**The Non-Indigenous Species Screening Tool (NISST) Guidance Document**

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# About The Non-Indigenous Species Screening Tool (NISST)

The Non-Indigenous Species Screening Tool (NISST) is a screening-level assessment tool for the prioritization of non-indigenous species that is both taxa and habitat independent and can be applied for assessing both currently introduced species and for horizon scanning (species not yet introduced). Each species’ assessment is designed to be completed within a single day by an informed assessor using easily accessible information from internet databases, primary literature, and grey literature. Assessments are semiquantitative consisting of a series of questions pertaining to many common processes associated with invasion potential (introduction, establishment, dispersal, and biological traits) and the consequences or impacts (ecological and socio-economic) of invasion. These are organized into three modules (Potential for Invasion, Ecological Impacts, and Socio-economic Impacts) consisting of 26 questions which are general enough to make the tool broadly applicable to many invasion situations where prioritization of species is important. For each question, assessors generate a probability distribution around potential outcomes, reflecting the assessor's likelihood of selecting the outcome. Using Monte Carlo techniques, both a score and an error are generated for each question using the question specific probability distribution generated by the assessor. The error around the module and total scores can then be calculated using propagation of error rules and embedded into those scores as error bounds, thus explicitly incorporating uncertainty into the scores which can directly inform management decision making. The resulting risk scores can be organized by risk level, thereby comparing species by module or overall risk, which, combined with information collected during the assessment, can be used to assist in management decisions and community outreach.

# Overview of NISST: How It Works

## Flow Chart/Overview

->Scope of assessment (determine variables)

->Customize questions (if needed)

->Collect data

-> Decide climate change parameters (if using climate modifiers)

->Perform assessments

->Prioritize species

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **NISST Overview** | | | | | | | |
|  |  |  |  |  |  |  |  |
| **A. Invasion Risk** | |  | **B. Ecological Impacts** | |  | **C. Socio-economic Impacts** | |
|  |  |  |  |  |  |  |  |
| **Introduction:** | |  | **Population impacts:** | |  | **Economic impacts:** | |
| -entrainment -propagule pressure | |  | -predation/herbivory/parasitism -competition -disease/parasites | |  | -industry -individuals -government | |
|  |  |  |  |  |  |  |  |
| **Dispersal potential** | |  | **Community impacts:** | |  | **Human health impacts** | |
|  |  |  | -multiple species -functional groups -productivity | |  |  |  |
|  |  |  |  |  |  |  |  |
| **Establishment:** | |  | **Ecosystem impacts:** | |  | **Natural resource impacts:** | |
| -environmental suitability -habitat suitability | |  | -nutrients or elements -physical environment -species which create biogenic habitat | |  | -food and drinking water -non-food resources | |
|  |  |  |  |  |  |  |  |
| **Life history traits:** | |  | **Conservation value impacts:** | |  | **Cultural or social impacts:** | |
| -reproduction -developmental rate | |  | -species of high conservation value -areas of high conservation value | |  | -species of cultural/social importance -areas of cultural/social importance | |

## Pre-assessment Considerations

### Scoping

Prior to the use of NISST, it is critical that the project be properly defined to ensure the end product meets the needs of those using the prioritized list. This includes describing the scope of the project (E.g., which species are considered, over what area the resulting prioritized list is being developed, what is the purpose of the list) which should accompany the final list as a scoping statement. The framework developed in Wilcox *et al*. (2024) provides a systematic method of developing a listing process through a series of considerations that define the scope, determine how an initial master list of species is compiled, how those species are filtered through a primary assessment, the resolution and criteria necessary to characterize risk through a secondary assessment, and finally, how the results of the assessments are used to develop lists. NISST would qualify as a secondary assessment through this framework and its use should be informed by a-priori determination of whether it fits (or can be modified to fit) the needs established in the scoping. Several of the other elements and considerations within the framework will directly impact how questions will be answered within NISST, and while we do not convey the entirety of the considerations within, several critical criteria are described below in greater detail.

### Defining Risk Assessment Area

One of the most fundamental steps in the scoping process is to clearly articulate the borders of the assessment area of interest. Risk assessment areas are often delineated using political boundaries such as national or state borders, however Vilizzi *et al*. (2022) and Copp *et al.* (2005) suggest biogeographical or climatic borders (i.e., ecoregions) be used where possible to reduce assessment overlap and increase consistency. Examples could include classification systems such as Freshwater Ecoregions of the World (FEOW; [Freshwater Ecoregions of the World](https://feow.org/)), which is a global biogeographical classification system that uses multiple variables to identify distinct assemblages of fish distributions largely contained within watershed regions (Abell *et al*., 2008). Other examples of classification systems includes Biogeoclimatic zones (BEC) zones for terrestrial organisms ([Biogeoclimatic Ecosystem Classification Program](https://www.for.gov.bc.ca/hre/becweb/resources/maps/CurrentVersion.html)), or the United States Department of Agriculture (USDA) Plant Hardiness Zones ([USDA Plant Hardiness Zone Map](https://planthardiness.ars.usda.gov/)) and the equivalent Canadian Plant Hardiness Site ([Canada's Plant Hardiness Site | Natural Resources Canada](https://planthardiness.gc.ca/?m=1)), among others. Defining the assessment area is directly applicable to all criteria as it will constrain potential variables that are present in the area of interest only (E.g., do not consider vectors that are not present to the area of interest or impacts to species which are not present, nor any species with similar biology or ecology).

### Compilation of a Master List

As outlined in Vilizzi *et al.* (2022) selection of species for screening could include a range of non-indigenous species already established (i.e., extant species) to potential invaders (i.e., horizon species) that are likely to invade due to their presence in a neighbouring assessment area, similar applicable vector (E.g., the aquarium trade), and/or have a suitable climate match. *A priori* categorization of chosen species as indigenous/non-indigenous should proceed using species-specific databases (E.g., [Global Biodiversity Information Facility: GBIF](https://www.gbif.org/)), global databases (E.g., [Centre for Agriculture and Bioscience International Invasive Species Compendium: CABI](https://www.cabi.org/)), region-specific databases (E.g[., Invasive and Exotic Species of North America: IESNA](https://www.invasive.org/)), and literature (Vilizzi *et al.,* 2022) to ensure only non-indigenous species are considered.

## Primary Assessment

There are thousands of species classified as invasive, and thus it is often necessary to reduce the list to facilitate assessment at a higher resolution using the NISST tool by reducing time and resources required. Filtering the list to species identified as having some degree of climate/habitat match, are in a known vector/pathway operating in the assessment area, or are a known invader elsewhere, allows the assessor to focus on more immanent threats. This process is a coarse filter which can be used to sequentially organize species to identify those that are more likely to invade or pose a higher risk. Such a step should be taken before using the NISST tool.

## Secondary Assessment

### Customizing NISST

As described above, NISST is applied in the secondary assessment step as outlined in Wilcox *et al*. (2024). Once it is decided that a secondary assessment is necessary and that NISST meets the required resolution, then it must be determined whether the criteria used to characterize risk are fit-for-purpose. NISST was designed and tested on a range of taxa and environments (Wilcox *et al.*, 2025; Mark Wilcox *personal communication*), and while we recommend the use of all the components of the tool to provide a robust and defensible assessment of the risks posed by non-indigenous species, it can be customized to reflect the objectives of the end users. Assessors can potentially omit or modify questions as needed to meet their desired goals. Modifications to the screening-tool such as omitting specific impact questions (E.g., omitting the climate change modifiers, or omitting specific questions that are deemed out of the scope of the assessment), or using the modules separately (E.g., eliminating the Socio-economic module or eliminating the impact modules altogether to focus only on the Invasion module) can easily occur based on the project goals. However, if modifications are made to the tool, it is prudent to document the adjustments and convey this to end users, and in the case of modifying the number of questions, assessors must adjust the R-coding for average calculations to reflect these changes.

### Defining Variables for Individual Questions

For many of the questions, it is necessary to determine the variables used to characterize risk to ensure consistency. These will be dependent on the scoping before using the tool to ensure consistency. Variables to be determined for the assessment area include:

* Vectors present (Invasion Q 1.1)
* Environmental conditions such as temperature (aquatic and/or terrestrial) (Invasion Q 3.1)
* Delineation of habitat types based on salinity, waterbody depth and velocity for aquatic systems (Invasion Q 3.2) or delineation of terrestrial habitat type (E.g., BEC zones or USDA Plant Hardiness Zone)
* Climate projections based on the scoped time limit (if applicable) (E.g., 10, 25, 50 years)
* Identify areas of conservation value (Ecological Impacts Q 4.2)
* Identify species of conservation value (Ecological Impacts Q 4.1)
* Species for human use: food/water and non-food resources (Socio-economic Impacts Q 3.1 and Q 3.2)
* Areas of cultural/social importance (Socio-economic Impacts Q 4.2)
* Species of cultural/social importance (Socio-economic Impacts Q 4.1)

## Data Collection Prior to Assessment

It is highly recommended to compile information for the assessment area and species to be assessed before an assessment. Each piece of information should be accompanied by corresponding literature references, to facilitate application of the screening tool. This reduces inter-assessor variability by standardizing the information gathered on the species and the assessment area. These parameters must be consistent across all assessments to maintain internal consistency for individual assessments among assessors: what are the metrics to be considered? What are the exact sources of information (i.e., links to scientific studies)? Clear documentation of justifications within the assessment is important for standardization and transparency to support more consistent interpretation of the results. Assessors need to refer to the justification for scoring which will allow greater potential for easier comparisons across assessments, thus it is recommended to populate a document to be shared among assessors so common knowledge is consistent. If changes or additions to this common database are made assessments should be revisited, we suggest gathering information pertaining to the following categories, if applicable:

* Identification (such as species and scientific names, family, taxonomic group)
* Are they present in the assessed area? In neighbouring ecoregions? What is the native and invasive range? What are the potential invasion vectors? How many propagules could arrive? Are there congeners (same genus) that are invasive elsewhere?
* Climate Environmental Match: temperature (polar, temperate, tropical etc.), habitat type (benthic, intertidal etc.), latitudinal match
* Tolerances from literature: Examples could include temperature (adult and juvenile), salinity (adult and juvenile), pH, depth (m), oxygen, other (Ca, minerals, nutrients, etc.)
* Reproduction: Asexual potential, reproductive rate (how often do they reproduce in a year), number of offspring per reproductive event, developmental rate (age of sexual maturity as well as lifespan), and length of planktonic stage if present
* Ecological impacts: Species impacted, genetics, population, competition, disease or parasites, physical habitat changes, impacts to species at risk and habitats of high conservation value, ecosystem function (geochemical cycling, productivity), community function (trophic, biodiversity)
* Socioeconomic Impacts: Impacted species or area of cultural importance, industries such as fisheries/aquaculture (jobs, equipment, operation costs), damage to infrastructure, human health, availability of resources etc.
* Management Options: Eradication, prevention, or impact mitigation. This section is not essential but helpful if the information gathered will be used for further management decisions.

# Applying NISST: How to Score the Questions

## Generating Probability Distributions

Once the information has been gathered and variables determined in the scoping of the project, assessors can begin assessments using the filtered list of species. Questions within the Invasion module A are provided with a 5-point scale scoring rubric while the Ecological Impacts module B and Socio-economic Impacts module C are provided with a 3-point scale scoring rubric. Unlike most assessment tools however, assessors do not score a single outcome within the rubric but instead will generate a question-specific probability distribution around the possible outcomes that reflects the assessor’s confidence based on the available data (Table 1). In other words, if the assessor were to score the question 100 times, how often would the assessor score each outcome? The higher the probability generated by an assessor for a particular outcome, the more confident the assessor is that the outcome reflects the likely response that would be observed (based on the literature):

E.g., If a species is known to have had a high impact on a native species within the area of interest, it would be reasonable to score a distribution of 0-0-100 for Low-Moderate- High impacts as the outcome is certainly known.

E.g., If a species is not documented to have caused impacts on native species within the area of interest, but is known to have high impacts in other areas it has invaded, assessors may score a distribution of 10-20-70 for Low-Moderate-High impacts as the outcome is less certain.

Confidence is also conveyed by the extent of the distribution, where the wider and flatter the distribution, the less confident the assessor is in selecting the outcome that reflects the likely response that would be observed. As in the above examples, when the outcome is certain, the distribution has non-zero probabilities for only a single outcome. In the second example, we are still certain that the impact will be high, but the wider distribution across all three outcomes suggests the assessor is less certain and potentially could have predicted both moderate and low impacts for the assessed system. Wider distributions may also arise if sources of information more weakly support any particular outcome.

E.g., If there was evidence of a non-native species consuming benthic invertebrates, without specifics as to the species or the magnitude of the impact, the assessor would likely have less confidence of predation impact to a species and thus have a wider distribution.

It is also possible that published literature could suggest more disparate outcomes such that distributions may in fact be more bimodal (i.e., the literature suggests likely outcomes that are greater than one scale difference on the scoring rubric. E.g., Two supporting pieces of information suggest scoring for a particular question for outcome 2 and 4). It is important to note that such a situation should not result in a gap, and thus the probability distribution should cover possible outcomes between (E.g., an invasion distribution of 0-40-20-40-0 rather than 0-50-0-50-0).

The sum of the generated probability distribution across all outcomes must equal 100 for each question. This scoring method provides the assessor more flexibility leading to more accurate reflections of the assessor’s uncertainty, which is particularly valuable in situations where two outcomes are highly probable or that the more probable outcomes are skewed. Suggested guidelines towards scoring distributions are provided below for the impact modules (3 point scoring) with various levels of assessor confidence.

* + *Low confidence:* Probability for all outcomes is <50
    - * E.g., 30-40-30 or 40-40-20
  + *Moderate confidence:* *T*he highest *probability for any outcome* is >50 up to a value of 70
* E.g., 0-30-70 or 20-60-20 or 50-50-0
  + *High confidence:* The highest probability for any outcome is >70 up to a value of 95
* E.g., 75-25-0 or 0-10-90
* *Very high confidence:* The highest probability for any outcome is >95
* E.g., 95-5-0 or 0-0-100)

As is evident from the examples, the higher the probability in any one score (low, medium or high) means the assessor is more certain of that outcome. The 5 point invasion module would similarly be scored using the low to very high confidence percentages above, but with a distribution spread over 5 rather than 3 scores (E.g., low confidence 5-10-20-40-25-0, or high confidence 0-0-10-20-70-0).

**Table 1**. Scoring guideline for impact modules: Ecological (B) and Socio-economic (C). Below are examples of Assessor Confidence Distributions totaling one hundred percent. The numbers provided are examples of distributions only to demonstrate how scoring Assessor Confidence distributions are used. There are many more variations possible than those that are listed.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | **Assessor Confidence Distribution** | | |
| **Magnitude of Impact Score** | **Assessor  Confidence** | **1 Low** | **2 Moderate** | **3 High** |
| **1** | Very low confidence All answers score below 40 | 40 | 35 | 25 |
| Low confidence Highest score is between 40 to 60 | 60 | 30 | 10 |
| Moderate confidence Highest score between 60 to 80 | 70 | 20 | 10 |
| High Confidence Highest score is between 80 to 95 | 80 | 15 | 5 |
| Very high confidence Highest score is above 95 | 95 | 5 | 0 |
| **2** | Very low confidence All answers score below 40 | 30 | 40 | 30 |
| Low confidence Highest score is between 40 to 60 | 20 | 60 | 20 |
| Moderate confidence Highest score between 60 to 70 | 15 | 70 | 15 |
| High Confidence Highest score is between 80 to 95 | 10 | 80 | 10 |
| Very high confidence Highest score is above 95 | 0 | 95 | 5 |
| **3** | Very low confidence All answers score <50 | 25 | 35 | 40 |
| Low confidence Highest score is between 50 to 60 | 0 | 40 | 60 |
| Moderate confidence Highest score between 60 to 80 | 0 | 30 | 70 |
| High Confidence Highest score is between 80 to 95 | 0 | 20 | 80 |
| Very high confidence Highest score is above 95 | 0 | 5 | 95 |

### Monte Carlo Techniques to Derive Score and Error

In R, the generated probability distribution is then used to simulate scoring using Monte Carlo procedures where the probability provided for each outcome represents the chance of selecting that outcome during scoring. Using 1000 iterations, the score for each question represents the mean value of the simulated scores. The error for each of the main questions is then calculated as the Standard Deviation of the simulated scores.

Modifier Questions

In addition to the main questions that form the bulk of the assessment, there are additional modifier questions which are designed to adjust the score of the basic questions to reflect either scenarios where species exhibit certain characters that would further increase the risk scored in the main question, or where the influence of climate change may be expected to increase, decrease or have no change on impacts or attributes assessed in the main question(s). Scoring for these questions apply a simple 1 point modifier (positively, negatively or nil) to the score for the main question(s) after Monte Carlo procedures have been applied, but can never increase or decrease the score beyond the maximum values of the question rubric (E.g., for a 5 point question, modifiers cannot result in scores lower than 1 or higher than 5).

### Climate Change

Climate change is introducing new dynamics to risk assessments (Hubbard *et al.,* 2023; 2024) and NISST incorporates these considerations within the tool. Assessors may elect to skip these questions if climate change is out of the scope of the assessments, however it is recommended to consider the impacts of climate change on the invasion potential of a given species to comply with the minimum standards for risk assessments as outlined in Roy *et al.* (2018). Many factors can vary with climate change such as the number of vectors, dispersal capability, propagule pressure, extension of suitable seasonal durations, or alterations to the suitability of the environment. These impacts can be both positive and negative and the rubric for climate change modifiers reflects this. To ensure consistency prior to the assessment, determine the time limit for the assessment (E.g., 10 years, 25, 50, 100) as this will impact which projections are considered and thus the magnitude of change.

A score for each sub-category adjusts for the potential impacts of climate change:

* + Invasion risk or Impacts predicted to increase (+1)
  + Invasion risk or Impacts predicted to decrease (-1)
  + Invasion risk or Impacts expected to remain at similar levels (0)
    - This is especially common for non-indigenous species that have large tolerances or given when the assessor is not certain of how the impact will change.

Examples of climate change impacting each sub-category are given in the sections below. As suggested in Vilizzi *et al.* (2022) this score is judgement-based and can vary with the availability and subjectivity of literature, and various methods by which to mediate this scoring is suggested. This is meant to be a broad level question, however climate match data is possible to inform invasion potential in more detail if desired (see Hubbard *et al.* (2023) for freshwater and terrestrial ecoregion climate matches that pair historic and climate projections; and Campbell *et al. (*2022) for an example of implementation of climate-match analysis).

### Customizing With Additional Modifier Questions

It is possible for additional modifiers to be added to the tool. One possible modifier could include invasion impacts related to anthropogenic sources which also may alter the number of vectors, dispersal capability, propagule pressure, or the suitability of the environment. This could consider changes in trade patterns, land use and land modifications, industrial expansion such as resource extraction, increasing human density, urban and rural expansion, and others. If additional modifiers are added to the tool, it is important to inform management of these changes, as discussed in the ‘Customizing NISST’ section above. Similar to climate change, this should be a simple adjustment, and scoring for those questions should also apply a simple 1 point modifier (positively or negatively) to the score for the main questions, as described above.

## Justification and References

To ensure defensibility and transparency, each of the questions must also be accompanied with justification and supporting references, which are documented within the assessment. In general, higher certainty exists with primary sources pertaining to the assessed species and area. If sources do not reflect the assessed species but rather a similar species (taxonomically similar), this should be reflected in the Assessor’s Confidence Distribution scoring (see Table 1 for scoring examples).

* *Justification* is a brief explanation of sufficient detail to provide end users information to understand the reasoning the assessor gave for the generated probability distribution.
* *Supporting references* are a list of primary literature, reference books, online databases, etc. that were used to score each question. In general, primary literature concerning the assessed species in the assessment area is the preferred source of information, but taxonomically similar species can also provide valuable information to be considered, as can similar areas. Online databases are readily available but come with some risk of accuracy or thoroughness and should be utilized with discretion.

If assessments are later revisited, it is important that the justification and supporting references are clear and concise so other assessors or decision makers can access this information. Knowledge of what variables were considered in the scoring and documentation of sources allows for more consistency in the interpretation of the results and allows for easier comparisons across assessments.

## Total Scores

Once assessors have generated probability distributions and modifier scores for each of the questions across each of the three modules (Invasion Potential, Ecological Impacts and Socio-economic Impacts) then total scores can be generated for the assessment. Module scores are calculated as the average score across questions after applying Monte Carlo procedures to generate a score and error and applying any modifiers. Error is propagated using the following error propagation rules:

For addition or subtraction operations such as

The error for Y is calculated as

Where δA and δB represent the independent errors for A and B

For multiplication or division operations such as

The error for Y is calculated as

This will generate both a module and a climate modified module score (if climate change is considered). To obtain a total score, the suggested formulation is the product of risk of invasion and impacts, the latter of which is calculated as the sum of both ecological and socioeconomic impact modules. Uncertainty is again propagated and reported along with all calculated indices.

These scores can be calculated by hand; however, it is far more efficient to use an established automation through the supplied R-script. It is important to note that the script has been designed to be generic and may require some modification of the code to reflect the current process (E.g., different number of assessors, different categorizations, and any modifications to the number of questions), some of which are highlighted within the script.

## Questions:

As the assessor works through the tool, three scores are attributed to each question, and each sub-category has an optional fourth score pertaining to climate change.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **A: Invasion Potential module** | **Scoring Rubric** | | | | | | | | |
| **A1: What is the likelihood of introduction or reintroduction in the area of interest?** | | | | | | | | | |
| **A1.1**: How many vectors are available that could entrain this species into the area of interest? | 0: <3 potential vectors | | 1: ≥3 potential vectors | |  | |  | |  |
| **A1.2**: What is the average annual entrainment potential from all potential vectors? | 1: 10s individuals | | 2: 100s individuals | | 3: 1000s individuals | | 4: 10000s individuals | | 5: >100000 individuals |
| **A1.3:** Do you expect the number of vectors or propagule pressure to change under a future climate? | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |  | |  |
| **A1 score = Sum of A1.1 and A1.2 to a maximum of 5** | **A1 Climate score = Sum of A1 score and A1.3 to a maximum of 5** | | | | | | | | |
| **A2: What is the dispersal potential within the area of interest?** | | | | | | | | | |
| **A2.1**: **What is the average or typical yearly dispersal range of spread through either natural or anthropogenic sources within the assessment area?** | 1: Unlikely to be dispersed | | 2: 100s of meters | | 3: 1-9 kms | | 4: 10s of kms | | 5: >100 km |
| **A2.2:** Do you expect the average dispersal range to change under a future climate? | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |  | |  |
| **A2 score = A2.1** | **A2 Climate score = Sum of A2 score and A2.2 to a maximum of 5** | | | | | | | | |
| **A3: What proportion of the assessment area is available for establishment by the species interest?**  **Score this question as the minimum score of 3.1 and 3.2** | | | | | | | | | |
| **A3.1**: How much of the assessment area offers suitable environmental conditions which are not outside the extreme tolerances of the species of interest | 1: <10% | | 2: 10-<25% | | 3: 25-<50% | | 4: 50-<75% | | 5: >75% |
| **A3.2**: How much of the assessment area offers suitable habitat types? | 1: <10% | | 2: 10-<25% | | 3: 25-<50% | | 4: 50-<75% | | 5: >75% |
| **A3.3:** Do you expect the percentage of assessment area that offers suitable environmental conditions or habitat types to change under a future climate? | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |  | |  |
| **A3 score = Minimum score for A3.1 and A3.2** | **A3 Climate score = Sum of A3 score and A3.3 to a maximum of 5** | | | | | | | | |
| **A4: Does the species exhibit life history and developmental traits that facilitate invasion?** | | | | | | | | | |
| **A4.1**: What is the per capita offspring the species can produce per year? | 1: 1-10 | | 2: 10-100 | | 3: 100-1000 | | 4: 1000-10000 | | 5: >10000 |
| **A4.2**: What is the developmental rate of the species, sexual or asexual? (For asexually reproducing species, consider how long before asexual reproduction might occur) | 0: If >1 year | |  | | 1: If ≤ 1 year | |  | |  |
| **A4.3:** Do you expect the life history characteristics and developmental traits to change under a future climate? | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |  | |  |
| **A4 score = Sum of A4.1 and A4.2 to a maximum of 5** | **A4 Climate score = Sum of A4 score and A4.3 to a maximum of 5** | | | | | | | | |
| **Invasion Potential score = Average of A1, A2, A3, A4 scores** | **Invasion Potential Climate modified score = Average of A1, A2, A3, A4 Climate scores** | | | | | | | | |
| **B: Ecological Impact module** | | | | **Scoring Rubric** | | | | | |
| **B1: Evidence of population levels impacts to native species** | | | | | | | | | |
| **B1.1**: Evidence the species could cause a considerable reduction in the size of any single population of a native species due to predation/herbivory/parasitism | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B1.2**: Evidence the species could cause a considerable reduction in the size of any single population of a native species due to competition | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B1.3:** Evidence the species is known to carry diseases or parasites that could infect a native species (either is known to already infect the species in a different region, or a species that is taxonomically similar) | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B1.4:** Do you expect the magnitude of impacts to differ in a future climate? | | | | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |
| **B1 Score = Sum of B1.1, B1.2, and B1.3** | | **B1 Climate score = Sum of B1 score and B1.4 to a maximum of 9 and a minimum of 3** | | | | | | | |
| **B2: Evidence of community level impacts to native species** | | | | | | | | | |
| **B2.1:** Evidence the species could cause a considerable reduction in the population size of more than one native species | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B2.2**: Evidence the species could cause considerable impacts to multiple functional groups | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B2.3**: Evidence the species could cause a considerable decrease in productivity of native communities | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B2.4:** Do you expect the magnitude of impacts to differ in a future climate? | | | | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |
| **B2 Score = Sum of B2.1, B2.2, and B2.3 scores** | | **B2 Climate score = Sum of B2 score and B2.4 to a maximum of 9 and a minimum of 3** | | | | | | | |
| **B3: Evidence of ecosystem level impacts** | | | | | | | | | |
| **B3.1**: Evidence the species could cause a considerable change in the availability of nutrients and essential elements (e.g., N, O, P, S, etc.) | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B3.2**: Evidence the species could damage, degrade, or modify the physical (abiotic) environment | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B3.3**: Evidence that species could cause impacts to species that create biogenic habitat | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B3.4:** Do you expect the magnitude of impacts to differ in a future climate? | | | | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |
| **B3 Score = Sum of B3.1, B3.2, and B3.3 scores** | | **B3 Climate score = Sum of B3 score and B3.4 to a maximum of 9 and a minimum of 3** | | | | | | | |
| **B4: Evidence of impacts to conservation units** | | | | | | | | | |
| **B4.1**: Evidence the species could represent a threat to species of high conservation value (consider most impacted) | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B4.2**: Evidence the species could represent a threat to areas of high conservation value | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **B4.3:** Do you expect the magnitude of impacts to differ in a future climate? | | | | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |
| **B4 score = Sum of B4.1 and B4.2 scores** | | **B4 Climate score = Sum of B4 score and B4.3 to a maximum of 6 and minimum of 2** | | | | | | | |
| **Ecological Impact score = Sum of B1, B2, B3, and B4 scores divided 11 (the number of non-climate sub-questions)** | | **Ecological Impact Climate score = Sum of B1, B2, B3, and B4 Climate scores divided 11 (the number of non-climate sub-questions)** | | | | | | | |
| **C: Socioeconomic Impact module** | | | | **Scoring Rubric** | | | | | |
| **C1: Evidence of economic costs** | | | | | | | | | |
| **C1.1**: Evidence the species could cause increased economic costs to industry | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **C1.2**: Evidence the species could cause increased economic costs to individuals | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **C1.3**: Evidence the species could cause increased economic costs to government | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **C1.4:** Do you expect the magnitude of impacts to differ in a future climate? | | | | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |
| **C1 score = Sum of C1.1, C1.2, and C1.3 scores** | | **C1 Climate score = Sum of C1 score and C1.4 to a maximum of 9 and minimum of 3** | | | | | | | |
| **C2: Human Health** | | | | | | | | | |
| **C2.1**: Evidence the species could cause impacts to physical human health | | | | 1: Low to no impacts to health | | 2: Moderate impacts to human health | | 3: Severe or lethal impacts | |
| **C1.2:** Do you expect the magnitude of impacts to differ in a future climate? | | | | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |
| **C2 score = C2.1 score** | | **C2 Climate score = Sum of C2 score and C2.2 to a maximum of 3 and minimum of 1** | | | | | | | |
| **C3: Evidence of impacts to available natural resources** | | | | | | | | | |
| **C3.1**: Evidence the species could impact accessibility of food and drinking water resources | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **C3.2**: Evidence that the species could impact accessibility of non-food resources  (e.g., wood, medicines, ornamental species, etc.) | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **C3.3:** Do you expect the magnitude of impacts to differ in a future climate? | | | | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |
| **C3 score = Sum of C3.1 and C3.2 scores** | | **C3 Climate score = Sum of C3 score and C3.3 to a maximum of 6 and minimum of 2** | | | | | | | |
| **C4: Impacts to species or areas of cultural or social importance** | | | | | | | | | |
| **C4.1:** Evidence the species could impact a species of cultural or social importance | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **C4.2:** Evidence the species could impact an area of culture or social importance | | | | 1: Low to no impact | | 2: Moderate impacts | | 3: High impacts | |
| **C4.3:** Do you expect the magnitude of impacts to differ in a future climate?  Apply score as a modifier to sum of sub-questions in C4 up to maximum of 6 and minimum of 2 | | | | -1: Decrease | | 0: Remain at similar levels | | 1: Increase | |
| **C4 score = Sum of C4.1 and C4.2 scores** | | **C4 Climate score = Sum of C4 score and C4.3 to a maximum of 6 and minimum of 2** | | | | | | | |
| **Socioeconomic Impact module score = Sum of C1, C2, C3, C4 scores divided by 8 (the number of non-climate sub-questions)** | | **Socioeconomic Impact Climate score = Sum of C1, C2, C3, C4 Climate scores** **divided by 8 (the number of non-climate sub-questions)** | | | | | | | |
| **Total Risk Score = Invasion Potential score \* (Ecological Impact score + Socioeconomic Impact score)** | | **Total Climate score = Invasion Potential Climate score \* (Ecological Impact Climate score + Socioeconomic Impact Climate score)** | | | | | | | |

# INVASION POTENTIAL MODULE (A)

## A1. Invasion Potential: What is the likelihood of introduction or reintroduction into the area of interest?

In general invasion risk increases with increased propagule pressure. Thus, this question is intended to characterize propagule pressure by thinking about what vectors/pathways could deliver potential invaders to the assessment area and in what numbers.

Within the scoping and prior to using the tool, users must determine which vectors are to be considered when answering the number of vectors and estimating propagule pressure. This list must be consistent across all assessments. Some suggested vectors include:

* ballast water (liquid or solid)
* boat hull fouling
* equipment fouling (such as fishing gear, farm equipment, boots, aquaculture gear)
* aquaculture accidental release or stock contamination
* intentional stocking and release
* aquarium and/or pond release or escape
* science/medical/educational release (accidental or intentional)
* marine debris fouling (for example Japanese tsunami marine debris or natural rafts)
* natural spread via ocean currents (impacted by duration of planktonic stage of life cycle) or freshwater flows, or natural migration or spread
* agricultural soil or seed contamination
* biotic transport/hitchhiking (birds, animals)
* others

### A1.1How many types of vectors are available that could entrain this species into the area of interest?

Conceptually this question represents a modifier to the score for question A1.1. Species which may be entrained in multiple vectors may represent an increased risk of introduction, but the total propagule pressure is the overriding consideration. However, note that the score for 1.2 cannot be elevated above a score of 5 (maximum value for A1.1). When considering the potential vectors associated with this species, determine how many could entrain the organism and which ones apply to the ecoregion being assessed.

* E.g., If a species is used in medical research but there are no known facilities within or near the area of interest, this vector would not be applicable.
* E.g., If a species is sold in the aquarium or pet trade but importation is prohibited to the ecoregion then this vector would not apply in the area.
  + - E.g., If a vector includes marine ballast water but the assessed area is land-locked, then ballast water will not be a vector in the same way it could be along coastlines or interconnected waterways such as the Great Lakes.
* Scoring:

|  |  |
| --- | --- |
| **0** | **1** |
| <3 vectors | ≥ 3 vectors |

### A1.2What is the average annual entrainment potential from all potential vectors?

This question quantifies how many individuals per year are expected to arrive via the associated vectors, and considers the frequency of potential introductions (i.e., propagule pressure). Species which may be entrained in large numbers may represent an increased risk of introduction. To answer the likelihood of introduction, consider how often the vector is present, the life stages involved in transport (tolerances, survivability, potential reproduction in transit, mobility), and how many viable propagules may be released to the assessment area. Bins are general and are based on orders of magnitude to allow discrimination among species.

* E.g., What is the number of pet stores/aquarium stores in the assessed area, and how many of the species are likely to be purchased, then subsequently released or escape?
* E.g., What is the number of agriculture or aquaculture areas/facilities in the area? How many individuals are likely to be transported into the ecoregion?
* E.g., Is the organism sold online in the ecoregion, and if so, what is the estimated number imported?
* Scoring:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** |
| 10s individuals | 100s individuals | 1000s individuals | 10,000s individuals | >10,000 individuals |

* Tips:
  + It may be difficult to find sources, so refer to similar species in the same genus.
* For colonial organisms (E.g., Ascidians) estimate the number of individuals in a colony rather than the number of colonies.
* For gravid females estimate the number of adults only, not the estimated number of offspring that have the potential to be released in transit, such as in ballast water.

### A1.3 Do you expect the number of vectors or propagule pressure to change under a future climate?

Are the number of propagules or vectors going to increase due to climate change, decrease, or remain at similar levels?

* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* Consider if propagules are more likely or less likely to survive transport given changing climate (not survival upon release to the environment).
* E.g., If ballast is loaded in warmer water but the vessel is entering an area with cold water below the organism’s tolerance level, it is not likely to survive (-1).
* E.g., If climate change induced storm events which are more likely to break apart rhizomes or plants into fragments, increasing the number of propagules (+1).
* Does climate change bring a new vector, or eliminate a vector?
  + E.g., Storm events creating the possibility of water transport (+1) when none existed before, such as rafting from a hurricane
  + E.g., Retreating sea ice increasing human activities in an area such as fishing, tourism, shipping (+1)
  + E.g., Seasonal drought eliminating connecting waterways and therefore natural spread between waterways (-1)
* Do not consider whether the climate is more suitable, that is applied in question 3 below.

## A2. Invasion Potential: What is the dispersal potential within the area of interest?

In general, invasion risk increases with increased dispersal potential. Thus, this question is intended to characterize propagule pressure by thinking about what distance those applicable vectors/pathways, paired with physical characteristics of the assessed area, could deliver potential invaders within the assessment area.

### A2.1 What is the average or typical yearly dispersal range of spread through either natural or anthropogenic sources within the assessment area?

This question considers how far, on **average**, the species will likely spread in a year once it has been introduced to the assessed area. Species which may be transported further may represent an increased risk. Bins are general and are based on orders of magnitude to allow discrimination among species. To answer consider the types of vectors, and estimate the average distance among the applicable vectors. In general:

* Recreational boats, farm equipment, cargo ships, vehicles etc. all have the potential to travel >100 km depending on the size of the ecoregion.
* On average ocean currents flow 4 kilometers per day. So passive transport on currents will depend on the length of the motile or planktonic stage.
* E.g., A planktonic larval stage of 10 days = 40 km (potentially).
* For passive downstream river transport consider velocity, length, and discharge of river systems.
* Consider natural barriers present in the assessed area, such as mountain ranges or lack of connecting waterways. If there are significant barriers there may be a reduced risk.
  + E.g., if an organism is only transported passively down river, then it is extremely unlikely it will be dispersed upriver by this means alone.
* Other examples to consider:
  + E.g., Birds that can fly long distances
  + E.g., Marine species that have a long planktonic larval stage
  + E.g., Plants that foul or entangle boats or farm equipment which are transported accidentally between lakes or agricultural areas
  + E.g., Bait organisms transported in bait buckets long distances between waterways

Once the vectors have been considered, estimate the AVERAGE the species could travel. For example Water hyacinth can entangle boat propellers (>100km potential), but natural dispersal via water currents carrying fragments is only local (1-9kms), ensure the confidence distribution is spread across those scores (E.g., 0-10-20-30-40, or 0-0-20-20-60, or 0-0-10-10-80, or any other combination), weighted towards the likely vector.

* Scoring:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** |
| Unlikely to be dispersed  (E.g., no planktonic larval stage, low motility, vectors currently non-existent | 100s of meters | 1-9 kilometers | 10s of kilometers | >100 kilometers (E.g., transported by ballast, boat, natural migrations) |

### A2.2 Do you expect the dispersal potential to change under a future climate?

* Is the organism more likely to be dispersed larger distances, less likely, or remain at similar levels given climate change?
* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* Consider weather events in dispersal capability such as storm surges, floods, precipitation events, drought, wind, seasonal timing, etc.
  + E.g., Large precipitation events due to climate change can carry seeds/fragments further downstream or along coastlines (+1)
  + E.g., Climate change could bring an increase of summer droughts impacting water levels in interconnecting channels or irrigation canals, thereby reducing or even eliminating the possibility of transport via connected waterways (-1)

## A3. Invasion Potential: What proportion of the assessment area is available for establishment by the species of interest?

In general risk increases with increased environmental suitability, so called ‘habitat matching’ (Blackburn *et al*., 2011; Capellini *et al*., 2015; Van Wilgen and Richardson, 2012). Thus, this set of questions is intended to characterize propagule pressure by thinking about what environmental conditions the assessed species needs to survive and reproduce. Within the scoping and prior to using the tool, as discussed above, users must determine which environmental variables are to be considered, such as temperature and precipitation, when answering the percent suitability based on environmental conditions and available habitat. These parameters must be consistent across all assessments but assessors must consider which parameters are most limiting to the assessed species in this particular area. These metrics need to be documented in the justification and provide context for the following questions. Species which have large tolerances may represent an increased risk of introduction.

### A3.1How much of the assessment area offers suitable environmental conditions which are not outside the extreme tolerances of the species?

Environmental conditions consider climatic variables such as temperature and precipitation. What are the tolerances of the species and what percent of the area is considered suitable? For instance, can the organism survive extended periods of drought or desiccation, freezing, etc.? For temperature consider tolerances not only for survival, but also for reproduction (E.g., some organisms have a threshold temperature to reproduce) and feeding (E.g., some organisms stop feeding at colder or warmer temperatures). Also consider whether an organism has a physiological or behavioural adaptation that allows it to withstand freezing or drought (E.g., burying in sediment), or has a growth form which can survive adverse conditions (E.g., turions, rhizomes, cysts, etc.). Bins are general and are based on orders of magnitude to allow discrimination among species.

* To evaluate the percent area that is suitable for the species, consider resources with average historical temperature or precipitation data for the given area, such as Environment Canada [Historical Data - Climate - Environment and Climate Change Canada](https://climate.weather.gc.ca/historical_data/search_historic_data_e.html) or USDA Plant Hardiness zones [2023 USDA Plant Hardiness Zone Map | USDA Plant Hardiness Zone Map](https://planthardiness.ars.usda.gov/)).
* Scoring:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** |
| <10%  (most of the area is unsuitable) | 10-25%  (some of the area is suitable) | 25-50%  (much of the area) | 50-75%  (most of the area) | 75-100%  (almost all of the area) |

* + - E.g., The organism cannot survive freezing, and a map of the mean coldest temperature in the assessed region shows half of the area is below 0oC in the coldest months. The assessor would give this a distribution weighted towards a score of 3.
    - E.g., The organism can bury in lake and river sediment and survive 6 months of drought conditions. The assessor would give this a distribution weighted towards a score of 5.
    - E.g., The organism is extremely tolerant of a large variation in temperature, and it can survive freezing for long durations by going dormant and can survive temperatures for short durations more than 50oC. The assessor would give this a distribution weighted towards a score of 5.

### A3.2How much of the assessment area offers suitable habitat types?

What are the physical environmental requirements of the species and what percentage of the area is considered suitable?

* For aquatic organisms, what percentage of the area has the adequate variables such as: water depth (E.g. the organism can only live to 10m max depth), velocity (E.g., the organism only inhabits slow moving water), direction of flow (E.g., if the species cannot move upstream as is the case for sedentary organisms, how much of the river is considered available and not ‘upstream’), salinity (freshwater/brackish/marine), substrate type and availability (E.g., lake margins, estuarine habitat, soft marine sediment, rocky marine shore etc.), or any other limited habitat.
* For terrestrial species such as plants consider variables such as soil type, soil chemistry, latitude, elevation, terrain type, tolerance of proximity to human development, etc.

To evaluate the percent area that is suitable, consider using Biogeoclimatic zones (BEC) zones for terrestrial organisms, E.g., BEC WEB (gov.bc.ca), see [www.for.gov.bc.ca/hre/becweb/resources/maps/CurrentVersion.html](http://www.for.gov.bc.ca/hre/becweb/resources/maps/CurrentVersion.html). Bins are general and are based on orders of magnitude to allow discrimination among species

* Scoring:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** |
| <10%  (the majority of the area is unsuitable) | 10-25%  (some of the area is suitable) | 25-50%  (much of the area) | 50-75%  (most of the area) | 75-100%  (almost all of the area) |

* E.g., The organism is freshwater but only survives in shallow water <5m with low or minimal flow. Most of the assessed area has fast flowing rivers and deep oligotrophic lakes, the assessor would give this a distribution weighted towards a score of 1.
* E.g., The organism is limited to brackish aquatic environments but only 10% of the area is composed of estuaries or tidal marshes so suitability is low, the assessor would give a distribution weighted towards a score of 1.
* E.g., The organism is marine and inhabits water to a depth of 200 m. The assessed area is all marine to a max depth of 400 m, so the assessor would give this a distribution weighted towards a score of 3.
* E.g., The organism can live in any type of fresh water body in the assessed area and is not limited at all by aquatic habitat type, the assessor would give this a distribution weighted towards a score of 5.

### A3.3 Do you expect the percentage of the assessment area that offers suitable environmental conditions or habitat types to change under a future climate?

* + Are changing climates likely to increase suitability, decrease suitability, or remain at similar levels? Consider climate matching (Hubbard *et al.,* 2023) for assistance.
* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* E.g., Rising ocean levels may decrease estuarine habitat, drought may decrease lake margins and sizes thereby reducing lake habitat, temperatures may raise tree line elevations on mountain slopes reducing alpine habitat, etc. (-1)
* E.g., The species has a temperature tolerance maximum of 10oC, so warming temperatures will likely result in a suitability decrease of the area as temperatures increase (-1)
* E.g., The species is xerophilic and the assessed area is modelled to have increasing drought-like conditions due to climate change (+1)

## A4. Invasion Potential: Does the species exhibit life history and developmental traits that facilitate invasion?

Numerous studies have documented that certain life history and developmental traits are characteristic of invasion success. Species which have a high fecundity (a high number of offspring or number of reproductive episodes per year, rapid development, and quick generation time) are commonly identified as having an increased risk of invasion. For instance, successful non-indigenous fish species have a larger body size, longer lifespan, higher fecundity, and delayed maturation (Liu *et al.*, 2017). Non-indigenous mammals often demonstrate high fecundity such as larger number of offspring, more frequent breeding, and/or long reproductive lifespans (Capellini *et al.*, 2015). Amphibians and reptiles have higher invasion success when paired with smaller body size and more frequent breeding with larger clutch sizes (Allen *et al.*, 2017), and similarly successful non-indigenous conifers produce larger numbers of small seeds (Richardson and Rejmánek, 2004). Other taxa-dependent life history traits are also important, for instance some species early maturity has proven successful (Pimm, 1991), while other organisms such as numerous bird species and some mammals have increased success when long-lived and possess the ability to postpone reproduction when environmental conditions are not conducive to reproductive success, so called ‘bet hedging’ (Sol *et al*., 2008; 2012), a strategy also evident in many plants (Venable, 2007). For insects, life history and developmental traits such as female dominant clutch sex-ratios, high fecundity and longevity all contribute to invasion success (Emiljanowicz *et al.*, 2017). This question seeks to parse out the relative importance of a variety of traits while general enough to consider all taxa and their corresponding invasion success.

### A4.1What is the per capita offspring the species can produce per year?

This question asks how many offspring ONE individual will potentially produce per year, regardless of generation time, or whether the organism is colonial or solitary, and does not consider the survival rate of offspring. Seek to find references in the assessed area, nearby regions, or areas of similar environmental conditions when possible, to have the highest Assessor’s Confidence. If multiple spawning events occur in a year calculate total possible per capita per year. Organisms with multiple generations per year (E.g., zooplankton) are considered in the next question A4.2. Bins are general and are based on orders of magnitude to allow discrimination among species.

* Scoring:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | 2 | 3 | 4 | 5 |
| 1-10 offspring | 10-100 offspring | 100-1000 offspring | 1000-10,000 offspring | >10,000 offspring |

* E.g., A fish spawns 1,000 eggs every 30 days when temperatures are above 15oC, which in the assessed area would be May to October. 6 months X 1,000 eggs = 6,000 eggs, so the assessor would give this a distribution weighted towards a score of 4 (1,000-10,000 offspring).
* E.g., A zooplankton lives 20 days and averages 12 offspring, but there are multiple generations possible during the summer months. The assessor would give this a distribution weighted towards a score of 2 (10-100 offspring), as only individual reproduction is considered in this question.

A4.2 What is the developmental rate of the species, sexual or asexual? (For asexually reproducing species, consider how long before asexual reproduction might occur)

This question acts as a modifier to consider rapid maturity and therefore faster generation time. Does this species sexually mature in less than a year (i.e., generational time of <1 year)? Species that sexually mature quickly and have multiple generations per year can have higher invasion impacts.

* Scoring:

|  |  |
| --- | --- |
| 0 | 1 |
| The species reaches sexual maturity in >1 year | The species reaches sexual maturity in ≤ 1 year |

* Consider if asexual reproduction occurs, as these will be considered reproductive in less than a year, such as:
* budding/binary fission
* parthenogenesis
* fragmentation
* rhizomes, runners, turions, bulbs, tubers, etc.
* Could the organism regenerate or grow right away such as from a fragment or rhizome (a score of +1), or does a certain size or life stage have to be attained? How long does it take to reach that life stage, Is it less than a year or more than a year?

This current iteration of NISST considers physical developmental rate only, not reproductive behaviours that may increase reproductive success, such as parental care. Future assessments can add another modifier to reflect these behaviours if assessors choose to do so, however management should be made aware of the changes to the tool.

### A4.3 Do you expect the life history characteristics and developmental traits to change under a future climate?

* Are changing climates likely to increase offspring or number of generations per year, decrease offspring, or remain at similar levels?
* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* + Consider minimum thresholds for reproduction to occur. Does climate change lengthen the reproductive season and hence increase the overall yearly per capita offspring production (+1), or does heat stress reduce its fecundity (-1)? Does climate change lengthen the reproductive season (+1), shorten it (-1), or does it remain unchanged (0)?
  + E.g., In the example from Question 4.1 a fish spawns above 15oC at a rate of 1,000 eggs per month, and climate change modelling suggests this will add another month to the typical 6-month breeding season, so 7,000 eggs could now be potentially spawned (+1).

# ECOLOGICAL IMPACT MODULE (B)

## B1. Ecological Impacts: Evidence of population level impacts to native species

In general, impacts to native populations, communities and ecosystems increase the risk associated with the assessed species invading. The questions in this section (B1) are intended to characterize negative impacts to only ONE species. Multiple species are considered in B2 (community impacts) and B3 (ecosystem impacts) of this module.

### B1.1Evidence the species could cause a considerable reduction in the size of any single population of a native species due to predation, herbivory, or parasitism.

This question considers the presence and/or extent of predation, parasitism, or herbivory on native species. In general, higher predation/herbivory/parasitism on native species means higher risk associated with invasion. Consider the abundance and feeding rate of the assessed species when scoring.

* Scoring:
  + *1 = Low to no impact*. A minor reduction in prey population, or no predation/herbivory/parasitism occurs.
* E.g., Snapping turtles (*Chelydra serpentina*) predating on frogs. This species predates infrequently, so the assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some predation/herbivory/parasitism occurs, and overall prey populations show some decline.
* E.g., Northern Pike (*Esox Lucius*) consuming cyprinids in shallow lakes. Northern pike are territorial and large and individually they predate frequently but likely have only a moderate impact on prey populations. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive predation/herbivory/parasitism occurs such that the prey population shows marked decline.
* E.g., Mysis shrimp (*Mysis relicta*) consuming cladocerans in Okanagan Lake: Mysis occurs in large numbers and individually they are voracious predators, and their presence demonstrates a marked decline in prey populations. The assessor would give this a distribution weighted towards a score of 3.
* E.g., Quagga mussel (*Dreissena rostriformis bugensis*) filter feeding phytoplankton in freshwater systems: ndividually Quagga mussel have a very high filtration rate, and they occur in high densities. Their presence demonstrates a marked decline in prey populations. The assessor would give this a distribution weighted towards a score of 3.

### B1.2Evidence the species could cause a considerable reduction in the size of any single population of a native species due to competition

This question considers the presence and/or extent of competition with native species. Consider interspecific competition for any limiting resource (E.g., prey, nesting sites, light, oxygen, etc.), and means of competition such as evidence of exudates or physical defenses which deter conspecifics or other competitors. In general, larger competition with native species means higher impacts. If the non-indigenous species has not invaded the assessed area but has demonstrated impacts to native species in other invaded areas, list the equivalent species of the same genus that have the potential to be impacted in the justifications.

* Scoring:
  + *1 = Low to no impact*. A minor impact to native populations, or no competition occurs
* E.g., American lobster (*Homarus americanus*) has shown little competitive impact to other decapods in British Columbia. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some competition occurs and overall native populations show some decline.
* E.g., Rusty crayfish (*Faxonius rusticus*) are aggressive, large, and have been demonstrated to outcompete native Signal crayfish (*Pacifastacus leniusculus*). The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive competition occurs such that the native populations show marked decline.
* E.g., Pancake batter tunicate (*Didemnum vexillum*) colonies can be large and smother mussel beds and barnacles and have chemical defenses effectively outcompeting sessile native species for space and access to prey. The assessor would give this a distribution weighted towards a score of 3.

### B1.3Evidence the species is known to carry disease or parasites that could infect a native species (either is known to already infect the species in a different region, or a species that is taxonomically similar)

This question considers the presence and/or extent of impacts the assessed species incurs with native species due to disease or parasites. In general, the extent of diseases/parasites transferred to native species means higher risk. This section refers to negative impacts only; associated species can also be included here for information purposes but if is commensal or mutual then it is not included in the scoring as this is a positive or neutral impact. In justification list specific species impacted anywhere in the world, and if possible, list equivalent similar species in the assessed area (same genus).

* Scoring:
  + *1 = Low to no impact*. A minor impact to native populations, or no diseases/parasites are present or transmissible.
* E.g., Asian skeleton shrimp (*Caprella mutica*) has no/little known diseases or parasites and so has a minimal impact on native species. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some disease transfer occurs and overall native populations show some decline.
* E.g., African clawed frog (*Xenopus laevis*) is a vector of the chytridiomycosis fungus which is transmissible to native frog species. The assessor would give this a distribution weighted towards a score of 2.
* E.g., Rusty crayfish (*Faxonius rusticus*) are a vector of ‘crayfish plague’ which is transmissible to native crayfish species and is known highly impact native species. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive impacts of diseases/parasites occur such that the native species show marked decline.
* E.g., Tench (*Tinca tinca*) are known to harbour many diseases and parasites that are transmissible and have large impacts to native fish species. The assessor would give this a distribution weighted towards a score of 3.
* E.g., Eastern flat oysters (*Ostrea edulis*) harbour a large number of diseases and parasites known to impact native bivalve species. The assessor would give this a distribution weighted towards a score of 3.

### B1.4 Do you expect magnitude of impacts to differ in a future climate?

* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* Is climate change likely to cause changes to assessed non-indigenous species ability to predate, compete, or transmit disease or parasites? Are these changes predicted to have larger impacts (+1), less impacts (-1) or no change (0)?
* Consider temperate impacts on feeding rates, competitive edge and survival, disease transmission or parasite survival, etc.
* E.g., Filtration rates of non-indigenous bivalves increase above a temperature threshold of 15oC. Climate change will be bringing warmer daytime temperatures and therefore competition for food resources with native species will increase (+1).

## B2. Ecological Impacts: Evidence of community level impacts to native species

In general, impacts to more than one native population (i.e., communities) increase the risk of the assessed species. This question is intended to be concerned with impacts to more than one native species as impacts on single species are characterized in B1.

### B2.1Evidence the species could cause a considerable reduction in the population size of more than one native species.

This question considers the presence and/or extent of impacts the assessed species incurs with populations of more than one native species. In general, the extent of impacts to population size of multiple native species means higher impacts. This section refers to negative impacts only. A reduction in population size could be via any of the means discussed above with respect to population impacts (B1.1 - B1.4) including competition, predation, and/or disease/parasites.

* Scoring:
  + *1 = Low to no impact*. An absence or only minor impact to more than one native population.
* E.g., White cloud mountain minnow (*Tanichthys albonubes*) has demonstrated very little impact on native populations in invaded areas. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some impact occurs and overall, more than one native population shows some decline.
* E.g., Hippopotamus (*Hippopotamus amphibius*) are grazers that consume terrestrial plants in invaded areas of S. America, consuming an average of 40 kg of food each night. They also alter riparian habitat impacting many species of aquatic plants and organism. The assessor would give this a distribution weighted towards a score of 2.
  + *3 = High impacts*. Extensive impacts occur such that more than one native population shows marked decline.
* E.g., Brown bullhead (*Ameiurus nebulosus*) is aggressive and consumes a variety of native prey species including minnows and sticklebacks, and their feeding actions increase turbidity which reduces visual predators from successful hunting. They are also a vector of several diseases reported to cause native fish die-offs. The assessor would give this a distribution weighted towards a score of 3.

### B2.2Evidence the species could cause considerable impacts to multiple functional groups

This question asks whether the assessed species will have significant impacts to multiple trophic levels (primary producers, primary consumers, secondary consumers, decomposers, etc.) through competition, predation, and/or disease/parasites. Impacts should be no more than one functional group removed. In general, the extent of impacts to multiple functional groups means higher risk.

* Scoring:
  + *1 = Low to no impact*. An absence or only minor impacts to more than one functional group.
* E.g., If the assessed organism is an herbivore and the direct impacts apply to only one functional group: primary producers. The assessor would give this a distribution weighted towards a score of 1. Impacts of consuming primary producers to other functional groups are further considered in B2.3.
* *2 = Moderate impacts*. Some impact occurs and overall, more than one trophic level is impacted.
* E.g., Marbled crayfish (*Procambarus virginalis*) which is an polytrophic omnivore and consumes both macrophytes as well as macroinvertebrates. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive impacts occur such that more than one functional group is impacted.
* E.g., The assessed species is a macrophyte such as Water hyacinth (*Eichhornia crassipes*) which forms dense mats that block light from reaching submerged macrophytes and phytoplankton below, which in turn impacts zooplankton and other herbivores such as macroinvertebrates. The assessor would give this a distribution weighted towards a score of 3.
* E.g., European green crab (*Carcinus maenas*) are omnivorous predators and excellent competitors which can transmit disease to native shore crabs. In addition, they also reduce eelgrass beds impacting numerous other species. The assessor would give this a distribution weighted towards a score of 3.
* Consider different life stages of the assessed organism, and differing feeding capabilities. For instance, some organisms throughout their life are polytrophic, consuming several types of prey at different life stages. Then it will score higher if considerable impacts occur.
* E.g., Many fish species consume zooplankton, macroinvertebrates, and fish/amphibian eggs as juveniles, but are piscivorous as adults. Therefore, they would score higher. The assessor would give this a distribution weighted towards a score of 2 or 3.

### B2.3 Evidence the species could cause a considerable decrease in productivity of native communities

This question asks whether the assessed species will have significant impacts on primary producers and therefore a decrease in overall community productivity through competition, predation, and/or disease/parasites. Impacts should be no more than one functional group removed. Primary productivity includes phytoplankton, macrophytes, or terrestrial plants, which can lead to changes in productivity of organisms in higher trophic levels such as zooplankton or macroinvertebrates, which are prey to many organisms. This question also considers trophic cascades and middle-out impacts due to alterations in primary productivity. In general, the extent of impacts to primary productivity means higher risk of invasion.

* Scoring:
  + *1 = Low to no impact*. An absence or only minor impacts to primary producers.
* E.g., American bullfrogs (*Lithobates catesbeianus*) do not consume vegetation as adults, but tadpoles are omnivores and can consume periphyton and macrophytes, however, overall impacts to primary productivity are low. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some impact occurs and overall primary production is impacted.
* E.g., Goldfish (*Carassius auratus*) are omnivores and polytrophic, consuming, among other things, fish eggs, invertebrates, and aquatic plants. Their feeding activity increases turbidity further reducing productivity of phytoplankton and macrophytes which contributes to detrimental algal blooms. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive impacts occur such that primary production is heavily impacted.
* E.g., Macrophytes such as Eurasian water milfoil (*Myriophyllum spicatum*) or Water hyacinth (*Eichhornia crassipes*) form dense mats blocking light from reaching submerged macrophytes and phytoplankton below, further impacting zooplankton and other herbivores and their predators. The assessor would give this a distribution weighted towards a score of 3.

### B2.4 Do you expect magnitude of impacts to differ in a future climate?

* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* Is climate change likely to cause changes to the population size of multiple species (predation, competition, or disease), to more than one functional group, or to productivity? Are these changes predicted to have larger impacts (+1), less impacts (-1) or no change (0)?

## B3. Ecological Impacts: Evidence of ecosystem level impacts

In general, impacts to more than one community (i.e., multiple native populations and functional groups) increase the risk of the assessed species. This question is intended to concern impacts to more than one community and impacts to ecosystem functioning.

### B3.1 Evidence the species could cause a considerable change in the availability of nutrients and essential elements (E.g., N, O, P, S, etc.)

This question addresses changes to nutrients or elements needed for growth or survival of native organisms. Consider changes resulting from activity such as feeding and waste production (ammonia), behavioural activities such as digging which stirs up sediment and frees nutrients, or processes such as decaying plant biomass releasing nitrogen and carbon into the water column encouraging algal blooms and creating anoxic sediment, etc. In general, larger impacts to nutrients and elements means higher risk.

* Scoring:
  + *1 = Low to no impact*. A minor change to nutrient or element availability but overall ecosystem is still functioning as normal.
* E.g., Common watercress (*Nasturtium officinale*) or Apple snail (*Pomacea maculata*) which have no evidence of nutrient impacts despite impacts to ecosystem composition and function. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some changes to nutrient or element availability occur and overall the ecosystem is demonstrating marked changes or decline.
* E.g., Cabomba (*Cabomba caroliniana*) forms dense mats and when winter die-offs occur, cause large nutrient releases and ‘manganese pulses’ which negatively impact water quality. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive changes to nutrient or element availability occur such that the ecosystem is drastically altered. If the assessed species is not established in the area but has large impacts somewhere else, it would receive a high score but a lower Assessor’s Confidence score.
* E.g., Chinese mystery snail (*Cipangopaludina chinensis*) bioaccumulates contaminants (mercury, arsenic, etc.), their feeding significantly reduces chlorophyll-*a* in the water column, and copious excretions lead to overall changes in water chemistry. The assessor would give this a distribution weighted towards a score of 3.

### B3.2 Evidence the species could damage, degrade, or modify the physical (abiotic) environment

This question addresses modifications to the physical environment which impact growth or survival of native organisms. Consider changes to light penetration (turbidity), altered water flow regimes such as floating biomass which blocks water flow, behavioural activities such as digging which erode riverbanks (crayfish or otters), organisms which bore (beetle larva), drill (sapsuckers), or chew (beavers), etc. In general, if a non-indigenous species significantly alters the physical environment in which it invades it will have a higher risk.

* Scoring:
  + *1 = Low to no impact*. A minor impact to the physical environment affecting native populations.
* E.g., Small barnacles such as Bay barnacle (*Amphibalanus improvisus*) will leave a calcium-based residue on settlement surfaces, but these will eventually erode with no significant alteration to the physical surface. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some competition occurs and overall native populations show some decline.
* E.g., Common carp (*Cyprinus carpio*) stir up sediment while they feed, increasing turbidity, and decreasing light availability in the water column. The assessor would give this a distribution weighted towards a score of 2.
* E.g., Dense macrophytes such as Reed canary grass (*Phalaris arundinacea*) reduce water flow which increases sedimentation. The assessor would give this a distribution weighted towards a score of 2.
  + *3 = High impacts*. Extensive impacts to the physical environment.
* E.g., Chinese mitten crab (*Eriocheir sinensis*) burrow into river and estuarine banks, increasing the risk of collapse and changes to stream morphology or erosion/reduction of estuarine shorelines. The assessor would give this a distribution weighted towards a score of 3.

### B3.3 Evidence the species could cause impacts to species that create biogenic habitat

* This question addresses impacts to native species whose presence creates habitat used by other organisms, such as marine ecosystem engineers like corals, beavers, burrowing mammals etc., that provide habitat for other native organisms either directly or indirectly. Impacted species can include terrestrial or aquatic plants (E.g., cattails, trees), marine seaweeds, kelp, and eelgrass, and includes a variety of habitat purposes like surfaces for planktonic larvae to settle in the marine environment, sites for nesting/denning, sites for ambushing prey, hunting territory, etc.
* Scoring:
  + *1 = Low to no impact*. A minor impact to native species that creates biogenic habitat.
* E.g., Red-eared slider turtles (*Trachemys scripta elegans*) are omnivorous and consume macrophytes used as habitat for invertebrates, however impacts are minimal due to their varied diet. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some impact to native populations creating biogenic habitat occurs and overall, these populations show some decline.
* E.g., Water soldier (*Stratiotes aloides*) which outcompetes native plants where it has invaded but with only moderate overall reduction in aquatic macrophytes used as habitat for native species. The assessor would give this a distribution weighted towards a score of 1.
  + *3 = High impacts*. Extensive impacts to species creating biogenic habitat occur such that the native populations show marked decline.
* E.g., Pacific oyster (*Crassostrea gigas*) outcompetes native bivalves such as mussels, leaving behind calcareous shells that are resistant to erosion and not as conducive to sessile organism settlement as native species. The assessor would give this a distribution weighted towards a score of 3.

### B3.4 Do you expect magnitude of impacts to differ in a future climate?

* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* Is climate change likely to change the impacts on species that create biogenic habitat? Are these changes predicted to increase impacts (+1), lessen impacts (-1) or no change (0)?

## B4. Ecological Impacts: Evidence of impacts to conservation units

This section concerns impacts to organisms or places that are of conservation concern. In general, impacts to conservation units increase the risk of the assessed species. Within the scoping and prior to using the tool, users must determine which species and areas of high conservation value are to be considered when answering threats to species and areas of high conservation value. These potential lists must be considered to increase consistency among assessors. To answer the two questions, consider the above ecological impacts (population, community, and ecosystem) and how they could potentially impact specific at-risk species or habitat that supports these at-risk species in the assessed area.

B4.1 Evidence the species could represent a threat to species of high conservation value (considered most impacted)

Impacted organisms include SARA and COSEWIC listed species, but also locally sensitive or threatened organisms. Consider if the assessed species can impact native at-risk species via any of the above means (i.e., competition, predation/herbivory, disease/parasites, nutrient/element availability, habitat alteration or reduction, or changes to ecosystem productivity etc.). In general, impacts to species of high conservation value means higher risk.

* Scoring:
  + *1 = Low to no impact*. A minor impact to native at-risk populations.
* E.g., Chinese mystery snail (*Cipangopaludina chinensis*) is an excellent herbivore/predator with high filtration and grazing rates, however impacts are not to any known COSEWIC species. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some impact to native at-risk populations occurs and overall native populations show some decline.
* E.g., Eastern oyster (*Crassostrea virginica*) competes with Pacific oyster (*Crassostrea gigas*), but to date it is unknown if they impact the COSEWIC listed Olympia oyster (*Ostrea lurida*) along British Columbia’s Pacific coast. The assessor would give this a distribution weighted towards a score of 2.
  + *3 = High impacts*. Extensive impacts to native at-risk populations occur such that the native population show marked decline.
* E.g., Water hyacinth (*Eichhornia crassipes*) significantly impacts spawning habitats for native fish species and reduces water quality for a variety of fish, birds, and plants on the COSEWIC list. The assessor would give this a distribution weighted towards a score of 3.
* E.g., Common carp (*Cyprinus carpio*) consume white sturgeon eggs (*Acipenser transmontanus*), a COSEWIC species, and other fish and amphibian species, and degrades water quality and damages ecosystem services which also impacts numerous other species of conservation concern. The assessor would give this a distribution weighted towards a score of 3.
* If the assessed species has impacts to at-risk species in another area outside of the assessment, adjust the scores accordingly to reflect the likelihood of impacts to similar species in the assessed area.

### B4.2 Evidence the species could represent a threat to areas of high conservation value

This question concerns ecological impacts to high conservation areas, which are threatened, rare, or important for organisms of high conservation value. Ecological impacts can include any of those outlined above.

* Conservation areas can include sensitive or rare habitats such as:
* estuaries
* eelgrass beds and saltmarshes
* areas which are stopover or nesting sites for migratory birds
* alpine meadows
* coral and glass sponge reefs
* others
* High conservation areas also can include regulated areas like:
* national and provincial parks
* regional parks
* wilderness areas
* marine parks
* others
* Scoring:
  + *1 = Low to no impact*. A minor impact on conservation areas.
* E.g., Clubbed tunicate (*Styela clava*) primarily inhabits man-made structures such as docks and pilings and aquaculture equipment but has little documented impact on marine conservation areas. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some impact to conservation areas occurs and overall ecological units are impacted in some way.
* E.g., Oriental weatherfish (*Misgurnus anguillicaudatus*) feed on macroinvertebrates, tadpoles and fish eggs creating impacts for spawning fish species in conservation areas. The assessor would give this a distribution weighted towards a score of 2.
  + *3 = High impacts*. Extensive impacts to conservation areas occur such that the ecological units are significantly altered.
* E.g., Chinese mitten crab (*Eriocheir sinensis*) causes substantial changes to riverbanks and estuarine margins, significantly threatening coastal conservation areas such as those for migratory birds. The assessor would give this a distribution weighted towards a score of 3.

### B4.3 Do you expect magnitude of impacts to differ in a future climate?

* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* Is climate change likely to cause the assessed organism to be a greater threat to a species or area of high conservation value? Are these changes predicted to have larger impacts (+1), less impacts (-1) or no change (0)?

# SOCIO-ECONOMIC IMPACT MODULE C

## C1. Socio-economic Impacts: Evidence of Economic Costs

The questions in this section consider any cost incurred in the assessed area due to the organism directly or indirectly, such as:

* physical damage and repairs
  + increased risk of flooding and costs associated with infrastructure damages
  + boats, equipment (machinery, fishing nets, aquaculture gear, etc.)
  + loss of income, time, and wages for staff
  + blockages of pipes (water intake or drainage)
  + erosion, or redirection or changes to water flow
* prevention costs
* control/eradication (E.g., biofouling removal, lake dredging, chemical treatments etc.)
* property value loss
* agricultural feed or aquaculture contamination (reduced quality or quantity)
* others
* Do not estimate actual projected costs, this is a high-level generalized question concerning the potential costs (actual costs need specific data which is often not found in journals, and this is beyond the scope of this screening-level tool).
* Consider searching news stories for industry programs, government websites, local Invasive Species Councils/Organizations, databases such as [Invacost](https://invacost.fr/en/accueil/) for broad potential expenses and considerations, or journal articles concerning management of the invasive species conducted in other areas.

### C1.1 Evidence the species could cause increased economic costs to industry

This question addresses costs incurred to industries and businesses which can include a large variety such as:

* sport-fishing
* aquaculture (mollusks, fish, kelp, other invertebrates)
* forestry
* tourism
* power generation (E.g., BC Hydro)
* agriculture
* others
* Scoring:
  + *1 = Low to no impact*. Minor costs associated with industry.
* E.g., American bullfrog (*Lithobates catesbeianus*) can have significant impacts to native amphibians due to predation, but unlikely to result in financial impacts to industry. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some demonstrated costs to industry occur.
* E.g., Pumpkinseed sunfish (*Lepomis gibbosus*) may have moderate financial impacts to the fishing industry due to their consumption of juvenile fish such as trout. The assessor would give this a distribution weighted towards a score of 2.
* E.g., Brown bullhead (*Ameiurus nebulosus*) impacts sportfish populations via disease, competition, predation, and habitat alteration, thereby impacting the fishing industry. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive costs to industry are evident.
* E.g., Quagga mussel (*Dreissena bugensis*) is likely to have large financial impacts as demonstrated in areas it has invaded, due to clogging of water intake and electrical generation facilities, as well as biofouling of vessels and equipment. The assessor would give this a distribution weighted towards a score of 3.
* E.g., Water hyacinth (*Eichhornia crassipes*) which has dense mats that reduce commercial fish production and interference with commercial fishing gear such as nets at significant annual costs. The assessor would give this a distribution weighted towards a score of 3.

### C1.2 Evidence the species could cause increased economic costs to individuals

This question concerns costs incurred to individuals and includes any of the above potential impacts concerning private property owners, or private owners of equipment (machinery, fishing gear, recreational boats, private docks, etc.).

* Scoring:
  + *1 = Low to no impact*. Minor costs to individuals.
* E.g., Rock bass (*Ambloplites rupestris*) is not documented to have significant economic costs. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some costs to individuals occur.
* E.g., Brazilian elodea (*Egeria densa*) is documented to block irrigation systems and water supply intakes and increase the risk of flooding in adjacent areas. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive costs to individuals are evident.
* E.g., As above Quagga mussel (*Dreissena rostriformis bugensis*) can cause similar issues for individuals, as can floating mats such as Water hyacinth (*Eichhornia crassipes*). The assessor would give this a distribution weighted towards a score of 3.

### C1.3 Evidence the species could cause increased economic costs to government

This question applies primarily to local governments such as municipal or provincial. Consider costs to infrastructure such as:

* Blockages and biofouling of water treatment plant intake pipes and equipment, or drainage pipes
* increased risk of forest fires due to desiccation of plant biomass
* increased risk of flooding due to plant biomass blockages or increased sedimentation
* biofouling of government docks and vessels
* damages to infrastructure such as bridges, roads, buildings, etc. from biofouling, flooding, manual wear-and-tear
* costs of providing education programs
* costs associated with public health (for example disease outbreaks, injuries etc.)
* potential business reimbursements for loss of income to industries
* Does not include management plans or volunteer-based organizations (non-governmental such as citizen councils and programs)
* Scoring:
  + *1 = Low to no impact*. Minor costs to the government.
* E.g., Prussian carp (*Carassius gibelio*) are unlikely to incur significant costs to government despite significant ecological impacts. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some costs to the government.
* E.g., Reed canary grass (*Phalaris arundinacea*) floods and constricts waterways and irrigation canals, invades wetlands, decreases shrub and tree establishment, and interferes with recreational activity such as boating, fishing, and swimming. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive costs to the government.
* E.g., Many invasive floating aquatic plants can incur high costs to government such as Camboba (*Camboba caroliniana*), Purple loosestrife (*Lythrum salicaria*) and Water lettuce (*Pistia stratiotes*) as they can block water drainage, leading to flooding which can cause large damage to infrastructure. The assessor would give this a distribution weighted towards a score of 3.

### C1.4 Do you expect magnitude of impacts to differ in a future climate?

* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* Are the economic costs more likely to increase (+1), decrease (-1) or stay the same (0)
* Answer will vary depending on impacts and species’ tolerances
* E.g., Floating macrophytes block drainage leading to flooding: are they more likely to do this given storm events and other weather changes?
* E.g., Growth rate of a colonial ascidian may increase with warming ocean temperatures: will it increase the costs due to biofouling of aquaculture gear?
* E.g., An organism that biofouls ship hulls but prefers cooler water: will rising oceanic temperatures decrease their survival and therefore decrease removal costs?

## C2. Socio-economic Impacts: Evidence of health impacts

This question concerns impacts to human health only, which may impair or alter the quality of human life. Impacts should only be one-step removed, not from a series of impacts (E.g., Mountain Pine Beetle (*Dendroctonus ponderosae*) parasitizing trees, which increase the risk of forest fires, which endangers lives and causes breathing problems, and so on).

### C2.1 Evidence the species could cause impacts to physical health

* Suggested impacts could include:
* zoonotic disease or parasite transmission
* toxins from handling or consumption
* defensive mechanisms such as spines
* inhaled airborne molds and spores (E.g., fungus)
* allergens causing an allergic response such as respiratory issues
* physical attacks (E.g., snapping turtles)
* water contamination where water is not treated but consumed
* others
* Mental health impacts are not considered physical health impacts. Invasive species can impact mental health in innumerable ways which are difficult to quantify, therefore mental health impacts are beyond the scope of this assessment.
* Scoring:
  + *1 = Low to no impact*. Minor impacts to human health are associated with invasion of the assessed species that do not significantly impair or alter quality of life.
* E.g., Pumpkinseed sunfish (*Lepomis gibbosus*) are not known to cause health impacts to humans. The assessor would give this a distribution weighted towards a score of 1.
* E.g., Striped barnacle (*Amphibalanus amphitrite*) can scrape hands and feet of people using beaches (Magnitude of Impact score of 1).
* E.g., Reed canary grass (*Phalaris arundinacea*) whose pollen is a known allergen, leading to minor impacts to human health. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some impacts are evident leading to impacts having impacts on quality of life.
* E.g., Common watercress (*Nasturtium officinale*) often carries the common liver fluke, which can infect humans through intermediary hosts causing fasciolosis. The assessor would give this a distribution weighted towards a score of 1.
* *3 = High impacts*. Extensive impacts to health are evident significantly affecting quality of life and in some cases could lead to death.
* E.g., Hippopotamus (Hippopotamus amphibius), which are invasive in South America, are aggressive and attacks can be deadly. The assessor would give this a distribution weighted towards a score of 3.

### C2.2 Do you expect magnitude of impacts to differ in a future climate?

* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* Is the organism more likely to cause health impacts (+1), less likely (-1) or no change (0)
* Answer varies depending upon impacts
* E.g., A disease hosted by the assessed organism becomes more prolific in warmer temperatures, such as Paralytic Shellfish Poisoning (+1).

## C3. Socio-economic Impacts: Evidence of impacts to available natural resources

This section concerns any naturally occurring resource that is needed for human use. Within the scoping and prior to using the tool, users must determine which species are to be considered when answering the impacts to accessibility of food and water, and non-food resources. Consider resources such as books or websites on herb-lore and traditional cultural practices, for example.

### C3.1 Evidence that the species could impact accessibility of food and drinking water resources

This question concerns impacts to food sources attained for individual or community survival rather than industry (such as sport or tourism which was considered in question C1.1). This would not include impacts to commercial shellfish harvesting, aquaculture facilities, fish farms, or commercial fishing, which are also considered as industry in C1.1. Rather, this concerns individually harvested food and water for personal consumption that is essential or important for survival. Examples could include wild harvested grains such as wild rice, wild caught fish for First Nations who rely on the fish as a food source, plants such as berries or leafy wild vegetables, or freshwater drawn for consumption in the absence of public drinking water sources, etc. The assessed species must limit the ability to access or harvest, either through reduced availability, or physical means such as interfering with modes of access.

Examples could include:

* floating macrophytes that impede fishing and boating when fishing is for non-sport related purposes.
  + - organisms that impact salmonid abundance (predation, habitat degradation, etc.) which are harvested for personal or community consumption.
      * mussels that block drinking water intake pipes when freshwater is not provided independently by the municipality.
* Scoring:
  + *1 = Low to no impact*. Collection of food and/or water is altered very little or not at all.
* E.g., Common periwinkle (*Littorina littorea*) is not known to impact the ability of people to fish for individual needs. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Collection of food and/or water is impeded but still accessible.
* E.g., Golden star tunicate (*Botryllus schlosseri*) which, while it can foul aquaculture equipment and commercial fishing gear, is likely to have only moderate impact to smaller-scale fishing for individual or community needs. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive impacts making collection of food and/or water very difficult or impossible.
* E.g., European green crab (*Carcinus maenas*) competes with native crab species such as Dungeness crab (*Metacarcinus magister*) on the Pacific coast and American lobster (*Homarus americanus*) on the Atlantic coast, which are both harvested for personal use. The assessor would give this a distribution weighted towards a score of 3.

### C3.2 Evidence that the species could impact accessibility of non-food resources? (E.g., wood, medicines (non-traditional), ornamental species, etc.)

This question is concerned with any other resources that humans utilize that are not for food, including medicinal plants, wood, flowers, shells, trees etc. Impacts are primarily concerned with current/active resource collecting, not historical.

* Scoring:
* *1 = Low to no impact*. Collection of resources is altered very little or not at all.
* E.g., Marbled crayfish (*Procambarus virginalis*) degrade habitat for invertebrates and fish via foraging activities but overall would have a minimal impact to resources for non-food collection. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Collection of resources is impeded but still accessible.
* E.g., Tench (*Tinca tinca*) have large ecosystem impacts related to an omnivorous diet and foraging activities which have impacts on growing macrophytes, potentially impacting species known to be harvested for traditional uses such as sweetgrass or cattail. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive impacts making collection of resources very difficult or impossible.
* E.g., Camboba (*Camboba caroliniana*) impacts growing macrophytes due to thick cover, with winter die-offs significantly impacting water quality. The assessor would give this a distribution weighted towards a score of 3.
* E.g., Killer alga (*Caulerpa taxifolia*) form dense mats which eliminate fish habitat, chokes out eelgrass beds impacting shellfish and invertebrate collection for shells, and native seaweeds that are important for human use. The assessor would give this a distribution weighted towards a score of 3.

### C3.3 Do you expect magnitude of impacts to differ in a future climate?

* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* Is the organism more likely to reduce availability or accessibility of resources (+1), less likely

(-1) or no change (0)?

* E.g., An aquatic reed that outcompetes wild rice will become more prolific and denser with warming temperatures, and therefore further reduce density or availability of wild rice (+1)
* E.g., Feeding rates of crayfish on salmon eggs increases with warming temperatures (+1)

## C4. Socioeconomic Impacts: Evidence of impacts to species or areas of cultural/social importance

This section concerns impacts to species or areas used traditionally for ceremonial or other social events, or purposes of any social importance. Within the scoping and prior to using the tool, users must determine which species and areas are to be considered when answering the impact to species and areas of cultural or social importance. This list must be consistent across all assessments.

### C4.1 Evidence the species could impact a species of cultural or social importance

This question considers currently important ethnobotanical or ethnozoological species. Species at risk are considered in the previous Ecological Impacts Module (B4). Examples are numerous but could include organisms such as *Dentalium* (tusk) shells, salmon, cedar trees, clams, cattails, wapato, etc.

* Scoring:
  + *1 = Low to no impact*. Culturally important species are altered very little or not at all.
* E.g., Striped barnacle (*Amphibalanus amphitrite*) is a well-known fouling organism, however impacts to culturally important species are minimal. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Culturally important species are impacted largely but still able to function.
* E.g., Reed canary grass (*Phalaris arundinacea*) can form dense mats that impede salmonids, degrade riparian habitats, and outcompete native macrophytes collected for cultural purposes such as cattails. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Culturally important species are greatly impacted and are not able to function or are at risk of becoming endangered or extirpated.
* E.g., Red lionfish (*Pterois volitans*) are voracious predators of fish and crustaceans in coral reefs in their native habitat which can include many culturally important species for human use. The assessor would give this a distribution weighted towards a score of 3.

### C4.2 Evidence the species could impact an area of cultural or social importance

This question considers areas of cultural or social importance for a variety of reasons, and may include areas used for activities such as:

* sports (swimming, boating, hunting, and fishing, etc.)
* ceremonies
* recreation (hiking trails, biking, beaches, bird watching habitat, etc.)
* The focus of this question is for the importance of areas for human use and while it may include those previously considered in ‘Ecological Impact Module B4.2: Evidence the species could represent a threat to areas of high conservation value’ due to overlap in the importance of conservation areas for many other considerations not included in previous questions (protection of rare or endangered areas, importance for conservation species, and cultural and social reasons for human use), the focus of this question should be on human importance rather than species at risk.
  + E.g., Creeks and rivers used for fishing.
  + E.g., Lakes used for swimming and boating.
  + E.g., Areas used for hunting.
  + E.g., Habitat such as estuaries or wetlands for migratory birds important for bird-watching and nature photography
* Scoring:
  + *1 = Low to no impact*. A minor impact on culturally important areas.
* E.g., Japanese acorn barnacle (*Megabalanus rosa*) is well known as a biofouling organism of man-made structures and equipment but poses less of a risk to areas of conservation value such as estuaries or protected coastal shores. The assessor would give this a distribution weighted towards a score of 1.
* *2 = Moderate impacts*. Some impact to culturally important areas occurs and overall ecological units are impacted in some way.
* E.g., Brazilian elodea (*Egeria densa*) acts as an ecosystem engineer and alters trophic dynamics, posing a risk to wetlands and other sensitive habitat for migratory birds (bird watching), as well as river and lake margins used for recreational boating, swimming, and fishing. The assessor would give this a distribution weighted towards a score of 2.
* *3 = High impacts*. Extensive impacts to culturally important areas occur such that the ecological units are significantly altered.
* E.g., Eurasian water milfoil (*Myriophyllum spicatum*) forms dense mats that clog waterways and impede recreational activities (boating, fishing, swimming…) in areas of high use such as lakes. The assessor would give this a distribution weighted towards a score of 3.

### C4.3 Do you expect magnitude of impacts to differ in a future climate?

* Scoring:

|  |  |  |
| --- | --- | --- |
| **+1** | **0** | **-1** |
| Increase due to climate change | Remain at similar levels | Decrease due to climate change |

* Is the organism more likely to impact culturally/socially important species/areas (+1), less likely (-1) or no change (0)?
* E.g., A floating non-indigenous macrophyte that has higher growth rates as climate warms leading to higher densities, which will further impede boating and swimming in lakes (+1)

# Outputs and Visualizations

The R-script supplied suggests several ways to visualize the data. The resulting total scores and associated uncertainties can be displayed as a simple figure, organized from highest to lowest total scores. Climate change scores can also be easily visualized on the same figure using vectors to indicate whether the score is likely to increase or decrease and the magnitude of that change. From this, a ranked list can be easily determined. The second method involves the development of biplots where the individual contribution of each module is graphically displayed, such that those species with higher risk for both invasion and impacts will appear in the upper right quadrant, while those which scored low in both modules will be more proximate to the bottom left quadrant. Given the potentially large number of species, it is easier to visualize climate change using a separate vector plot. At present, these biplots compare invasion potential to either impact score. Note that this is a prioritization tool; however, determining criteria to categorize species into desired levels of risk (e.g., High, Moderate, Low) will be based on the end user’s risk tolerances. As such no specific thresholds are provided.

R-script is provided at Git Hub: [GitHub - MarkAlanWilcox/Non-Indigenous-Species-Screening-Tool-NISST.](https://github.com/MarkAlanWilcox/Non-Indigenous-Species-Screening-Tool-NISST) along with the generalized data input sheet.

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# Contacts

Questions can be addressed to:

Mark Wilcox, Biologist

Mark.Wilcox@dfo-mpo.gc.ca

3190 Hammond Bay Rd, Nanaimo, BC V9T 6N7

Thomas Therriault, Research Scientist

[Thomas.Therriault@dfo-mpo.gc.ca](mailto:Thomas.Therriault@dfo-mpo.gc.ca)

3190 Hammond Bay Rd, Nanaimo, BC V9T 6N7

Karen Dyke, Biological Technician

[Karen.Dyke@dfo-mpo.gc.ca](mailto:Karen.Dyke@dfo-mpo.gc.ca)

3190 Hammond Bay Rd, Nanaimo, BC V9T 6N7

Devan Johnson, Biologist

[Devan.Johnson@dfo-mpo.gc.ca](mailto:Devan.Johnson@dfo-mpo.gc.ca)

3190 Hammond Bay Rd, Nanaimo, BC V9T 6N7