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# GUIDE FOR RISK ANALYSIS ASSESSING THE IMPACTS OF THE INTRODUCTION OF NON-INDIGENOUS SPECIES

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# 1 Introduction

Risk analysis is an objective, systematic and standardized method of assessing the likelihood of negative consequences occurring due to a proposed action or activity and the likely magnitude of those consequences (Bondad-Reantaso *et al.*, 2008). In the context of NIS management risk analysis is part of decision-making at nearly every stage of the invasion process in order to support cost-effective allocation of resources in a prioritisation process (McGeoch *et al.*, 2016).

Even though a variety of definitions and frameworks for risk analysis have been developed, the core stages and elements are common and discernible and consist of 1) endpoint identification; 2) hazard identification; 3) risk assessment; 4) risk management and 5) risk communication. In the context of alien species prioritization and management, risk analysis can be applied at the species level, on vectors or pathways and their nodes (i.e. the hazards and their characterization) and has a specific geographic scope. The present guide is intended to provide the general principles of risk analysis as applied to non-native species and give examples of the most up-to-date protocols currently used in the Mediterranean and European context.

# 2 Components of Risk Analysis

## 2.1 Endpoint identification

The endpoint of the risk analysis is a critical stage in scoping the context of the assessment and determines the detail of consequence analysis to be applied (Hewitt *et al.*, 2011). The endpoint may be any of the four main stages in the invasion process, i.e., introduction (entry), establishment, spread, impact. Species-based risk assessments tend to be impact driven, whereby the risk assessment examines the effect/impact/harm the alien species will have as the basis of decision making; on the other hand, pathway-focused risk assessments may stop at evaluating introduction and establishment risk, although combined approaches that also consider species impacts are now becoming more common.

## 2.2 Hazard identification

Hazard analysis (a technique often confused with risk assessment) determines the actions, events, substances, environmental conditions, or species that could result in an undesired event, but does not identify the likelihood or the level of consequence. Introduced species, vectors or transport pathways are all examples of hazards (Campbell, 2006). There are many different techniques and approaches to identify hazards in risk analysis which can range from unstructured brainstorming to sophisticated exercises (Lind *et al.*, 2015).

## 2.3 Risk assessment

Risk assessment is the most data intensive and critical part of the process as it identifies the likelihood of the event happening and its consequences. Depending on the endpoint of the assessment the likelihood determination can extend to introduction (entry) only or also establishment and spread. Invasion risk may be evaluated quantitatively (with numerical probabilities or descriptors), qualitatively (with categorical descriptors), semi-quantitatively (by representing quantitative data with categorical descriptors), or using rule sets or decision trees with arbitrary risk thresholds (in which a single criterion determines the outcome) Davidson et al (2017).

### Likelihood determination

Likelihood measures are typically represented as qualitative descriptions (e.g., ranging from very unlikely to very likely), or they can be represented as a probability. Different risk assessment schemes used different likelihood scales; a representative example is displayed in Table 1.

**Table 1**. Likelihoods of Events (taken from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

| Score | Description | Frequency |
|---|---|---|
| Very unlikely | This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur | 1 in 10,000 years |
| Unlikely | This sort of event has occurred somewhere at least once in the last millennium | 1 in 1,000 years |
| Moderately likely | This sort of event has occurred somewhere at least once in the last century | 1 in 100 years |
| Likely | This sort of event has happened on several occasions elsewhere, or on at least once in the last decade | 1 in 10 years |
| Very likely | This sort of event happens continually and would be expected to occur | Once a year |

### Impact evaluation

Consequence measures the impact an alien species may have on the regional core values (Campbell & Hewitt, 2008). Article 5 of the EU IAS Regulation (Regulation (EU) No 1143/2014) (EU) identifies as essential elements on which impacts need to be assessed the following: biodiversity and related ecosystem services, including on native species, protected sites, endangered habitats, as well as human health, safety, and the economy. Consequence matrices (or impact classification schemes) have been developed for different core values that explicitly delineate rankings of impact (consequence) to aid impact assessment, either within the framework of full risk assessment schemes or as stand-alone methods. It is important to assess impact against consequence matrices that are specifically developed for each core value and provide guidance in determining level of impact to enable consistency in scoring across different assessors and sufficient understanding by stakeholders and decision-makers. Indicatively, two such schemes are the Environmental Impact Classification for Alien Taxa (EICAT) (Blackburn *et al.*, 2014; Hawkins *et al.*, 2015) and the Socio-economic impact classification of alien taxa (SEICAT) (Bacher *et al.*, 2018) (Table 2). Katsanevakis *et al.* (2016) produced an adaptation of the EICAT scheme specifically for the marine environment (Annex, Table A1) and used it to map the impact of alien species in the Mediterranean Sea.

**Table 2**. Summary of EICAT and SEICAT impact categories with brief description of the severity of impacts (adapted from Blackburn *et al.*, 2014 and Bacher *et al.*, 2018).

| | **Massive (MV)** | **Major (MR)** | **Moderate (MO)** | **Minor (MN)** | **Minimal concern (MC)** |
|---|---|---|---|---|---|
| EICAT | Causes at least local extinction of native species, and irreversible changes in community composition; even if the alien taxon is removed the system does not recover its original state | Causes at least local extinction of native species and thus changes in community composition, which are reversible if the alien taxon is removed | Causes population declines in native species, but no changes in community composition due to local extinction of one or more native species | Causes reductions in individual fitness, but no declines in native population sizes. | No effect on fitness of individuals of native species |
| SEICAT | Local disappearance of an activity from a local community, irreversible for at least a decade ("regime shift") | Local disappearance of an activity from at least part of the area invaded by the alien taxon, likely to be reversible within a decade after removal or control of the alien taxon | Changes in activity size, fewer people participating in an activity, but the activity is still carried out | Difficult for people to participate in their normal activities, but no changes in activity size | Unlikely to have caused deleterious impacts on individual people's wellbeing |

## Overall risk determination

There is no single correct way to combine individual scores to arrive at a final risk score for an identified hazard. Typically, likelihood and consequence scores are multiplied to produce the overall risk score and then a risk matrix is used to determine the level of risk (Figure 1).

| | | **Likelihood** | | | |
|---|---|---|---|---|---|
| | | **Remote (1)** | **Unlikely (2)** | **Possible (3)** | **Likely (4)** |
| **Consequence** | **Minimal (1)** | 1 | 2 | 3 | 4 |
| | **Moderate (2)** | 2 | 4 | 6 | 8 |
| | **High (3)** | 3 | 6 | 9 | 12 |
| | **Major (4)** | 4 | 8 | 12 | 16 |

| **Risk Category / Level** |
|---|
| 1 Negligible |
| 2 Low |
| 3 Moderate |
| 4 High |
| 5 Severe |

**Figure 1. Standard Consequence — Likelihood Risk Matrix (from Webster *et al.*, 2018).**

Nevertheless, this is not always the case and it ultimately depends on the scope of the assessment and the chosen methodologies and scoring schemes, keeping in mind that not all steps along the invasion process are necessarily equal for the purposes of a specific assessment.

### Assessment of uncertainty

This step occurs throughout the risk assessment process. Regardless of the method used, evaluations will have uncertainty surrounding the outcomes. Uncertainties in NIS risk assessment can arise from insufficient data on species, lack of direct evidence concerning pathways of introduction for most species, where inference is used instead (Ojaveer *et al.*, 2018), limited strength of evidence regarding species impacts, where empirical knowledge or non-experimental correlations are often all assessors can rely on (Katsanevakis *et al.*, 2016), and an incomplete understanding of the complex biological and physical recipient systems hampering predictions. Some measure of uncertainty (confidence score) is typically assigned to both likelihood and consequence scores, without necessarily being formally used in the overall scoring (but see Katsanevakis *et al.*, 2016; Tsiamis *et al.*, 2020). Nevertheless, confidence scores can prove useful in guiding discussion during consensus building approaches and are considered crucial in communicating the outcome of the risk assessment to a wider scientific or public audience (Roy *et al.*, 2018).

## 2.4 Risk management

Risk management of IAS involves the evaluation and selection of options to reduce or mitigate the risks of introduction and spread of an invasive alien species (Roy *et al.*, 2014). Risk management is an integral part of the risk analysis framework and it is increasingly being a part of the prioritization and decision-making procedure (Kumschick *et al.*, 2020; Tsiamis *et al.*, 2020; Robertson *et al.*, 2021; CBD, 2022).

## 2.5 Risk communication

Risk communication takes place throughout the risk analysis process. Ideally, stakeholders should be engaged from early on in the process as they can provide valuable input that can help inform the analysis (see Table 3). Furthermore, risk communication is important to provide stakeholders with sufficient information to understand the recommendations, comment on the feasibility of recommended management and prepare for implementation (Lind *et al.*, 2015; Kumschick *et al.*, 2020).

Risk communication seeks to reconcile the views of all interested parties in order to achieve a common understanding of the risks posed by invasive alien species, develop credible risk management options and consistent regulations, and promote awareness of issues concerning invasive alien species (CBD, 2022)

**Table 3.** Example of an approach for a risk communication strategy, adapted from Lind *et al.* (2015)

| What | Who | When | How |
|---|---|---|---|
| Informing proposal initiator of the conduct of a risk analysis | Competent authorities | Initial proposal for introduction | Government policy briefs or fact sheets |
| Obtaining initial stakeholder input on valued components of the system and acceptable level of risk | All affected stakeholders | After boundaries and objectives have been defined but before the risk assessment has been conducted | Targeted letters to major stakeholders; stakeholders register as an interested or affected party, followed by workshop or meeting |
| Specialist scientific input from outside RA team | Scientific experts and scientific community | During and after completion of risk assessment stage, before final decision or recommendation is made | Peer review; symposia or workshop meeting |

| | | | |
|---|---|---|---|
| Communicate the results of the risk assessment and risk management and explain recommendations for management and regulation | Competent authorities<br><br>All affected stakeholders | After completion of risk assessment stage | Joint authorities / stakeholder meeting<br><br>Community event |

# 3 Types of Risk Assessment

Before going any further into this Guide, it is important to note the key significance of using a unified system of pathway classification, as it enables a comparison across countries and regions and ensures transparency in the process (WGIAS, 2018); the Convention for Biological Diversity classification for pathways (CBD, 2014a) is recommended at the regional level. This document will adopt this recommendation and use the definitions adopted by the CBD, which identifies six principal pathway categories (for a full pathway list see Annex Table A2).

*Related to transport of a **commodity**:*

(1) **Release** in nature refers to the intentional introduction of live alien organisms for the purpose of human use in the natural environment.

2) **Escape** refers to the movement of (potentially) invasive alien species from confinement (e.g., in zoos; aquaria; botanic gardens; agriculture; horticulture; aquaculture and mariculture facilities; scientific research or breeding programmes; or from keeping as pets) into the natural environment.

(3) Transport–**Contaminant** refers to the unintentional movement of live organisms as contaminants of a commodity that is intentionally transferred through e.g., international trade.

*Related to a transport **vector**:* (4) Transport–**Stowaway** refers to the moving of live organisms attached to transporting vessels and associated equipment and media. The physical means of transport-stowaway include various conveyances, ballast water and sediments, biofouling of ships, boats, offshore oil and gas platforms, etc.

*Related to **spread from a neighbouring region:*** (5) **Corridor** refers to movement of alien organisms into a new region following the construction of transport infrastructures in whose absence spread would not have been possible.

(6) **Unaided** refers to the secondary *natural* dispersal of invasive alien species that have been introduced by means of any of the foregoing pathways.

Another term commonly used in invasion literature is the vector, i.e., the physical means or transfer mechanism by which species are transported from one geographic region to another. The term vector has been used to encompass different, and at times disparate, groups of pathways (sensu CBD – Annex 1), more conveniently related to human activities, e.g., shipping (which contains a multitude of pathways), aquaculture (including both escape of the intentionally introduced commodity and contaminants of the commodity), aquarium trade (encompassing both intentional release from private aquaria and accidental escape from large private/public aquaria as well as breeding facilities) .

Thus, in order to avoid ambiguities and confusion related to terminology, particularly the terms vector and pathways risk analysis (as used in older literature), this guide follows the framework established by

McGeoch *et al.* (2016) for risk assessment and prioritisation, focusing on 3 components: species, pathways and sites (Figure 2).

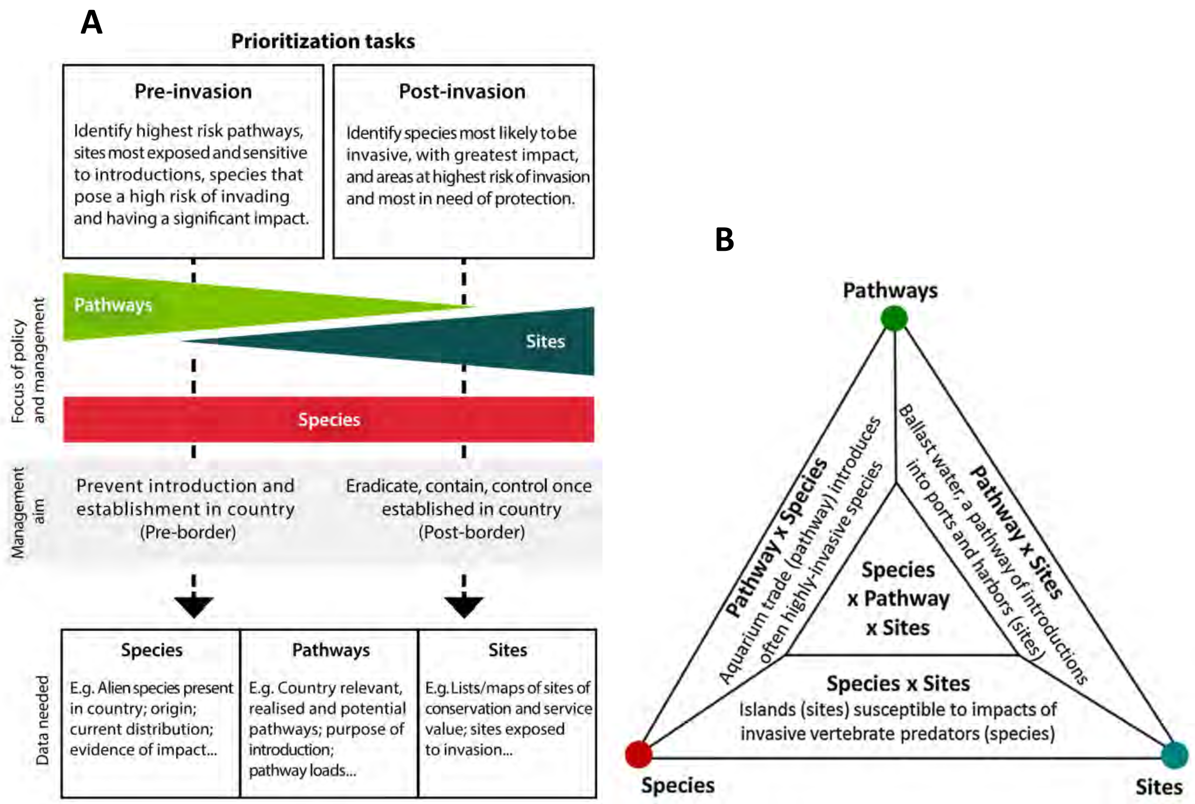


**Figure 2. A) Stages in the invasion process where risk analysis can be applied, indicating possible RA objectives pre- and post- invasion, management aims and data needs; B) The three components where risk analysis of biological invasions can be applied with examples of their combinations. An example of a Species x Pathway x Sites risk assessment being species associated with hull fouling (pathway) into ports, marinas and fishing harbours (sites). Adapted from McGeoch *et al.* (2016)**

Any of these components can be assessed separately or in combination (as displayed in Figure 3b); moreover, risk assessments can consider one or multiple elements, i.e., one or multiple species/pathways/sites. In practice, pairwise risk assessment and prioritization is more common as it will be seen from the examples below (e.g., Pathways x Species in NOBANIS, 2015 or Sites x Species considering a single Pathway in the case of ballast water, hull fouling). Sites may be prioritised based on their vulnerability to invasion (susceptible sites, e.g. harbours, ports, marinas, aquaculture areas) or on their conservation importance (sensitive sites, e.g. protected areas).

## 3.1 Species-based Risk Assessment

### 3.1.1 *Minimum standards*

Species-based risk assessment is the most common and best-developed among the three components, with by far the largest number of existing frameworks and protocols, ranging from screening of future threats (horizon scanning) to impact assessment and full risk assessment and, depending on the assessment, covering a range of different groups of species / organisms. The endpoint of species-based risk assessments is the impact of the species. In order to arrive at a set of minimum standards considered as essential to achieve overarching assessment of the risk of an alien species regardless of specific methodology, Roy *et al.* (2014; 2017) employed consensus methods among a team of experts to distil the critical components of risk assessments included in a large number of protocols. These minimum standards are outlined below.

1. Description (Taxonomy, invasion history, distribution range (native and introduced), geographic scope, socio-economic benefits)
2. Includes the likelihood of entry, establishment, spread and magnitude of impact
3. Includes description of the actual and potential distribution, spread and magnitude of impact
4. Has the capacity to assess multiple pathways of entry and spread in the assessment, both intentional and unintentional
5. Can broadly assess environmental impact with respect to biodiversity and ecosystem patterns and processes
6. Can broadly assess environmental impact with respect to ecosystem services
7. Broadly assesses adverse socio-economic impact
8. Includes status (threatened or protected) of species or habitat under threat
9. Includes possible effects of climate change in the foreseeable future
10. Can be completed even when there is a lack of data or associated information
11. Documents information sources
12. Provides a summary of the different components of the assessment in a consistent and interpretable form and an overall summary
13. Includes uncertainty
14. Includes quality assurance

### 3.1.2 *Species-specific and Organism Risk Assessment*

Species-specific risk analysis and risk assessment frameworks and protocols have been developed to address specific hazards and risks posed by certain sectors or in the framework of specific Regulations e.g., Import Health Standards used to assess risk associated with intentional introductions of goods, including live aquatic species (Campbell, 2006). Of highest relevance to risk analysis of marine NIS is the system of permits and risk assessment introduced with Council Regulation (EC) No 708/2007 'concerning use of alien and locally absent species in aquaculture', modelled on the ICES Code of Practice on the Introductions and Transfers of Marine Organisms (ICES, 2005). According to the Regulation, all aquaculture operators who intend to introduce an alien species, or translocate a locally absent species, must first apply for a permit from the competent authority of the Member State where the transfer will take place. The Regulation specifies the information to be provided by the applicant and the basic structure of the risk assessment (both for target and non-target species) that the applicant must perform to accompany the application. It is important to re-iterate that there are two major pathways of introducing exotic organisms through aquaculture activities: intentional introduction of exotic species as culture organisms that may eventually enter the natural environment (usually via accidental escape) and unintentional introduction of exotic organisms associated with imported culture organisms as contaminants to the culture species consignment (Leung & Dudgeon, 2008). Thus, it is important to evaluate both the escape risks in relation to the aquaculture system and facilities and the contamination risks of the transported organisms, as well as the impacts of both target and non-target species.

Hazard identification in aquaculture imports is not restricted to alien non-target species but pertains also to the environmental impacts and genetic risks of escaped culture animals and the introduction of infectious agents, like pathogens and parasites. Therefore, risk assessment for the intentional introduction and/or translocation of culture species is a complicated process that needs to consider multiple elements.

The permit application under Council Regulation (EC) No 708/2007 should contain information on:

- The purpose and objectives of the introduction;

- The stage(s) in the life cycle proposed for introduction, the native range, the donor location, and the target area(s) of release;

- A review of the biology and ecology of the species as these pertain to the introduction (such as the physical, chemical, and biological requirements for reproduction and growth, and natural and human-mediated dispersal mechanisms);

- Any links of the species with known non-target species and their distribution in the area of origin of the stock to be introduced

- Information on the receiving environment;

- The ecological, genetic, and disease impacts and relationships of the proposed introduction in its natural range and donor location as well as in the release site;

- Monitoring plans of the proposed introduction and any potential impacts

- Management plan, with information on measures taken to ensure that no other species (non-target species) accompany the shipment and a contingency plan for the removal of species in case of an accidental escape or release

The risk assessment under Article 9 of Council Regulation (EC) No 708/2007 requires the assessment of the likelihood of establishment and spread of the target species beyond its intended area of introduction and the evaluation of both the ecological and genetic impacts of such an escape; moreover, similar risks need to be assessed for possible accompanying non-target species.

In response to these requirements, Copp *et al.* (2016) developed the European Non-Native Species in Aquaculture Risk Assessment Scheme (ENSARS), a modular decision support tool, consisting of eight modules. ENSARS provides protocols for evaluating the risks of introduction to the environment (including unintentional release of target and non-target organisms from the facility, during transport and at destination use), establishment, dispersal and impacts of the organism, including infectious agents and socio-economic risks to ecosystem services (Figure 3).

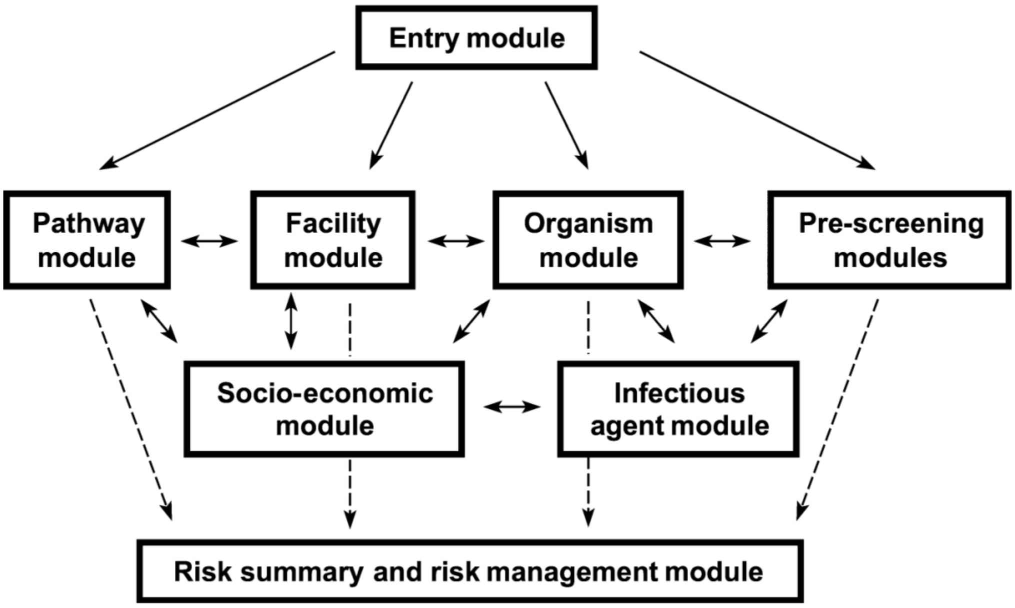


**Figure 3. Schematic diagram of the European Non-native Species Risk Analysis Scheme (ENSARS) regarding the use of alien and locally absent species in aquaculture, which consists of seven risk assessment modules (upper boxes) and a Risk Summary and Risk Management Module (bottom box) into which the risk assessment outcomes feed information (from Copp *et al*., 2016).**

Another European legislative instrument that requires full species risk assessment is Regulation (EU) No 1143/2014 for Invasive Alien Species (IAS Regulation), which has set out very detailed specifications on the structure and content of RA required with Commission Delegated Regulation (EU) 2018/968. In response, a risk assessment template has been developed under a European Commission funded project "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention" (EC DG-ENV,2018), which is predominantly being used to risk assess species proposed for inclusion in the IAS Regulation Union list (i.e., a list of invasive alien species of Union concern for which dedicated management measures are required across the Union).

The template (EU template for Risk Assessment) is organised in 5 sections:

(1) Organism information and screening: organism taxonomy, identification, distribution and invasiveness outside its native range (corresponding to hazard identification)
(2) Probability of Introduction and Entry: qualitative assessment of all potential pathways for the species
(3) Probability of Establishment: qualitative assessment of environmental suitability, propagule pressure, reproductive biology and population dynamics, complemented by Species Distribution Models
(4) Probability of Spread: qualitative assessment of all potential pathways of spread (including natural dispersal), their importance and rate of spread
(5) Magnitude of impact: qualitative assessment employing modified UK Non-native Organism Risk Assessment Scheme scoring schemes (GBNNRA) of the following elements:
- Biodiversity and ecosystem impacts, including impacts on species & areas of conservation concern
- Ecosystem Services impacts, following the CICES V5.1 Classification
- Economic impacts
- Social and human health impacts

It is worth noting that the conclusion of the risk assessment (overall risk) does not employ some fixed formulation or matrix to combine likelihood and impact scores but relies on expert judgement of the assessing team to combine the elements of the assessment, recognising that not all assessment scores along the invasion continuum (introduction, entry, establishment, spread, impact) are necessarily equal. All questions of the risk assessment are accompanied by a confidence score, which is propagated to the section scores and overall risk based on expert judgement as described above. The scoring schemes for the template can be found in Annex Tables A4-A7 and the template is available at circabc.europa.eu/RA Template

### 3.1.3 *Risk screening for future threats & Prioritisation - Horizon scanning*

Horizon scanning is "a technique for detecting early signs of potentially important developments through a systematic examination of potential threats and opportunities (EEA, 2023). Expert workshops including consensus approaches have been extensively employed as an approach to horizon scanning within environmental science. Roy *et al.* (2015; 2018) employed such a systematic consensus horizon scanning procedure to derive a ranked list of potential IAS in Europe for terrestrial, freshwater and marine realms. In broad strokes, the approach is as follows:

1. teams of experts assess species' likelihood to arrive (A), establish (B), spread (C) and have an impact on biodiversity (D) in the region over the next decade, using a likelihood scale of 1 = very low to 5 = very high and an environmental impact scoring scheme based on EICAT (Blackburn *et al.*, 2014). The product of the 4 scores (A*B*C*D) is the overall risk score of each species.
2. Experts within groups are then asked to discuss and if necessary moderate their scores to arrive at a consensus, high-ranking list per broad group.
3. In a final round of review and moderation among all experts, group scores are compared to those of other groups, to increase the alignment of results among groups and thus produce the final ranked list.

Tsiamis *et al.* (2020) employed a similar consensus methodology, dividing marine organisms into seven thematic taxonomic groups: (1) microalgae and foraminiferans; (2) macrophytes; (3) polychaetes; (4) molluscs; (5) arthropods and ascidians; (6) fishes; and (7) bryozoans, cnidarians, and remaining taxonomic groups, and assigning respective taxonomic experts to each group to provide the initial species lists and scoring. Compiling the initial species lists (i.e., hazard identification) can be based on worldwide/regional alien species databases (see Annex Table A3 for an indicative list), complemented by Atlases (CIESM Atlas of exotic species in the Mediterranean), current literature and expert knowledge; these are then filtered by a set of criteria determined by the scope of the assessment. In the Tsiamis *et al.* (2020) study the criteria were rather broad, consisting of the following conditions:

- alien species that are absent from or with limited distribution in EU Member States marine areas
- species likely to arrive or further spread across EU marine waters within the next 10 years
- species that are already or would be alien across the whole EU marine waters
- species with a potential impact on the native species and habitats of EU marine waters

The endpoint of the assessment was impact and the scoring criteria for likelihood and consequence were specifically adapted for marine species in EU waters (Table 4). Each score was assigned a confidence level (high, medium, low) and the score of each parameter of each species was subsequently weighted based on the confidence level, following the principle that higher confidence gives a higher weighted score. A discussion on the overall list was carried out, involving all workshop participants, in order to better harmonize the assessments presented by each group and reduce as much as possible the bias of single groups before arriving at the final consensus ranked list.

Among the plethora of risk assessment protocols available, it is worth mentioning the Aquatic Species Invasiveness Screening Kit (AS-ISK) tool (Copp *et al.*, 2016), which has ensured consistency with the minimum standards (Roy *et al.*, 2017) and has been extensively used for prioritisation of both freshwater and marine species (Stasolla *et al.*, 2020; Copp *et al.*, 2021; Vilizzi *et al.*, 2021).

**Table 4**. Overall basis for scoring the likelihood of arrival, establishment, spread, and potential impact of each marine horizon scanning species in EU marine waters (from Tsiamis *et al.*, 2020).

| | |
|---|---|
| **Likelihood of arrival** based on a consideration of previous invasion history of the species in other marine regions worldwide and its known introduction pathway(s). | |
| Score 4 | Species already introduced in EU marine waters, or<br>species introduced in European seas, but still outside EU marine waters (e.g. North Africa Mediterranean coasts) which are expected to reach EU marine waters within the next 10 years; |
| Score 3 | Species absent from European seas but with an invasive history in two or more marine realms worldwide, or<br>species native in the Red Sea which are expected to reach EU marine waters within the next 10 years through the Suez Canal (or through shipping via the Suez Canal); |
| Score 2 | Species absent from European seas, with an invasive history in one marine realm worldwide only, known to be associated with introduction pathways that commonly apply for primary introductions in the European seas (shipping, aquaculture, aquarium trade); |
| Score 1 | Species absent from European seas, with no invasive history or an invasion history in one marine realm worldwide only, associated with uncommon or unknown pathways of introduction. |
| **Likelihood of establishment**, based on the life-history characteristics of the species, its reproductive cycle, and its tolerance to a broad range of environmental conditions. It was also considered whether the bioclimatic conditions and habitat types of the native distribution range of the species are comparable to those of the EU marine waters. | |
| Score 4 | Species with broad ecological tolerance and high ability of adaptation to new habitats and environmental conditions, being native in marine realms with similar bioclimatic conditions and habitat types compared to the EU marine waters;<br>species already established in EU marine waters; |
| Score 3 | Species absent from European seas but with an invasive history in two or more marine realms worldwide, or<br>species native in the Red Sea which are expected to reach EU marine waters within the next 10 years through the Suez Canal (or through shipping via the Suez Canal); |
| Score 2 | Species with narrow ecological tolerance and low ability of adaptation to new habitats and environmental conditions, being native in marine realms with similar bioclimatic conditions and habitat types compared to the EU marine waters; |
| Score 1 | Species with narrow ecological tolerance and low ability of adaptation to new habitats and environmental conditions, being native in marine realms with different bioclimatic conditions and habitat types compared to the EU marine waters |
| **Likelihood of spread**, primarily determined by the dispersal capacity of the species, associated with the reproductive capacity and the ability to achieve a population size/density that would prompt dispersal, and its history and speed of spread in other regions. Dispersal through secondary anthropogenic pathways (e.g. fouling, fishing nets) was also considered. | |
| Score 4 | Species with high dispersal capacity, commonly associated with secondary pathways of introduction; |
| Score 3 | Species with high dispersal capacity, but not known to be associated with secondary pathways of introduction; |
| Score 2 | Species with low dispersal capacity, commonly associated with secondary pathways of introduction; |
| Score 1 | Species with low dispersal capacity, but not known to be associated with secondary pathways of introduction. |
| **Potential impact**, based on the known history of environmental impact in European seas or in other | |

| | |
|---|---|
| marine regions of the world. | |
| Score 4 | Species that would cause large or massive losses on the population of at least one native species (75–100% of the population is lost), and/or<br>Species that would cause large or massive alterations or losses of at least one native habitat type (75–100% of the habitat is altered or lost); |
| Score 3 | Species that would cause considerable losses on the population of at least one native species (50–75% of the population is lost), and/or species that would cause considerable alterations or losses of at least one native habitat type (50–75% of the habitat is altered or lost); |
| Score 2 | Species that would cause some losses on the population of at least one native species (25–50% of the population is lost), and/or species that would cause some alterations or losses of at least one native habitat type (25–50% of the habitat is altered or lost); |
| Score 1 | Species that would cause inconsequential losses on the population of at least one native species (< 25% of the population is lost), and/or species that would cause inconsequential alterations or losses of at least one native habitat type (< 25% of the habitat is altered or lost). |

### 3.1.4 *Risk prioritization taking into account Efficacy of Management*

Multi-criteria decision-making approaches can be used when applying risk analysis, to support risk-based prioritization; such methods should be in a form compatible and complementary to existing approaches to risk assessment (CBD, 2022). Invasive alien species prioritized by actual or potential impacts using such rapid methods can then be considered in more detail to ensure that management, based on clear objectives, is indeed cost-effective and feasible. Management of NIS involves multiple actions at different stages in the invasion process (Robertson *et al.* 2020) and all these actions can be evaluated in terms of their effectiveness, practicality, feasibility, likelihood of success, cost, public acceptability (e.g., see Booy *et al.*, 2017 – Table 5).

**Table 5**. Assessment criteria and response scores for the evaluation of eradication feasibility; 1 is least favorable and 5 the most (Booy *et al.*, 2017)

| **Criteria** | **Response score** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| **Effectiveness** | Very ineffective | Ineffective | Moderate effectiveness | Effective | Very effective |
| **Practicality** | Very impractical | Impractical | Moderate practicality | Practical | Very practical |
| **Cost** | >£10 M | £1–10 M | £200 k–1 M | £50–200 k | <£50 k |
| **Negative impact** | Massive | Major | Moderate | Minor | Minimal |
| **Acceptability** | Very unacceptable | Unacceptable | Moderate acceptability | Acceptable | Very acceptable |
| **Window of opportunity** | <2 months | 2 months– 1 year | 1–3 years | 4–10 years | >10 years |
| **Likelihood of reinvasion** | Very likely | Likely | Moderate likelihood | Unlikely | Very unlikely |
| **Conclusion (overall feasibility of eradication)** | Very low | Low | Medium | High | Very high |

In the marine environment, the feasibility of management has been applied sequentially as a second step to species Horizon Scanning for the top-priority HS species of EU waters (Tsiamis *et al.*, 2020), taking into consideration the following criteria:

(1) External morphology/appearance, the ease of species identification in the field;
(2) Mobility and mode of natural dispersal;
(3) Management potential of the primary introduction pathway(s) into Europe (for species that are not present yet in any European sea);
(4) Management potential of the secondary pathway(s) of dispersal to or across EU countries (from already established European populations); and
(5) cost-efficiency of eradication or mitigation of the population, bearing in mind the species distribution status and natural dispersal capabilities.

Alternatively, risk assessment and risk management scores can be combined with a risk matrix argued to improve the cost-effectiveness of management (Booy *et al.*, 2020; Robertson *et al.*, 2021). In these studies, there was no correlation between eradication feasibility and risk assessment scores, indicating that risk management criteria evaluate information that is different to risk assessment.

It should be emphasized here that assessment and prioritization of management actions does not pertain only to eradication but can be equally applied to management options for established populations. For example, a similar set of criteria as those applied by Booy *et al.* (2017) is employed to complete a Risk Management Note accompanying full species risk assessments proposed for inclusion in the Union List of the EU IAS Regulation (EC DG-ENV, 2018). Assessors are asked to describe a potential suite of management measures (eradication, control, containment) by considering the following questions:

- How effective has this approach proven to be in the past or in an analogous situation?
- How publically acceptable is the approach likely to be?
- Over what period of time would this approach need to be applied to be effective?
- What is the direct cost of implementing this approach?
- How likely are the methods used in the approach to be available?
- How likely is it that relevant licences or other approvals to undertake the approach would be difficult to obtain?
- How likely is it that health and safety issues would prevent the use of this approach?
- How significant is the environmental harm caused by this approach?
- How significant is the economic harm caused by this approach?
- How significant is the social harm caused by this approach?
- How likely is it that the approach will be criticised on welfare grounds?
- How likely is it that the approach with be acceptable to other stakeholders?

Another example of a risk analysis framework which integrates risk management considerations in its risk assessment structure and further provides a decision-making tree is that of “Risk Analysis for Alien Taxa (RAAT)” developed for South Africa (Kumschick *et al.*, 2020 – see Annex Table A8 and Figure A1), where the ease of management is assessed on the basis of several criteria, including a) accessibility of populations, b) whether detectability is time-dependent, c) time to reproduction, and d) propagule persistence of the Taxon.

## 3.2 Pathway-based Risk Assessment and Prioritisation

Pathway risk assessment seldom takes place separately but usually considers species simultaneously and may also consider sites. Moreover, it can consider multiple pathways when it aims at pathway prioritisation or focus on a single pathway to prioritise sites or species. Pathway risk analysis and prioritisation is a requirement of the EU IAS Regulation, under Article 13, alongside the elaboration of Pathway Action Plans to address the priority pathways that require action to prevent the unintentional introduction and spread of IAS into the Union. Guidelines for this process were prepared by the Working Group on Invasive Alien Species (WGIAS, 2018) and they will constitute the primary source for this section, followed by typical examples of pathway risk analysis.

The CBD (2014b) recommends that an analysis of a pathway of introduction and spread should include the following;

- An assessment of the impact of the IAS
- Identification of the key locations to apply prevention and management measures
- Identification of causal chains between a pathway and levels of invasion in the relevant area
- An assessment of the diversity, abundance, and survivorship of IAS
- A description of how the pathway is changing spatially (for example, with the establishment of new - trade routes or new trade partners) and temporally (rate and magnitude of introductions), as well as changes in the species introduced through the pathway
- A distinction between pathways where introductions carry high impacts from those with minor impacts
- Present means to assess and implement means to mitigate the problems posed by the pathways
- Identification of new and emerging pathways (through horizon scanning).

In practice, much of this data and information is rarely available and assessments have to resort to available information and suitable proxies while clearly indicating uncertainties. For many species, there is insufficient scientific data available and expert opinion must be used rather than evidence in order to infer pathways.

Prioritization of pathways uses information on the full suite of vectors and routes by which alien propagules are introduced, and should ideally include the propagule loads of such pathways (Hulme *et al.* 2008; Essl *et al.* 2015). Typically, there are two ways in which a particular pathway may be prioritized: (1) according to the number of different invasive species that are introduced and spread by the pathways, and (2) based on the severity of the impact caused by the invasive species introduced and spread by the pathway (Essl *et al.* 2015).

### 3.2.1 *Data needs*

**An indication of propagule pressure**, e.g., estimated volume or number of specimens or frequency of passage through the pathway. This information is usually only available for specific pathways with strict reporting requirements. However, the volume of alien species that a particular pathway carry can be approximated by considering transport routes or import statistics for various commodities that are associated with alien species (for example as a contaminant of a commodity) (Essl 2015).

**Number of alien species introduced through a pathway.** Until now the most common method for prioritising pathways of introduction of alien species. Drawbacks include a lack of knowledge and uncertainties about the pathway of introduction of a species (Essl et al. 2015), the existence of multiple pathways of introduction for a species, and the importance and relevance of pathways may change with time. Furthermore, the most frequently used pathways for alien species do not always contribute the IAS with the greatest impact on biodiversity (Madsen *et al.* 2014, Nobanis 2015).

**Invasiveness of species introduced through a pathway**. Prioritising pathways by species impacts uses species risk assessment/prioritisation information to determine which pathways are associated with species with the greatest magnitude of impact.

**Temporal development of pathways.** Analysing trends in pathway frequency is important to know which pathways are active and which pathways may develop over time with anthropogenic changes or climate change; this could be significant for pathway management.

**BOX 1.** From WGIAS, 2018

**Recommendations for Prioritisation of Pathways**

1. Methods for prioritising pathways are being rapidly developed. At present, the most useful method is probably a combination of the methods for determining impact of IAS and quantification of pathways (volume of IAS, frequency of introductions, characteristics of the receiving environment, etc.) developed in cooperation with the CBD and described by Essl *et al*. (2015) and Blackburn *et al*. (2014). These methods ensure a standardization of the prioritisation results that can be compared with other countries and regions. Unfortunately, this method requires a large amount of data that is presently not available for the majority of pathways.

2. Using simpler methods and proxy information for missing data is perhaps the reality in prioritising most pathways. Recommended methods are those that consider the frequency of IAS using a pathway weighed together with the actual and potential impacts of the IAS using the pathway, similar to the approach of Madsen *et al*. (2014) and Nobanis (2015). Including conservation values of managing the pathways and feasibility of management would add a greater value to the prioritisation results, but this approach requires further testing.

3. It is important to consider both the volume of the alien species transported through a pathway, which includes the number of individuals transported through that pathway and the number of introduction events, as well as the actual impacts of the species. Potential impacts of the species should also be considered, as well as impacts on ecosystem services.

### 3.2.2 Examples

**Multiple Pathways x Species simultaneous prioritisation**

Invasive Alien Species Pathway Analysis and Horizon Scanning for Countries in Northern Europe (NOBANIS, 2015)

The NOBANIS study contains a pathway analysis that examines the pathways of introduction for alien species into the Nordic region and a species horizon scanning that identifies species that may potentially become invasive in the participating countries or territories. Pathway analysis considered the number of species per pathway, the invasiveness of species (based on database information), taxonomic groups and species origins.

For the Horizon Scanning a list of potential *door knocker species* was compiled using:

- The NOBANIS database to search and list invasive or potentially invasive species established in neighbouring countries that are part of the NOBANIS network.
- Data from existing alert lists Denmark, Norway, Germany and Ireland

With a procedure similar to that used by Roy et al (2015) and outlined in previous sections, groups of experts scored species on their probability of arrival, establishment and their impact on biodiversity, human health and socio-economy. Scores were combined in a risk matrix to produce 3 risk categories; high, medium and low risk door knocker species.

The factors considered to rank pathways in the NOBANIS study were: number of alien species that use a pathway, percentage of the alien species using a pathway that are invasive, and the number of IAS identified in the horizon scanning as being 'high risk' and 'medium risk' as well as 'potentially invasive'.

**Single Pathway x Species**

These are studies that are typically referred to in the literature as vector risk analyses and may cover more than one pathway (sensu CBD). A characteristic example is the risk analysis conducted by Grosholz *et al.* (2015) on shellfish culture associated NIS, including both target (escapees) and non-target species (contaminants). Vector risk analyses may take into account some or all of the following elements; a measure of vector strength and estimate of propagule pressure (Annex Table A10), the species associated with the vector/pathway, the likelihood they will be entrained in the pathway in the first place, their survival likelihood in the recipient area, as well as the impacts associated with the transportable taxa (Brancatelli & Zalba, 2018).

**Ballast water**

The most widely established pathway-focused risk assessments have been applied to the management of ballast water and sediments, motivated by the adoption in 2004 and build-up to full implementation by 2024 of the Ballast Water Management Convention (IMO, 2004).

There are three broad risk assessment methods outlined in the G7 Guidelines of the Convention (IMO, 2017) for assessing the risks in relation to granting an exemption from the obligations of the BWMC for a vessel operating between two ports, in accordance with Regulation A-4 of the Convention:

• Environmental matching risk assessment;
• Species' biogeographical risk assessment;
• Species-specific risk assessment.

Environmental matching risk assessment relies on comparing environmental conditions between locations; species' biogeographical risk assessment compares the environmental similarity and species composition in source and destination ports/areas to identify high risk invaders, while species-specific risk assessment evaluates the distribution and characteristics of identified target species. Dependent on the scope of the assessment being performed, the three approaches could be used either individually or in any combination, recognizing that each approach has its limitations.

Environment matching and species' biogeographical risk assessment may be best suited to assessments between biogeographic regions. It is worth highlighting here the appropriate use of scale in environmental matching approaches. To the extent that environmental matching is meant to create a surrogate measure for species tolerance range (Hewitt & Hayes, 2002), working at a large biogeographical scale (e.g., bioregion or province, sensu Spalding *et al.* (2007)) represents better the environmental tolerances of species in their native distribution (Hewitt *et al.*, 2011). On the other hand, if the donor location is restricted to a port, then an artificial limit to the range of environmental values will be derived. Choice of scale as well as the variables employed will of course depend on the scope and purpose of the assessment and the combination of approaches used. Species-specific risk assessment may be best suited to situations where the assessment can be conducted on a limited number of harmful species within a biogeographic region, where environmental conditions (at least temperature) are expected to be more homogeneous and the majority of native species are shared.

**BWMC RA model for the granting of exemptions**

Under article A-4 of the BWMC, a State has the ability to grant exemptions from the obligations of the Convention under certain conditions (e.g. for a vessel operating exclusively between two ports). Harmonised procedures for the uniform implementation of the BWMC have been elaborated by Regional Seas Conventions (HELCOM-OSPAR, 2020; REMPEC/WG.56/5, 2023). These include a standardised procedure for the granting of exemptions in accordance with Regulation A-4 and Guidelines G7 (IMO, 2017), that details a risk analysis approach for the vessel/route in question.

The process requires environmental and biological data collected during port surveys; it combines an environmental matching approach (water salinity difference) as a first screening step with a species-based risk assessment approach, relying on a regional Target Species (TS) list and the presence of target species in either port/location being visited by the vessel. Any previously undocumented species found in the two locations needs to be evaluated against a set of TS selection criteria. Target species lists are dynamic documents that need to be periodically updated as new information emerges and new introductions occur.

Target Species selection criteria are described in detail in Gollasch *et al.* (2020) but are outlined below in brief:

Species found during the port surveys which have not been documented before should be evaluated based on the TS selection criteria. At least **all** following criteria need to be considered:

1. relationship with ballast water as a transport vector, i.e., when the species was already found in a ballast tank or if the life cycle of the species includes a larval phase or planktonic adult which makes a ballast water transport likely;
2. impact on human health, economy and/or environment and its severeness, i.e., does the species may cause unacceptable high impact (TS selection criteria background document); in case the impact is not known, the species will automatically appear as TS;
3. evidence of prior introduction(s), i.e., the species showed its capability to become introduced outside its native range; and
4. current distribution within the native biogeographic region and in other biogeographic regions species prioritisation in the form of a regionally determined list of Target Species

A risk assessment can take different forms. A simple assessment can be undertaken of whether a target species is present in the donor port but not in a recipient port and can be transported through ballast water. However, if considered appropriate, the likelihood of target species surviving each of the following stages may be assessed, including:

1. Uptake – probability of viable stages entering the vessel's ballast water tanks during ballast water uptake operations;
2. Transfer – probability of survival during the voyage;
3. Discharge – probability of viable stages entering the recipient port through ballast water discharge on arrival; and

4. Population establishment – probability of the species establishing a self-maintaining population in the recipient port.

Same Risk Area

The RA process for the granting of exemptions may include considerations of natural dispersal of target species between the two ports with a methodology termed Same Risk Area (Hansen *et al.*, 2018; Stuer-Lauridsen *et al.*, 2018; HELCOM-OSPAR, 2020), i.e., if dispersal modelling indicates that there is a high likelihood of natural dispersal of TS propagules within an area including the two ports, the risk of ballast water transfer may be modified/downgraded.

**Individual Port RAs (GloBallast)**

The principles of the BWMC model can be applied for individual port risk assessments in order to identify high-risk donor ports or regions for the recipient port. During the GloBallast partnership project, a combined environmental matching x biogeographical risk assessment approach, incorporating ballast water discharge data, was applied to a number of pilot ports to exemplify case studies (Clarke *et al.*, 2003; Anil *et al.*, 2004). However, the biogeographic RA approach is very data intensive and quite often NIS data at the bioregional level is missing or incomplete.

**Single Pathway X Sites prioritisation**

A way to circumvent the large data needs of the biogeographical approach is to apply a probabilistic model to identify high-risk invasion routes and invasion hot spots at a global level, combining information on ballast water discharge, ship travel time, port environmental conditions and biogeography of ports, as done by Seebens *et al.* (2013).

The model term which expresses biogeography was the probability that a native species in a donor port is non-native in a recipient port “P(Alien)”. This probability is estimated by biogeographical dissimilarity, which is assumed to increase with geographical distance between ports. The probability P(Alien) accounts for the fact that the likelihood of new introductions increases with the dissimilarity between the donor and recipient communities and ensures that the invasion risks between two closely located ports are negligible which is a natural assumption as the vicinity of a port should contain almost only species that are already present at the port. The probability of establishment was calculated on the basis of port surface water temperature and salinity and the probability of introduction as a function of ballast water volume and travel time. This methodology or less intricate approaches (e.g. see Keller *et al.*, 2011; Faulkner *et al.* 2017, employing only environmental similarity and BW discharge data) could be applied to identify high-risk recipient ports in the Mediterranean, as planned within the framework of the Ballast Water Management Strategy 2022-2027 (UNEP/MAP, REMPEC & IMO, 2021) and the updated NIS Action Plan 2023 (UNEP/MAP SPA/RAC, 2023).

**Hull fouling**

**Single Pathway x Species**

One of the most comprehensive single Pathway x Species risk assessments was conducted by Hewitt *et al.* (2011) in relation to biofouling species in Australia. The assessment addressed biofouling on a number of different vessels (commercial vessels, including merchant vessels and cruise ships; petroleum production and exploratory industry vessels; naval vessels; non-trading vessels which encompass a wide variety of vessel types, including the subcategories of tugs, research vessels, dredges, barges and yachts >25 m or superyachts; fishing vessels and recreational vessels <25m)

Endpoints

This risk assessment focused primarily on the international entry of vessels (introduction endpoint) with less extensive evaluations of risk of establishment and spread, which were considered equal for all species at the pan-Australian scale (Figure 4).

Hazard Identification

Hazards were defined as non-indigenous marine species that:

- are associated with biofouling
- have potential to transcend the Australian quarantine border
- have demonstrated or inferred potential to cause a negative impact

Starting from a database of global marine and estuarine introductions developed in Hewitt & Campbell (2010) including 1781 species, the application of the selection criteria resulted in 162 species which were further assessed for their impacts on the environment, economy, social/cultural values and human health.

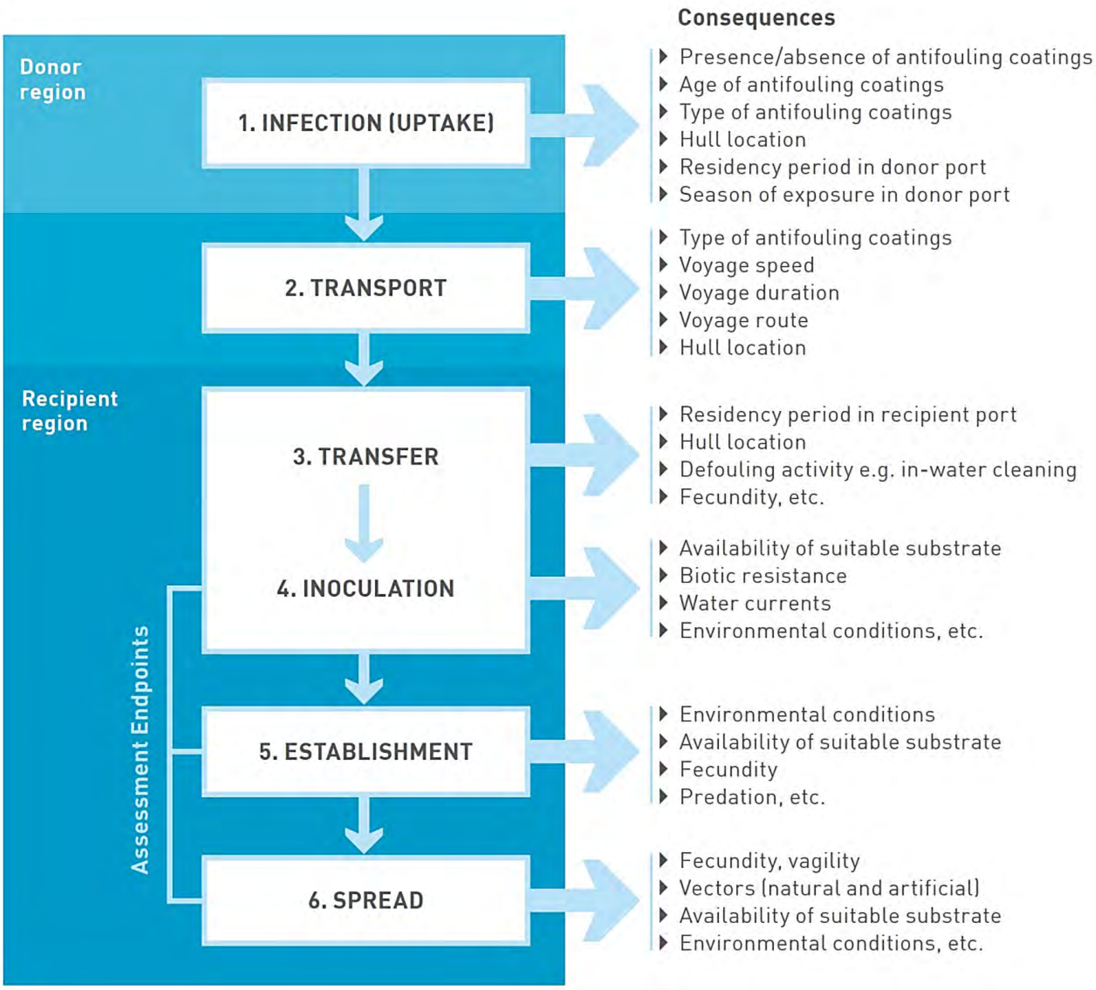


**Figure 4. Conceptual model of biofouling species invasion process and contributing factors (from Hewitt *et al*., 2011).**

Likelihood

The introduction likelihood assessment took into account:

- Association with biofouling (based on life history characteristics and a literature review based on demonstration of association)

• Transport pressure for each species, using marine traffic data, and derived from:
  - o Settlement opportunity to colonise the vessel based on duration in overseas ports
  - o The number of vessels arriving from regions where the species is present based on extended voyage characteristics
  - o Transport survival based on physical and physiological stress during the voyage
  - o Inoculation opportunity based on duration in an Australian port.

Calculation of the overall risk (likelihood of introduction against impact, using a risk matrix) indicated that 56 of the 162 species were identified as having extreme, high or moderate risk in at least one core value category examined. Further risk ranking can take place after that stage, depending on the core value of interest.

**Single Pathway x Sites**

Another example of biofouling risk analysis specifically from the recreational boating sector comes from Canada (Simard *et al.*, 2017; Pelletier-Rousseau *et al.*, 2019). In this case, the endpoint was primary and secondary introduction and the focus was the single vessel (and by extension recipient marinas that can be further grouped at a larger geographic scale). The approach involves information on the level of infestation of NIS (Regional NIS Background) in different Canadian and international ecoregions serving as a source for Canadian waters, the probability that boats will be fouled by NIS (Boat Infestation Probability), information on boat movements (Arrival Probability), and environmental similarity between source and receiving ecoregions (Survival Probability). This information was combined with estimates of annual boat traffic to evaluate the relative risk of boating in different Canadian marine ecoregions for the introduction and spread of NIS (Final Ecoregion Invasion Risk) (Figure 5).

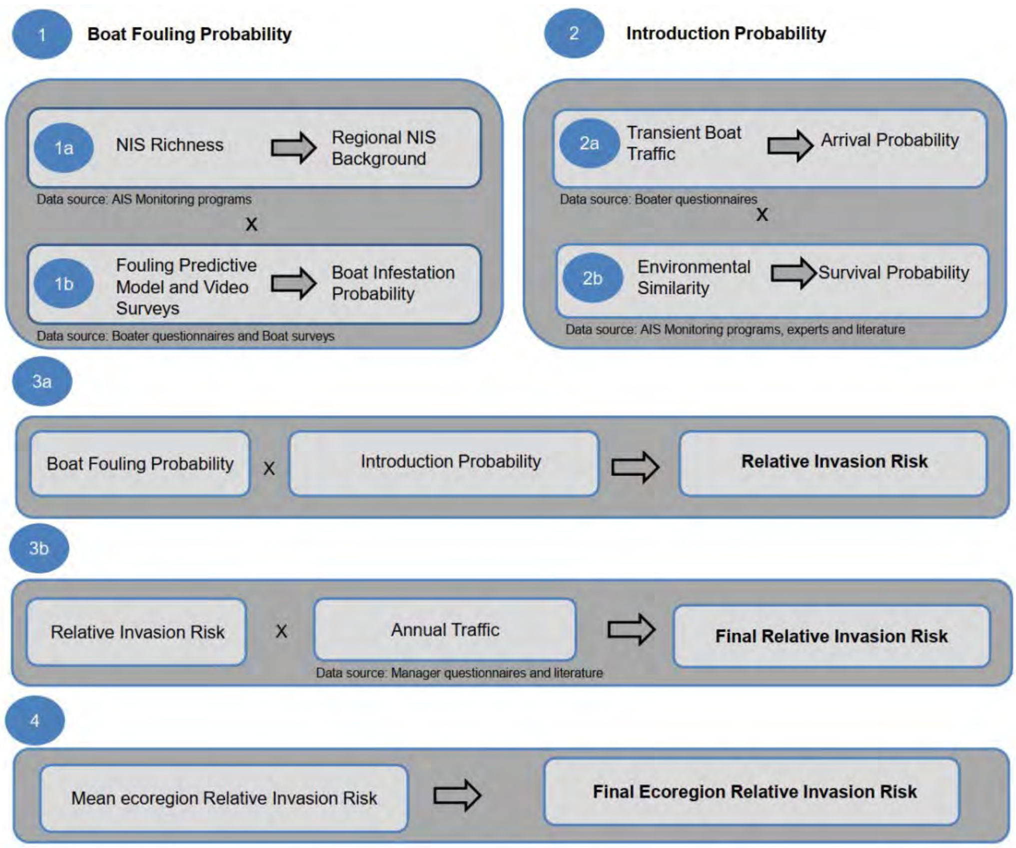


**Figure 5. Flow chart illustrating steps for recreational boating invasion risk assessment for Canadian ecoregions (from Simard *et al.*, 2017).**

The main data source about boating traffic and individual vessels characteristics was questionnaires distributed to marina operators and boaters, while data from monitoring programmes was used to validate a model constructed to calculate boat fouling infestation probability. The model used a number of parameters, among which time in water, time since last cleaning and boat type were the most significant predictors of fouling state.

A comprehensive guide to fouling risk analysis at the national level, encompassing many of the principles described above, can be found in GEF-UNDP-IMO (2022), published in the framework of the GloFouling Partnership Project. A National Fouling Status Assessment should aim to:

1) Identify and characterise the various biofouling transmission pathways that may lead to the introduction and secondary spread of IAS;
2) Identify the status of IAS in the country and how IAS might be dispersed from an initial point of entry point;
3) Identify and document the natural resources and activities of socio-economic importance that are vulnerable to the introduction of IAS;
4) Document how existing governance processes inform management practices, and the efficacy of those practices in relation to biofouling management;
5) Identify the broad measures employed in each country to manage the risks posed by IAS; and
6) Identify knowledge and capacity gaps, institutional needs and technical skills and tools required to ensure an adequate and effective national biofouling management framework.

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# Annex

**Table A1.** Classification of the magnitude of alien species impacts, based on Blackburn *et al.* (2014), adapted for the marine environment (from Katsanevakis *et al.*, 2016)

| Impact | Description |
| --- | --- |
| Minimal | No effect on fitness of native species; negligible impact on native species due to competition, predation, parasitism, toxicity, bio-fouling, or grazing/herbivory; negligible impact on ecosystem processes and ecosystem functioning; negligible impact on keystone species or species of high conservation value; no chemical, physical or structural impact on the ecosystem (not an ecosystem engineer). |
| Minor | Reduction in individual fitness due to competition, predation, parasitism, toxicity, bio-fouling, or herbivory, but no substantial population declines; minor impact on ecosystem processes and ecosystem functioning with no related population declines; negligible impact on keystone species or species of high conservation value; or causes changes in chemical, physical or structural habitat characteristics without decline of native populations. |
| Moderate | Declines in population densities because of competition, predation, parasitism, toxicity, bio-fouling, or herbivory, but no changes in community composition; or displacement of no more than one species of similar niche; or impact on ecosystem processes and ecosystem functioning resulting in population declines but no substantial change in species composition; or reduction in individual fitness of at least one keystone species or species of high conservation value, but no substantial population declines; or ecological engineering, resulting in population declines but no substantial change in community composition. |
| Major | Changes in community composition and local or population extinction of at least one native species, because of competition, predation, parasitism, toxicity, bio-fouling, or herbivory; impact on ecosystem processes and ecosystem functioning resulting in species composition changes; or population decline of at least one keystone species or species of high conservation value; or ecological engineering, resulting in change in community composition. Induced changes are reversible in the short term (<1 decade) with proper management measures or if the alien species population declines naturally. |
| Massive | The same as in 'major' but changes are irreversible in the short term (<1 decade) or currently there is no known effective management action for the control of the invasive alien species and a natural decline of its population seems highly unlikely. |

**Table A2.** Categorization of pathways for the introduction of alien species (CBD, 2014)

| | Category | Subcategory |
|---|---|---|
| MOVEMENT OF COMMODITY | RELEASE IN NATURE (1) | Biological control |
| | | Erosion control/ dune stabilization (windbreaks, hedges, …) |
| | | Fishery in the wild (including game fishing) |
| | | Hunting |
| | | Landscape/flora/fauna "improvement" in the wild |
| | | Introduction for conservation purposes or wildlife management |
| | | Release in nature for use (other than above, e.g., fur, transport, medical use) |
| | | Other intentional release |
| | ESCAPE FROM CONFINEMENT (2) | Agriculture (including Biofuel feedstocks) |
| | | Aquaculture / mariculture |
| | | Botanical garden/zoo/aquaria (excluding domestic aquaria) |
| | | Pet/aquarium/terrarium species (including live food for such species) |
| | | Farmed animals (including animals left under limited control) |
| | | Forestry (including afforestation or reforestation) |
| | | Fur farms |
| | | Horticulture |
| | | Ornamental purpose other than horticulture |
| | | Research and *ex-situ* breeding (in facilities) |
| | | Live food and live bait |
| | | Other escape from confinement |
| | TRANSPORT – CONTAMINANT (3) | Contaminant nursery material |
| | | Contaminated bait |
| | | Food contaminant (including of live food) |
| | | Contaminant on animals (except parasites, species transported by host/vector) |
| | | Parasites on animals (including species transported by host and vector) |
| | | Contaminant on plants (except parasites, species transported by host/vector) |
| | | Parasites on plants (including species transported by host and vector) |
| | | Seed contaminant |
| | | Timber trade |
| | | Transportation of habitat material (soil, vegetation…) |
| VECTOR | TRANSPORT - STOWAWAY (4) | Angling/fishing equipment |
| | | Container/bulk |
| | | Hitchhikers in or on airplane |
| | | Hitchhikers on ship/boat (excluding ballast water and hull fouling) |
| | | Machinery/equipment |
| | | People and their luggage/equipment (in particular tourism) |
| | | Organic packing material, in particular wood packaging |
| | | Ship/boat ballast water |
| | | Ship/boat hull fouling |
| | | Vehicles (car, train, …) |
| | | Other means of transport |
| SPREAD | CORRIDOR (5) | Interconnected waterways/basins/seas |
| | | Tunnels and land bridges |
| | UNAIDED (6) | Natural dispersal across borders of invasive alien species that have been introduced through pathways 1 to 5 |

**Table A3.** Alien species databases – indicative list

| Database | Coverage and scope | Link or reference |
|---|---|---|
| NEMESIS (National Exotic Marine and Estuarine Species Information System) | Global<br>Marine and estuarine | https://invasions.si.edu/nemesis/overview |
| GISD (Global Invasive Species Database) | Global<br>Terrestrial, marine, freshwater | http://www.iucngisd.org/gisd/ |
| CABI (Centre for Agriculture and Bioscience International) | Global<br>Terrestrial, marine, freshwater | https://www.cabi.org/ |
| WRiMS (World Register of Introduced Marine Species) | Global<br>marine | https://www.marinespecies.org/introduced/ |
| EASIN (European Alien Species Information Network) | European<br>terrestrial, freshwater, marine | https://alien.jrc.ec.europa.eu/easin |
| MAMIAS | Mediterranean<br>Marine and estuarine | http://dev.mamias.org/ |
| AquaNIS (Information system on Aquatic Non Indigenous and Cryptogenic Species) | Global with European focus. Marine, brackish water, and coastal freshwater biota from viruses to mammals | www.corpi.ku.lt/databases/aquanis/ |
| NIMPIS | Australia<br>Marine estuarine | https://nimpis.marinepests.gov.au/ |

**EU TEMPLATE FOR RISK ASSESSMENT (EC DG-EV, 2018)**

**Table A4.** Scoring of Likelihoods of Events

| Score | Description | Frequency |
|---|---|---|
| Very unlikely | This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur | 1 in 10,000 years |
| Unlikely | This sort of event has occurred somewhere at least once in the last millenium | 1 in 1,000 years |
| Moderately likely | This sort of event has occurred somewhere at least once in the last century | 1 in 100 years |
| Likely | This sort of event has happened on several occasions elsewhere, or on at least once in the last decade | 1 in 10 years |
| Very likely | This sort of event happens continually and would be expected to occur | Once a year |

**Table A5.** Scoring of Magnitude of Impacts (EC DG-ENV, 2018)

| Score | Biodiversity and ecosystem impact | Ecosystem Services impact | Economic impact (Monetary loss and response costs per year) | Social and human health impact, and other impacts |
|---|---|---|---|---|
| Minimal | Local, short-term population decline, no significant ecosystem impact | No services affected[1] | Up to 10,000 Euro | No social disruption. Local, mild, short-term reversible effects to individuals. |
| Minor | Local, short-term population loss, Localized reversible ecosystem impact | Local and temporary, reversible effects to one or few services | 10,000-100,000 Euro | Significant concern expressed at local level. Mild short-term reversible effects to identifiable groups, localised. |
| Moderate | Local to regional long-term population decline/loss, Measureable reversible long-term damage to ecosystem, little spread, no extinction | Measureable, temporary, local and reversible effects on one or several services | 100,000-1,000,000 Euro | Temporary changes to normal activities at local level. Minor irreversible effects and/or larger numbers covered by reversible effects, localised. |
| Major | Long-term irreversible ecosystem change, spreading beyond local area, population loss or extinction of single species | Local and irreversible or widespread and reversible effects on one / several services | 1,000,000-10,000,000 Euro | Some permanent change of activity locally, concern expressed over wider area. Significant irreversible effects locally or reversible effects over large area. |
| Massive | Long-term irreversible ecosystem change, widespread, population loss or extinction of several species | Widespread and irreversible effects on one / several services | Above 10,000,000 Euro | Long-term social change, significant loss of employment, migration from affected area. Widespread, severe, long-term, irreversible health effects. |

[1] Not to be confused with "no impact".

**Table A6.** Scoring of Confidence Levels (EC DG-ENV, 2018)

| Confidence level | Description |
|---|---|
| Low | There is no direct observational evidence to support the assessment, e.g. only inferred data have been used as supporting evidence *and/or* Impacts are recorded at a spatial scale which is unlikely to be relevant to the assessment area *and/or* Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous *and/or* The information sources are considered to be of low quality or contain information that is unreliable. |
| Medium | There is some direct observational evidence to support the assessment, but some information is inferred *and/or* Impacts are recorded at a small spatial scale, but rescaling of the data to relevant scales of the assessment area is considered reliable, or to embrace little uncertainty *and/or* The interpretation of the data is to some extent ambiguous or contradictory. |
| High | There is direct relevant observational evidence to support the assessment (including causality) *and* Impacts are recorded at a comparable scale *and/or* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and/or* Data/information are not controversial or contradictory. |

**Table A7.** Ecosystem services classification (CICES V5.1, simplified) and examples (EC DG-ENV, 2018)

Assessors are free to use what seems as the most appropriate category / level / combination of impact (Section – Division – Group), reflecting information available.

| Section | Division | Group | Examples (i.e. relevant CICES "classes") |
|---|---|---|---|
| **Provisioning** | **Biomass** | **Cultivated *terrestrial* plants** | Cultivated terrestrial plants (including fungi, algae) grown for <u>nutritional purposes</u>;<br>Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials);<br>Cultivated plants (including fungi, algae) grown as a source of energy<br><br>*Example: negative impacts of non-native organisms to crops, orchards, timber etc.* |
| | | **Cultivated *aquatic* plants** | Plants cultivated by in- situ aquaculture grown for nutritional purposes;<br>Fibres and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials);<br>Plants cultivated by in- situ aquaculture grown as an energy source.<br><br>*Example: negative impacts of non-native organisms to aquatic plants cultivated for nutrition, gardening etc. purposes.* |

| | | | |
|---|---|---|---|
| | | **Reared animals** | Animals reared for nutritional purposes;<br>Fibres and other materials from reared animals for direct use or processing (excluding genetic materials);<br>Animals reared to provide energy (including mechanical)<br><br>*Example: negative impacts of non-native organisms to livestock* |
| | | **Reared *aquatic* animals** | Animals reared by in-situ aquaculture for nutritional purposes;<br>Fibres and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials);<br>Animals reared by in-situ aquaculture as an energy source<br><br>*Example: negative impacts of non-native organisms to fish farming* |
| | | **Wild plants** (terrestrial and aquatic) | Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition;<br>Fibres and other materials from wild plants for direct use or processing (excluding genetic materials);<br>Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy<br>*Example: reduction in the availability of wild plants (e.g. wild berries, ornamentals) due to non-native organisms (competition, spread of disease etc.)* |
| | | **Wild animals** (terrestrial and aquatic) | Wild animals (terrestrial and aquatic) used for nutritional purposes;<br>Fibres and other materials from wild animals for direct use or processing (excluding genetic materials);<br>Wild animals (terrestrial and aquatic) used as a source of energy<br><br>*Example: reduction in the availability of wild animals (e.g. fish stocks, game) due to non-native organisms (competition, predations, spread of disease etc.)* |
| | **Genetic material** from all biota | **Genetic material** from plants, algae or fungi | Seeds, spores and other plant materials collected for maintaining or establishing a population;<br>Higher and lower plants (whole organisms) used to breed new strains or varieties;<br>Individual genes extracted from higher and lower plants for the design and construction of new biological entities<br><br>*Example: negative impacts of non-native* |

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|---|---|---|---|
| | | | *organisms due to interbreeding* |
| | | **Genetic material** from animals | Animal material collected for the purposes of maintaining or establishing a population;<br>Wild animals (whole organisms) used to breed new strains or varieties;<br>Individual genes extracted from organisms for the design and construction of new biological entities<br><br>*Example: negative impacts of non-native organisms due to interbreeding* |
| | **Water**[2] | **Surface water** used for nutrition, materials or energy | Surface water for drinking;<br>Surface water used as a material (non-drinking purposes);<br>Freshwater surface water, coastal and marine water used as an energy source<br><br>*Example: loss of access to surface water due to spread of non-native organisms* |
| | | **Ground water** for used for nutrition, materials or energy | Ground (and subsurface) water for drinking;<br>Ground water (and subsurface) used as a material (non-drinking purposes);<br>Ground water (and subsurface) used as an energy source<br><br>*Example: reduced availability of ground water due to spread of non-native organisms and associated increase of ground water consumption by vegetation.* |
| **Regulation & Maintenance** | **Transformation** of biochemical or physical inputs to ecosystems | **Mediation of wastes or toxic substances** of anthropogenic origin by living processes | Bio-remediation by micro-organisms, algae, plants, and animals;<br>Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals<br><br>*Example: changes caused by non-native organisms to ecosystem functioning and ability to filtrate etc. waste or toxics* |
| | | **Mediation of nuisances** of anthropogenic origin | Smell reduction; noise attenuation; visual screening (e.g. by means of green infrastructure)<br><br>*Example: changes caused by non-native organisms to ecosystem structure, leading to reduced ability to mediate nuisances.* |
| | **Regulation** of physical, chemical, biological | **Baseline flows and extreme event** regulation | Control of erosion rates;<br>Buffering and attenuation of mass movement;<br>Hydrological cycle and water flow regulation (Including flood control, and coastal protection); |

[2] Note: in the CICES classification provisioning of water is considered as an abiotic service whereas the rest of ecosystem services listed here are considered biotic.

| | | | |
|---|---|---|---|
| | conditions | | Wind protection;<br>Fire protection<br><br>*Example: changes caused by non-native organisms to ecosystem functioning or structure leading to, for example, destabilisation of soil, increased risk or intensity of wild fires etc.* |
| | | **Lifecycle maintenance**, habitat and gene pool protection | Pollination (or 'gamete' dispersal in a marine context);<br>Seed dispersal;<br>Maintaining nursery populations and habitats (Including gene pool protection)<br><br>*Example: changes caused by non-native organisms to the abundance and/or distribution of wild pollinators; changes to the availability / quality of nursery habitats for fisheries* |
| | | **Pest and disease control** | Pest control;<br>Disease control<br><br>*Example: changes caused by non-native organisms to the abundance and/or distribution of pests* |
| | | **Soil quality** regulation | Weathering processes and their effect on soil quality;<br>Decomposition and fixing processes and their effect on soil quality<br><br>*Example: changes caused by non-native organisms to vegetation structure and/or soil fauna leading to reduced soil quality* |
| | | **Water** conditions | Regulation of the chemical condition of freshwaters by living processes;<br>Regulation of the chemical condition of salt waters by living processes<br><br>*Example: changes caused by non-native organisms to buffer strips along water courses that remove nutrients in runoff and/or fish communities that regulate the resilience and resistance of water bodies to eutrophication* |
| | | **Atmospheric** composition and conditions | Regulation of chemical composition of atmosphere and oceans;<br>Regulation of temperature and humidity, including ventilation and transpiration<br><br>*Example: changes caused by non-native organisms to ecosystems' ability to sequester carbon and/or evaporative cooling (e.g. by urban trees)* |
| **Cultural** | **Direct, in-situ** | **Physical and** | Characteristics of living systems that that enable |

| | | | |
|---|---|---|---|
| | **and outdoor interactions** with living systems that depend on presence in the environmental setting | **experiential** interactions with natural environment | activities promoting health, recuperation or enjoyment through active or immersive interactions;<br>Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions<br><br>*Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that make it attractive for recreation, wild life watching etc.* |
| | | **Intellectual and representative** interactions with natural environment | Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge;<br>Characteristics of living systems that enable education and training;<br>Characteristics of living systems that are resonant in terms of culture or heritage;<br>Characteristics of living systems that enable aesthetic experiences<br><br>*Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that have cultural importance* |
| | **Indirect, remote, often indoor interactions** with living systems that do not require presence in the environmental setting | **Spiritual, symbolic** and other interactions with natural environment | Elements of living systems that have symbolic meaning;<br>Elements of living systems that have sacred or religious meaning;<br>Elements of living systems used for entertainment or representation<br><br>*Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that have sacred or religious meaning* |
| | | Other biotic characteristics that have a **non-use value** | Characteristics or features of living systems that have an existence value;<br>Characteristics or features of living systems that have an option or bequest value<br><br>*Example: changes caused by non-native organisms to ecosystems designated as wilderness areas, habitats of endangered species etc.* |

Kumschick *et al.* (2020) - A framework to support alien species regulation: the Risk Analysis for Alien Taxa (RAAT)

**Table A8.** A list of the parameters and information needed to complete the Risk Analysis for Alien Taxa.

| Section | Parameter | Description | Definition and purpose |
|---|---|---|---|
| Background | BAC1 | Name of assessor(s) | To identify the person who performed the assessment |
| | BAC2 | Contact details of assessor(s) | For means of contacting the assessors in case of questions, further information required or if the assessment needs revision. |
| | BAC3 | Name(s) and contact details of expert(s) consulted | Identifies experts which were consulted. |
| | BAC4 | Scientific name (including the authority) of *Taxon* under assessment | Gives information on the species, sub-species, variety, genus or other taxonomic entity under assessment. |
| | BAC5 | Synonym(s) considered | Information on which synonyms were considered for the assessment. |
| | BAC6 | Common name(s) considered | Information on which common names were considered for the assessment. |
| | BAC7 | What is the native range of the *Taxon*? | Information on the distribution range of the taxon is important for the assessment as the framework is designed for alien species specifically. |
| | BAC8 | What is the global alien range of the *Taxon*? | This is crucial as, for some questions, only information in the alien range is considered. |
| | BAC9 | The *Area* under consideration | Delimits the geographic scope of the assessment area |
| | BAC10 | Is the *Taxon* present in the *Area*? | Crucial for management recommendations (e.g. prevention vs. control). |
| | BAC11 | Availability of physical specimen | To link the identification of the taxon to a physical sample, as it is important to be able to refine the identity (BAC 4) in the light of new information and following taxonomic revision or the detection of errors in identification. |
| | BAC12 | Is the *Taxon* native to the *Area* or part of the *Area*? | Important for management as this framework only deals with alien species. |
| | BAC13 | What is the *Taxon's* introduction status in the *Area*? | Knowing the introduction status of populations (e.g. as per the Unified Framework of Biological Invasions, Blackburn *et al.* 2011) can aid with management decisions. |
| | BAC14 | Primary (introduction) pathways | This information will be used to answer questions on likelihood of entry. |
| Likelihood | LIK1 | Likelihood of entry via unaided primary pathways | The probability of the T*axon* to arrive and enter an area without human assistance. |
| | LIK2 | Likelihood of entry via human aided primary pathways | The probability of the *Taxon* to arrive and enter an area human aided. |
| | LIK3 | Habitat suitability | Forms part of the likelihood of a *Taxon* to establish |
| | LIK4 | Climate suitability | Forms part of the likelihood of establishment |
| | LIK5 | Unaided secondary (dispersal) pathways | Assesses spread potential. |
| | LIK6 | Human aided secondary (dispersal) pathways | Assesses spread potential aided by humans |
| Consequence | CON1 | Environmental impact | Includes impacts caused by the *Taxon* on the environment through different mechanisms, based on EICAT (Hawkins *et al.* 2015). |
| | CON2 | Socio-economic impact | Includes impacts caused by the *Taxon* on human well-being |

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| | | | and livelihood, based on SEICAT (Bacher *et al.* 2018). |
| | *CON3 | Closely related species' environmental impact | If no data on the *Taxon* itself are available, this includes impacts caused by related taxa on the environment through different mechanisms. |
| | *CON4 | Closely related species' socio-economic impact | If no data on the *Taxon* itself are available, this includes impacts caused by related taxa on different socio-economic sectors. |
| | CON5 | Potential impact | Assesses the potential impact of the T*axon* in the A*rea*, if invasive. |
| Management | #MAN1 | What is the feasibility of stopping future immigration? | Important for effectiveness of control, as new influx of propagules needs to be stopped to control the *Taxon* effectively and sustainably. |
| | #MAN2 | Benefits of the *Taxon* | Socio-economic and environmental benefits are included to assess the need of stakeholders for the *Taxon* |
| | #MAN3 | Ease of management | To provide indication of how easy the *Taxon* is to manage in the *Area* as this will influence risk management decisions. |
| | #MAN4 | Has the feasibility of eradication been evaluated? | Indicates whether the feasibility of eradicating the *Taxon* from the *Area* has been formally evaluated. Note the evaluation of eradication feasibility is a separate process to the risk analysis framework. |
| | #MAN5 | Control options and monitoring approaches available for the Taxon | Provides an overview of control options available. |
| | #MAN6 | Any other considerations to highlight? | Can aid the development of management plans, permit conditions and exemptions. |

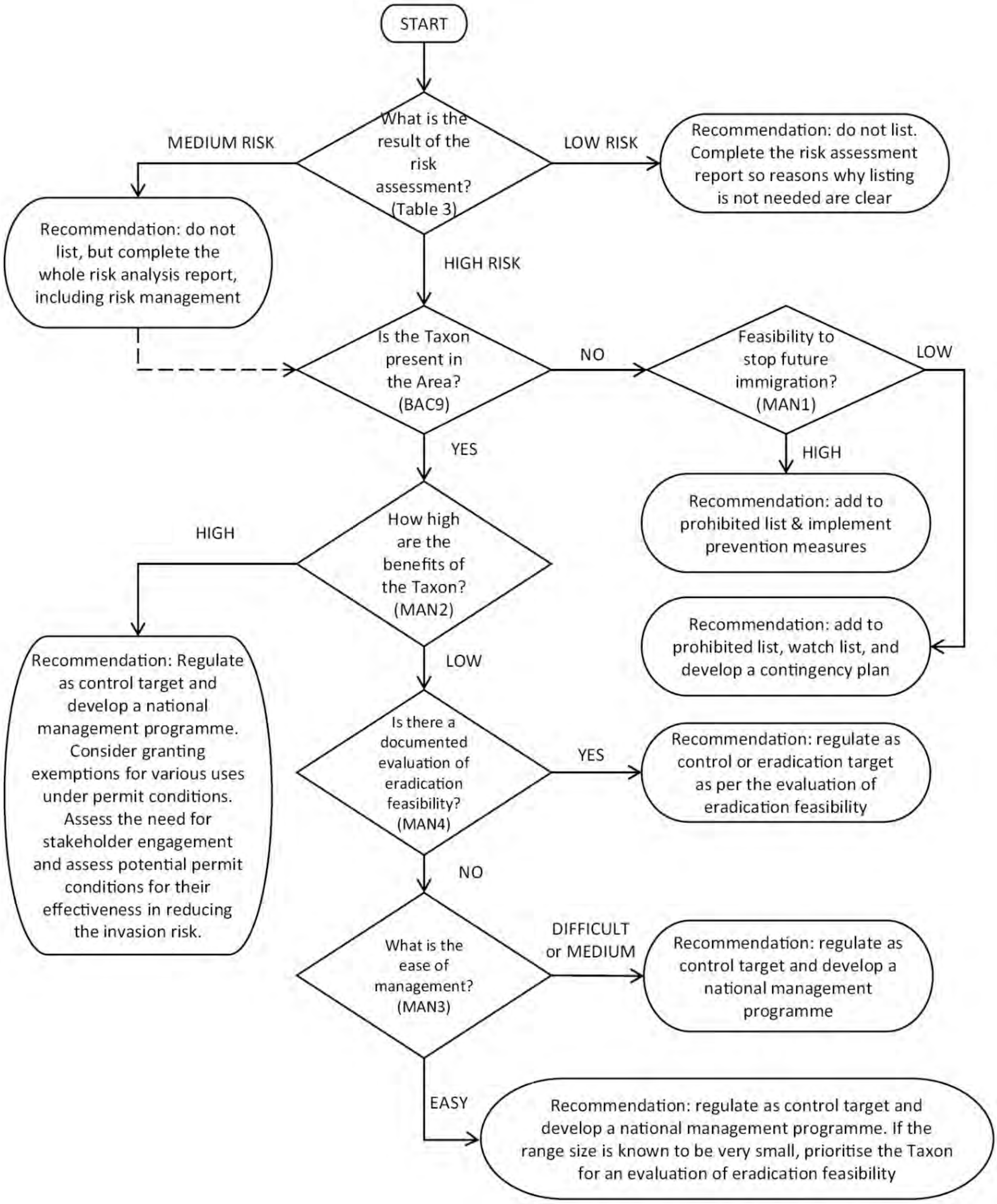


**Figure A1. A decision tree for determining the appropriate regulatory response for species which are considered to be of medium or high risk during the risk assessment process. The information in brackets refers to question numbers in the RAAT framework (Table A7 above). From Kumschick *et al*. (2020)**

**Table A9**. Examples of parameters used to estimate pathway (vector) strength as a proxy for propagule pressure

| **Pathway** | **Proxy for propagule pressure** | **Source / Reference** |
|---|---|---|
| Ballast water | Ballast water volume, number of vessel arrivals, marine traffic patterns | Ballast management reports, empirical formulas (e.g., Enshaei and Mesbahi, 2009)<br>marinetraffic.com |
| Hull fouling & Niche areas | Wetted Surface Area (WSA), number of vessel arrivals, marine traffic patterns | Empirical formulas (e.g., Van Maanen and Van Oossanen, 1988; Moser *et al.* 2017)<br>marinetraffic.com<br>Marina & boater questionnaires |
| Escape from confinement (aquaculture target species) | State import permits, stocking permits | Grosholz *et al.* (2015) |
| Contaminant (aquaculture non-target species) | Import permits, stocking permits | Grosholz *et al.* (2015) |
| Release or escape (ornamental species) | Importation inspection records, CITES permits, customs declarations, trade financial data | Williams *et al.* (2015)<br>EUROSTAT<br>Leal *et al.* (2015) |

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