affects pine wood and seed yields and quality, but it may also have indirect, environmental side-effects. *G. circinata* was listed as a significant agent of biological disturbance in forests, which can increase the probability of fires (Ayres and Lombardero, 2000). In addition, pitch canker can reduce recreational uses, tourism, and aesthetic amenity of the affected forests (Templeton et al., 1997). This latter effect is of relevant concern (Bell et al., 2007).	Negative impact on native biodiversity Impact of pest risk reduction options Alteration of ecosystem processes and patterns
Risk assessment of the oriental chestnut gall wasp, *Dryocosmus kuriphilus* for the EU territory and identification and evaluation of risk management options **(Question No EFSA-Q-2009-00677)**	29-30	2.5.1.2. Environmental effects on forest systems It is stated that where chestnut (*C. sativa* and other susceptible species) is planted in Europe for timber and to stabilize slopes, *D. kuriphilus* could cause serious decline (EPPO, 2005). However, no evidence was found by the Panel to confirm tree mortality. A gradual reduction in vigour in the longer term is likely to be a consequence of annual parasitism by *D. kuriphilus* causing a gradual reduction in biomass. However, the environmental consequences are considered by the Panel to be low, as the effects of *D. kuriphilus* are unlikely to adversely affect provisioning, regulating or sustaining ecosystem services provided by *Castanea* spp., although some loss of aesthetic quality and amenity value is identified with regard to cultural services. Abandonment of traditional chestnut cultivation in the Cévennes (France) is reported as leading to a reduction of diversity in the local annual flora (Gondard et al., 2001; Romane et al., 2001), but abandonment of orchards is attributed to changes in agricultural practices and rural depopulation starting at the end of the 19th century (O'Rourke, 2006) and had no relationship with chestnut mortality. Regarding the environmental impact of potential control measures, a preliminary environmental risk assessment has been conducted by the Panel (Appendix E) to consider potential non-target effects of the introduction from Japan of the parasitoid, *Torymus sinensis* for biological control of *D. kuriphilus*.	Negative impact on native biodiversity Impact of pest risk reduction options Ecosystem services
Scientific opinion on a quantitative pathway analysis of the likelihood of *Tilletia indica* M. introduction into EU with importation of US wheat		N/A	

(Question No EFSA-Q-2009-00760)			
Scientific Opinion on a composting method proposed by Portugal as a heat treatment to eliminate pine wood nematode from bark of pine trees **(Question No EFSA-Q-2009-00946)**		N/A	
Scientific Opinion on a technical file submitted by the Japanese Authorities to support a derogation request from the EU import requirements for bonsai and topiary trees that are host plants of *Anoplophora chinensis*. **(Question No EFSA-Q-2010-00945)**		N/A	

B. EFSA PLH METHOD FOR ASSESSING THE ENVIRONMENTAL RISK OF PLANT PESTS

The EFSA "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA" (EFSA Panel on Plant Health (PLH), 2010) presents a method proposed by the EFSA PLH Panel for assessing environmental impacts.

2.4. How important are environmental consequences caused by the pest within its current area of distribution?

Note: Pests which principally have effects on crop yield or quality may also have environmental side-effects. If the main effects are already large, detailed consideration of such side-effects may not be necessary.

On the other hand, other pests principally have environmental effects and the replies to this and the following question are then the most important of this part of the analysis.

In accordance with current ecological concepts, two orders of considerations should be analysed:

(1) Impacts on ecosystem services, considering the four main classes of ecosystem services one by one;

- *are there any possible impacts on organisms providing **Provisioning services**? (genetic resources, food, fibre, water and soil),*
- *are there any possible impacts on organisms providing **Regulating services**? (biological control by natural enemies and antagonists, mitigation of local weather extremes, shoreline stability, river channel stability),*
- *are there any possible impacts on organisms providing **Sustaining services**? (pollination, soil fertility maintenance, decomposition),*
- *are there any possible impacts on organisms providing **Cultural services**? (these are psychological benefits from contact with nature).*

Consider indirect impacts on species connected to the above function/s, also via direct, indirect, and apparent competition, changes in mutualism, mesopredator release (when a predator of a smaller predator becomes rare, the smaller predator's impact may be higher on its prey), impact on natural enemies or antagonists of the above organisms that may result in considerable negative effect for the above species providing the ecosystem function, or, if an important species cannot be identified, assess the impact on the function itself.

(2) Impacts on biodiversity itself, especially on rare species, culturally important species, their genetic diversity, population viability, fragmentation. Consider the different levels of biodiversity: within individual diversity (genetic diversity), species-level diversity, guild (functional group), landscape and ecosystem diversity.

2.5. How important are the environmental consequences likely to be in the risk assessment area (see note for question 2.4)?

C. RATING SYSTEM

Risk assessment for structural biodiversity

There are K = 2 questions (Q2 and Q3) on structural biodiversity, both with I = 5 sub-questions. The proposed method makes it possible to a) evaluate the level of risk for each sub-question and b) categorize the risk for each question (Section 5.3.), through a simple procedure with 4 steps.

Step 1. Rate the magnitude L of consequences for each hazard or sub-question, H.

Magnitude of consequences of each sub-question is rated in three categories, denoted by j = 1 (Minor), 2 (Moderate), 3 (Major) (Section 5.3.).

Step 2. Define the probability distribution of the magnitude of consequences, $P(L)$, for each sub-question.

The probability of each category of the potential consequences, $P(L=j)$, j = 1, 2, 3, is estimated. For instance, the magnitude of the consequence could be Minor with probability null ($P(L=1)$ = 0%), Moderate with probability 30% ($P(L=2)$ = 30%) and Major with probability 70% ($P(L=3)$ = 70%) (see also the example of Table 1 and Figure 1). Since the magnitude is evaluated on a categorical basis, any arithmetic combination of magnitude and likelihood of occurrence to obtain risk like that presented in the case of ecosystem services (Section 4.3.2.), is prevented.

Table 1: Example of possible probability distributions of the magnitude of consequences, L_i, for the i-th sub-question of any question. The set of the values $P(L_i = j)$, j = 1, 2, 3, represents the probability distribution of the categorical variable L_i.

Sub-question (hazard, H_i)	**Magnitude of consequences L_i**			
	Minor $j = 1$	**Moderate $j = 2$**	**Major $j = 3$**	
		Probability of occurrence, $P(L_i=j)$ (%)		Check sum
i =1	20	50	30	100
i =2	10	80	10	100
i =3	0	20	80	100
i =4	60	30	10	100
i =5	30	40	30	100

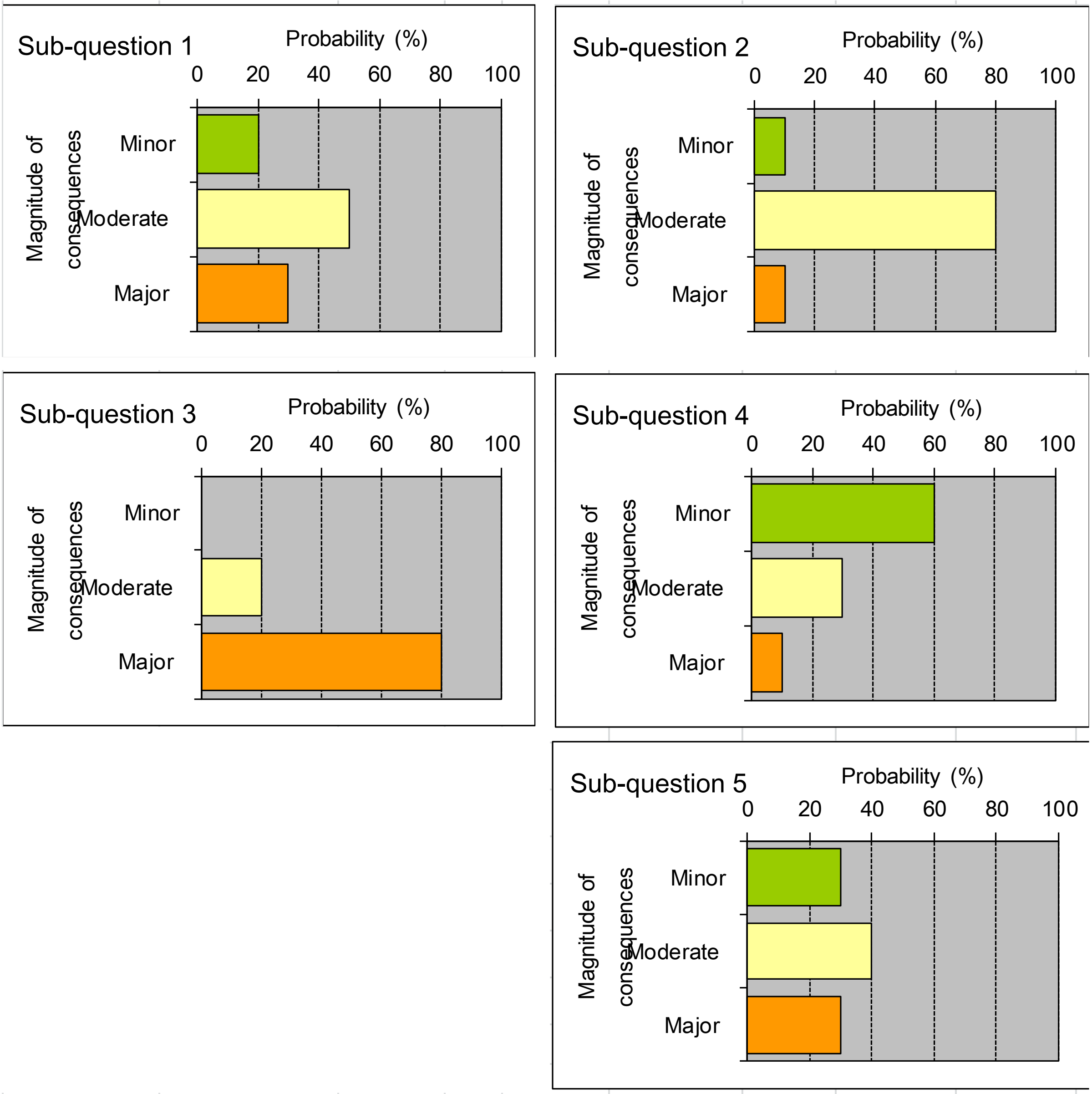


Figure 1: Graphical representation of the probability distributions of Table 1.

The probability distribution of the magnitude L_i of the consequences coming from the hazard H_i considered in the i-th sub-question reflects the uncertainty about the extent of the magnitude. Methods for the assessment of this probability distribution can be different for each particular threat addressed in the risk assessment, depending on the available knowledge.

For instance, probability distributions can be elicited from a panel of experts and combined to obtain a unique distribution. Let P^m be the probability distribution subjectively expressed by expert m-th on any magnitude L and M the total number of experts. The linear opinion pool:

$$P(L=j)=\sum_{m=1}^{M} w_m P^m(L=j) \qquad j = 1, 2, 3 \qquad [1]$$

with non negative weights such that $\Sigma_{m=1}^{M}\ w_m = 1$ is attributed to Laplace by Bacharac (1979). Other approaches for combining experts' opinions could be considered (for critical review Genest and Zidek, 1986; Cooke, 1991; Wallsten et al., 1997; Clemen and Winkler, 1999, 2007). Values w_m in [1] can be used to represent the relative weights assigned to the different expert opinions. In the simplest case the experts can be viewed as equivalent so that equal weights are assigned to them, as in the example shown in Figure 2. The determination of the weights is a subjective matter, and numerous interpretations can be given to the weights (Genest and McConway, 1990).

Alternatively, the panel of experts can collectively reach a judgment about the relative likelihood of the alternative consequences.

Experts (m)	Magnitude of consequences		
	Minor $P^m(L=1)$	Moderate $P^m(L=2)$	Major $P^m(L=3)$
1	40%	30%	30%
2	60%	30%	10%
3	40%	40%	20%
4	30%	50%	20%

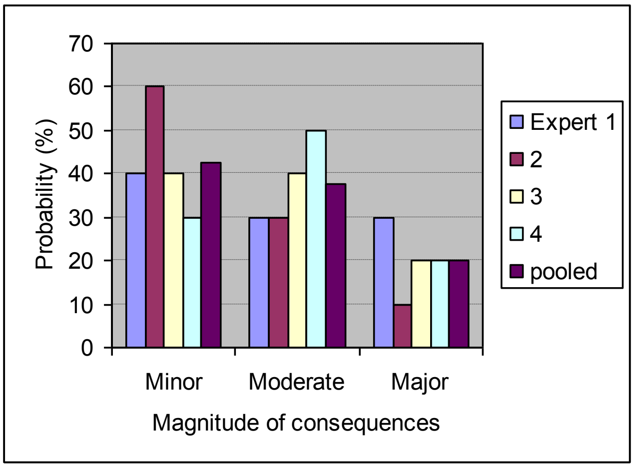


Figure 2: Example of linear opinion pooling with four experts (M = 4) and equal weights ($w_1 = w_2 = w_3 = w_4 = 0.25$). Raw m-th of the table represents the probability distribution subjectively expressed by expert m-th on the magnitude L for any hazard H based on the 3-level rating system. Coloured bars represent the probability distributions of the expert opinions, while violet bars represent the pooled probability distribution.

Step 3. Assess the risk of each sub-question in categorical terms.

To define the risk associated to each sub-question, an approach based on quantiles is proposed, combining magnitude of the consequences and its probability by taking into account the fact that magnitude as defined here is an ordinal variable. For each sub-question, the category j such that with probability > 50 % the magnitude of the consequences is as higher as j is selected as representative of the impact of the hazard. This is easily done by summing the probability of each category from the highest category (i.e. Major) backward until this sum is > 50 %. In the example of Table 4, the ratings assigned are: sub-question 1 = Moderate; sub-question 2 = Moderate; sub-question 3 = Major; sub-question 4 = Minor; sub-question 5 = Moderate (Table 2).

Table 2: Example of assignment of the rating associated to each sub-question (in bold), by using the data of Table 1.

Sub-question (hazard, H_i)	Magnitude of consequences L_i		
	Minor $j = 1$	**Moderate $j = 2$**	**Major $j = 3$**
	Cumulated probability of occurrence, $P(L_i=j)$ (%)		
i =1	100	**80**	30
i =2	100	**90**	10
i =3	100	100	**80**
i =4	**100**	40	10
i =5	100	**70**	30

Step 4. Assess the risk of the question from the risks of the sub-questions, in categorical terms.

At the end of the assessment process, the risks assessed for the sub-questions are summarized by an index of risk, *R'*, for the related question. The assessment of *R'* is based on the three categories Minor, Moderate, or Major. Different methods are proposed, which are based on: i) the modal rating (i.e., the rating with the highest frequency), ii) the highest rating assigned, or iii) the range of ratings. The assessor should select the most appropriate index/es case by case and carefully explain the reasons of his/her choice.

In the example of Tables 1 and 2, the index of risk is Moderate by using the mode (because the rating Moderate was assigned to 3 out of 5 sub-questions), Major by using the highest rating, and 'Minor to Major' by using the range.

Risk assessment for ecosystem services

The question on ecosystem services (Q4.1 and Q4.2) considers 14 hazards or sub-questions, i.e. $K = 2$ and $I = 14$. Sub-questions are rated in five categories denoted by $j = 1, \ldots, 5$ and based on a quantitative assessment of the potential impact (Minimal, Minor, Moderate, Major, Massive; from 1 to 5 respectively) (Section 5.4.). The risk, R, associated to any hazard H, i.e. to any sub-question, is determined by combining the magnitude L of the potential consequence and the probability that the consequence will occur, $P(L)$, by the simple product $L\,P(L)$.

If the assessor is absolutely certain that only one kind of consequence, $L_0 = l_0$, can happen, then $P(L_0 = l_0) = 100$ % and the risk coincides with this consequence, that is $R(H) = l_0$. However, if the consequence L is uncertain, and two assessments about its magnitude can be made, say l_1 and l_2, but the assessor believes that l_1 is two times more likely than l_2, then $P(L = l_1) = 66.7$ % (2/3) and $P(L = l_2) = 33.3$ % (1/3). In the latter case, the risk is computed as the combination $R(H) = l_1\,P(L = l_1) + l_2\,P(L = l_2)$. Formally, if the magnitude of the consequence can be completely described by J different levels, l_j ($j = 1, \ldots, J$), and the probability of each level is assessed, then the risk is computed by the following formula:

$$R(H) = \sum_{j=1}^{J} l_j P(l_j) \qquad [2]$$

The formula [2] defines the risk R associated to the hazard H whose consequences can be described by a number J of recognized levels of magnitude, as the weighted sum of the risk of each possible effect. This corresponds to the average (or expected) magnitude of the consequence.

By using formula [2], the proposed method makes it possible to a) evaluate the level of risk for each sub-question and b) calculate an index of risk for each question on ecosystem services (Section 5.4.), through a simple procedure with 7 steps.

Step 1. Rate the magnitude L of consequences for each hazard or sub-question, H.

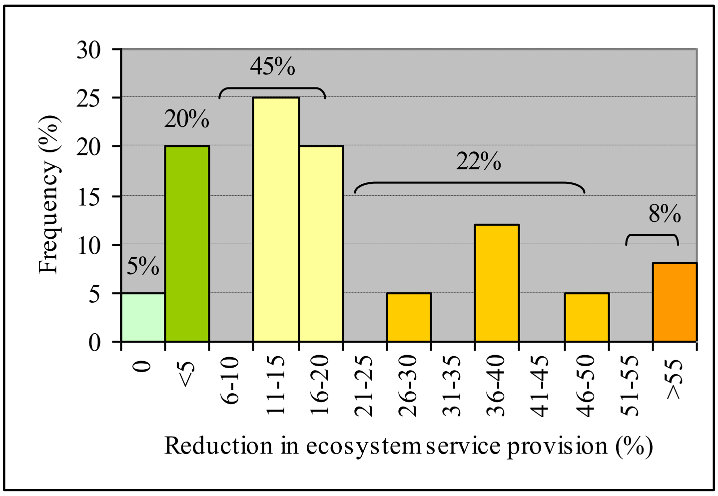
For any sub-question, the magnitude L of the consequences is expressed as a % reduction in the service provision, and classified according to a scoring system based on 5 ratings (therefore, $J = 5$). Assessors can use Table 6 as a guidance to rate the magnitude from 1 to 5; explanations are provided in Section 5.4. on how to answer the sub-questions, and a rating guidance is included to help assessors to give a consistent rating for the sub-questions. As previously mentioned, rating is based solely on the potential negative consequences. Assessors can alternatively agree to modify the magnitude of consequences based on the available knowledge. To apply formula [2] to the scoring system, the midpoint of each rating class is considered as the representative of the class, as commonly done (Newbold et al., 2009) (Table 3).

Table 3: Scoring system for the assessment of magnitude L of consequences, in %, using 5 ratings (J = 5), and examples of possible intervals and midpoints of the ratings.

Rating (*j*)	**Magnitude of consequences, in %** (***L***)	**Midpoint of the rating, in %** (***L*****)
Minimal	Zero or negligible	0
Minor	$0 < L \leq 5$ %	2.5
Moderate	$5 < L \leq 20$ %	12.5
Major	$20 < L \leq 50$ %	35
Massive	$L > 50$ %	75

Step 2. Define the probability distribution of the magnitude of consequences, $P(L)$, for each sub-question.

For each sub-question, the probability of occurrence of each class of magnitude, $P(L = j)$ can be defined as explained in Section 4.3.1. In addition, since the magnitude of consequences for ecosystem services is expressed quantitatively, it is possible to infer the probability distribution from experimental data, whenever these data are available. In Figure 3, an example of how probabilities can be assigned by using data of the frequency of reduction in the provision of any ecosystem service is presented.



Rating (*j*)	**Magnitude of Consequences in %** (***L***)	**Probability of occurrence in %** ***P*(*L*= *j*)**
Minimal	Zero or negligible	5
Minor	$0 < L \leq 5$ %	20
Moderate	$5 < L \leq 20$ %	45
Major	$20 < L \leq 50$ %	22
Massive	$L > 50$ %	8
Check sum		100

Figure 3: Example of assignment of the probability of occurrence, $P(L = j)$, to each of 5 ratings of magnitude of consequence ($J = 5$) for a generic hazard H, when the frequency distribution of the magnitude of consequences is known.

Step 3. Calculate the risk for each sub-question, by combining L and $P(L)$.

Let H_i the hazard considered in the i-th sub-question, the corresponding risk R_i is computed, according to the rating by modifying formula [2] as:

$$R_i = \sum_{j=1}^{J} L_j^* P(L_i = j) \qquad [3]$$

where L_j^* is the midpoint of the class representing rating j (Table 6). The procedure for calculating the risk R_i is shown, step by step, in the example of Table 4 and Figure 4.

Table 4: Example showing, step by step, the process of calculation of the risk R_i for the i-th hazard H_i according to formula [3]. The example considers only 5 sub-questions for shortness.

Sub-question (hazard, H_i)	**Minimal $j = 1$**	**Minor $j = 2$**	**Moderate $j = 3$**	**Major $j = 4$**	**Massive $j = 5$**	
	Step 1: define the magnitude of consequences, L_j^* (%), from Table 6					
i =1	0.0	2.5	12.5	35.0	75.0	
i =2	0.0	2.5	12.5	35.0	75.0	
i =3	0.0	2.5	12.5	35.0	75.0	
i =4	0.0	2.5	12.5	35.0	75.0	
i =5	0.0	2.5	12.5	35.0	75.0	
	Step 2: define the probability of occurrence, $P(L_i=j)$ (%) [(1)]					Check sum
i =1	90.0	10.0	0.0	0.0	0.0	100
i =2	0.0	0.0	20.0	80.0	0.0	100
i =3	90.0	10.0	0.0	0.0	0.0	100
i =4	90.0	10.0	0.0	0.0	0.0	100
i =5	0.0	0.0	10.0	30.0	60.0	100
	Step 3: calculate L_j^* $P(L_i=j)$ (%)					Risk, R_i
i =1	0.00	0.25	0.00	0.00	0.00	0.25
i =2	0.00	0.00	2.50	28.00	0.00	30.50
i =3	0.00	0.25	0.00	0.00	0.00	0.25
i =4	0.00	0.25	0.00	0.00	0.00	0.25
i =5	0.00	0.00	1.25	10.50	45.00	56.75

[(1)] The probability distributions shown in this table are only examples of possible distributions.

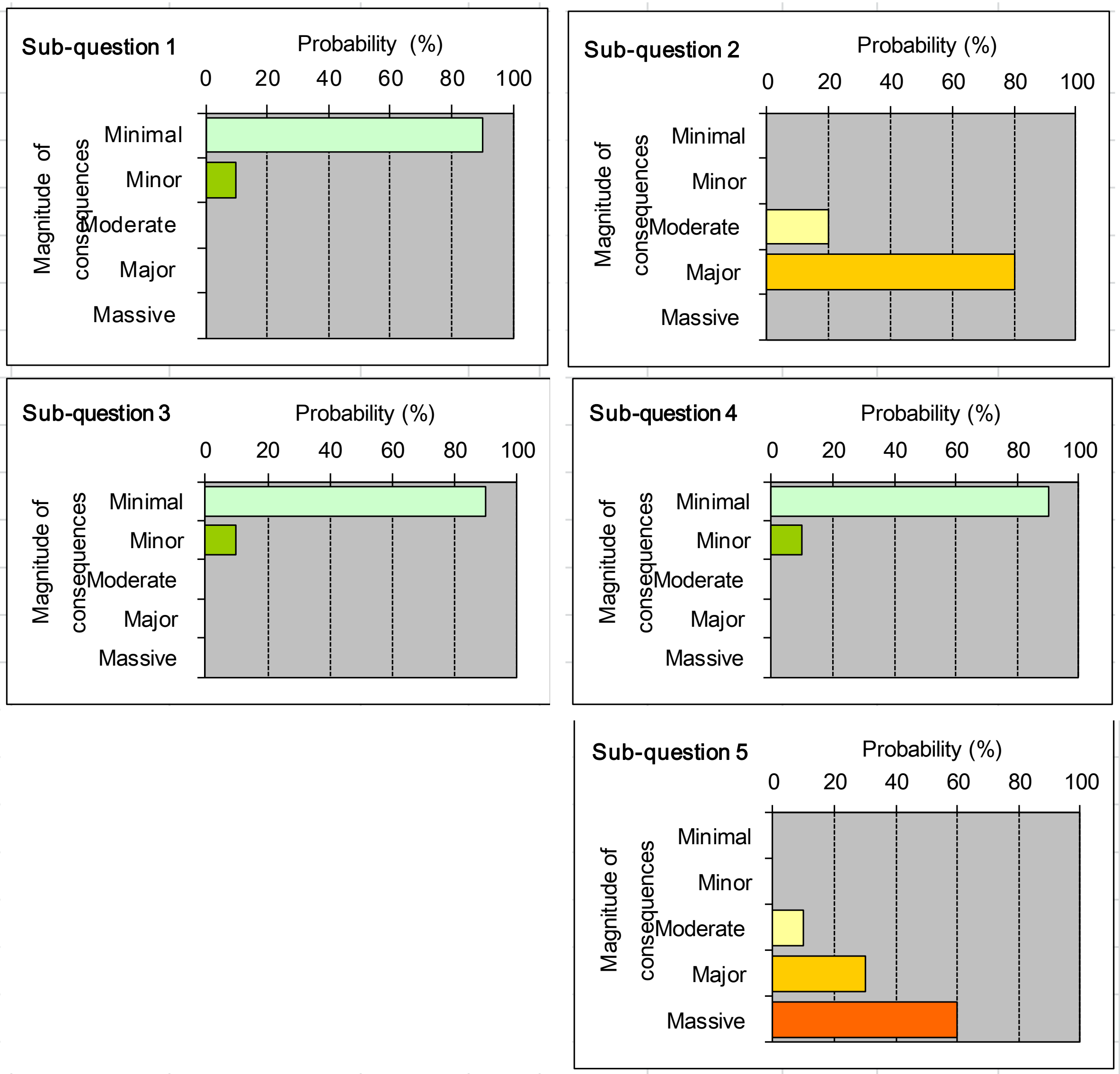


Figure 4: Graphical representation of the probability distributions of Table 4, step 2.

Step 4. Scale the calculated risk for each sub-question in a percent value.

Because of ratings (that is, midpoints of classes) are used in place of the true values of L, the value of R calculated for each sub-question is scaled from 0 to 100 % through a linear transformation:

$$R^* = (R - L_1^*)/(L_J^* - L_1^*) \qquad [4]$$

In the example of Table 7, the values of R^* for the 5 sub-questions are: $R^*_1 = 0.33$ %, $R^*_2 = 40.67$ %, $R^*_3 = 0.33$ %, $R^*_4 = 0.33$ %, $R^*_5 = 75.67$ %.

Step 5. Categorize the risk of each sub-question.

The risk R^* calculated in Step 4 is then categorized in five categories based on the following scheme:

Rating	Index of Risk R^*
Minimal	Zero
Minor	$0 < R^* \leq 5$ %
Moderate	$5 < R^* \leq 20$ %
Major	$20 < R^* \leq 50$ %
Massive	$50 < R^* \leq 100$ %

Step 6 and 7. Calculate the risk index for the question by combining the calculated risks of the sub-questions; categorize the risk of the question.

At the end of the assessment process, the risks calculated for the sub-questions are summarized by an index of risk, *R'*, for the question, and this index is categorized as either Minimal, Minor, Moderate, Major, or Massive by using the five categories of Step 5. Different risk indexes are proposed:

$$R' = \frac{1}{I}\sum_{i=1}^{I} R^*_i \quad [5]$$

$$R' = \max_{1 \leq i \leq I} R^*_i \quad [6]$$

$$R' = \left[R^*_{min}, R^*_{max}\right] \quad [7]$$

where $R^*_{max} = \max_{1 \leq i \leq I} R^*_i$ and $R^*_{min} = \min_{1 \leq i \leq I} R^*_i$.

The formula [5] considers as index of risk the mean percentage of reduction in the ecosystem services considered in the sub-questions, regardless of the kind of service. The formula [6] considers as index of risk the highest risk obtained from the sub-questions, while the formula [7] provides the whole range of losses, in percentage. As for the assessment of structural biodiversity, the assessor should select the most appropriate index/es case by case and carefully explain the reasons of his/her choice.

According to formulas [5] to [7], the indexes of risk associated to the example of Table 4 are 23.5 % (Major), 75.67 % (Massive), and [0.33 %, 75.67 %] (Minor to Massive), respectively. As the number of ratings is small, the median could be considered in place of the mean in formula [5]. By considering the median (i.e., the numerical value separating the higher half of the risks from the lower half), the risk index from Table 7 would be 0.33 % (Minor) in place of 23.5 % (Major). Using the median in place of the mean makes the risk index less sensitive to sub-questions whose risk is very high or very low. The median is easily obtained by arranging the risks R_i in order from least to greatest and by taking the central one.

Assessment of the uncertainty

Regardless of how ratings are obtained (that is, regardless of the magnitude is a continuous variable as in the case of ecosystem services or a categorical variable as in the case of biodiversity), an assessment of the uncertainty U_i associated to the *i*-th sub-question is carried out and then combined to define an index of the uncertainty of the related question, *U'*.

Uncertainties are calculated based on the probabilities of occurrence assigned to each magnitude of consequences, $P(L_i = j)$, for each hazard, H_i.

For the sub-question *i*-th of any question, the Shannon entropy, U_i, associated to the probability distribution of the magnitude of the consequences is computed as:

$$U_i = -\sum_{j=1}^{J} P(L_i = j) Log P(L_i = j)$$ [8a]

and normalized on a 0-100 scale:

$$U_i^* = 100 \cdot U_i / U_{max}$$ [8b]

where U_{max} = Log J, according to ii and [8a].

Finally, the obtained value will be classified according to a rating system based on 3 categories of uncertainty: Low, Medium, High as follows:

Rating	Uncertainty U_i^*
Low	$0 < U_i^* \leq 33$ %
Medium	$33\% < U_i^* \leq 67$ %
High	$67\% < U_i^* \leq 100$ %

In [8a] and [8b], the choice of the basis of the logarithm corresponds to the choice of the unity of measure. Traditionally, the basis 2 is considered. The value U_i describes the uncertainty arising from the difficulty in predicting the magnitude of the consequences of the hazard H_i considered in the sub-question. Table 8 shows the values of the Shannon entropy for the probability distributions considered in Table 5.

Table 5: Shannon entropy, U_i, its standardization U_i^*, and rating for each sub-question of the example of Table 4.

Sub-question (hazard, H_i)	Minimal $j = 1$	Minor $j = 2$	Moderate $j = 3$	Major $j = 4$	Massive $j = 5$	U_i	U_i^* (%)	rating
	- $P(L_i = j)$ Log $P(L_i = j)$, from Table 4							
i =1	0.14	0.33	0.00	0.00	0.00	0.47	20.2	Low
i =2	0.00	0.00	0.46	0.26	0.00	0.72	31.1	Low
i =3	0.14	0.33	0.00	0.00	0.00	0.47	20.2	Low
i =4	0.14	0.33	0.00	0.00	0.00	0.47	20.2	Low
i =5	0.00	0.00	0.33	0.52	0.44	1.29	55.8	Medium

To summarize the uncertainty of each sub-question as measured by the Shannon entropy and obtain an evaluation of the uncertainty for the related question, U', several indexes could be used, analogously to formulas [5]-[7] introduced for risk.

$$U' = \frac{1}{I} \sum_{i=1}^{I} U_i^*$$ [9]

$$U' = \max_{1 \leq i \leq I} U_i^*$$ [10]

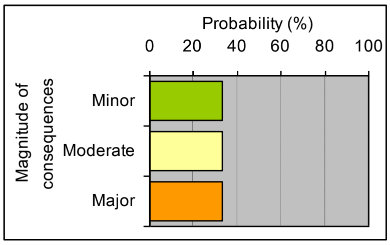
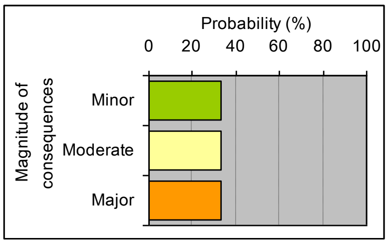
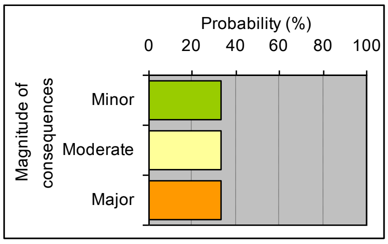
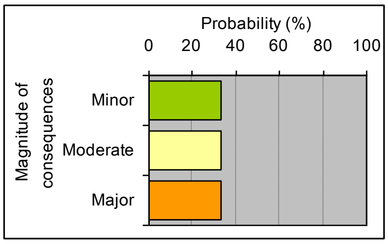
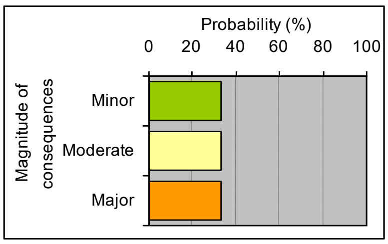
$$U' = \left[U_{min}^*, U_{max}^* \right]$$ [11]

where $U^*_{max} = max_{1 \leq i \leq I} U^*_i$ and $U^*_{min} = min_{1 \leq i \leq I} U^*_i$.

According to formulas [9] to [11], the index of uncertainty associated to the question corresponding to Table 4 is 29.5 % (Low), 55.8 % (Medium) and [20.2 %, 55.8 %] (Low to Medium), respectively. By considering the median in place of the mean in formula [9], we obtain 20.2 % (Low). Note that *U'* is not the Shannon entropy associated to the probability distribution of the answers to the question, as this distribution remains unknown.

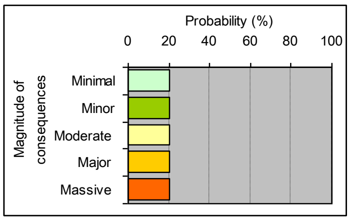
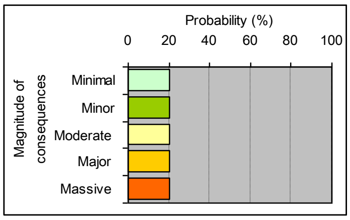
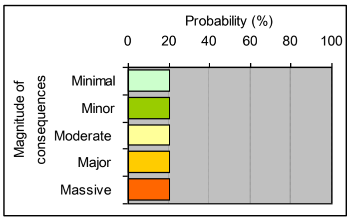
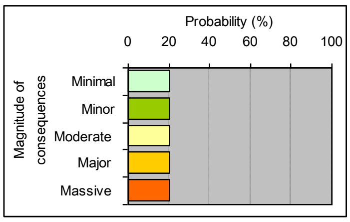
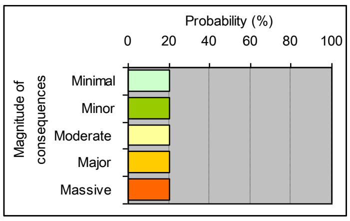
Tables 6 and 7 present the proposed format for showing the results of the assessment of the consequences on structural biodiversity and on ecosystem services.

Table 6: Proposed format for showing the results of the assessment of the consequences on structural biodiversity.

<table>
<tr><th>Sub-question</th><th>Risk Uncertainty</th><th>Explanation</th><th>Probability distribution graph</th></tr>
<tr><td rowspan="2">1</td><td>SCORE</td><td></td><td rowspan="2">
</td></tr>
<tr><td>$U_1^* =$ SCORE</td><td></td></tr>
<tr><td rowspan="2">2</td><td>SCORE</td><td></td><td rowspan="2">
</td></tr>
<tr><td>$U_2^* =$ SCORE</td><td></td></tr>
<tr><td rowspan="2">3</td><td>SCORE</td><td></td><td rowspan="2">
</td></tr>
<tr><td>$U_3^* =$ SCORE</td><td></td></tr>
<tr><td rowspan="2">4</td><td>SCORE</td><td></td><td rowspan="2">
</td></tr>
<tr><td>$U_4^* =$ SCORE</td><td></td></tr>
<tr><td rowspan="2">5</td><td>SCORE</td><td></td><td rowspan="2">
</td></tr>
<tr><td>$U_5^* =$ SCORE</td><td></td></tr>
<tr><td>QUESTION</td><td>SCORE</td><td colspan="2"></td></tr>
</table>

	U' = ***SCORE***	

Table 7: Proposed format for showing the results of the assessment of the consequences on ecosystem services.

Sub-question	**Risk Uncertainty**	**Explanation**	**Probability distribution graph**
1	***R_1* = SCORE***		
	U_1^* = SCORE		
2	***R_2* = SCORE***		
	U_2^* = SCORE		
3	***R_3* = SCORE***		
	U_3^* = SCORE		
…	***$R_{...}$* = SCORE***		
	$U_{...}^*$ = SCORE		
14	***R_{14}* = SCORE***		
	U_{14}^* = SCORE		
QUESTION	***R' = SCORE***		
	U' = SCORE		

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GLOSSARY

Autotroph: an organism that assimilates energy from either sunlight (green plants) or inorganic compounds (sulfur bacteria) (Ricklefs and Miller, 1999).

Beneficial exotic species: a biological control agent [ISPM No 3, 1996; revised ISPM No 3, FAO, 2005] (FAO, 2009), living outside its native distributional range, which has arrived to the pest risk assessment area by human activity, either deliberate or accidental.

Biodiversity: the variety of living organisms and the ecological complexes of which they are part (Harrington et al., 2010). It covers genetic, structural and functional components, which are represented at different organisational levels, from within- organism to individual organism, species, population, community and ecosystem levels (adapted from Secretariat of the CBD 2001, MEA 2003a and extended according to Noss, 1990).

Biological control agent: a natural enemy, antagonist or competitor, or other organism, used for pest control (ISPM No 5, FAO, 2010).

Competitor: An **organism** which competes with pests for essential elements (e.g. food, shelter) in the environment (ISPM No 5, FAO, 2010).

Community or Biocenosis: an association of interacting populations, usually defined by the nature of their interactions or by the place in which they live (Ricklefs and Miller, 1999).

Cultural service: non-material benefits obtained from ecosystems (Harrington et al., 2010).

Detritivore / Decomposer: an organism that feeds on freshly dead or partially decomposed organic matter (Krebs, 1990).

Direct impact: impact straight from a pest to a plant or any part of the environment (see also indirect impact).

Disease agent: any organism, including parasites and prions which causes or contributes to the development of a disease (ICES, 2005).

Disturbance: an event or change in the environment that alters the composition and successional status of a biological community and may deflect succession onto a new trajectory, such as a forest fire or hurricane, glaciation, agriculture, and urbanization (Art, 1993).

Driving factor (also called driving forces or simply driver): factor directly or indirectly causing ecosystem change. A direct driver unequivocally influences ecosystem processes by itself, while an indirect driver operates by altering one or more direct drivers. The indirect drivers are underlying (root) causes that are formed by a complex of social, political, economic, demographic, technological, and cultural variables. Collectively, these factors influence the level of production and consumption of ecosystem services. The causal linkage is almost always mediated by other factors (Tomich et al., 2010).

Ecological disturbance: see Disturbance.

Ecological niche: the ecological role of a species in the community; the many ranges of conditions and resource qualities within the organism or species persists, often conceptualised as an abstract multidimensional space (Ricklefs, 1990).

Ecological habitat of a species place where an organism normally lives, often characterized by a dominant plant form (e.g. forest habitat) or physical characteristic (stream habitat) (Ricklefs, 1990).

Ecosystem: a dynamic complex of plant, animal and microorganism communities and their nonliving environment interacting as a functional unit (MA, 2003).

Ecosystem engineer: an ecosystem engineer is an organism that directly or indirectly modulates the availability of resources to other species, by causing physical state changes in biotic or abiotic materials. In so doing they modify, maintain and/or create habitats (Jones et al., 1994).

Ecosystem function: see Ecosystem processes.

Ecosystem processes: actions or events that result in the flow of energy and the cycling of matter (Ellis and Duffy, 2008). Examples of ecosystem processes include decomposition, production, water and nutrient cycling (MEA, 2003b).

Ecosystem services: benefits that humans recognise as obtained from ecosystems that support, directly or indirectly, their survival and quality of life; ecosystem services include provisioning, regulating and cultural services that directly benefit people, and the supporting services needed to maintain the direct services (MA, 2003; Harrington et al., 2010).

Ecosystem structure: attributes related to the instantaneous physical state of an ecosystem. There are several characteristics to describe ecosystem structure. For example, species population density, species richness or evenness, and standing crop biomass (US Environmental Protection Agency, 2009).

Endemic: confined to a certain area (Ricklefs, 1990)**.**

Environmental risk assessment: a process of predicting whether there may be a risk of adverse effects on the environment caused by the presence of a pest (EFSA, 2010).

Environment: natural environment, encompassing all living and non-living entities occurring naturally on earth or some region thereof. (Johnson et al., 1997).

Food web: a representation of the various paths of energy flow through populations in the community (Ricklefs, 1990).

Functional group: a collection of organisms with similar functional trait attributes (Gitay and Noble, 1997; Harrington et al., 2010).

Functional trait: a feature of an organism, which has demonstrable links to the organism's function (Lavorel et al., 1997; Harrington et al., 2011). As such, a functional trait determines the organism's response to pressures (Response trait), and/or its effects on ecosystem processes or services (Effect trait). Functional traits are considered as reflecting adaptations to variation in the physical and biotic environment and trade-offs (ecophysiological and/or evolutionary) among different functions within an organism. In plants, functional traits include morphological, ecophysiological, biochemical and regeneration traits, including demographic traits (at population level). In animals, these traits are combined with life history and behavioural traits (e.g. guilds: organisms that use similar resources/habitats).

Genetic diversity: genetic variation between and within species. This can be characterised by the proportion of polymorphic loci (different genes whose product performs the same function within the organism), or by the heterozygous individuals in a population (Frankham and Briscoe, 2002).

Herbivore: an organism that consumes living plants or their parts (Ricklefs, 1990).

Heterotroph: an organism that utilizes organic materials as a source of energy and nutrients (Krebs, 1990).

Impact / consequence: a measure of whether the changes in the state variables have a negative or positive effect on individuals, society and/or environmental resources. There is an impact if the state no longer equates to service provision (Harrington et al., 2010).

Indirect impact: impact produced to the environment by

- *indirectly affect plants:* In addition to pests that directly affect host plants, there are those, like most weeds/invasive plants, which affect plants primarily by other processes such as competition (e.g. for cultivated plants: Canada thistle (*Cirsium arvense*) [weed of agricultural crops], or for uncultivated/unmanaged plants: Purple loosestrife (*Lythrum salicaria*) [competitor in natural and semi-natural habitats]). (ISPM No 11, in FAO, 2009).

- *indirectly affect plants through effects on other organisms*: Some pests may primarily affect other organisms, but thereby cause deleterious effects on plant species, or plant health in habitats or ecosystems. Examples include parasites of beneficial organisms, such as biological control agents. (ISPM No 11, in FAO, 2009).

Additionally, ISPM defines indirect impact as "impact produced to the environment by the management options put in place against a pest".

Invasibility: the ease with which a habitat is invaded (Booth et al., 2003).

Invasive alien species: an alien species whose introduction and/or spread threatens biological diversity (CBD, 2002).

Keystone species: Keystone species are, in an ecosystem, a set of species that are so important in determining the ecological functioning of a community that they warrant special conservation efforts. They consist of a limited number of species whose loss would precipitate many further extinctions (Mills et al., 1993).

Landscape: an area that is spatially heterogeneous in at least one factor of interest (Turner et al., 2005), and contains two or more ecosystems in close proximity (Sanderson and Harris, 2000).

Life History Strategy (LHS): theory from evolutionary biology that describes the strategic allocation of bioenergetic and material resources among different components of fitness (e.g., calories and nutrients devoted to growth vs. reproduction) (Figueredo et al., 2006).

Mutualism: a biological interaction between two organisms, where each individual derives a fitness benefit (e.g. survival or food provisioning) (Turbé et al., 2010).

Omnivore; an organism whose diet is broad, including both plant and animal foods; specifically, an organism that feeds on more than one trophic level (Krebs, 1990).

Parasite: an organisms living in an obligatory association with the host and in which the parasite depend metabolically on the host (it can be a Protozoa or a Metazoa, e.g. Helminths, Arthropods) (Krebs, 1994).

Parasitoid: an insect parasitic only in its immature stages, killing its host in the process of its development, and free living as an adult (ISPM No 3, 1996; FAO, 2009).

Pathogen: micro-organism causing disease (ISPM No 3, 1996; FAO, 2009).

Pest: any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products (FAO, 2009).

Phytophage: see Herbivore.

Predator: an animal organism that preys and feeds on other animal organisms, more than one of which are killed during its lifetime (after ISPM No 3, 1996; FAO, 2009).

Provisioning services: products obtained from ecosystems (Harrington et al., 2010).

Regulating services: benefits obtained from regulation of ecosystem processes (Harrington et al., 2010).

Resilience: an ecosystem's ability to recover and retain its structure and function following a transient and exogenous shock event (Harrington et al., 2010).

Resistance: the ability of the ecosystem to continue to function without change when stressed by a disturbance that is internal to the system (Harrington et al., 2010).

Robustness: an ecosystem's ability to adapt to or maintain its function under chronic exogenous drivers and pressures (Harrington et al., 2010). An ecosystem is robust when it is capable of resisting changes caused by long-term drivers or pressures that are external to the ecosystem, such as global warming, nutrient loading or hunting pressure.

Service providing unit: functional unit in which the components (individuals, species or communities) are characterized by functional traits defining their ecological role (Vanderwalle et al., 2008).

Scale (extent and grain): Scale is the spatial or temporal dimension of an object or process characterized by both grain and extent (Turner and Gardner, 1991). Grain is the spatial and temporal resolution chosen to analyze a given data set, whereas extent is the size of the study and the total duration over which measurements are made (Schneider, 1994).

Stability: an ecosystem's tolerance to transient and endogenous perturbations (Harrington et al., 2010). An important component of stability is resistance, the ability of the ecosystem to continue to function without change when stressed by a disturbance that is internal to the system.

Social-ecological systems: the dynamics and interconnectedness of human and non-human components in the same system (Harrington et al., 2010).

Supporting services: services necessary for the production of all other ecosystem services (Harrington et al., 2010).

Symbiotis: intimate, and often obligatory, association of two species (Ricklefs, 1990).

Trait-service clusters: multiple associations between traits and services. (De Bello et al., 2010).

Trophic links: A trophic link is any reported feeding or trophic relation between two species in a web (Cohen and Briand, 1984). This association means that one species consumes any part or product of another species: an insect feeding on any part of a plant, or ants feedings on honeydew excreted by aphids form a trophic link.

Uncertainty: Uncertainty is the inability to determine the true state of affairs of a system (Haimes, 2009) and it may arise in different stages of risk assessment due to lack of knowledge and to natural variability (EFSA, 2010).

Vector: Any living or non-living carrier that transports living organisms intentionally or unintentionally (ICES, 2005).

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