Harmonia[+] and *Pandora*[+] :

risk screening tools for potentially invasive organisms

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Contents

Preamble

Harmonia$^+$ is a first-line risk assessment scheme for potentially invasive organisms, i.e. organisms that may raise concerns for environmental, plant, animal or human health. *Pandora*$^+$ is a complementary version of *Harmonia*$^+$, suited as a first-line risk assessment scheme for pathogenic or parasitic (micro)organisms, the results of which may feed into *Harmonia*$^+$.

Harmonia$^+$ is named after *Harmonia axyridis*, a notoriously invasive ladybird beetle. *Pandora*$^+$ is named after a fungal pathogen of insects, the spread of which seems to be accelerated by *Harmonia* (Roy et al. 2008).

The protocol is discussed in length by D'hondt et al. (2014).

Structure

The *Harmonia*$^+$ and *Pandora*$^+$ questionnaires present a series of questions concerning an organism, the answers of which need to be provided by one or more assessors. The answers can subsequently be used to calculate indices that reflect the risks posed by that organism.

The *Harmonia*$^+$ questionnaire includes three types of questions. The assessment consists of 30 core questions, which are grouped in modules representing the different stages of invasion (questions `a01-30`). Some of these questions have subsidiary questions that ask for the assessor's confidence in the answers provided (questions `aconf01-26`). Finally, text fields are included with every core question for the assessor to clarify the answer provided and mention his/her sources used (questions `acomm01-31`).

Not all questions are applicable for all species, and it is not necessary to answer all questions for the protocol to yield output. Twenty-five of the core questions have a semiquantitative meaning and may therefore contribute to the calculation of the risk scores (`a06-A30`). For these questions, the assessor needs to choose among a set of pre-defined alternative answers. Mostly three alternative answers are provided. Five answers are included only when cut-off values are precise, or when two sub-questions become combined into one.

The protocol's concepts of invasion, risk and confidence are fully explained in addendum A. Addendum B explains how answers become used to calculate risk indices, and addendum C lists some elements that should be decided on before an assessment is undertaken. Anyone using the schemes should first go through these three addenda in order to understand the structure of the scheme and how (s)he should work.

Guidance on risk scoring

There is ample guidance provided with every single question, and it is highly advised to read this carefully before answering. Taking this information into account, the assessor always needs to follow his/her personal opinion when answering a question.

Alternative answers refer to cut-off values where possible, though in many cases, the choice for a particular answer will need to be made on a more 'fuzzy' basis. For this reason, we have included specific examples

that may serve as a calibration. The examples merely reflect the opinion from the authors, so if the assessor disagrees with a given example, the assessor should follow his/her opinion instead.

Answers should be provided as much as possible based on evidence, and not on a purely hypothetical or speculative basis. Since appropriate data is very often lacking, cases that are similar (in biology, geography...) may be used as a source of information (the higher the similarity, the better).

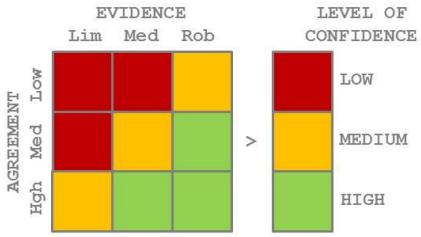
It is advised to always employ the precautionary approach. E.g. when doubting among two options, the most 'pessimistic' option would be the option of choice. Similarly, when a question relates to multiple cases, the worst of these cases is to be emphasized (e.g. when a negative effect is mostly 'medium' but sometimes 'high', the preferred answer is 'high').

Please refer to addendum A whenever a concept or term is unclear.

Guidance on confidence scoring

The degree of certainty associated with a given answer is scored as a 'level of confidence', following the framework for the consistent treatment of uncertainties by the Intergovernmental Panel on Climate Change (Mastrandrea et al. 2010).

Confidence is evaluated as a function of two dimensions: *evidence* and *agreement*. The former more specifically deals with the type, amount, quality and internal consistency of *evidence*, and is summarized as either 'limited', 'medium' or 'robust'. The latter more specifically deals with the degree of *agreement* between different pieces of evidence, and is summarized as either 'low', 'medium' or 'high'. They relate to confidence as shown below (Mastrandrea et al. 2010).



Here too, the assessor always needs to follow his/her personal opinion when answering questions.

Digital version

This is a fillable document file. You can use the buttons, check boxes and text fields to complete the assessment, and then save the file containing your answers.

A fully digitized version of the protocol that allows for risk score calculation, is available online through http://ias.biodiversity.be.

Harmonia⁺ - overview

CONTEXT

a1 - Provide the name(s) of the **assessor(s)** : _____

a2 - Provide the name of the **organism** under assessment : _____

a3 - Define the **area** under assessment : _____

a4 - *Describe the* **status** *of The Organism within The Area* : _____

a5 - This assessment is considering potential impacts within the following **domains** : [the environmental domain | the cultivated plant domain | the domesticated animal domain | the human (health) domain | (an)other domain].

INTRODUCTION

a6 - The probability for *The Organism* to be introduced into *The Area*'s wild by **natural means** is [low | medium | high].

a7 - The probability for *The Organism* to be introduced into *The Area*'s wild by **unintentional human actions** is [low | medium | high].

a8 - The probability for *The Organism* to be introduced into *The Area*'s wild by **intentional human actions** is [low | medium | high].

ESTABLISHMENT

a9 - *The Area* provides [non-optimal | sub-optimal | optimal] **climate** for establishment of *The Organism*.

a10 - *The Area* provides [non-optimal | sub-optimal | optimal] **habitat** for establishment of *The Organism*.

SPREAD

a11 - *The Organism's* capacity to disperse within *The Area* by **natural means** is [very low | low | medium | high | very high].

a12 - *The Organism's* frequency of dispersal within *The Area* by **human actions** is [low | medium | high].

IMPACTS: environmental targets

a13 - *The Organism* has a(n) [inapplicable | low | medium | high] effect on native species, through **predation, parasitism or herbivory**.

a14 - *The Organism* has a [low | medium | high] effect on native species, through **competition**.

a15 - *The Organism* has a(n) [no / very low | low | medium | high | very high] effect on native species, through **interbreeding**.

a16 - *The Organism* has a [very low | low | medium | high | very high] effect on native species, by hosting **pathogens or parasites** that are harmful to them.

a17 - *The Organism* has a [low | medium | high] effect on ecosystem integrity, by affecting its **abiotic properties**.

a18 - *The Organism* has a [low | medium | high] effect on ecosystem integrity, by affecting its **biotic properties**.

IMPACTS: plant targets

a19 - *The Organism* has a(n) [inapplicable | very low | low | medium | high | very high] effect on plant targets, through **herbivory or parasitism**.

a20 - *The Organism* has a(n) [inapplicable | very low | low | medium | high | very high] effect on plant targets, through **competition**.

a21 - *The Organism* has a(n) [inapplicable | no / very low | low | medium | high | very high] effect on plant targets, by **interbreeding** with related organisms or with the target itself.

a22 - *The Organism* has a [very low | low | medium | high | very high] effect on plant targets, by affecting the **cultivation system**'s integrity.

a23 - *The Organism* has a(n) [inapplicable | very low | low | medium | high | very high] effect on plant targets, by hosting **pathogens or parasites** that are harmful to them.

IMPACTS: animal targets

a24 - *The Organism* has a(n) [inapplicable | very low | low | medium | high | very high] effect on individual animal health or animal production, through **predation or parasitism**.

a25 - *The Organism* has a [very low | low | medium | high | very high] effect on individual animal health or animal production, by having properties that are hazardous upon **contact**.

a26 - *The Organism* has a(n) [inapplicable | very low | low | medium | high | very high] effect on individual animal health or animal production, by hosting **pathogens or parasites** that are harmful to them.

IMPACTS: human targets

a27 - *The Organism* has a(n) [inapplicable | very low | low | medium | high | very high] effect on human health, through **parasitism**.

a28 - *The Organism* has a [very low | low | medium | high | very high] effect on human health, by having properties that are hazardous upon **contact**.

a29 - *The Organism* has a(n) [inapplicable | very low | low | medium | high | very high] effect on the health of human targets, by hosting **pathogens or parasites** that are harmful to them.

IMPACTS: other targets

a30 - *The Organism* has a [very low | low | medium | high | very high] effect on causing damage to **infrastructure**.

PLEASE REFER TO THE REST OF THE DOCUMENT FOR ALL NECESSARY INFORMATION TO ANSWER THESE QUESTIONS. QUESTIONS ON THE LEVELS OF CONFIDENCE HAVE BEEN EXCLUDED FROM THIS OVERVIEW.

Pandora⁺ - overview

CONTEXT

b1 - Provide the name(s) of the **assessor(s)** : _____

b2 - Provide the name of the **pathogen** under assessment: _____

b3 - Provide the name of the **host** organism under assessment: _____

b4 - Define the **area** under assessment: _____

b5 - This assessment is considering potential impacts within the following **domains** : [the environmental domain | the cultivated plant domain | the domesticated animal domain | the human (health) domain | (an)other domain].

b6 - *The Pathogen* is / would be the cause of a(n) [endemic | (re)emerging] infectious **disease** to the targets within *The Area*.

EXPOSURE

IN ENDEMIC PATHOGENS

b7 - Because of *The Organism*, the probability for *The Pathogen* to become increasingly **prevalent** within targets in *The Area* is [inapplicable | low | medium | high].

IN EMERGING PATHOGENS

b8 - The probability of *The Pathogen* to be **introduced** with *The Organism* into *The Area* is [inapplicable | low | medium | high].

b9 - *The Pathogen* has a(n) [inapplicable | low | medium | high] probability to be **maintained and spread** within *The Organism* population in *The Area*.

b10 - The probability for *The Pathogen* to be **transmitted** from individual *Organisms* to individual targets is [inapplicable | low | medium | high].

CONSEQUENCE: environmental targets

b11 - *The Pathogen* has a [low | medium | high] effect on **native species individuals**.

b12 - *The Pathogen* has a [no / very low | low | medium | high | very high] effect on **native species populations**.

CONSEQUENCE: plant targets

b13 - *The Pathogen* has a(n) [inapplicable | low | medium | high] effect on **individual plants**.

b14 - *The Pathogen* has a(n) [inapplicable | no / very low | low | medium | high | very high] effect on **plant populations**.

CONSEQUENCE: animal targets

b15 - *The Pathogen* has a(n) [inapplicable | low | medium | high] effect on the health (physical well-being and welfare) of **individual animals**.

b16 - *The Pathogen* has a(n) [inapplicable | no / very low | low | medium | high | very high] effect on the health (physical well-being and welfare) or production of **animal populations**.

CONSEQUENCE: human targets

b17 - *The Pathogen* has a(n) [inapplicable | low | medium | high] effect on the health (physical, mental or social well-being) of **individual humans**.

b18 - *The Pathogen* has a(n) [inapplicable | no / very low | low | medium | high | very high] effect on the health (physical, mental or social well-being) of the **human population**.

CONSEQUENCE: other targets

b19 - *The Pathogen* has a(n) [inapplicable | low | medium | high] effect on international **trade and tourism**.

b20 - *The Pathogen* has a(n) [inapplicable | low | medium | high] effect on **public attention and perception**.

A – *Harmonia*$^{+}$: a screening procedure for potentially invasive **organisms**

A0 | Context

Questions from this module identify the assessor and the biological, geographical & social context of the assessment.

a01. Provide the name(s) of the **assessor(s)** : _____

acomm01. Comments : _____

More info:

Provide a (the) name(s) for the person(s) performing the assessment.

a02. Provide the name of the **organism** under assessment : _____

acomm02. Comments : _____

More info:

Identify the biological entity under consideration. This can be a genus, species, subspecies or any other taxon. The organism under assessment will henceforth briefly be referred to as '*The Organism*'.

The questionnaire is notably designed to suit multicellular plants and animals. Note that pathogenic or parasitic micro-organisms are covered by the *Pandora*$^{(+)}$ protocol, the results of which may feed into this assessment.

a03. Define the **area** under assessment : _____

acomm03. Comments : _____

More info:

Identify the geographic entity under consideration. This can be defined as widely as from the local up to the international level. The area under assessment will henceforth briefly be referred to as '*The Area*'.

Currently, much of the guidance refers to Belgium as *The Area*. When different, it may be necessary to search for analogous information.

a04. *The Organism* is [○ native to *The Area* ○ alien to, and absent from *The Area* ○ alien to, and present in *The Area*, but not established in the wild ○ alien to, and established in *The Area*'s wild].

aconf01. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm04. Comments : _____

More info:

Indicate the current status of *The Organism* with regard to *The Area*. Present / absent refers to the presence of *The Organism* within *The Area*'s geographic boundaries (e.g. in captivity). Established / not established refers to the presence of self-sustaining populations in the wild.

This question is only for reporting purposes and does not affect the questionnaire or score calculation.

a05. This assessment is considering potential impacts within the following **domains** : [□ the environmental domain □ the cultivated plant domain □ the domesticated animal domain □ the human (health) domain □ (an)other domain].

acomm05. Comments : _____

More info:

A target is an entity potentially bearing impacts from *The Organism*. Sectors that deal with specific targets are collectively referred to as a 'domain'.

Specify your targets of interest by choosing one or more domain.

Targets from the 'environmental domain' refer to wild animals and plants, habitats and ecosystems.

Targets from the 'plant domain' refer to cultivated plants (e.g. from agriculture, forestry, horticulture; i.e. crops, pastures, horticultural stock).

Targets from the 'animal domain' refer to domesticated animals (e.g. from agriculture, aquaculture; i.e. production animals, companion animals).

Targets from the 'human domain' refer to humans, the health of which is defined as a state of complete physical, mental and social well-being (and not merely the absence of disease or infirmity).

Targets from the 'other domain' refer to targets that are not included in the domains above.

A1 | Introduction

Questions from this module assess the risk for *The Organism* to overcome geographical barriers and -if applicable- subsequent barriers of captivity or cultivation. This leads to Introduction, defined as the entry of *The Organism* within the limits of *The Area* and subsequently into the wild.

a06. The probability for *The Organism* to be introduced into *The Area*'s wild by **natural means** is [○ low ○ medium ○ high].

aconf02. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm06. Comments : _____

More info:

Estimate the probability that individuals from *The Organism* enter *The Area*'s wild from the outside, through natural pathways, within the time span of a decade.

Low : 0-33% probability (≈ expected to occur less than once every 30 years). **Medium** : 33-66% (once every 15 to 30 years). **High** : 66-100% (within 15 years).

Examples

+ There is a single established population of Russian ratsnake (*Elaphe schrenckii*) in the north of the Netherlands (Leewis et al. 2013). It is highly unlikely to reach Belgium from there by natural pathways. – **LOW**
+ Natural dispersal of the alien House crow (*Corvus splendens*) to Belgium from the (sole European) population in the Netherlands is not so likely since the species rarely undertakes long flights (Leewis et al. 2013, GB non-native species secretariat [fact sheet]). – **MEDIUM**
+ The current alien range of Raccoon dogs (*Nyctereutes procyonoides*) in Germany is very near to the Belgian border, without any geographical barrier in between. – **HIGH**
+ Sacred ibis (*Threskiornis aethiopicae*) wander over great distances, thereby easily crossing boundaries, as illustrated by the finding that the Dutch population is at least partly founded by birds born in France (Lemaire 2013). – **HIGH**

a07. The probability for *The Organism* to be introduced into *The Area*'s wild by **unintentional human actions** is [○ low ○ medium ○ high].

aconf03. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm07. Comments : _____

More info:

Estimate the probability that individuals from *The Organism* enter *The Area*'s limits through human-mediated pathways in which *The Organism* itself is not the focus of transport (e.g. as a hitchhiker or contamination in trade or travel). Subsequent entry into the wild is assumed.

Low : ≤ 1 event expected per decade. **Medium** :]1-9] events per decade. **High** : ≥ 10 events per decade.

Examples

+ The Chinese muntjac (*Muntjacus reevesi*) is a very secretive cervid that is unlikely to act as a hitchhiker in transport. – **LOW**
+ Pet dogs traveling to southern Europe may be exposed to alien ticks like *Rhipicephalus sanguineus* (Dantas-Torres 2010), which may then enter the wild after having returned home. – **MEDIUM**
+ There have been a handful observations of the butterfly Geranium bronze (*Cacyreus marshalli*) in the Netherlands during the past decade. These most probably represent re-newed introductions together with *Pelargonium* plants from Southern Europe (Veling 2012). – **MEDIUM**
+ Agricultural weed species regularly contaminate grain commodities, easily entering the wild at their new destination (Shimono & Konuma 2008). E.g., *Ambrosia* seeds are generally found as contaminants in products such as bird feed (CONTAM et al. 2010). – **HIGH**

a08. The probability for *The Organism* to be introduced into *The Area*'s wild by **intentional human actions** is [○ low ○ medium ○ high].

aconf04. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm08. Comments : _____

More info:

Consider human-mediated pathways in which *The Organism* itself is the focus of transport and may therefore enter *The Area*'s limits (e.g. trade). Since *The Organism* may escape captivity or cultivation, estimate the combined probability that such entry and subsequent (accidental) escape or (deliberate) release leads to introduction into *The Area*'s wild.

Low : ≤ 1 event expected per decade. **Medium** :]1-9] events per decade. **High** : ≥ 10 events per decade.

Examples

+ The Russian ratsnake (*Elaphe schrenckii*) is rarely used in greenhouses or as a pet (Leewis et al. 2013). Escapes or releases from such populations may occur. – **MEDIUM**
+ *Aster salignus* is a garden ornamental that is offered by horticultural professionals, though not that commonly (Vanderhoeven et al. 2011). It could enter the wild through escape or stowaway. – **MEDIUM**
+ Pond sliders (*Trachemys scripta*) once proved a popular aquarium pet. As adults grew to large sizes, many pet owners intentionally released animals into the wild. – **HIGH**
+ *Amelanchier lamarckii* is a garden ornamental that is very commonly offered by horticultural professionals (Vanderhoeven et al. 2011). It could enter the wild through escape or stowaway. – **HIGH**
+ In Belgium, there is a limited industry in the fur of farmed American mink (*Neovison vison*). Containment of this species proves to be hard; e.g., in a Danish study, about half of the caught mink had escaped from fur farms within the two most recent months (Hammershøj et al. 2005). – **HIGH**

A2 | Establishment

Questions from this module assess the likelihood for *The Organism* to overcome survival & reproduction barriers. This leads to Establishment, defined as the growth of a population to sufficient levels such that natural extinction within *The Area* becomes highly unlikely.

a09. *The Area* provides [○ non-optimal ○ sub-optimal ○ optimal] **climate** for establishment of *The Organism*.

aconf05. Answer provided with a [○ low ○ medium ○ high] level of confidence.

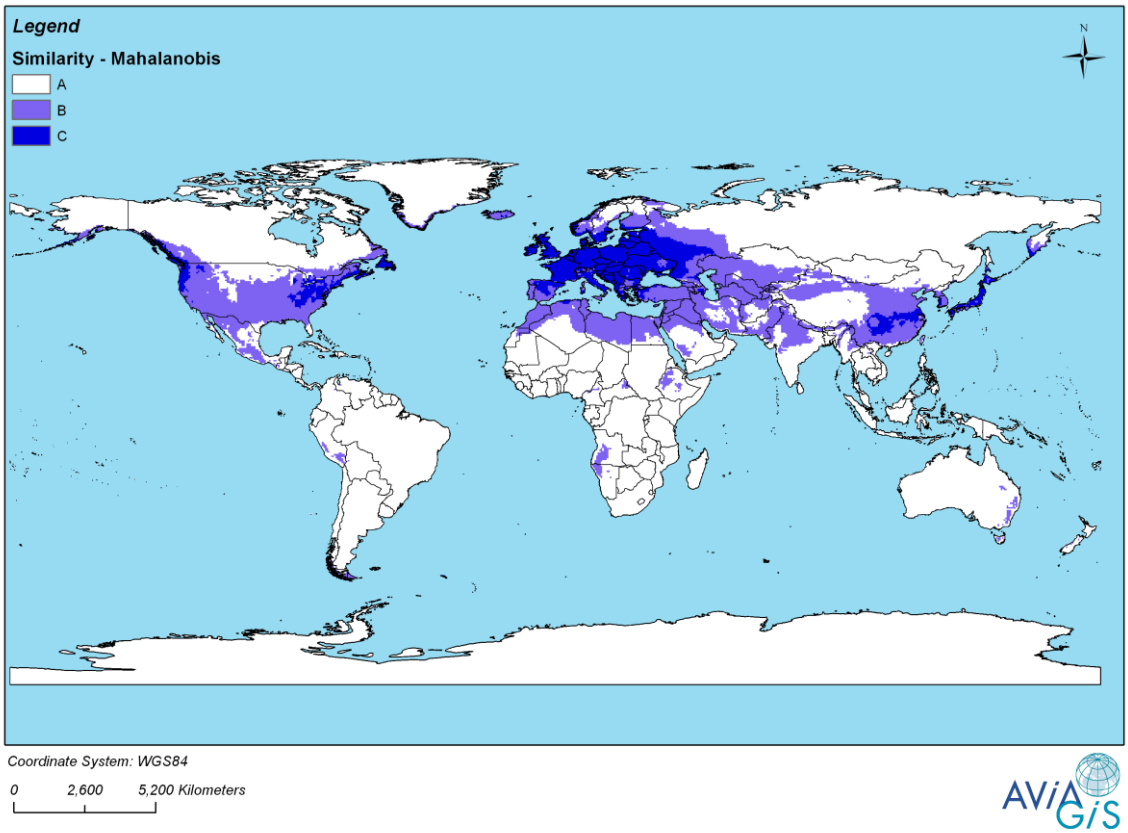
acomm09. Comments : _____

More info:

Indicate the suitability of *The Area*'s climate for survival & reproduction of *The Organism*.

This can be achieved by considering the climatic similarity between *The Area* and *The Organism*'s current range, both native and alien. Several ways exist for doing this, e.g. by consulting bioclimatic maps or constructing climate envelope models.

As a simple guidance, we have constructed a climatic similarity map for Belgium relative to the world, shown below. A detailed map for Europe can be consulted through http://ias.biodiversity.be.



Global map of climatic similarity with Belgium, using the CRU TS3.20 set as climatic variables and the Mahalanobis distance as a similarity index (cf. Farber & Kadmon 2003). Categories A, B, C respond to [0-45%|, |45-94%| and |94-100%] similarity, respectively.

Non-optimal : *The Organism*'s climatic requirements are not properly met. Its current range generally falls into category A from the map above. **Sub-optimal** : *The Organism*'s climatic requirements are partly met. Its current range generally falls into category B from the map above. **Optimal** : *The Organism*'s climatic requirements are fully met. Its current range generally falls into category C from the map above.

Examples

+ Water hyacinth (*Eichhornia crassipes*) originates from Brazil, but is now found almost throughout the tropics (CABI Invasive Species Compendium). In Belgium, species survival is poor as it does not resist winter temperatures well. – **NON-OPTIMAL**

+ The Himalayan striped squirrel (*Tamiops mcclellandii*) is being traded as a pet species. It is naturally found in forests of the (sub)tropic far east. – **NON-OPTIMAL**

+ The turtle *Trachemys scripta elegans* is native to the Midwest of the USA, the similarity of which to Belgium is mediocre. Indeed, it seems that reproduction is hampered due to insufficient summer temperatures, here. – **SUB-OPTIMAL**

+ *Ambrosia artemisiifolia* survives and reproduces within Belgium, yet recruitment seems too low for the species to persist over longer periods (Bullock et al. 2012). – **SUB-OPTIMAL**

+ When considering the distribution of the squirrel *Sciurus carolinensis*, available at http://data.gbif.org/, the native (Eastern America) and alien (United Kingdom) range together suggest no climatic barrier for the species in Belgium. – **OPTIMAL**

+ The native (Eastern Asia) and alien (Central Europe) range of the Raccoon dog *Nyctereutes procyonoides* (http://en.wikipedia.org/) indicate no climatic barrier for the species in Belgium. – **OPTIMAL**

a10. *The Area* provides [○ non-optimal ○ sub-optimal ○ optimal] **habitat** for establishment of *The Organism*.

aconf06. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm10. Comments : _____

More info:

Indicate the suitability of the habitats within *The Area* for survival & reproduction of *The Organism*. Habitat includes the presence of suitable food items, hosts, pollinators, seed dispersers, and (other) biotic conditions.

If *The Area* encompasses multiple habitats, consider those that are most likely suited. Thus also take the habitat specificity of *The Organism* into account.

Non-optimal : *The Area* does not provide habitat suitable to *The Organism*; some key condition is not met. **Sub-optimal** : *The Area* provides habitat that is only partly suited to *The Organism*. **Optimal** : *The Area* does provide habitat suitable to *The Organism*; all key biotic conditions are met.

Examples

+ Plants of shingle beaches, such as *Inula chritmoides*, would not find proper habitat in Wallonia. – **NON-OPTIMAL**

+ *Hyalomma aegyptium* is a tick species that is recurrently introduced in Belgium, yet not established (Obsomer et al. 2013). This is because its main host, tortoises of the genus *Testudo*, are lacking in the wild. – **NON-OPTIMAL**

+ *Cyromium falcatum* is an Asian species of fern that naturally grows on rocks (Manual of the Alien Plants of Belgium). In Belgium, isolated individuals sometimes get a foothold in wall crevices. – **SUB-OPTIMAL**

+ *Sarracenia* is an obligate out-crossing plant native to the Americas. The flowers require pollinators of an appropriate size and strength, which is only found in (some) native species of bumblebees. – **SUB-OPTIMAL**

+ *Rosa rugosa* naturally grows in sandy dune systems of Eastern Asia. In Western Europe, it now occupies the same niches (Kelager et al. 2013). – **OPTIMAL**

+ *Cochlearia danica* is a generalist, salt-tolerating plant. It Belgium, it finds prime habitat in salt-treated road(sides). – **OPTIMAL**

+ The American bullfrog (*Lithobates catesbeianus*) colonizes a wide variety of lakes, ponds, reservoir, irrigation ditches and marshes (CABI Invasive Species Compendium). These habitats occur readily throughout Europe. – **OPTIMAL**

+ The Asian long-horned beetle (*Anoplophora glabripennis*) is a generalist feeder of trees, thus easily finding suitable host plants. – **OPTIMAL**

+ The Rhododendron cicada (*Graphocephala fennahi*) is a specialist feeder of *Rhododendron*, but this is a widely planted (as well as feral) ornamental in Belgium. – **OPTIMAL**

A3 | Spread

Questions from this module assess the risk of *The Organism* to overcome dispersal barriers & (new) environmental barriers within *The Area*. This leads to spread, in which vacant patches of suitable habitat become increasingly occupied from (an) already-established population(s) within *The Area*.

Note that spread is considered different from range expansions that stem from new introductions (covered by the Introduction module).

a11. *The Organism's* capacity to disperse within *The Area* by **natural means** is [○ very low ○ low ○ medium ○ high ○ very high].

aconf07. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm11. Comments : _____

More info:

Indicate the capacity of *The Organism* to disperse from (an) established population(s) within *The Area* to vacant habitat patches, through natural pathways. Standard and non-standard natural dispersal modes need to be considered together.

Consider only modes that act yearly, and estimate the maximum dispersal distance involved. Dispersal modes that act more rarely can be neglected.

Several types of data can be used, but their validity may differ. We advise to use the following data in decreasing order of preference (A>B>C).

The suggested cut-off values below apply to Belgium as *The Area*. Note that we consider absolute values as decisive; it is therefore normal for species from the same taxonomic group to score almost always equally.

A : Single-source dispersal – Using data on the distance covered by (propagules from) an individual. This is the preferred type of data because it disentangles true dispersal from secondary introductions or human-mediated spread.

Very low : ≤ 50 m per year. **Low** :]50 m – 500 m] per year. **Medium** :]500 m – 5 km] per year. **High** :]5 km – 50 km] per year. **Very high** : > 50 km per year.

B : Population expansion – Using data on the distance covered by the front of *The Organism*'s range. This is less preferred because it does not disentangle true dispersal from secondary introductions or human-mediated spread.

Very low : ≤ 10 m per year. **Low** :]10 m – 100 m] per year. **Medium** :]100 m – 1 km] per year. **High** :]1 km – 10 km] per year. **Very high** : > 10 km per year.

C : Approximation – Without data, an estimation of *The Organim*'s intrinsic mobility may be based on life-history traits such as size, fecundity, dispersal traits, behaviour *et cetera* (taking the above cut-off values into consideration).

Examples

+ Seeds of the bog plant *Sarracenia purpurea* rarely disperse beyond 1 meter when shed; other means of dispersal are unlikely (Ellison & Parker 2002). – Data type A - **VERY LOW**
+ *Spiraea douglassii* has not been observed to set seed in Belgium, its sole means of natural expansion being through reproductive growth. – Data type C - **VERY LOW**
+ The Common slider (*Trachemys scripta*) is a turtle that seems to be rather resident at the local level. – Data type C - **LOW**
+ *Ailanthus altissima* has fruits that can float at least 1200 m on waterways (Säumel & Kowarik 2013). – Data type A - **MEDIUM**
+ When introduced outside its natural range, the natural spread of Italian crested newts (*Triturus carnifex*) and other closely related newt species averages a maximum speed of 1 km per year (Arntzen & Thorpe 1999, Arntzen & Wallis 1999). – Data type B - **MEDIUM**
+ In the initial years after its introduction in 1967 in The Netherlands, the spread rate of the Egyptian goose (*Alopochen aegyptiacus*) was 3,0 km per year (Lensink 1998). – Data type B - **HIGH**

+ Sacred ibis (*Threskiornis aethiopicus*) is a large bird species that easily undertakes long flights, as illustrated by the finding that the Dutch population is at least partly founded by birds born in France (Lemaire 2013). – Data type A - **VERY HIGH**

+ After the removal of critical barriers in potential invasions corridors (i.e. Main-Danube canal), the invasion of the killer shrimp (*Dikerogammarus villosus*) towards Western Europe was estimated to occur at an average spread speed of 112 km per year (Leuven et al. 2009). – Data type B - **VERY HIGH**

a12. *The Organism's* frequency of dispersal within *The Area* by **human actions** is [○ low ○ medium ○ high].

aconf08. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm12. Comments : _____

More info:

Indicate the probability of *The Organism* to disperse from (an) established population(s) within *The Area* to vacant habitat patches, through human-mediated pathways. Intentional and unintentional human dispersal modes need to be considered together.

More precisely, try to estimate the probability that human-mediated dispersal takes (propagules of) an individual > 50 km.

Low : ≤ 1 such event expected per decade. **Medium** :]1-9] events per decade. **High** : ≥ 10 events per decade.

Examples

+ The Coypu (*Myocastor coypu*) is a secretive animal that is unlikely to be taken by people and released into the environment elsewhere. – **LOW**

+ *Gaillardia* x *grandiflora* is a showy flower that occurs rarely in the Belgian coastal dunes (http://waarnemingen.be). Yet it is not so likely that fertile seeds from these populations are taken by people and are moved to suitable wild habitat elsewhere. – **LOW**

+ Deliberate capture of alien amphibians like the Bullfrog (*Lithobates catesbeianus*) or Italian crested newt (*Triturus carnifex*) often results in release (or escape) at the new location. – **MEDIUM**

+ Adults and eggs of the Spanish slug (*Arion lusitanicus*) are regularly found with transported goods, such as garden material, pellets, crates and containers (Leewis et al. 2013). – **HIGH**

A4a | Impacts: environmental targets

Questions from this module qualify the consequences of *The Organism* on wild animals and plants, habitats and ecosystems.

Impacts are linked to the conservation concern of targets. Native species that are of conservation concern refer to keystone species (e.g. heather, beech), threatened species (e.g. many orchids or butterflies) or emblematic species (e.g. ladybirds, squirrel). See, for example, Red Lists, protected species lists, or Annex II of the 92/43/EEC Directive. Ecosystems that are of conservation concern refer to natural systems that are the habitat of many threatened species. These include natural forests, dry grasslands, natural rock outcrops, sand dunes, heathlands, peat bogs, marshes, rivers & ponds that have natural banks, and estuaries (see e.g. Annex I of the 92/43/EEC Directive).

Native species population declines are considered on the local scale: limited decline is considered as a (mere) drop in numbers; severe decline is considered as a (near) extinction. Similarly, limited ecosystem change is considered as transient and easily reversible; severe change is considered as persistent and hardly reversible.

a13. *The Organism* has a(n) [○ inapplicable ○ low ○ medium ○ high] effect on native species, through **predation, parasitism or herbivory**.

aconf09. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm13. Comments : _____

More info:

Indicate whether *The Organism* can locally affect native species through its feeding habits (predation, parasitism or herbivory).

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the consequence of it feeding on targets.

Low : at worst, *The Organism* causes limited population declines in species that are not of conservation concern. **Medium** : at worst, *The Organism* causes severe population declines in species that are not of conservation concern, or limited population declines in species that are of conservation concern. **High** : at worst, *The Organism* causes severe population declines in species that are of conservation concern.

Choosing **Inapplicable** omits the question from calculation.

Examples

+ Predation has no meaning if *The Organism* is a plant. – **INAPPLICABLE**
+ The bug *Nysius huttoni* is a polyphagous bug native to New-Zealand that now occurs in the Netherlands, often at very high densities (>10^6 ha^{-1}). It has been found on various plant species, but all of these are very common weeds (Smit et al. 2007). – **LOW**
+ The cicada *Graphocephala fennahi* exclusively (and not severely) feeds on alien *Rhododendron ponticum*. – **LOW**
+ The Harlequin ladybird (*Harmonia axyridis*) predates on a variety of native ladybird species and this has been linked to their concurrent decline (Hautier et al. 2011, Adriaens et al. 2012). – **HIGH**

a14. *The Organism* has a [○ low ○ medium ○ high] effect on native species, through **competition**.

aconf10. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm14. Comments : _____

More info:

Indicate whether *The Organism* can locally affect native species through competition. This includes competition for plant pollinators and competition that is mediated through allelopathic chemicals.

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the consequence of competition.

Low : at worst, *The Organism* causes limited population declines in species that are not of conservation concern. **Medium** : at worst, *The Organism* causes severe population declines in species that are not of conservation

concern, or limited population declines in species that are of conservation concern. **High** : at worst, *The Organism* causes severe population declines in species that are of conservation concern.

Examples

+ The preferred microhabitat of the alien moss *Orthodontium lineare* at the foot of certain tree species does not harbor native mosses, avoiding any effect (Sparrius 2013). – **LOW**
+ Outbreaks of Minute duckweed (*Lemna minuta*) result in dense floating mats at the water surface, but these are usually limited in time and space. Competition with native macrophytes is poorly documented but seems to be less severe than with other invasive aquatic plants. – **MEDIUM**
+ *Rosa rugosa* forms very dense stands in coastal dune grasslands or scrub, where little opportunity remains for other plants to grow. – **HIGH**

a15. *The Organism* has a(n) [○ no / very low ○ low ○ medium ○ high ○ very high] effect on native species, through **interbreeding**.

aconf11. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm15. Comments : _____

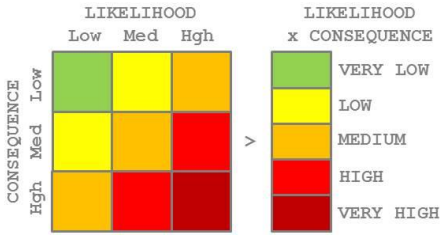
More info:

Indicate whether *The Organism* can locally affect native species through genetic effects, such as hybridisation or introgression (the production of fertile hybrids that backcross with their parents to form hybrid swarms).

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the likelihood (frequency) for *The Organism* to show interbreeding within the time span of a year, and the consequence of this happening.

Likelihood – Ideally corresponds to the following probabilities. **Low** :]0-33% probability (≈ expected to occur less than once every 3 years). **Medium** : 33-66% (once every 1.5 to 3 years). **High** : 66-100% (more than once every 1.5 years).

Consequence – **Low** : at worst, *The Organism* causes limited losses of genetic integrity in species that are not of conservation concern. **Medium** : at worst, *The Organism* causes severe losses of genetic integrity in species that are not of conservation concern, or limited losses of genetic integrity in species that are of conservation concern. **High** : at worst, *The Organism* causes severe losses of genetic integrity in species that are of conservation concern.



If the likelihood to interbreed is nil, choose **No** as an answer.

Examples

+ The North American beaver (*Castor canadensis*) and Eurasian beaver (*Caster fiber*) are not genetically compatible and cannot interbreed to create a hybrid subspecies (likelihood = nil). – **VERY LOW**
+ Canada geese (*Branta canadensis*) may hybridise with other geese (likelihood = medium), but there are few native breeding geese in Western Europe, and most reported incidences have been with other feral species (consequence = low GB non-native species secretariat [risk analysis]). – **LOW**
+ Current hybridisation with the Italian crested newt (*Triturus carnifex*) puts the native crested newt (*Triturus cristatus*) –an already-threatened & protected species– at risk in the Netherlands (van Delft 2012). – **VERY HIGH**

a16. *The Organism* has a [○ very low ○ low ○ medium ○ high ○ very high] effect on native species, by hosting **pathogens or parasites** that are harmful to them.

aconf12. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm16. Comments : _____

More info:

Identify all pathogens or parasites that are known to be considerably hosted by both *The Organism* and the targets under consideration, and estimate the risk that these may pose to the targets.

Pathogens (parasites) may be of viral, bacterial, fungal or animal origin, and may either be endemic (already present in *The Area*) or (re)emerging (new or returning).

If no shared pathogens between *The Organism* and targets are known, or there is good reason to assume that no shared pathogens exist, choose **Very low** as an answer.

Pathogenicity is a complex issue, for which a lot of data needs to be compiled. We advise to use the following sources in decreasing order of preference (A>B>C>D).

A : *Pandora*$^{+}$ – In analogy to this risk assessment, we have created a screening tool for pathogens that directly refers to *The Organism* as a host.

If you have used *Pandora*$^{+}$ for one or more individual pathogens, select the pathogen with the highest score for the environmental domain impact (see output for 'Entry x Exposure x Environmental IMPACTS' using the default methods). We suggest the following cut-off values.

Very low : 0. **Low** :]0-0.25]. **Medium** :]0.25-0.50]. **High** :]0.50-0.75]. **Very high** :]0.75-1.00].

B : OiE – The World Organisation for Animal Health's working group on wildlife diseases has issued a list of important diseases for which surveillance is advisable.

Consult this list at http://www.oie.int/wahis_2/public/wahidwild.php# and count the number of shared infectious agents. We suggest the following cut-off values.

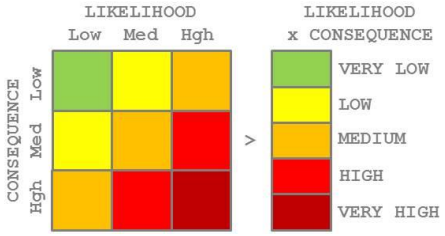
Very low : *The Organism* is known to host pathogens, but none are on the list. **Low** : 1 or 2. **Medium** : 3 or 4. **High** : 5 or 6. **Very high** : 7 or higher.

C : WILDTOOL – WILDTOOL is a flexible system for assessing the risk that wildlife-borne pathogens may pose to different target groups within Belgium (Tavernier et al. 2011). It is available at http://wildtool.var.fgov.be. See addendum D for further instructions.

Consider the risks that pathogens borne by *The Organism* may pose to 'wildlife'. Consider the pathogen that yields the highest score.

Low : pathogen not in top-15. **High** : pathogen in top-15.

D : Short-cut version – In case of serious data absence, select the worst of the shared pathogens, and try to estimate the *likelihood* of harm (i.e., the likelihood to become more prevalent and exposed to targets, in case of endemic diseases; or the likelihood to enter and be exposed to targets, in case of [re]emerging diseases) and the *consequence* of harm (as in previous questions).



Examples

+ A panel of six experts assessed the risk of the amphibian-infecting fungus *Batrachochytrium dendrobatidis* using the *Pandora*$^{+}$ protocol, yielding an overall risk score of 0.84. (The alien Bullfrog acts as a resistant vector for this pathogen.) – Data type A - **VERY HIGH**

a17. *The Organism* has a [○ low ○ medium ○ high] effect on ecosystem integrity, by affecting its **abiotic properties**.

aconf13. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm17. Comments : _____

More info:

Indicate whether *The Organism* can affect particular ecosystems by interacting with its physical, chemical or structural properties. Properties may pertain to soil (through processes such as erosion, sedimentation or litter mineralization), water (e.g. O_2, turbidity, pH, salinity), nutrient pools (e.g. eutrophication), vegetation structure, light *et cetera*.

The changes in these properties may cause changes in the composition and/or rate of succession of communities that share the same habitat.

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the consequence of such abiotic change.

Low : at worst, *The Organism* causes easily reversible process changes in ecosystems that are not of conservation concern. **Medium** : at worst, *The Organism* causes hardly reversible process changes in ecosystems that are not of conservation concern, or easily reversible process changes in ecosystems that are of conservation concern. **High** : at worst, *The Organism* causes hardly reversible process changes in ecosystems that are of conservation concern.

Examples

+ Outbreaks of Minute duckweed (*Lemna minuta*) result in dense floating mats at the water surface, reducing light penetration and gas exchanges. However, outbreaks are usually limited in time and space and are favoured by increased levels of water eutrophication that already affects vegetation itself. – **MEDIUM**
+ As *Rhododendron ponticum* can completely dominate the understory of forests in the British Isles, tree regeneration becomes prevented, ultimately interrupting tree canopy layer. – **HIGH**
+ The Coypu (*Myocastor coypus*) is a South American rodent that escaped from fur farms, and now occurs in the wild in Southern Europe. The animals dig large burrows in the banks of rivers and canals, also suppressing reed beds. – **HIGH**

a18. *The Organism* has a [○ low ○ medium ○ high] effect on ecosystem integrity, by affecting its **biotic properties**.

aconf14. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm18. Comments : _____

More info:

Indicate whether *The Organism* can affect particular ecosystems by (cascading) effects in the food web, pollination, dispersal *et cetera*.

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the consequence of such biotic change.

Low : at worst, *The Organism* causes easily reversible process changes in ecosystems that are not of conservation concern. **Medium** : at worst, *The Organism* causes hardly reversible process changes in ecosystems that are not of conservation concern, or easily reversible process changes in ecosystems that are of conservation concern. **High** : at worst, *The Organism* causes hardly reversible process changes in ecosystems that are of conservation concern.

Examples

+ The encroachment by the alien moss *Campylopus introflexus* in the Dutch dunes has been suggested as a causal agent for the disappearance of the Tawny pipit (*Anthus campestris*) by decreasing arthropod availability (van Turnhout 2005). – **HIGH**
+ *Helicorophium curvispinum* is a species of amphipod crustacean that causes river bed substrates to be inaccessible to many other animals, such as mussels, and this eventually cascades into negative effects on diving ducks that prey on these (Leewis et al. 2013). – **HIGH**

+ Plants that form monospecific populations in ecosystems of conservation concern cause assemblages of phytophagous organisms to be replaced. – **HIGH**

A4b | Impacts: plant targets

Questions from this module qualify the consequences of *The Organism* on cultivated plants (e.g. crops, pastures, horticultural stock).

For the questions from this module, consequence is considered 'low' when *The Organism*'s presence in (or on) a population of target plants is sporadic and/or causes little damage. Harm is considered 'medium' when *The Organism*'s development causes local yield (or plant) losses below 20%, and 'high' when losses range > 20%.

a19. *The Organism* has a(n) [○ inapplicable ○ very low ○ low ○ medium ○ high ○ very high] effect on plant targets, through **herbivory or parasitism**.

aconf15. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm19. Comments : _____

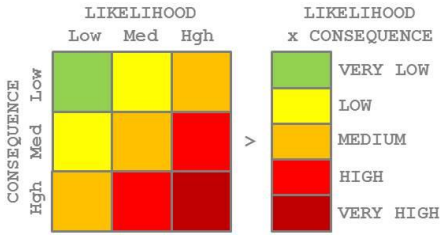
More info:

Indicate whether *The Organism* can affect plant quality (vitality) or yield through its feeding habits (herbivory or parasitism).

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the frequency for *The Organism* to feed on targets (likelihood) and the consequence of this happening.

Likelihood – Ideally corresponds to the following probabilities. **Low** : expected to affect less than 1/3th of plant target populations. **Medium** : 1/3-2/3th of populations. **High** : more than 2/3th of populations.

Consequence – **Low** : at worst, quality or yield is decreased with ≤ 5% within a population. **Medium** : ≤ 20% at worst. **High** : > 20% at worst.



Choosing **Inapplicable** omits the question from calculation.

Examples

+ Predation has no meaning if *The Organism* is a carnivorous animal. – **INAPPLICABLE**
+ *Arceuthobium minutissimum* is a parasitic plant that is (almost) exclusively hosted by *Pinus wallichiana*, which is a very rare ornamental in Belgium (likelihood = low, consequence = medium). -- **LOW**
+ The bug *Nysius huttoni* is native to New-Zealand, where it is a significant agricultural pest (consequence = high). The species now occurs in Belgium and the Netherlands, but it seems to be currently confined to waste ground, roadsides and abandoned fields instead of crops (likelihood = low; Smit et al. 2007, Bonte et al. 2010). – **MEDIUM**
+ The Horse chestnut leafminer (*Cameraria ohridella*) has become very prevalent among its host tree, which is a highly planted ornamental (likelihood = high). It does not kill trees, but causes a severe defoliation and decrease of reproductive effort (Thalmann et al. 2003; consequence = high). – **VERY HIGH**

a20. *The Organism* has a(n) [○ inapplicable ○ very low ○ low ○ medium ○ high ○ very high] effect on plant targets, through **competition**.

aconf16. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm20. Comments : _____

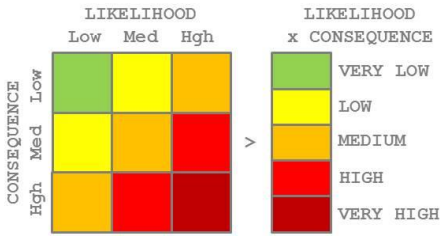
More info:

Indicate whether *The Organism* can affect plant quality or yield through competition. This includes competition for plant pollinators and competition that is mediated through allelopathic chemicals.

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the frequency for *The Organism* to compete with targets (likelihood) and the consequence of this happening.

Likelihood – Ideally corresponds to the following probabilities. **Low** : expected to affect less than 1/3th of plant target populations. **Medium** : 1/3-2/3th of populations. **High** : more than 2/3th of populations.

Consequence – **Low** : at worst, quality or yield is decreased with ≤ 5% within a population. **Medium** : ≤ 20% at worst. **High** : > 20% at worst.



If *The Organism* is not a plant, choosing **Inapplicable** (this omits the question from calculation).

Examples

+ Competition is irrelevant if *The Organism* is an animal. – **INAPPLICABLE**
+ *Anthoxanthum aristatum* is an alien grass that behaves primarily as a weed in rye crops (Manual of the Alien Plants of Belgium; likelihood = high). It is an annual species that does not behave aggressively (consequence = low). – **MEDIUM**
+ *Ambrosia artemisiifolia* is an alien herb that grows in disturbed soils, including arable lands, plenty of which are available in Belgium (likelihood = high). The species amounts up to 1000 plants m^{-2} in the French Drôme, leading to losses of 20-80% for sunflower (Bruzeau 2007 in Bullock et al. 2012; consequence = high). – **VERY HIGH**

a21. *The Organism* has a(n) [○ inapplicable ○ no / very low ○ low ○ medium ○ high ○ very high] effect on plant targets, by **interbreeding** with related organisms or with the target itself.

aconf17. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm21. Comments : _____

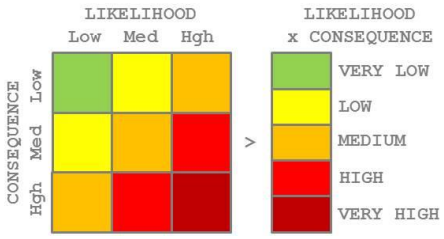
More info:

Indicate whether *The Organism* can affect plant quality or yield through genetic mechanisms, such as hybridisation or introgression. This can either be with the target itself, or with related organisms that thereby increase the threats posed by them (weeds developing into 'superweeds'; Ellstrand & Schierenbeck 2000, Campbell et al. 2006).

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the likelihood (frequency) for *The Organism* to show interbreeding within the time span of a year, and the consequence of this happening.

Likelihood – Ideally corresponds to the following probabilities. **Low** :]0-33% probability (≈ expected to occur less than once every 3 years). **Medium** : 33-66% (once every 1.5 to 3 years). **High** : 66-100% (more than once every 1.5 years).

Consequence – **Low** : at worst, quality or yield is decreased with ≤ 5% within a population. **Medium** : ≤ 20% at worst. **High** : > 20% at worst.



If the likelihood to interbreed is nil, choose **No** as an answer. If *The Organism* is not a plant, choose **Inapplicable** (this omits the question from calculation).

Examples

+ Interbreeding is irrelevant if *The Organism* is an animal. – **INAPPLICABLE**

+ In France, cultivated varieties of sunflower (*Helianthus annuus*) are prone to hybridization with introduced populations of wild-type sunflower (same species; likelihood = high). Here, local densities of weedy sunflowers can decrease crop yield to more than 50% (consequence = high; Muller et al. 2009). – **VERY HIGH**

a22. *The Organism* has a [○ very low ○ low ○ medium ○ high ○ very high] effect on plant targets, by affecting the **cultivation system**'s integrity.

aconf18. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm22. Comments : _____

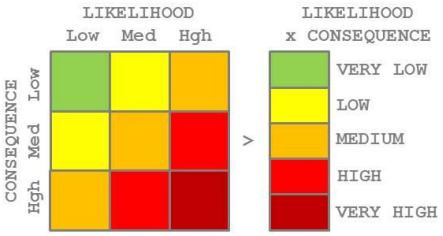
More info:

Indicate whether *The Organism* can affect plant quality or yield by affecting properties of the system: i.e., by affecting nutrient cycles, hydrology, the physical habitat, food webs, *et cetera*.

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the frequency for *The Organism* to affect cultivation systems (likelihood) and the consequence of this happening.

Likelihood – Ideally corresponds to the following probabilities. **Low** : expected to affect less than 1/3th of plant target populations. **Medium** : 1/3-2/3th of populations. **High** : more than 2/3th of populations.

Consequence – **Low** : at worst, quality or yield is decreased with ≤ 5% within a population. **Medium** : ≤ 20% at worst. **High** : > 20% at worst.



Examples

+ In Spain, the aquatic plant *Eichhornia crassipes* affects irrigation farming practices by blocking channels (Téllez et al. 2008; consequence = high). However, these practices are less important in Belgium, and established populations are not expected to build-up to a similar extent due to less-suited climatic conditions (likelihood = low). – **MEDIUM**

+ The tree *Prunus serotina* is now a common colonizer of suitable, clear-cut areas in forests (likelihood = high). Its presence may cause temporary freezing of ecological successions, leading to mid-term succession dominance and a slow-down of forest recovery (Closset-Kop et al. 2007, Decocq 2007, Chabrerie et al. 2010; consequence = medium). – **HIGH**

a23. *The Organism* has a(n) [○ inapplicable ○ very low ○ low ○ medium ○ high ○ very high] effect on plant targets, by hosting **pathogens or parasites** that are harmful to them.

aconf19. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm23. Comments : _____

More info:

Identify all pathogens or parasites that are known to be considerably hosted by both *The Organism* and the targets under consideration, and estimate the risk that these pathogens may pose to the targets.

Pathogens (parasites) may be of viral, bacterial, fungal or animal origin, and may either be endemic (already present in *The Area*) or (re)emerging (new or returning).

If no shared pathogens between *The Organism* and targets are known, or there is good reason to assume that no shared pathogens exist, choose **Very low** as an answer. Choosing **Inapplicable** omits the question from calculation.

Pathogenicity is a complex issue, for which a lot of data needs to be compiled. We advise to use the following sources in decreasing order of preference (A>B>C).

A : *Pandora*$^{+}$ – In analogy to this risk assessment, we have created a screening tool for pathogens that directly refers to *The Organism* as a host.

If you have used *Pandora*$^{+}$ for one or more individual pathogens, select the pathogen with the highest score for the plant domain impact (see output for 'I x E x S x plant IMPACTS' using the default methods). We suggest the following cut-off values.

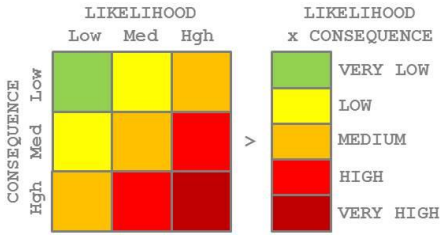
Very low : 0. **Low** :]0-0.25]. **Medium** :]0.25-0.50]. **High** :]0.50-0.75]. **Very high** :]0.75-1.00].

B : EPPO – The list of pests that are recommended for regulation, as issued by the European & Mediterranean Plant Protection Organization may be used as a source.

Consult the EPPO list at http://archives.eppo.int/EPPOStandards/PM1_GENERAL/pm1-02%2822%29_A1A2_2013.pdf and consider the shared prokaryotes, fungi, viruses and nematodes (but not the other groups) from the A1 and A2 lists.

Very low : no shared pathogens known or assumed. **Low** : shared pathogens known or assumed, but not on the lists. **Medium** : ≥ one A2-listed species. **High** : ≥ one A1-listed species. **Very high** : ≥ one A2-listed species and ≥ one A1-listed species.

C : Short-cut version – In case of serious data absence, select the worst of the shared pathogens, and try to estimate the *likelihood* of harm (i.e., the likelihood to become more prevalent and exposed to targets, in case of endemic diseases; or the likelihood to enter and be exposed to targets, in case of [re]emerging diseases) and the *consequence* of harm (as in previous questions).



Examples

+ *Monochamus alternatus* is a species of beetle that acts as a vector of three *Bursaphelenchus* nematode species, one of which is on the A2 list of EPPO (Cooperative Agricultural Pest Survey). – Data type B - **MEDIUM**

+ *Pseudopityophthorus* beetles are important vectors of the A1-listed pathogen *Ceratocystis* (Rexrode & Jones 1970). – Data type B – **HIGH**

A4c | Impacts: animal targets

Questions from this module qualify the consequences of *The Organism* on domesticated animals (e.g. production animals, companion animals).

It deals with both the well-being of individual animals and the productivity of animal populations.

a24. *The Organism* has a(n) [○ inapplicable ○ very low ○ low ○ medium ○ high ○ very high] effect on individual animal health or animal production, through **predation or parasitism**.

aconf20. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm24. Comments : _____

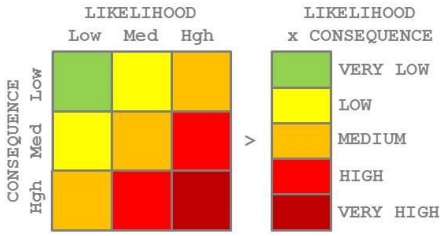
More info:

Indicate whether *The Organism* affects animal targets by feeding on them (predation or parasitism).

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the frequency for *The Organism* to feed on targets (likelihood) and the consequence of this happening.

Likelihood – Ideally corresponds to the following probabilities (based on Havelaar et al. 2010). **Low** : incidence <1 per 100,000 target animals per year. **Medium** : 1-100 per 100,000 animals per year. **High** : >100 per 100,000 animals per year.

Consequence - Refers to the signs of disease, duration of illness and recovery. **Low** : mild signs of disease, illness is short, recovery is complete. **Medium** : moderate signs of disease, illness is prolonged, recovery is incomplete. **High** : severe signs of disease, illness is lasting or results in death, recovery is unlikely.



Choosing **Inapplicable** omits the question from calculation.

Examples

+ Predation has no meaning if *The Organism* is a plant or herbivorous animal. – **INAPPLICABLE**
+ *Rhipicephalus sanguineus* is a (sub)tropical to Mediterranean tick that primarily feeds on dogs, thereby acting as a nuisance (Dantas-Torres 2010; likelihood = medium, consequence = low). – **LOW**
+ American mink (*Neovison vison*) rarely kills domestic poultry, ducks and geese (likelihood = low, consequence = high; Harrison & Symes 1989). – **MEDIUM**
+ The Asian hornet (*Vespa velutina*) exclusively feeds on honeybees (likelihood = medium), which support a specific, yet vulnerable economy (consequence = high). –**HIGH**
+ Varroa mites (*Varroa destructor*) have contributed largely to the global decline of honeybee colonies. - **VERY HIGH**

a25. *The Organism* has a [○ very low ○ low ○ medium ○ high ○ very high] effect on individual animal health or animal production, by having properties that are hazardous upon **contact**.

aconf21. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm25. Comments : _____

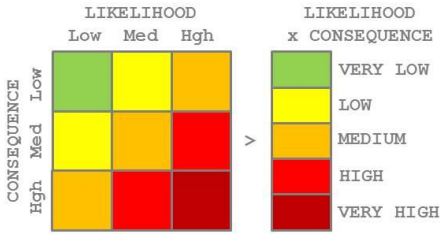
More info:

Indicate whether *The Organism* has biological, physical and/or chemical properties that are harmful upon contact with the targets (e.g. through toxins or allergens). This also includes events where animals may perform aggressive behaviour. (Note that parasitism is dealt with elsewhere, as is pathogen transmission.)

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the frequency for *The Organism* to come in contact with the targets (likelihood) and the consequence of this happening.

Likelihood – Ideally corresponds to the following probabilities (based on Havelaar et al. 2010). **Low** : incidence <1 per 100,000 target animals per year. **Medium** : 1-100 per 100,000 animals per year. **High** : >100 per 100,000 animals per year.

Consequence - Refers to the signs of disease, duration of illness and recovery. **Low** : mild signs of disease, illness is short, recovery is complete. **Medium** : moderate signs of disease, illness is prolonged, recovery is incomplete. **High** : severe signs of disease, illness is lasting or results in death, recovery is unlikely.



Examples

+ Raccoons (*Procyon lotor*) may behave aggressively towards dogs, e.g. by biting when feeling threatened (likelihood = low, consequence = medium). – **LOW**
+ *Conium maculatum* is a poisonous plant that only marginally occurs in grasslands. It is avoided during grazing, but may contaminate hay (likelihood = low). When eaten, it may be lethal to cattle (Galey et al. 1992; consequence = high). – **MEDIUM**
+ When grazing on common grounds, livestock may come into contact with (alien) geese, their feathers or droppings (likelihood = high). However, this does not invoke any direct harm (consequence = low). – **MEDIUM**
+ Pollen of Ragweed (*Ambrosia artemisiifolia*) are widespread (likelihood = high) and can cause clinically manifested allergenic reactions in dogs, being second only to house dust mites (Ognjenovic et al. 2013; consequence = medium). – **HIGH**

a26. *The Organism* has a(n) [○ inapplicable ○ very low ○ low ○ medium ○ high ○ very high] effect on individual animal health or animal production, by hosting **pathogens or parasites** that are harmful to them.

aconf22. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm26. Comments : _____

More info:

Identify all pathogens or parasites that are known to be considerably hosted by both *The Organism* and the targets under consideration, and estimate the risk that these pathogens may pose to the targets.

Pathogens (parasites) may be of viral, bacterial, fungal or animal origin, and may either be endemic (already present in *The Area*) or (re)emerging (new or returning).

If no shared pathogens between *The Organism* and targets are known, or there is good reason to assume that no shared pathogens exist, choose **Very low** as an answer. Choosing **Inapplicable** omits the question from calculation.

Pathogenicity is a complex issue, for which a lot of data needs to be compiled. We advise to use the following sources in decreasing order of preference (A>B>C>D).

A : *Pandora*$^{+}$ – In analogy to this risk assessment, we have created a screening tool for pathogens that directly refers to *The Organism* as a host.

If you have used *Pandora*$^{+}$ for one or more individual pathogens, select the pathogen with the highest score for the animal domain impact (see output for 'I x E x S x animal IMPACTS' using the default methods). We suggest the following cut-off values.

Very low : 0. **Low** :]0-0.25]. **Medium** :]0.25-0.50]. **High** :]0.50-0.75]. **Very high** :]0.75-1.00].

B : OiE – The list of notifiable diseases issued by the World Organisation for Animal Health could be used as a source.

Consult the OiE list at http://www.oie.int/animal-health-in-the-world/oie-listed-diseases-2013/ and count the number of shared pathogens. We suggest the following cut-off values.

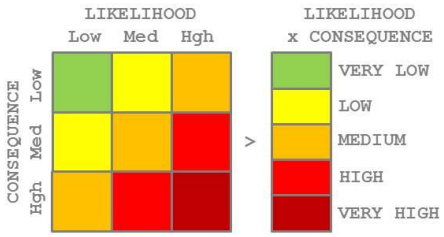
Very low : *The Organism* is known to host pathogens, but none are notifiable. **Low** : 1 or 2. **Medium** : 3 or 4. **High** : 5 or 6. **Very high** : 7 or higher.

C : WILDTOOL – WILDTOOL is a flexible system for assessing the risk that wildlife-borne pathogens may pose to different target groups within Belgium (Tavernier et al. 2011). It is available at http://wildtool.var.fgov.be. See addendum D for further instructions.

Consider the risks that pathogens borne by *The Organism* may pose to 'production animals' or 'companion animals'. Consider the pathogen that yields the highest score.

Low : pathogen not in top-15. **High** : pathogen in top-15.

D : Short-cut version – In case of serious data absence, select the worst of the shared pathogens, and try to estimate the *likelihood* of harm (i.e., the likelihood to become more prevalent and exposed to targets, in case of endemic diseases; or the likelihood to enter and be exposed to targets, in case of [re]emerging diseases) and the *consequence* of harm (as in previous questions).



Examples

+ Plants may be considered irrelevant candidate hosts for pathogens of animal targets. – **INAPPLICABLE**

+ The pigeon-infecting *Argas reflexus*, an alien tick to Belgium, readily bites chickens and horses (Obsomer et al. 2013) and is known to host pathogens that may cause borreliosis and piroplasmosis (Fain 1990). Yet, these pathogens are not on the notifiable list. – **VERY LOW** - Data Type B.

+ Fallow deer, alien to Western Europe, is a known competent host of the following notifiable disease agents: bovine tuberculosis, foot-and-mouth disease, epizootic haemorrhagic disease, and bovine viral diarrhoea (Böhm et al. 2007). – **MEDIUM** - Data Type B.

+ When it comes to horses as targets, Canada geese are a known host for three notifiable diseases: Eastern and Western Equine Encephalitis, and West Nile Virus (Fraser & Fraser 2010). – **MEDIUM** - Data Type B.

+ When it comes to all livestock species as targets, Canada geese are a known host for six notifiable diseases. Apart from the three listed above, this includes *Mycoplasma*, avian influenza and Newcastle disease (Fraser & Fraser 2010). – **HIGH** - Data Type B.

+ From the list of pathogens that are borne by Canada geese (as listed by Fraser & Fraser 2010), Eastern equine encephalitis virus is the highest-ranked in a WILDTOOL-generated list, i.e. 2nd (following the instructions from addendum D). –**HIGH** – Data Type C.

A4d | Impacts: human targets

Questions from this module qualify the consequences of *The Organism* on humans.

It deals with human health, being defined as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (definition adopted from the World Health Organization).

a27. *The Organism* has a(n) [○ inapplicable ○ very low ○ low ○ medium ○ high ○ very high] effect on human health, through **parasitism**.

aconf23. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm27. Comments : _____

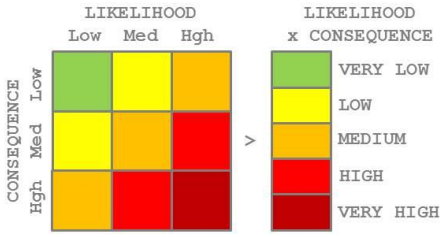
More info:

Indicate whether *The Organism* has the capacity to feed on humans and whether this may cause harm to the physical, mental or social well-being of humans (biting and having blood meals, causing irritation).

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the frequency for *The Organism* to parasitize humans (likelihood) and the consequence of this happening.

Likelihood – Ideally corresponds to the following probabilities (based on Havelaar et al. 2010). **Low** : incidence <1 per 100,000 humans per year. **Medium** : 1-100 per 100,000 humans per year. **High** : >100 per 100,000 humans per year.

Consequence - Refers to the symptoms, duration of illness, recovery, or the amount of stress involved (cf. Krause 2008). **Low** : medical consultation is rare, no work loss, no persisting handicaps, low amounts of stress. **Medium** : medical consultation is frequent, work loss of 1-5 days may occur, persisting handicaps rare, medium amounts of stress. **High** : medical consultation is common, work loss of > 5 days may occur, persisting handicaps may occur, high amounts of stress.



Choosing **Inapplicable** omits the question from calculation.

Examples

+ Parasitism has no meaning if *The Organism* is a plant or herbivorous animal. – **INAPPLICABLE**
+ *Rhipicephalus sanguineus* is primarily a parasite of dogs, but can also parasitize humans, particularly during the summer (Dantas-Torres 2010; likelihood = medium, consequence = medium). – **MEDIUM**
+ Where dense populations build up, the Asian tiger mosquito (*Aedes albopictus*) can develop into an aggressive daytime stressor in their search for human blood (likelihood = medium; consequence = high). – **HIGH**

a28. *The Organism* has a [○ very low ○ low ○ medium ○ high ○ very high] effect on human health, by having properties that are hazardous upon **contact**.

aconf24. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm28. Comments : _____

More info:

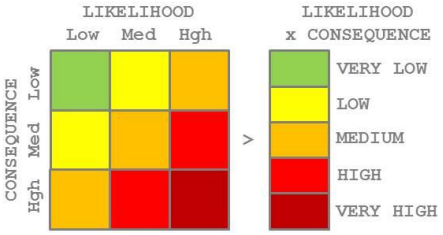
Indicate whether *The Organism* has biological, physical and/or chemical properties that, upon contact, affect the physical, mental or social well-being of humans (e.g. through toxins or allergens). This also includes events

where animals may perform aggressive behaviour. (Note that parasitism is dealt with elsewhere, as is pathogen transmission.)

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the frequency for *The Organism* to come into contact with humans (likelihood) and the consequence of this happening.

Likelihood – Ideally corresponds to the following probabilities (based on Havelaar et al. 2010). **Low** : incidence <1 per 100,000 humans per year. **Medium** : 1-100 per 100,000 humans per year. **High** : >100 per 100,000 humans per year.

Consequence - Refers to the symptoms, duration of illness, recovery, or the amount of stress involved (cf. Krause 2008). **Low** : medical consultation is rare, no work loss, no persisting handicaps, low amounts of stress. **Medium** : medical consultation is frequent, work loss of 1-5 days may occur, persisting handicaps rare, medium amounts of stress. **High** : medical consultation is common, work loss of > 5 days may occur, persisting handicaps may occur, high amounts of stress.



Examples

+ Shrubs such as *Gleditsia triacanthos* are very thorny, so that people working with them (likelihood = low) can get easily injured (consequence = medium). – **LOW**
+ The saliva of some alien tick species can be paralyzing (consequence = high), but this seems to be very rare in Europe (Obsomer et al. 2013; likelihood = low). – **MEDIUM**
+ Asian predatory wasps (*Vespa velutina*) sting people, but only when they feel severely disturbed (likelihood = medium; consequence = medium). – **MEDIUM**
+ The alien mushroom *Leucocoprinus birnbaumii* is not harmful upon contact, but is poisonous if eaten (Boomsluiter 2013; likelihood = low, consequence = high). – **MEDIUM**
+ The Black widow spider (*Latrodectus mactans*) is venomous to humans (cf. physical well-being) and generally causes strong reactions of fear (cf. mental and social well-being; likelihood = medium, consequence = high). – **HIGH**
+ Sap of hogweed *Heracleum mantegazzianum* may cause serious irritation upon contact with the skin (likelihood = medium, consequence = high). –**HIGH**
+ Pollen of ragweed *Ambrosia artemisiifolia* may evoke allergenic, hay fever-like reactions in a substantial percentage of the human population (likelihood = high; consequence = high). – **VERY HIGH**

a29. *The Organism* has a(n) [○ inapplicable ○ very low ○ low ○ medium ○ high ○ very high] effect on the health of human targets, by hosting **pathogens or parasites** that are harmful to them.

aconf25. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm29. Comments : _____

More info:

Identify all pathogens or parasites that are known to be considerably hosted by both *The Organism* and the targets under consideration, and estimate the risk that these pathogens may pose to the targets.

Pathogens (parasites) may be of viral, bacterial, fungal or animal origin, that are naturally transmissible from animals to humans and *vice versa* (i.e. zoonotic). They may either be endemic (already present in *The Area*) or (re)emerging (new or returning).

If no shared pathogens between *The Organism* and targets are known, or there is good reason to assume that no shared pathogens exist, choose **Very low** as an answer. Choosing **Inapplicable** omits the question from calculation.

Pathogenicity is a complex issue, for which a lot of data needs to be compiled. We advise to use the following sources in decreasing order of preference (A>B>C>D).

A : *Pandora*$^{+}$ – In analogy to this risk assessment, we have created a screening tool for pathogens that directly refers to *The Organism* as a host.

If you have used *Pandora*$^{+}$ for one or more individual pathogens, select the pathogen with the highest score for the human domain impact (see output for 'I x E x S x animal IMPACTS' using the default methods). We suggest the following cut-off values.

Very low : 0. **Low** :]0-0.25]. **Medium** :]0.25-0.50]. **High** :]0.50-0.75]. **Very high** :]0.75-1.00].

B : other protocols – Several protocols exist that prioritize zoonotic pathogens and provide lists of them. They differ in many aspects (for one thing, they are rarely restricted to wildlife-borne diseases) but may still be found useful. Such studies are provided by, e.g., Cardoen et al. (2009), Krause et al. (2008) and Havelaar et al. (2010).

If you have access to any of such studies, consider the risks of the respective pathogens. When considering multiple pathogens, consider the one with the highest score. We suggest the following guidance.

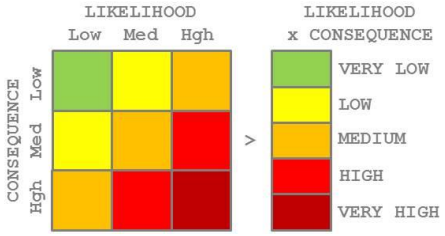
Very low : no shared pathogens known or assumed. **Low** : within the lower quartile of the presented scores. **Medium** : 3/4th – 2/4th. **High** : 2/4th – 1/4th. **Very high** : within the upper quartile of the presented scores.

C : WILDTOOL – WILDTOOL is a flexible system for assessing the risk that wildlife-borne pathogens may pose to different target groups within Belgium (Tavernier et al. 2011). It is available at http://wildtool.var.fgov.be. See addendum D for further instructions.

Consider the risks that pathogens borne by *The Organism* may pose to 'man'. Consider the pathogen that yields the highest score.

Low : pathogen not in top-15. **High** : pathogen in top-15.

D : Short-cut version – In case of serious data absence, select the worst of the shared pathogens, and try to estimate the *likelihood* of harm (i.e., the likelihood to become more prevalent and exposed to targets, in case of endemic diseases; or the likelihood to enter and be exposed to targets, in case of [re]emerging diseases) and the *consequence* of harm (as in previous questions).



Examples

+ Plants may be considered irrelevant candidate hosts for pathogens of human targets. – **INAPPLICABLE**
+ Using the *Pandora*$^{+}$ protocol, a panel of three experts assessed the human risk of rabies (re)emergence by Raccoon dogs in Belgium to be (on average) 0.22. No other pathogens were assessed, however. – Data type A - **LOW**
+ Of the pathogenic agents hosted by Raccoon dogs, *Echinococcus* is the one ending up highest in WILDTOOL, on rank 12. – Data type C - **HIGH**

A4e | Impacts: other targets

Questions from this module qualify the consequences of *The Organism* on targets not considered in modules A4a-d.

a30. *The Organism* has a [○ very low ○ low ○ medium ○ high ○ very high] effect on causing damage to **infrastructure**.

aconf26. Answer provided with a [○ low ○ medium ○ high] level of confidence.

acomm30. Comments : _____

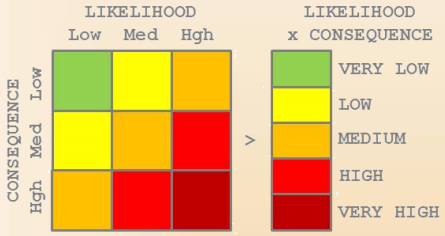
More info:

Indicate whether *The Organism* affects infrastructure or the way it is used. Infrastructure includes real property (immovable property; terrains and their vegetation cover, buildings, wells, dams, ponds, mines, canals, roads, *et cetera*) and personal property (movable property).

Assume that *The Organism* becomes widespread in *The Area*. Then, estimate the frequency for *The Organism* to come in contact with infrastructure (likelihood) and the consequence of this happening (damage).

Likelihood – Ideally corresponds to the following probabilities (based on Havelaar et al. 2010). **Low** : incidence <1 per 100,000 items per year. **Medium** : 1-100 per 100,000 items per year. **High** : >100 per 100,000 items per year.

Consequence – **Low** : completely reversible. **Medium** : partly reversible. **High** : irreversible.



Examples

+ Alien squirrel species sometimes nibble on plastics (likelihood = low), damaging bits of personal property (consequence = medium). –**LOW**
+ If large stands of Himalayan balsam (*Impatiens glandulifera*) build up on canal banks (likelihood = medium), its sudden disappearance at the end of the season may invoke a peak of soil erosion (consequence = medium). – **MEDIUM**
+ Growth of the mushroom *Allopsalliota geesterani* has the capacity to lift up paving stones (Boomsluiter 2013; likelihood = medium, consequence = medium). – **MEDIUM**
+ Canada geese (*Branta canadensis*) readily colonise a variety of waterbodies in urban landscapes (likelihood = high), deteriorating the appeal of its shores for recreation with their droppings (consequence = medium). – **HIGH**
+ Giant salvinia (*Salvinia molesta*) readily colonises a variety of waterbodies of interest to humans (likelihood = high). Monospecific stands can entirely block waterways, hindering anglers and boaters, and cause severe water loss through evaporation (consequence = high). – **VERY HIGH**

A5 | Comments

Use the following field to provide any comments or additions you may have on the assessment performed.

acomm31. Comments : _____

B – *Pandora*$^{+}$: screening **pathogens** for *Harmonia*$^{+}$

Pandora^{+} is a first-line risk assessment scheme for pathogenic or parasitic (micro)organisms that may be of concern to environmental, plant, animal or human health. It refers directly to a particular host organism, and as such, is designed to support assessments within *Harmonia*$^{+}$.

B0 | Context

Questions from this module identify the assessor and the biological, geographical & social context of the assessment.

b01. Provide the name(s) of the **assessor(s)** : _____

bcomm01. Comments : _____

More info:

Provide a (the) name(s) for the person(s) performing the assessment.

b02. Provide the name of the **pathogen** under assessment : _____

bcomm02. Comments : _____

More info:

Identify the biological entity under consideration. This can be a genus, species, subspecies or any other taxon. The organism under assessment will henceforth briefly be referred to as '*The Pathogen*'.

The Pathogen may be a pathogen or parasite, of viral, bacterial, fungal or animal origin.

b03. Provide the name of the **host** organism under assessment : _____

bcomm03. Comments : _____

More info:

Identify the host or vector under consideration. This can be a genus, species, subspecies or any other taxon. The organism under assessment will henceforth briefly be referred to as '*The Organism*'.

The questionnaire is notably designed to suit multicellular animals and plants as host organisms. As such, the results of this assessment may feed into a *Harmonia*$^{+}$ assessment of *The Organism*.

b04. Define the **area** under assessment : _____

bcomm04. Comments : _____

More info:

Identify the geographic entity under consideration. This can be defined as widely as from the local up to the international level. The area under assessment will henceforth briefly be referred to as '*The Area*'.

Currently, much of the guidance refers to Belgium as *The Area*. When different, it may be necessary to search for analogous information.

b05. This assessment is considering potential impacts within the following **domains** : [□ the environmental domain □ the cultivated plant domain □ the domesticated animal domain □ the human (health) domain □ (an)other domain].

bcomm05. Comments : _____

More info:

A target is an entity potentially bearing impacts from *The Pathogen*. Sectors that deal with specific targets are collectively referred to as a 'domain'.

Specify your targets of interest by choosing one or more domain.

Targets from the 'environmental domain' refer to wild animals and plants, habitats and ecosystems.

Targets from the 'plant domain' refer to cultivated plants (e.g. from agriculture, forestry, horticulture; i.e. crops, pastures, horticultural stock).

Targets from the 'animal domain' refer to domesticated animals (e.g. from agriculture, aquaculture; i.e. production animals, companion animals).

Targets from the 'human domain' refer to humans, the health of which is defined as a state of complete physical, mental and social well-being (and not merely the absence of disease or infirmity).

Targets from the 'other domain' refer to targets that are not included in the domains above.

b06. *The Pathogen* is / would be the cause of a(n) [○ endemic ○ (re)emerging] infectious **disease** to the targets in *The Area*.

bconf01. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm06. Comments : _____

More info:

Indicate the status of *The Pathogen* in *The Area*. Different questions need to be answered depending on whether it classifies as endemic or (re)emerging.

Endemic : *The Pathogen* is currently present within target populations in *The Area*. The main importance of *The Organism* is in acting as an important reservoir or an efficient vector for *The Pathogen* (spillback to targets).
(Re)emerging : *The Area* is currently considered free from *The Pathogen*. The main importance of *The Organism* is in potentially (re)introducing *The Pathogen* (spillover to targets).

(More generally, an emerging disease means a 'new infection resulting from the evolution or change of an existing pathogenic agent, a known infection spreading to a new geographic area or population, or a previously unrecognized pathogenic agent or disease diagnosed for the first time and which has a significant impact on animal or public health' [OiE 2012a]).

If you have answered **Endemic**, questions B8 to B10 are inapplicable. If you have answered **(Re)emerging**, question B7 is inapplicable.

Examples

+ Fox tapeworm (*Echinococcus multilocularis*) can be hosted by several carnivore mammals (Kapel et al. 2006). It is currently present in Belgium, though rarely diagnosed. **– ENDEMIC**

+ The Netherlands were declared free of bovine tuberculosis in 1994. Any new case would make it a re-emerging disease. – **(RE)EMERGING**

+ Belgium is currently considered free from Bluetongue virus BTV8. However, a (very) low prevalence in wildlife cannot be excluded. – **(RE)EMERGING**, but level of confidence **LOW**

Exposure in **endemic** pathogens (cf. question B6)

Ben2 | Exposure

Questions from this module assess the pathways necessary for exposure of pathogenic agents to targets in *The Area*.

b07. Because of *The Organism*, the probability for *The Pathogen* to become increasingly **prevalent** within targets in *The Area* is [○ inapplicable ○ low ○ medium ○ high].

bconf02. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm07. Comments : _____

More info:

Indicate the importance of *The Organism* to act as a reservoir or vector.

Estimate the likelihood for *The Pathogen* to become increasingly prevalent in target populations (by spillback), when compared to a no-*Organism*-scenario. Transmission to targets may be directly from *The Organism*, or through intermediate hosts.

Low : prevalence of *The Pathogen* is unlikely to be enhanced by *The Organism*'s establishment in *The Area*. **Medium** : prevalence is likely to be slightly increased. **High** : prevalence is likely to be strongly increased.

Choose **Inapplicable** if *The Pathogen* is (re)emerging in *The Area* (this omits the question from calculation).

Examples

+ A survey on the prevalence of the chicken disease agent *Mycoplasma gallisepticum* in Canada geese in Belgium yielded no positive results (96 geese samples). It was therefore concluded that wild geese do not play an important role in the spread of this bacterium (Michiels et al. 2013). – **LOW**

+ Diverse routes of transmission are known for endemic diseases that are carried by alien deer (Böhm et al. 2007). Yet, in practice, these routes may not be easily bridged towards human targets (cf. meat consumption, faecal contact, via livestock). – **MEDIUM**

+ In Germany, Raccoon dogs have been linked to an increased prevalence of *Trichinella* in pigs, most likely through the feeding of backyard-held pigs with offal of boar (Pannwitz et al. 2010). – **MEDIUM**

+ Raccoon dogs are equally competent hosts for the Fox tapeworm (*Echinococcus multilocularis*) as native foxes (Kapel et al. 2006). The emergence of Raccon dogs in Belgium is therefore expected to significantly increase the pathogen's reservoir, and thus to increase prevalence in wildlife, animal or human targets. – **HIGH**

+ In Scandinavia and Baltic countries, Raccoon dog establishment is responsible for an increase of rabies prevalence compared to a fox-only scenario (Holmala & Kauhala 2006, Singer et al. 2009). – **HIGH**

+ Introduced chipmunks in France (*Tamias sibiricus barberi*) produced nearly 8.5 times more infected questing tick nymphs than native hosts (voles and mice) and contributed to a higher diversity of tick-borne *Borrelia* genospecies. It should therefore amplify *Borrelia* infection, hence increasing the risk of Lyme borreliosis in human targets (Marsot et al. 2013). – **HIGH**

Exposure in **emerging** pathogens (cf. question B6)

Bem1 | Entry

Questions from this module assess the likelihood for (re)emerging pathogenic agents to be (re)introduced into the environment of *The Area*.

b08. The probability of *The Pathogen* to be **introduced** with *The Organism* into *The Area* is [○ inapplicable ○ low ○ medium ○ high].

bconf03. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm08. Comments : _____

More info:

Indicate the likelihood for *The Organism* to introduce *The Pathogen*. Take into account the introduction pathways of *The Organism* and the probability for *The Organism* to be infected (infection probability may be different by whether *The Organism* is introduced as a hitch-hiker or as an escape from captivity).

Ideally corresponds to the following probabilities. **Low** : 0-33% of individual *Organisms* newly entering *The Area* carry *The Pathogen*. **Medium** : 33-66%. **High** : 66-100%.

Choose **Inapplicable** if *The Pathogen* is endemic in *The Area* (this omits the question from calculation).

Examples

+ Some mosquito-borne viruses like Japanese encephalitis or Chikungunya virus appear not to be introduced with their vectors, because parent-to-egg transmission of the virus is rare in nature, and it is only the egg stages that are subject to long-distance translocation (Clements 2012). – **LOW**

+ Raccoon populations can reach high prevalence for the roundworm *Baylisascaris procyonis*, also in Europe (>70% among German raccoons; Kazacos 2001). Natural spread of this mammal is thus likely to introduce the pathogen in Belgium. – **HIGH**

Bem2 | Exposure

Questions from this module assess the pathways necessary for exposure of pathogenic agents to targets in *The Area*.

b09. *The Pathogen* has a(n) [○ inapplicable ○ low ○ medium ○ high] probability to be **maintained and spread** within *The Organism* population in *The Area*.

bconf04. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm09. Comments : _____

More info:

Pathogen maintenance & spread include processes of exposure, release & transmission among individuals of *The Organism*, ultimately creating a reservoir for the disease in *The Area*.

Low : possibilities for *The Pathogen* to establish and spread in *The Area* are limited; expected prevalence of *The Pathogen* is low. **Medium** : possibilities to establish and spread are moderate; expected prevalence is medium. **High** : possibilities to establish and spread are good; expected prevalence is high.

Choose **Inapplicable** if *The Pathogen* is endemic in *The Area* (this omits the question from calculation).

Examples

+ The Chinese mitten crab (*Eriocheir sinensis*) acts an intermediate host of the worm infection paragonimiasis. However, establishment of this pathogen is unlikely for the Netherlands due to low winter temperatures (Leewis et al. 2013). – **LOW**

+ American Grey squirrels (*Sciurus carolinensis*) are resistant to squirrelpox. As squirrels establish and spread, so does the virus (Strauss et al. 2012). – **HIGH**

b10. The probability for *The Pathogen* to be **transmitted** from individual *Organisms* to individual targets is [○ inapplicable ○ low ○ medium ○ high].

bconf05. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm10. Comments : _____

More info:

Indicate the likelihood for *The Pathogen* to spillover to target populations.

If you are considering more than one domains, choose the worst of these cases.

Low : transmission is highly unlikely because of a high separation in space and time. **Medium** : transmission is only likely given sufficient space and/or time. **High** : transmission is likely even with limited space and/or time.

Choose **Inapplicable** if *The Pathogen* is endemic in *The Area* (this omits the question from calculation).

Examples

+ American mink (*Neovison vison*) can act as a reservoir for various diseases. In their review, Barrat et al. (2010) estimate the risk of transmitting these diseases to farmed animal targets as rather low, compared to other diseases in the wildlife species reservoir. – **LOW**
+ Diverse routes of transmission are known for emerging diseases carried by alien deer (Böhm et al. 2007). Yet, in practice, these routes may not be easily bridged from deer to human targets: cf. meat consumption, faecal contact, through livestock. – **MEDIUM**
+ Where (alien) deer and livestock share access to agricultural pastures, vector-borne, faecal-oral and urinary-oral transmission routes render transmission of pathogens to animal targets likely (Böhm et al. 2007). – **HIGH**

B3a | Consequence: environmental targets

Questions from this module qualify the consequences of *The Pathogen* on wild animals and plants, habitats and ecosystems.

Impacts are linked to the conservation concern of targets. Native species that are of conservation concern refer to keystone species (e.g. heather, beech), threatened species (e.g. many orchids or butterflies) or emblematic species (e.g. ladybirds, squirrel). See, for example, Red Lists, protected species lists, or Annex II of the 92/43/EEC Directive. Ecosystems that are of conservation concern refer to natural systems that are the habitat of many threatened species. These include natural forests, dry grasslands, natural rock outcrops, sand dunes, heathlands, peat bogs, marshes, rivers & ponds that have natural banks, and estuaries (see e.g. Annex I of the 92/43/EEC Directive).

Native species population declines are considered on the local scale: limited decline is considered as a (mere) drop in numbers; severe decline is considered as a (near) extinction.

b11. *The Pathogen* has a [○ low ○ medium ○ high] effect on **native species individuals**.

bconf06. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm11. Comments : _____

More info:

Indicate the burden of illness of *The Pathogen* on individuals from native species.

Assume that an individual target becomes infected by *The Pathogen*, and estimate the consequence of this happening.

Low : mild signs of disease, illness is short, recovery is complete. **Medium** : moderate signs of disease, illness is prolonged, recovery is incomplete. **High** : severe signs of disease, illness is lasting or results in death, recovery is unlikely.

If no native host species exist in *The Area*, choose **Low** as an answer.

b12. *The Pathogen* has a [○ no / very low ○ low ○ medium ○ high ○ very high] effect on **native species populations**.

bconf07. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm12. Comments : _____

More info:

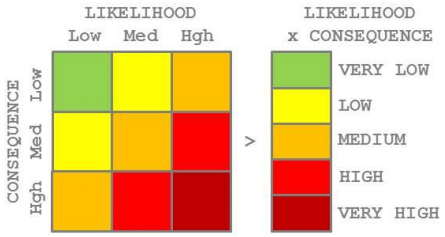
Indicate the burden of illness of *The Pathogen* on environmental targets.

Assume that *The Pathogen* becomes endemic in *The Area*. Then, estimate the likelihood for *The Pathogen* to infect some native species population within the time span of a year, and the consequence of this happening.

Likelihood – Ideally corresponds to the following probabilities. **Low** :]0-33% probability (≈ expected to occur less than once every 3 years). **Medium** : 33-66% (once every 1.5 to 3 years). **High** : 66-100% (more than once every 1.5 years).

Consequence – **Low** : at worst, limited population declines occur in species that are not of conservation concern. **Medium** : at worst, severe population declines occur in species that are not of conservation concern, or limited population declines occur in species that are of conservation concern. **High** : at worst, severe population declines occur in species that are of conservation concern.

Likelihood and consequence can then become combined as follows:



If no native host species exist in *The Area*, choose **No** as an answer.

Examples

+ The tick *Hyalomma aegyptium* is primarily hosted by *Testudo* tortoises, which are alien to Belgium but have become established here. Only rarely, *Hyalomma* is found on other hosts in Europe, such as hedgehogs and hares (likelihood = low; Paştiu et al. 2012). Such occasional infection would presumably not lead to local decline in these species (consequence = low). – **VERY LOW**

+ The plant pathogen *Phytophtora ramorum* has a very broad host range, and new infections on native species in the Netherlands are frequently observed (*Fagus*, *Quercus*; likelihood = high). Sub-optimal conditions for sporulation appear to preclude significant damage to these species (consequence = medium; Leewis et al. 2013). -- **HIGH**

+ *Batrachochytrium salamandrivorens* is a fungal pathogen of amphibians that seems to spread rapidly (likelihood = high). It is lethal, and has devastated populations of the already-rare Fire salamander in the Netherlands (consequence = high; Martel et al. 2013). – **VERY HIGH**

+ American squirrel species have introduced *Parapox* virus into Europe. This causes squirrelpox, which is lethal to the native Red squirrel (*Sciurus vulgaris*) and has contributed to their decline and local extinction (likelihood = high; consequence = high; Strauss et al. 2012). – **VERY HIGH**

B3b | Consequence: plant targets

Questions from this module qualify the consequences of *The Pathogen* on cultivated plants (e.g. crops, pastures, horticultural stock).

It deals with both the quality of individual plants and the yield of plant populations.

b13. *The Pathogen* has a(n) [○ inapplicable ○ low ○ medium ○ high] effect on **individual plants**.

bconf08. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm13. Comments : _____

More info:

Indicate the burden of illness of *The Pathogen* on individual plants.

Assume that an individual target becomes infected by *The Pathogen*, and estimate the consequence of this happening.

Low : mild signs of disease, illness is short, recovery is complete. **Medium** : moderate signs of disease, illness is prolonged, recovery is incomplete. **High** : severe signs of disease, illness is lasting or results in death, recovery is unlikely.

If *The Pathogen* is not a plant pathogen, choose **Inapplicable** (this omits the question from calculation). If no cultivated plant host species exist in *The Area*, choose **Low** as an answer.

b14. *The Pathogen* has a(n) [○ inapplicable ○ no / very low ○ low ○ medium ○ high ○ very high] effect on **plant populations**.

bconf09. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm14. Comments : _____

More info:

Indicate the burden of illness of *The Pathogen* on plant quality or yield.

Several types of data can be used, outlined below. We advise to use the following data in decreasing order of preference (A>B>C).

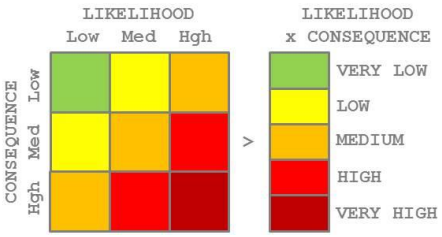
If *The Pathogen* is not a plant pathogen, choose **Inapplicable** (this omits the question from calculation). If no cultivated plant host species exist in *The Area*, choose **No** as an answer.

A : Likelihood x Consequence – Assume that *The Pathogen* becomes endemic in *The Area*. Then, estimate the likelihood for *The Pathogen* to infect some plant target population within the time span of a year, and the consequence of this happening.

Likelihood : Ideally corresponds to the following probabilities. **Low** :]0-33% probability (≈ expected to occur less than once every 3 years). **Medium** : 33-66% (once every 1.5 to 3 years). **High** : 66-100% (more than once every 1.5 years).

Consequence : Refers to the signs of disease, duration of illness and recovery. **Low** : mild signs of disease, illness is short, recovery is complete. **Medium** : moderate signs of disease, illness is prolonged, recovery is incomplete. **High** : severe signs of disease, illness is lasting or results in death, recovery is unlikely.

Likelihood x Consequence : Likelihood and consequence can then become combined as follows:



B : Monetary – If available, costs of the disease to the government and agricultural sector may be used as a proxy.

C : Expert opininon – If no appropriate data is available at all, a direct estimate is needed through expert opinion.

Examples

+ *Batrachochytrium* is not a plant pathogen, but an animal pathogen. – **INAPPLICABLE**
+ The plant pathogen *Phytophtora ramorum* has a very broad host range, and new infections in the Netherlands are frequently observed (likelihood = high). Some ornamental species like *Rhododendron* and *Camellia* suffer leaf and branch die-back; mortality is regularly observed in *Viburnum* (consequence = high). – Data type A - **VERY HIGH**

B3c | Consequence: animal targets

Questions from this module qualify the consequences of *The Pathogen* on domesticated animals (e.g. production animals, companion animals).

It deals with both the well-being of individual animals and the productivity of animal populations.

b15. *The Pathogen* has a(n) [○ inapplicable ○ low ○ medium ○ high] effect on the health (physical well-being and welfare) of **individual animals**.

bconf10. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm15. Comments : _____

More info:

Indicate the burden of illness of *The Pathogen* on individual animals.

Assume that an individual animal becomes infected by *The Pathogen*, and estimate the consequence of this happening.

Low : mild signs of disease, illness is short, recovery is complete. **Medium** : moderate signs of disease, illness is prolonged, recovery is incomplete. **High** : severe signs of disease, illness is lasting or results in death, recovery is unlikely.

If *The Pathogen* is not an animal pathogen, choose **Inapplicable** (this omits the question from calculation).

Examples

+ *Phytophtora* is not an animal pathogen, but a plant pathogen. – **INAPPLICABLE**
+ Feline viral rhinotracheitis in cats may be severe in some cases (e.g. in kittens). – **MEDIUM**
+ Rabies is deadly to cattle. – **HIGH**

b16. *The Pathogen* has a(n) [○ inapplicable ○ no / very low ○ low ○ medium ○ high ○ very high] effect on the health (physical well-being and welfare) or production of **animal populations**.

bconf11. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm16. Comments : _____

More info:

Indicate the burden of illness of the pathogen on animal populations (cf. the industry).

Several types of data can be used, outlined below. We advise to use the following data in decreasing order of preference (A>B>C).

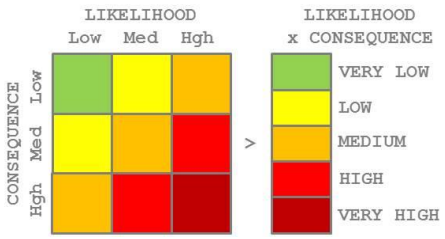
If *The Pathogen* is not an animal pathogen, choose **Inapplicable** (this omits the question from calculation). If no domesticated animal host species exist in *The Area*, choose **No** as an answer.

A : Likelihood x Consequence – Assume that *The Pathogen* becomes endemic in *The Area*. Then, estimate the likelihood for *The Pathogen* to cause an infection in targets, and the consequence of this happening.

Likelihood : Ideally refers to the *incidence* of disease (the number of new cases arising in a population over a given period). E.g., **low** : <1 infections per 100,000 animals per year; **medium** : 1-100 ; **high** : >100 (based on Havelaar et al. 2010). Alternatively, one may use *prevalence* as a proxy.

Consequence : Refers to signs of disease, duration of illness and recovery. **Low** : mild signs of disease, illness is short, recovery is complete. **Medium** : moderate signs of disease, illness is prolonged, recovery is incomplete. **High** : severe signs of disease, illness is lasting or results in death, recovery is unlikely.

Likelihood x Consequence : Likelihood and consequence can then become combined as follows:



B : Monetary – If available, costs of the disease to the government and agricultural sector may be used as a proxy. These include costs of control (culling, vaccination, compensation) and the loss of breeding animals, lost returns and damage to the market. E.g. at the scale of the Netherlands (Havelaar et al. 2010): **very low** : < 0.1 M Euro per year; **low** : < 1 M ; **medium** : 1-10 M ; **high** : 10-100 M ; **very high** : > 100 M.

C : Expert opininon – If no appropriate data is available at all, a direct estimate is needed through expert opinion.

Examples

+ *Phytophtora* is not an animal pathogen, but a plant pathogen. – **INAPPLICABLE**
+ The (inter)national economic consequences of Rabies disease in 2008 for France were estimated low by Dufour et al. (2011). – Data type C - **LOW**
+ The total direct costs of the Classical Swine Fever Outbreak in Belgium of 1997 (Limburg Province) were estimated at about 11 M Euro (Mintiens et al. 2001). – Data type B - **HIGH**
+ Foot-and-mouth disease may take on very severe epidemiological proportions, as exemplified by the 2001 United Kingdom outbreak, where 2,000 cases of the disease were reported on farms across the country, and 10 million sheep and cattle were killed preventively (Dufour et al. 2011). – Data type C - **VERY HIGH**
+ The net costs of the bluetongue BTV8 epidemic of 2006 and 2007 in the Netherlands were estimated at 32 M Euro (2006) and 164-175 M Euro (2007) by Velthuis et al. (2010). – Data type B - **VERY HIGH**
+ The overall cumulative incidence for the Bluetongue virus outbreak of 2007 in Belgium was estimated at 11.5% (cattle populations) and 7.5% (sheep; likelihood = high). Clinical sings are diverse; mortality is typically 10-20% but may reach 70% in individual flocks (consequence = high; Méroc et al. 2009). – Data type A - **VERY HIGH**

B3d | Consequence: human targets

Questions from this module qualify the consequences of *The Pathogen* on humans.

It deals with human health, being defined as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (definition adopted from the WHO; World Health Organization).

b17. *The Pathogen* has a(n) [○ inapplicable ○ low ○ medium ○ high] effect on the health (physical, mental or social well-being) of **individual humans**.

bconf12. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm17. Comments : _____

More info:

Indicate the burden of illness of *The Pathogen* on individual humans.

Assume that an individual human becomes infected by *The Pathogen*, and estimate the consequence of this happening.

Low : hospitalization is rare, work loss is < 2 days, no persisting handicaps, low amounts of stress. **Medium** : hospitalization is rare, work loss of > 5 days is rare, few persisting handicaps, medium amounts of stress. **High** : hospitalization is frequent, work loss of > 5 days is frequent, persisting handicaps occur, high amounts of stress (based on Krause et al. 2008).

If *The Pathogen* is not an animal pathogen, choose **Inapplicable** (this omits the question from calculation). If *The Pathogen* does not infect humans, choose **No** as an answer.

Examples

+ *Phytophtora* is not an animal pathogen, but a plant pathogen. – **INAPPLICABLE**
+ Most cases of Salmonellosis last four to seven days, with people recovering without treatment. – **LOW**
+ Worms of the waterfowl-transmitted genus *Trichobilharzia* are essentially considered as not harmful to man, though very unpleasant (cf. swimmers' itch; mental stress). – **MEDIUM**
+ Early symptoms of tick-transmitted Lyme borreliosis are fairly mild, though delayed or inadequate treatment can lead to more serious symptoms. – **MEDIUM**
+ Generally, the effects of parrot fever (*Chlamydia psittaci*) on humans are moderate. – **MEDIUM**
+ If untreated, rabies leads to death in humans. – **HIGH**

b18. *The Pathogen* has a(n) [○ inapplicable ○ no / very low ○ low ○ medium ○ high ○ very high] effect on the health (physical, mental or social well-being) of the **human population**.

bconf13. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm18. Comments : _____

More info:

Indicate the burden of illness of *The Pathogen* on human populations.

Several types of data can be used, outlined below. We advise to use the following data in decreasing order of preference (A>B>C>D).

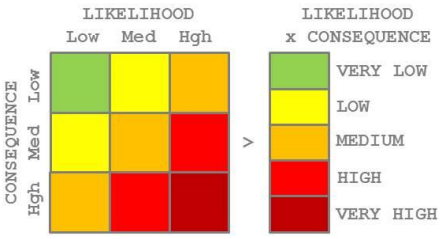
If *The Pathogen* is not an animal pathogen, choose **Inapplicable** (this omits the question from calculation). If *The Pathogen* does not infect humans, choose **No** as an answer.

A : Likelihood x Consequence – Assume that *The Pathogen* becomes endemic in *The Area*. Then, estimate the likelihood for *The Pathogen* to cause an infection in humans, and the consequence of this happening.

Likelihood : Ideally refers to the *incidence* of disease (the number of new cases arising in a population over a given period. E.g., **low** : <1 infections per 100,000 humans per year; **medium** : 1-100 ; **high** : >100 (based on Havelaar et al. 2010). Alternatively, one may use *prevalence* as a proxy.

Consequence : Refers to symptoms, duration of illness, recovery and the amount of stress involved. **Low** : hospitalization is rare, work loss is < 2 days, no persisting handicaps, low amounts of stress. **Medium** : hospitalization is rare, work loss of > 5 days is rare, few persisting handicaps, medium amounts of stress. **High** : hospitalization is frequent, work loss of > 5 days is frequent, persisting handicaps occur, high amounts of stress (based on Krause et al. 2008).

Likelihood x Consequence : Likelihood and consequence can then become combined as follows:



B : Monetary – If available, costs of the disease to the government and health sector may be used as a proxy.

C : Mortality – An estimate of the case-fatality rate. E.g. **very low** : < 0.001 % ; **low** : < 0.01 % ; **medium** : 0.01-0.1 %; **high** : 0.1-1 %; **very high** : > 1 % (based on Krause et al. 2008).

D : Expert opininon – If no appropriate data is available at all, a direct estimate is needed through expert opinion.

Examples

+ *Phytophtora* is not an animal pathogen, but a plant pathogen. – **INAPPLICABLE**
+ Bluetongue virus is a pathogen of ruminants, not of humans. – **NO**
+ Raccoons are ubiquitous hosts of the roundworm *Baylisascaris procyonoides*. Human infection may be through ingestion of soil-borne eggs or contact with faeces, e.g. children's exploratory behavior (likelihood = low). Baylisascariasis typically results in fatal disease or severe sequelae (consequence = high). – Data type A - **MEDIUM**
+ In 2003, 617 cases of West-Nile Virus infection were reported among the 700,000 inhabitants or so of North Dakota state (likelihood = medium). 94 of these cases (15%) were classified as cases of neuroinvasive disease (forms of meningitis, encephalitis or acute flaccid paralysis), with some related deaths (consequence = high; Carson et al. 2006). – Data type A – **HIGH**

B3e | Consequence: other targets

Questions from this module qualify the consequences of *The Pathogen* on targets not considered in modules B3a-d.

b19. *The Pathogen* has a(n) [○ inapplicable ○ low ○ medium ○ high] effect on international **trade and tourism**.

bconf14. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm19. Comments : _____

More info:

Indicate whether *The Pathogen* may indirectly invoke complications for free trade or tourism.

Examples

+ The 2004 H5N1 epidemic had a clear negative impact on international tourist arrivals to Asian countries, though to a lesser degree than the SARS epidemic did (McAleer et al. 2010, Kuo et al. 2008). – **MEDIUM**
+ The 2003 SARS epidemic severely impacted international tourist arrivals to Asian countries (McAleer et al. 2010). – **HIGH**
+ The emergence of the lethal influenza strain H1N1 resulted in the estimated loss of almost a million overseas visitors to Mexico around 2009 (Rassy & Smith 2013). – **HIGH**

b20. *The Pathogen* has a(n) [○ inapplicable ○ low ○ medium ○ high] effect on **public attention and perception**.

bconf15. Answer provided with a [○ low ○ medium ○ high] level of confidence.

bcomm20. Comments : _____

More info:

Indicate whether presence of *The Pathogen* may attract disproportional reactions from the general public and media.

Examples

+ Anthrax (*Bacillus anthracis*) was used in a bioterrorism attack in September 2001, the reporting of which was covered in the news worldwide. Drawing on this connotation of fear, new occurrences of anthrax are likely to receive disproportionate attention. – **HIGH**

B4 | Comments

Use the following field to provide any comments or additions you may have on the assessment performed.

bcomm21. Comments : _____

C – *Pandora* : a screening procedure for **pathogens**

Pandora is a first-line risk assessment scheme for pathogenic or parasitic (micro)organisms that may cause human health concerns, economic losses and/or environmental damage. It is an adapted version of *Harmonia*$^{+}$, drawing on the same concepts. In contrast to *Pandora*$^{+}$, *Pandora* does not refer to a particular host organism.

The questionnaire is designed to suit (re)emerging diseases, referring to new infections that result 'from the evolution or change of an existing pathogenic agent, a known infection spreading to a new geographic area or population, or a previously unrecognized pathogenic agent or disease diagnosed for the first time and which has a significant impact on animal or public health' (OiE 2012a). This opposes to endemic diseases, which are already present in the area under assessment, and are not the focus of *Pandora*.

Only those questions that differ from *Pandora*$^{+}$ are shown here. A full version can be found online through http://ias.biodiversity.be.

C0 | Context

c01. As with *Pandora*$^{+}$, question b01, on the '**assessor(s)**'.

ccomm01. As with *Pandora*$^{+}$, question bcomm01 ('Comments').

c02. As with *Pandora*$^{+}$, question b02, on the '**pathogen**'.

ccomm02. As with *Pandora*$^{+}$, question bcomm02 ('Comments').

c03. As with *Pandora*$^{+}$, question b04, on the '**area**'.

ccomm03. As with *Pandora*$^{+}$, question bcomm04 ('Comments').

c04. As with *Pandora*$^{+}$, question b05, on '**domains**'.

ccomm04. As with *Pandora*$^{+}$, question bcomm05 ('Comments').

C1 | Entry

c05. The probability of *The Pathogen* to be **introduced** into *The Area* is [○ low ○ medium ○ high].

cconf01. Answer provided with a [○ low ○ medium ○ high] level of confidence.

ccomm05. Comments : _____

More info:

Estimate the probability that *The Pathogen* enters *The Area* from the outside, by any pathways, within the time span of a decade.

Low : 0-33% probability (≈ expected to occur less than once every 30 years). **Medium** : 33-66% (once every 15 to 30 years). **High** : 66-100% (within 15 years).

Examples

+ Raccoon populations can reach high prevalence for the roundworm *Baylisascaris procyonis*, also in Europe (>70% among German raccoons; Kazacos 2001). If not present already, then the ongoing spread of the mammal from Germany to Belgium will almost certainly introduce *Baylisascaris* here. – **HIGH**

C2 | Exposure

c06. *The Pathogen* has a(n) [○ low ○ medium ○ high] probability to be **maintained and spread** in *The Area*.

cconf02. Answer provided with a [○ low ○ medium ○ high] level of confidence.

ccomm06. Comments : _____

More info:

Pathogen maintenance & spread include processes of exposure, release & transmission among individual organisms (any species) or the environment, ultimately creating a reservoir for the disease in *The Area*.

Low : possibilities for *The Pathogen* to establish and spread in *The Area* are limited; expected prevalence of *The Pathogen* is low. **Medium** : possibilities to establish and spread are moderate; expected prevalence is medium. **High** : possibilities to establish and spread are good; expected prevalence is high.

Examples :

+ The sylvatic cycle for anthrax (*Bacillus anthracis*) depends on mammal and avian scavengers feeding on herbivore carcasses (Dragon & Rennie 1995). This, and other conditions do not seem to be well-met in Western Europe. – **MEDIUM**
+ *Phytophtora ramorum* is a plant pathogen, for which sporulation conditions within The Netherlands do not seem to be suited as compared to, e.g., the United Kingdom (Leewis et al. 2013). – **MEDIUM**
+ The fungus *Batrachochytrium*, the causative agent of chytridiomycosis in amphibians, is presumably present on a wide variety of subtrates, including amphibians, but also waterfowl, water plants *et cetera*. These pose little barrier for the species to spread. – **HIGH**

c07. The probability for *The Pathogen* to be **transmitted** from its reservoir to individual targets is [○ low ○ medium ○ high].

cconf03. Answer provided with a [○ low ○ medium ○ high] level of confidence.

ccomm07. Comments : _____

More info:

Indicate the likelihood for *The Pathogen* to spillover to target populations.

If you are considering more than one domains, choose the worst of these cases.

Low : transmission is highly unlikely because of a high separation in space and time. **Medium** : transmission is only likely given sufficient space and/or time. **High** : transmission is likely even with limited space and/or time.

Examples : as with *Pandora*+, question b10.

C3a | Consequence: environmental targets

c08. As with *Pandora*+, question b11, on '**native species individuals**'.

cconf04. As with *Pandora*+, question bconf06 ('level of confidence').

ccomm08. As with *Pandora*+, question bcomm11 ('Comments').

c09. As with *Pandora*+, question b12, on '**native species populations**'.

cconf05. As with *Pandora*+, question bconf07 ('level of confidence').

ccomm09. As with *Pandora*+, question bcomm12 ('Comments').

C3b | Consequence: plant targets

c10. As with *Pandora*+, question b13, on '**individual plants**'.

cconf06. As with *Pandora*+, question bconf08 ('level of confidence').

ccomm10. As with *Pandora*+, question bcomm13 ('Comments').

c11. As with *Pandora*+, question b14, on '**plant populations**'.

cconf07. As with *Pandora*+, question bconf09 ('level of confidence').

ccomm11. As with *Pandora*+, question bcomm14 ('Comments').

C3c | Consequence: animal targets

c12. As with *Pandora*+, question b15, on '**individual animals**'.

cconf08. As with *Pandora*+, question bconf10 ('level of confidence').

ccomm12. As with *Pandora*+, question bcomm15 ('Comments').

c13. As with *Pandora*+, question b16, on '**animal populations**'.

cconf09. As with *Pandora*+, question bconf11 ('level of confidence').

ccomm13. As with *Pandora*+, question bcomm16 ('Comments').

C3d | Consequence: human targets

c14. As with *Pandora*+, question b17, on '**individual humans**'.

cconf10. As with *Pandora*+, question bconf12 ('level of confidence').

ccomm14. As with *Pandora*+, question bcomm17 ('Comments').

c15. As with *Pandora*+, question b18, on '**human population**'.

cconf11. As with *Pandora*+, question bconf13 ('level of confidence').

ccomm15. As with *Pandora*+, question bcomm18 ('Comments').

C3e | Consequence: other targets

c16. As with *Pandora*$^{+}$, question `b19`, on '**trade and tourism**'.

cconf12. As with *Pandora*$^{+}$, question `bconf14` ('level of confidence').

ccomm16. As with *Pandora*$^{+}$, question `bcomm19` ('Comments').

c17. As with *Pandora*$^{+}$, question `b20`, on '**public attention and perception**'.

cconf13. As with *Pandora*$^{+}$, question `bconf15` ('level of confidence').

ccomm17. As with *Pandora*$^{+}$, question `bcomm20` ('Comments').

C4 | Comments

Use the following field to provide any comments or additions you may have on the assessment performed.

ccomm18. Comments : _____

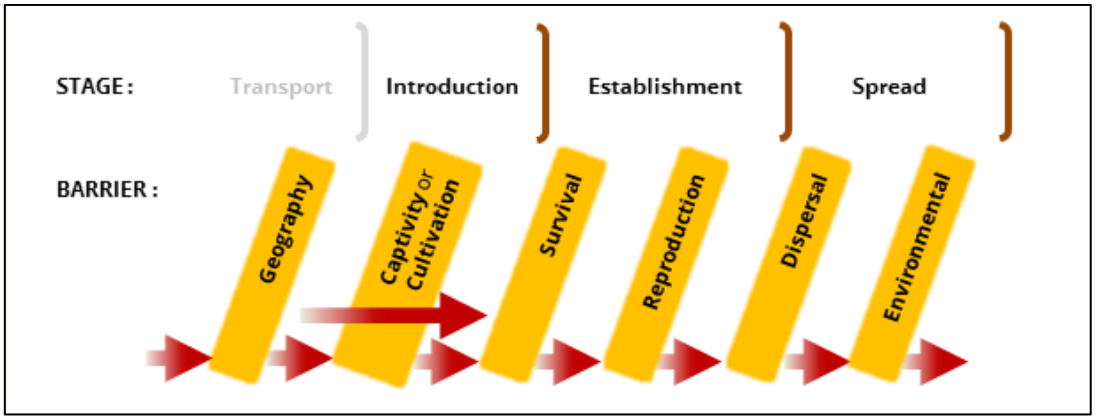
Addendum A – Conceptual framework

Concepts of invasion

Concepts of invasion in *Harmonia*$^+$ are taken from the framework of Blackburn et al. (2011). The invasion process is divided into a series of stages, and for each stage, there are barriers to be overcome for an organism to pass on to the next stage. These stages and their barriers are: Transport (Geographical barriers), Introduction (Captivity/Cultivation barriers), Establishment (Survival and Reproduction barriers) and Spread (Dispersal and Environmental barriers).

Since it is recognized that many organisms do not encounter Captivity/Cultivation barriers upon Transport (notably those aliens that have been introduced unintentionally), we have incorporated Transport into the Introduction stage.

Impacts fall outside the framework of Blackburn et al. (2011), but are added here after the Spread stage.



An overview of the invasion stages and barriers adopted in *Harmonia*$^+$ (after Blackburn et al. 2011).

Concepts of risk

Concepts of risk are taken from Kinney & Wiruth (1976). The word "risk" indicates the chance that some particular hazard may actually cause damage. The risk increases (1) with *exposure* to the hazardous event, (2) with the *likelihood* that hazardous event will actually occur, and (3) with possible *consequences* of that event happening. Risk is regarded as a product of these three factors: *exposure* x *likelihood* x *consequence*.

The overall invasion framework is linked to this risk framework (see figure below). *Exposure* expresses how often targets come into contact with *The Organism*, which is the end result of the Introduction, Establishment & Spread stages. *Likelihood* and *consequence*, on the other hand, have a meaning for the Impact stages. E.g., whether the poisonous mushroom *Leucocoprinus birnbaumii* is of human health concern is a question (i) of whether it successfully enters, establishes & spreads, thus getting exposed to human targets, (ii) of the likelihood for it to be eaten, when exposed, and (iii) of the consequence of consumption, when eaten.

Depending on the context, we may use ‘probability’ or ‘frequency’ as interchangeable synonyms for *likelihood*. While likelihood is an *a priori* perspective of ‘probability’, ‘frequency’ is an *a posteriori* approach of the same thing. Following the framework of Mastrandrea et al. (2010) for the consistent treatment of uncertainties, ‘low’, ‘medium’ and ‘high’ likelihood refers to a 0-33%, 33-66% and 66-100% probability, respectively (unless stated otherwise, e.g. question a07).

‘Severity’ or ‘magnitude’ may be used as synonyms for *consequence*.

Questions within the Introduction, Spread and Establishment modules were also informed by the framework of Kinney & Wiruth (1976), though for simplicity we used a more condensed two-component formulation in these modules: i.e., *likelihood* (now incorporating exposure) and *consequence*.

Introduction

In the Introduction module, *consequence* is regarded as a binary event (entry into *The Area*'s wild, or not). Therefore, it is sufficient to ask for the *likelihood* of an entry in these questions.

Establishment

In the Establishment module, *consequence* is regarded as a binary event (establishment in *The Area*'s wild, or not). Therefore, it is sufficient to ask for the *likelihood* of successful establishment.

Spread

In the Spread module, *likelihood* refers to the frequency of *The Organism* to engage in a specific dispersal mode, while *consequence* refers to the distance traveled by that dispersal mode. For natural dispersal, such *likelihood* is assumed to be 1 (on a yearly basis), so only *consequence* (distance) is asked for in that question. On the contrary, for human-mediated dispersal, it is assumed that great distances are readily traveled (i.e. *consequence* is maximal), and it is *likelihood* that is asked for.

Impacts

Likelihood and *consequence* have a direct meaning for the overall framework, here. For several criteria, both components need to be asked for (collectively referred to as 'effect' by us). E.g. for hybridization, it is relevant to disentangle the probability of fertilization apart from the product of such fertilization. However, other impacts are nearly certain to occur (e.g. within natural environments: eating and competing), so only *consequence* is asked for.

Given the overall framework (*exposure* x *likelihood* x *consequence*; with *exposure* being the result of the former modules), it is necessary for the Impact questions to operate under the assumption that targets are fully exposed to *The Organism*: i.e. the assumption must be made that *The Organism* has entered *The Area*'s wild, has successfully Established there, and becomes widespread in *The Area*.

The figure below summarizes how the invasion and risk framework become linked, both conceptually and mathematically (see addendum B).

CONCEPTUAL FRAMEWORK

$$\text{INVASION} = f(Introduction; Establishment; Spread; Impact_E; Impact_P; Impact_A; Impact_H; Impact_O)$$
$$\text{RISK} = Exposure \times Likelihood \times Consequence$$

INVASION = RISK ?

$$Exposure \equiv f_1(Introduction; Establishment; Spread) = 'Invasion\ score'$$
$$Likelihood \times Consequence \equiv f_2(Impact_E; Impact_P; Impact_A; Impact_H; Impact_O) = 'Impact\ score'$$

$$\text{RISK} = Exposure \times Likelihood \times Consequence \equiv f_3('Invasion\ score'; 'Impact\ score') = \text{INVASION}$$

MATHEMATICAL FRAMEWORK

f_1 : (weighted) geometric mean or product
f_2 : (weighted) arithmetic mean or maximum
f_3 : product

An overview of conceptual frameworks within *Harmonia*$^+$.

Note that *Harmonia*$^+$ and *Pandora*$^{(+)}$ are risk-screening procedures. Such procedures inherently deal with negative impacts only, and leave positive impacts outside of scope.

Concepts of confidence

The degree of certainty associated with a given answer is scored as a level of confidence, following the framework of Mastrandrea et al. (2010) for the consistent treatment of uncertainties.

Concepts in *Pandora*$^{(+)}$

The assessment of a pathogen's risk in *Pandora*$^{(+)}$ follows the three steps outlined by the World Organisation for Animal Health (OiE 2012b). These are (i) entry, (ii) exposure and (iii) consequence.

Although the concepts are very similar to *Harmonia*$^{+}$, note that we have chosen to use different terminology in order to comply better with the fields of human and animal health.

Addendum B – Mathematical framework

Score aggregation

Within modules

The alternative answers to each question within a module classify as ordinal data (i.e.: low < medium < high). Therefore, the rank of the provided answer is taken, but converted to a [0,1]-scale as to accommodate for different numbers of alternative answers (0 = lowest, 1 = highest). Two possibilities for further calculation are given. The choice should reflect the assessors' objectives and conceptual approach of the invasion process.

Arithmetic mean : the arithmetic mean (average) of the (re-scaled) ranks is taken. This approach allows for questions to be given different weights.

Maximum : the maximum of the (re-scaled) ranks is taken. This approach does not allow for questions to be given different weights.

> Example
>
> Suppose that the answers provided to three questions are 'very low' on a 5-point scale, 'low' on a 5-point scale and 'medium' on a 3-point-scale.
>
> These answers correspond to ranks 1 out of 5, 2 of 5 and 2 of 3, which are re-scaled as (1-1)/(5-1) = 0, (2-1)/(5-1) = 0.25 and (2-1)/(3-1) = 0.50.
>
> Average : the mean of these values = (0+0.25+0.50)/3 = 0.25.
>
> Max : the maximum of these values = 0.50.
>
> Using the average allows for weighting. For instance, if the three questions were assigned weights of 1, 1 and 2, respectively, the weighted arithmetic mean is calculated as (1*0+1*0.25+2*0.50)/(1+1+2) = 0.31.

Please select the method of calculation.

- Introduction score : ○ Arithmetic mean ○ Maximum
- Establishment score : ○ Arithmetic mean ○ Maximum
- Spread score : ○ Arithmetic mean ○ Maximum
- Environmental impact score : ○ Arithmetic mean ○ Maximum
- Plant impact score : ○ Arithmetic mean ○ Maximum
- Animal impact score : ○ Arithmetic mean ○ Maximum
- Human impact score : ○ Arithmetic mean ○ Maximum
- Other impact score : ○ Arithmetic mean ○ Maximum

Among modules

Aggregation of Introduction, Establishment & Spread

Following the framework of Blackburn et al. (2011), an organism is to be considered invasive only when it scores high on the stages of Introduction, Establishment & Spread. Impacts are considered subsidiary issues to the process of invasion.

Several possibilities exist to combine the Introduction score, Establishment score & Spread score.

Geometric mean : the geometric mean of the module scores is taken. This approach allows for modules to be given different weights. Zeros are allowed, which yield a mean of zero.

Product : the product of the module scores is taken. This approach does not allow for questions to be given different weights.

Example

Suppose that the scores for Introduction, Establishment and Spread are 0.500, 0.750 and 0.125, respectively.

Geometric mean : = $(0.500*0.750*0.125)^{1/3}$ = 0.361.

Product : = (0.500*0.750*0.125) = 0.047.

Using the geometric mean allows for weighting. For instance, if the three modules were assigned weights of 1, 1 and 2, respectively, the weighted geometric mean is calculated as $(0.500^{1}*0.750^{1}*0.125^{2})^{1/(1+1+2)}$ = 0.277 .

Please select the method of calculation.

- Invasion score : ○ Geometric mean ○ Product

Aggregation of impacts

The Environmental impact score (EI), Plant impact score (PI), Animal impact score (AI), Human impact score (HI) & Other impact score (OI) can become aggregated in different ways.

Maximum : the maximum of EI, PI, AI, HI and OI is taken. This approach does not allow for different weights to be given.

Arithmetic mean : the arithmetic mean (average) is taken. This approach allows for domains to be given different weights.

Please select the method of calculation.

- Impact score : ○ Maximum ○ Arithmetic mean

Overall risk

The Invasion score (see above) and the Impact score (see above) may become aggregated by taking the product. This yields an ultimate score for the Invasion risk posed by the organism assessed.

Weighting

As exemplified above, the protocol allows for weighting at three different levels.

Within modules

Different questions within the same module can be given different weights, which may affect the calculation of the arithmetic mean. Weights are equal by default.

Example

in the following example, question a08 is considered twice as important as both question a06 and a07 (which themselves are considered equally important). Since weights only have a meaning relative to other questions *within the same module*, the values provided for questions a09-a10 will not make any difference compared to the default values.

Introduction (questions a06-a08) – question a06 : weight 1; question a07 : weight 1; question a08 : weight 2.

Establishment (questions a09-a10) – question a09 : weight 3; question a10 : weight 3.

You can provide the weights by filling in the following table.

Q	Keyword	Weight	Q	Keyword	Weight
Introduction			**Impacts: plant targets**		
a06	natural means		a19	herbivory or parasitism	
a07	unintentional human actions		a20	competition	
a08	intentional human actions		a21	interbreeding	
Establishment			a22	cultivation system	
a09	climate		a23	pathogens or parasites	
a10	habitat		**Impacts: animal targets**		
Spread			a24	predation or parasitism	
a11	natural means		a25	contact	
a12	human actions		a26	pathogens or parasites	
Impacts: environmental targets			**Impacts: human targets**		
a13	predation, parasitism or herbivory		a27	parasitism	
a14	competition		a28	contact	
a15	interbreeding		a29	pathogens or parasites	
a16	pathogens or parasites		**Impacts: other targets**		
a17	abiotic properties		a30	infrastructure	
a18	biotic properties				

Among modules

Aggregation of Introduction, Establishment & Spread

These modules can be given different weights, which may affect the calculation of the geometric mean (see above). Weights are equal by default.

> Example
>
> In the following example, the Spread module is considered twice as important as both the Introduction and Establishment modules (which themselves are considered equally important).
>
> **Introduction –** weight 1. **Establishment –** weight 1. **Spread –** weight 2.

You can provide the weights by filling in the following table.

Module	Weight
A1 **Introduction**	
A2 **Establishment**	
A3 **Spread**	

Aggregation of impacts

These modules can be given different weights, which may affect the calculation of the arithmetic mean (see above). Weights are equal by default.

You can provide the weights by filling in the following table.

Module	Weight
A4a **Impacts: environmental targets**	
A4b **Impacts: plant targets**	
A4c **Impacts: animal targets**	
A4d **Impacts: human targets**	
A4e **Impacts: other targets**	

Score aggregation and weighting options in *Pandora*$^{+}$ and *Pandora* are similar to those in *Harmonia*$^{+}$. Please see above for all underpinnings.

Within modules

Two possibilities for module score calculation are given. The choice should reflect the assessors' objectives and conceptual approach of the invasion process.

Please select the method of calculation.

- Entry score : ○ Arithmetic mean ○ Maximum
- Exposure score : ○ Arithmetic mean ○ Maximum
- Environmental consequence score : ○ Arithmetic mean ○ Maximum
- Plant consequence score : ○ Arithmetic mean ○ Maximum
- Animal consequence score : ○ Arithmetic mean ○ Maximum
- Human consequence score : ○ Arithmetic mean ○ Maximum
- Other consequence score : ○ Arithmetic mean ○ Maximum

You can provide the weights by filling in the following table.

Q	*Keyword*	*Weight*	*Q*	*Keyword*	*Weight*
Endemic diseases - Exposure			**Consequence: animal targets**		
b07	prevalent	*n/a*	b15	individual animals	____
Emerging diseases - Entry			b16	animal populations	____
b08	introduced	*n/a*	**Consequence: human targets**		
Emerging diseases - Exposure			b17	individual humans	____
b09	maintained and spread	____	b18	human population	____
b10	transmitted	____	**Consequence: other targets**		
Consequence: environmental targets			b19	trade and tourism	____
b11	native species individuals	____	b20	public attention and perception	____
b12	native species populations	____			
Consequence: plant targets					
b13	individual plants	____			
b14	individual plants	____			

Among modules

Aggregation of Entry & Exposure

Several possibilities exist to combine the Entry score & Exposure score (for emerging diseases). Please select the method of calculation.

- Entry-Exposure score : ○ Geometric mean ○ Product

You can provide the weights by filling in the following table.

Module	*Weight*
Bem1 **Entry**	_____
Bem2 **Exposure**	_____

Aggregation of consequence

The Environmental consequence score (EC), Plant consequence score (PC), Animal consequence score (AC), Human consequence score (HC) & Other consequence score (OC) can become aggregated in different ways. Please select the method of calculation.

- Consequence score : ○ Maximum ○ Arithmetic mean

You can provide the weights by filling in the following table.

Module		*Weight*
B3a	**Consequence: environmental targets**	_____
B3b	**Consequence: plant targets**	_____
B3c	**Consequence: animal targets**	_____
B3d	**Consequence: human targets**	_____
B3e	**Consequence: other targets**	_____

Overall risk

The Entry-Exposure score (see above) and the Consequence score (see above) may become aggregated by taking the product. This yields an ultimate score for the Invasion risk posed by the organism assessed.

Addendum C – Using the protocol

Note that the *Harmonia*$^+$ and *Pandora*$^+$ schemes can be used in a variety of ways. For instance, an organism may become assessed by one or more assessors, and in the latter case, the objective may be to reach a consensus, or not. Such choices fall outside the scope of this document, but it is to be emphasized that the assessment process needs to become well-considered beforehand.

In any case, there are several decisions with regard to the scheme that also need to be decided beforehand.

- The organisms under assessment (cf. question `a02`).
- The area under assessment (cf. question `a03`).
- The targets of interest (cf. question `a05`).
- The modules to be assessed, depending on the purpose of the assessment. (For instance, one may choose to omit the Introduction module if the species is already established in *The Area*. Or one may include it when the risk of re-introduction is to be taken into account.)
- All choices concerning the score aggregation (cf. addendum B)
- All weights of questions and modules (cf. addendum B)

One might also consider to provide more (specific) guidelines for (i) sources to be used, (ii) confidence scoring, (iii) context (spatial scales and time frames; if needed), (iv) precise cut-off values, *et cetera*.

Make sure that all assessors get sufficiently acquainted with the scheme before undertaking an assessment.

Addendum D – WILDTOOL

WILDTOOL is an electronic tool for risk assessment with dynamic ranking of wildlife-borne pathogens in function of their need for surveillance (Tavernier et al. 2011). These ranks can be used as a proxy to answer questions `a16`, `a26` or `a29` on the effects of pathogens and parasites within the *Harmonia*$^+$ protocol.

WILDTOOL draws on literature and expert data about pathogens, their hosts and occurrences. The current version of WILDTOOL is limited to pathogens originating from wild mammals and birds in Belgium and its regions.

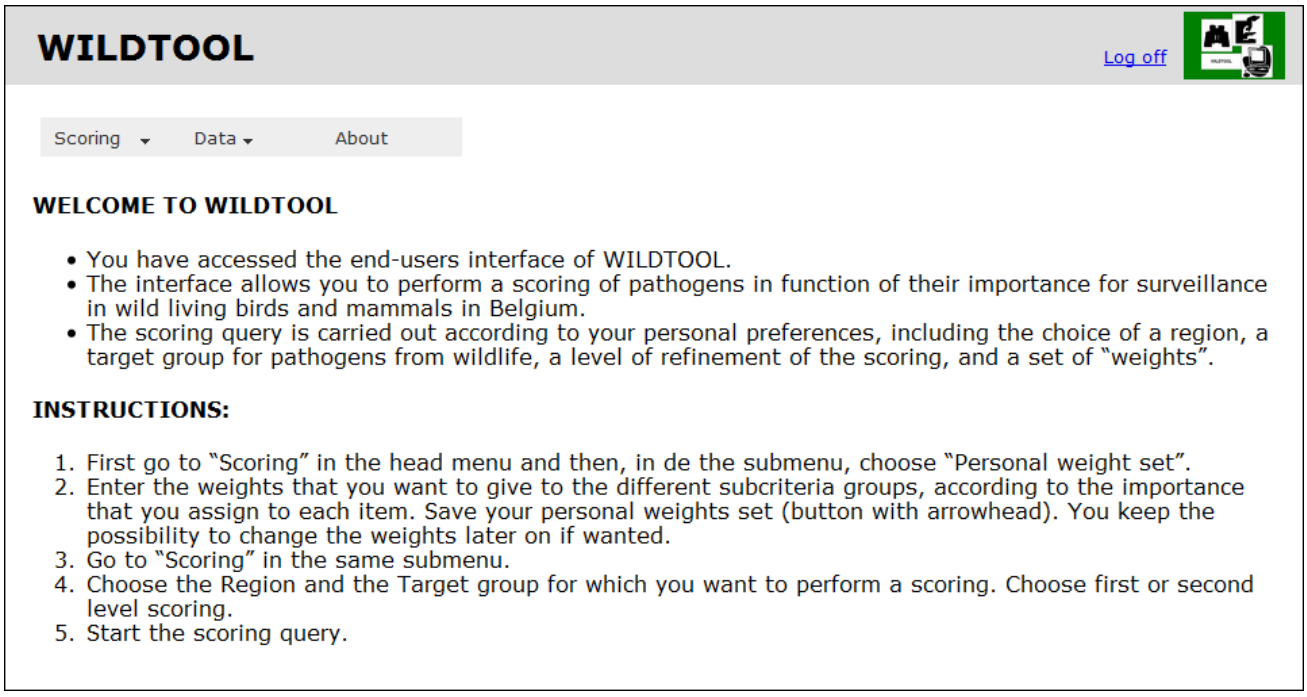
When using WILDTOOL, please respect the following disclaimer:

DISCLAIMER – WILDTOOL merely serves as a source of information, the managers of which cannot be held responsible for any decisions based on this information. If your use of WILDTOOL leads to a communication or publication, please mention that the 'WILDSURV project (RT 07/5) was funded by the Belgian Federal Public Service Health, Food Chain Safety and Environment'.

WILDTOOL can be accessed through http://WILDTOOL.var.fgov.be/. If you have no login yourself, you can use the following details.

- Login : guest
- Password : gast

Instructions for using WILDTOOL are outlined on the opening screen.



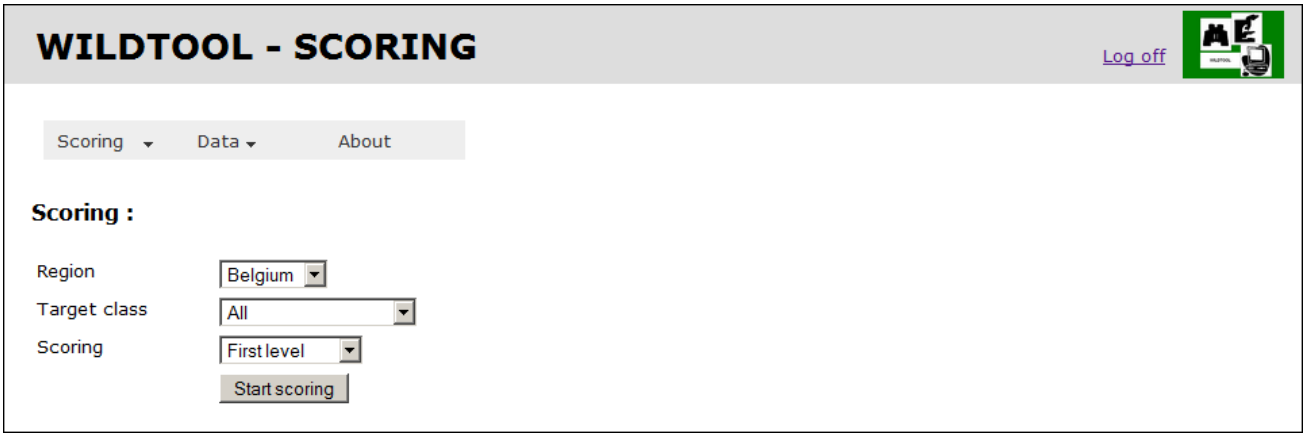
For assessments in function of *Harmonia*$^+$, we suggest to use the weights set out in the appendices of Tavernier et al. (2011).

Case fatality	85
Contagiousness	70
Control possibilities (...)	60
Economic impact (...)	75
Genetic stability	50
Impact on life comfort (...)	65
Influence of occupation (...), production type (...) or way of living (...) in transmission	40

Morbidity	75
Mortality	95
Notifiable disease (...)	20
Possible use as a weapon in bioterrorism	30
Probability of transmission from wildlife to target species	90
Resistance of the agent (...)	50
Risk of introduction	65
Risk of population decrease	90
Risk of secundary transmission from target species (...)	60
Role of extrinsic factors (...) in transmission	45

In the 'Scoring' menu, define the following options before you 'Start scoring'.

- Choose the 'Region' considered most relevant to you.
- The 'Target class' depends on the targets of your interest.
    - For question A16 (environmental targets), choose 'Wildlife' as a target class, and subsequently choose 'All'.
    - For question A26 (animal targets), choose either 'Production animals' or 'Companion animals' according to your main interests.
    - For question A29 (human targets), choose 'Man' as a target class.
- Choose 'First level' for 'Scoring'.



You can check whether a pathogen is included in the system, or learn on additional issues, under the 'Data' menu (PA = pathogen).

Contact details can be found under the 'About' section. Note that anyone is welcomed to contribute or review data for WILDTOOL.

Addendum E – References

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