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# Proceedings of the National Peer Review on the Marine Screening-Level Risk Assessment Protocol for Aquatic Non-Indigenous Species

**February 4-6, 2015**
**Dartmouth, Nova Scotia**

**Chairperson: Eddy Kennedy**
**Editor: Danielle Scriven**

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Canada

## Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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## SUMMARY

A national peer-review science advisory process was held to provide science advice on a new marine screening-level risk assessment (SLRA) tool for non-indigenous species (NIS). This process consisted of three parts: Part 1 was held in Montreal, Quebec, from 22-24 November 2011; Part 2 was held in Burlington, Ontario, from 19-21 March 2013; Part 3 (these Proceedings) was held in Dartmouth, Nova Scotia at the Bedford Institute of Oceanography from 4-6 February 2015. The purpose of Part 3 of this process was to address the following three objectives:

i) to review a new marine screening-level risk assessment tool (CMIST – Canadian Marine Invasive Screening Tool) and optimization methods;

ii) to provide a list of higher-risk non-indigenous invertebrates already introduced and others not reported in three Canadian ecoregions (i.e. Gulf of St. Lawrence, Scotian Shelf, and Strait of Georgia); and

iii) to provide science advice on the suitability of CMIST to classify the level of risk presented by marine non-indigenous species (NIS) in other taxa.

Based on the presentation of two Working Papers, participants at the meeting determined that CMIST is a scientifically defensible and relatively quick SLRA tool to screen and prioritize marine NIS. However, despite general over-parameterization of risk assessment tools, participants agreed that, in part due to the small sample size of the study, optimization of CMIST is not necessary for DFO purposes at this time. Through the use of CMIST and an expert knowledge survey, a list of higher risk marine invertebrates in the three Canadian ecoregions was generated. NIS were scored on their likelihood of invasion and impact of invasion, and these scores were presented in a heat matrix to identify higher risk marine invertebrate species. Further, participants acknowledged that CMIST is a robust tool that likely can be adapted and should be tested as a SLRA tool for taxa other than marine invertebrates. The resulting publications from Part 3 of this process include a CSAS Science Advisory Report (DFO 2015), two Working Papers to be published in the primary literature (Drolet et al. 2015a, 2015b[1]), and these CSAS Proceedings.


[1] Drolet, D., DiBacco, C., Locke, A., McKenzie, C. H., McKindsey, C. W., and Therriault, T. W. 2015b (Submitted). Optimizing screening protocols for non-indigenous species: Are currently used tools over-parameterized? Biological Invasions.

## SOMMAIRE

Un processus consultatif scientifique d'examen national par des pairs a eu lieu pour offrir un avis scientifique sur un nouvel outil d'évaluation préalable des risques (ÉPR) pour les espèces aquatiques marines non indigènes. Ce processus s'est tenu en trois parties : la partie 1 a eu lieu à Montréal, au Québec, du 22 au 24 novembre 2011; la partie 2 a eu lieu à Burlington, en Ontario, du 19 au 21 mars 2013; et la partie 3 (faisant l'objet du présent compte rendu) a eu lieu à Dartmouth, en Nouvelle-Écosse, à l'Institut océanographique de Bedford, du 4 au 6 février 2015. La partie 3 de ce processus visait à aborder les trois objectifs suivants :

i) examiner un nouvel outil d'évaluation préalable des risques pour les espèces marines (outil canadien d'évaluation préalable pour les espèces marines envahissantes [outil canadien]) ainsi que les méthodes d'optimisation;

ii) fournir une liste des invertébrés non indigènes à haut risque déjà introduits et de ceux qui n'ont pas encore été signalés dans trois écorégions canadiennes (à savoir le golfe du Saint-Laurent, le plateau néo-écossais et le détroit de Georgie);

iii) fournir un avis scientifique sur le caractère adapté de l'outil canadien lorsqu'il s'agit de classer le niveau de risque associé aux espèces marines non indigènes d'autres taxons.

En s'appuyant sur la présentation de deux documents de travail, les participants à la réunion déterminent que l'outil canadien représente un outil d'ÉPR scientifiquement défendable et relativement rapide pour évaluer les espèces marines non indigènes et les classer par ordre de priorité. Cependant, malgré le caractère généralement « surparamétré » des outils d'évaluation des risques, les participants s'accordent sur le fait que, notamment en raison de la faible taille de l'échantillon de l'étude, l'optimisation de l'outil canadien pour le MPO n'est pas nécessaire à ce jour. Grâce à l'outil canadien et à une étude des connaissances spécialisées, une liste des invertébrés marins à haut risque a été dressée pour les trois écorégions canadiennes. Les espèces non indigènes sont notées en fonction de la probabilité d'invasion et des répercussions d'une telle invasion, et ces notes sont présentées dans une matrice de points chauds permettant de recenser les espèces d'invertébrés marins représentant le plus grand risque. En outre, les participants reconnaissent que l'outil canadien est un outil robuste qui devrait pouvoir être adapté et qui devrait être mis à l'essai en tant qu'outil d'ÉPR pour des taxons autres que les invertébrés marins. Les publications qui découlent la partie 3 de ce processus comprennent un avis scientifique du SCCS (MPO 2015), deux documents de travail qui seront publiés dans la littérature primaire (Drolet *et al*. 2015a, 2015b[2]), et le présent compte rendu du SCCS.

[2] Drolet, D., DiBacco, C., Locke, A., McKenzie, C. H., McKindsey, C. W. et Therriault, T. W., 2015b (soumis). Optimizing screening protocols for non-indigenous species: Are currently used tools over-parameterized? Biological Invasions.

# INTRODUCTION

Non-indigenous species (NIS) can threaten the ecosystems to which they are intentionally or unintentionally introduced. The challenge for invasion biologists is to determine which NIS are high risk in order for managers to appropriately allocate resources. With regards to NIS, risk represents both the likelihood of invasion and the predicted consequences or impacts of that invasion. Risk assessment tools (RATs) are necessary to determine which NIS are most likely to complete the invasion process (introduction, survival, establishment, and spread) and cause ecological, environmental or socioeconomic damage. RATs, in particular screening-level risk assessment (SLRA) tools, are needed in order to rapidly assess (e.g., within days) a species' threat.

SLRA tools can be utilized by managers to determine if an invading species is a threat (high risk) or not (low risk). SLRA tools generally consist of a series of questions that can be answered to rapidly assess a species' threat. These assessments can be used to evaluate species already identified or established in the assessment area and others that represent potential future introductions to that area. SLRA tools that generate quantitative scores, such as CMIST, have an additional advantage since they create a relative ranking of species-specific risk that can be used to help prioritize limited resources to manage them. If accurate, these tools are able to rapidly screen and rank species and focus limited resources on those posing the greatest risk. Validated SLRA tools can be used to quickly identify risk associated with newly reported NIS to inform monitoring programs that target early detection of high risk species, and to identify high risk species for regulatory actions.

Work on SLRA and prioritization tools for both freshwater and marine NIS was initiated in 2011 as part of the national Canadian Science Advisory Secretariat (CSAS) process. This work was a joint request from DFO Science and DFO Legislative and Regulatory Affairs (subsequently assumed by DFO Ecosystems and Fisheries Management (EFM)). The overall objective was to develop a common national SLRA and prioritization tool that was score-based and that would be used to identify, rank, and prioritize potential aquatic invasive species (AIS) (i.e., freshwater and marine). The tool would be employed to generate a list of high risk aquatic NIS, including ones already introduced and others not reported in Canadian ecoregions.

This CSAS process occurred in three parts: Part 1 was held from 22-24 November 2011 in Montreal, Quebec; Part 2 was held from 19-21 March 2013 in Burlington, Ontario, and; Part 3 was held from 4-6 February 2015 at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. These Proceedings document only the results of Part 3 of the CSAS process.

The objectives for Part 1 of this CSAS process were sub-divided into two parts. The first set of objectives were to: evaluate the presented working papers; review the criteria and methodology used to evaluate risk assessment (RA) protocols; develop a framework for a SLRA prioritization protocol for aquatic NIS by evaluating the Alberta RAT and major gaps therein; develop an evaluation method and list of aquatic NIS to use in testing and calibrating the SLRA prioritization protocol, and; discuss and recommend how to define geographical boundaries of the distribution of aquatic NIS already present in Canada. The second set of objectives for Part 1 of this CSAS process were to: finalize a national SLRA prioritization protocol for aquatic NIS for assessing the risk and relative importance of known and future aquatic NIS; identify what modifications need to be made to this protocol for its use in listing aquatic NIS; identify a preliminary list of high risk aquatic NIS not yet in Canada or already present in Canada whose transport into "non-infected" areas in Canada should be limited, and; identify sources of distributions of aquatic NIS in Canada whose transport into non-invaded areas in Canada should be limited (DFO, 2012).

The objectives of Part 2 of this CSAS process were to: peer-review three working papers on SLRA protocols for freshwater NIS; recommend the protocols that are suitable for SLRA prioritization of freshwater NIS in Canada, and; apply the protocols to recommend lists of priority freshwater NIS for regulatory consideration and other management actions (DFO, 2014b).

The objectives (see Appendix 1 for complete Terms of Reference) of Part 3 of this CSAS process were to:

1. Review a newly developed SLRA tool for marine NIS (CMIST) and optimization methods for CMIST, and to provide science advice on the application of the tool as a scientifically defensible and relatively quick protocol to screen and prioritize NIS invertebrates already introduced and others not reported in three Canadian ecoregions (Gulf of St. Lawrence, Scotian Shelf, and Strait of Georgia) (DFO 2009);
2. If CMIST is deemed appropriate in fulfilling Objective 1, then based on the testing of CMIST to date, provide a prioritized list of higher risk marine invertebrate species for each of the three Canadian ecoregions that were assessed as well as details of why they are higher risk.
3. Provide Science advice on the suitability of CMIST for assessing likelihood of invasion and potential impact by marine NIS in other taxa (e.g., fish, marine plants).

## THE CANADIAN MARINE INVASIVE SCREENING TOOL (CMIST)

The Canadian Marine Invasive Screening Tool (CMIST) is a new score-based SLRA tool designed to assess both the likelihood and impact of invasion by NIS on a scale of 1 (low risk) to 9 (high risk). A CMIST guidance document assists assessors in consistently and correctly scoring the species of focus. The specific objectives of CMIST are to:

1. Rank species to determine which ones to focus on;
2. Inform potential AIS regulatory listings in order to allocate resources properly, and;
3. Inform monitoring programs.

In the case of CMIST, the risk of invasion is defined as:

$$Risk\ Score = likelihood\ of\ invasion\ \times potential\ magnitude\ of\ impact$$

The only other SLRA tool currently available to rank invasiveness in marine environments is the Marine Invertebrate Invasiveness Scoring Kit (MI-ISK). MI-ISK asks 49 questions regarding species domestication, climate requirements, distribution, history of invasion, biological traits, feeding biology, reproduction biology, dispersal, and persistence attributes. Conversely, CMIST asks only 17 questions relating to the likelihood of invasion, potential rate of introduction and severity of impact, and probability of survival, establishment, and spread of NIS.

With regards to testing CMIST, there were three distinct phases of testing:

1. Develop a tool that follows the invasion process and also incorporates uncertainty;
2. Test the tool against NIS already introduced and with known impacts in select Canadian ecoregions, and;
3. Evaluate the tool's application for other NIS not yet reported in Canadian ecoregions.

During this meeting, there was some general discussion regarding the divergence of freshwater and marine approaches. The freshwater approach involved applying the Montreal RAT (a predecessor to CMIST) to freshwater fish in the Great Lakes Basin, which appeared to work well (DFO, 2014b): however, the desire for a single, national RAT to use across taxa and

ecoregions remains. Although freshwater and marine approaches are not comparing SLRA tools or working on the development of a common SLRA tool at the present time, there are similarities between regional approaches (e.g., CMIST was derived from the Montreal RAT).

## PRESENTATION OF WORKING PAPERS

### WORKING PAPER 1: EVALUATING CMIST (Drolet et al., 2015a)

The first working paper that was presented assesses and evaluates the performance of CMIST and MI-ISK using 60 marine invertebrate NIS and ecosystem combinations. The three ecoregions evaluated are the Gulf of St. Lawrence, Scotian Shelf, and Strait of Georgia (DFO, 2009). The assessment scores were compared to the results of an expert knowledge survey, which is thought to provide the best means to assess the impact of NIS with known invasion histories, and is also considered the most effective way to test and assess CMIST results. Results indicate that CMIST more strongly correlates with expert knowledge surveys than does MI-ISK. In addition, the authors concluded that since CMIST is not taxon specific, it could easily be applied to other taxa.

### Discussion of Key Points

#### CMIST Question 1

There was significant discussion regarding Question 1 of CMIST (see Appendix 4 for a list of questions), specifically: “Is the *species established* in the *assessment area*?” If a species is already established in the assessment area, a score of 2 is assigned; if a species is observed but not reported as established, a score of 1 is assigned; finally, if a species is not observed, a score of 0 is assigned. NIS invertebrates already introduced to the three ecoregions in question (Gulf of St. Lawrence, Scotian Shelf, and Strait of Georgia) are therefore assigned a score of 2; other NIS invertebrates not yet reported in the three ecoregions are assigned a score of 0. The species being tested here are all being compared (e.g., see relative ranking in Figures 2 and 3 in DFO, 2015), and thus by definition, the first group will always score higher than the second group in Question 1.

The reviewers of Working Paper 1 raised concerns that already introduced species will automatically be scored higher (i.e. artificially inflated) than those species not yet reported. However, it was clarified that in order for CMIST to be properly utilized, managers must look at the accompanying risk assessment for each species (e.g., see Table 1 in DFO, 2015) instead of the absolute score alone. In addition, the species that have already been introduced in the assessment area are being used as a baseline for those that have not yet been reported, and therefore species must be ranked together to complement one another. Finally, it was clarified that Question 1 is a strong predictor of a high risk NIS, and thus is an important question in this assessment.

Ultimately, meeting participants reached consensus and decided to retain Question 1, and also decided that CMIST performs well when comparing species that are not yet reported relative to ones that have already been introduced to the assessment area.

#### Adjusted or Original Scores and Incorporating Uncertainty

The expert knowledge survey was completed in order to compare expert answers to the results generated by CMIST. Survey respondents were asked to quantify the level of risk (low, moderate, or high) for each species in the ecoregions to which they have been introduced, resulting in the generation of a species original score. In addition, experts were also asked to rate their level of uncertainty. The combination of the risk and the uncertainty scores returned by

experts were then assigned a value of 1, 2, or 3 to make scores comparable to those employed for CMIST assessment scores. The resulting scores were termed “adjusted scores”, and incorporated uncertainty.

There was considerable discussion surrounding the use of original versus adjusted scores, and how to best incorporate uncertainty into CMIST. In addition, the reviewers questioned why experts were forced to answer each question, instead of being allowed to answer “unknown”. The researchers clarified that by forcing experts to answer each question instead of being allowed to forego answering, more information could be generated, even if the respondent was uncertain with their answer. Because many SLRA tools are over-parameterized, the researchers clarified that any answer is better than “unknown”.

There is a tradeoff between using original and adjusted scores, such that the original scores do not incorporate uncertainty, and adjusted scores do not reflect invasion risk. Participants decided that both scores have merit, and both scores should be presented in some way moving forward. Participants also decided to use adjusted scores in the CSAS SAR (see Figures 2 and 3 in DFO, 2015).

### Binning Numbers

Participants discussed at length how to best present ranked species data. While the continuous relative and numerical ranking system is useful (e.g., see Figure 2 in DFO, 2015), some participants suggested that it may be better for managers to have species results categorized (i.e., high risk, moderate risk, low risk categories) to more easily and clearly differentiate which species require action; otherwise, functionality of CMIST may be lost.

Participants at the meeting reached consensus and decided that providing a continuous score (e.g., see Figure 2 in DFO, 2015) as an output from CMIST was important as it provided relative species-specific scores that most accurately reflected CMIST assessment scores. It was suggested that heat matrices were an appropriate way to categorize scores as the likelihood of invasion score and impact of invasion score could both be presented in a single graphic (see Appendix 5; also see section on review of Objective 2 – pg. 5).

### Temporal Considerations

Meeting participants spent some time discussing whether or not CMIST Questions adequately encompassed temporal considerations, specifically with regards to future climate change. It was suggested that the questions should reflect both whether the species has a present impact on its environment as well as whether it will have a future impact. However, due to the level of uncertainty surrounding present climate models and invasive species, temporal boundaries are difficult to quantify.

CMIST is meant to be a rapid response SLRA tool, and thus future environmental changes (e.g., ocean temperature and salinity) are not explicitly considered; instead, general impacts based on current conditions are the primary consideration. Because climate is expected to continue changing, these assessments should be considered living documents, and should be reassessed as warranted.

Participants agreed that what necessitates a species’ review should be incorporated into the CMIST guidance document. In addition, how temporal boundaries were considered within the RAT should be included.

## WORKING PAPER 2: OPTIMIZING CMIST (Drolet et al., 2015b)

There is a growing body of evidence that RATs are over-parameterized, and that some questions add noise to the assessment of a species. This paper evaluated CMIST to determine

if this SLRA tool can be made more accurate through a series of statistical optimization procedures. In this case, accuracy was defined as the correspondence of scores returned by CMIST with the results on an expert knowledge survey. By removing questions from the RAT that did not improve accuracy of the results, and by adjusting the weight of each question, CMIST's accuracy was tested. The authors concluded in Working Paper 2 that the current application of CMIST (DFO, 2015) had too many parameters, and that some questions were not necessary for the analysis: thus, CMIST could be made faster and more accurate via optimization (i.e., removal of questions determined to not be helpful).

### Discussion of Key Points

#### Enhancing Clarity

Less time was spent discussing the second Working Paper than the first one. The reviewers' main concerns were with regards to clarity of the methodology, and whether weighting questions was scientifically defensible given the small sample size. It was suggested that an example to demonstrate weights would enhance clarity in the paper.

Ultimately, participants decided that although optimization of RATs is a useful exercise, at this time, it is not appropriate or necessary for use by DFO with respect to CMIST. Although some of the questions were found not to contribute to accuracy, those questions provided managers and tool-users with valuable information about, for example, the impacts of AIS on aquaculture or species at-risk. In the future, should sample sizes increase, optimization in conjunction with CMIST may be revisited.

## REVIEW AND SUMMARY OF TERMS OF REFERENCE

This section reviews the main discussion points from 5 February 2015 related to the three Terms of Reference for Part 3 of the CSAS meeting.

### OBJECTIVE 1: REVIEW CMIST AND OPTIMIZATION

Both CMIST and the optimization of CMIST were reviewed on Day 1 of the meeting. It was decided that CMIST is a scientifically defensible and relatively quick protocol to screen and prioritize marine NIS invertebrates already introduced and others not reported in three Canadian ecoregions (Gulf of St. Lawrence, Scotian Shelf, and Strait of Georgia). Further, it was decided that optimization of CMIST will not be employed at this time.

### OBJECTIVE 2: PROVIDE A PRIORITIZED LIST OF HIGHER RISK SPECIES

There was significant discussion regarding how to best fulfill the second objective of the meeting.

First, participants debated whether there should be a threshold that dictates which species are considered high, medium, and low risk species. However, the available data did not allow for the identification of scientifically-defensible threshold values to separate high, medium, and low risk species. Additionally, there was no natural break between species when graphing the original scores (e.g., see Figure 2 in DFO, 2015), indicating that perhaps thresholds may not be appropriate, as a high-ranking medium risk species that falls slightly below the threshold may mistakenly not be considered for management if the score alone is considered.

Second, participants discussed whether the CMIST scores, expert scores, or detailed RAs should be used to rank and determine the level of risk posed by NIS that have not yet been introduced. It was pointed out that there are very few people that are qualified to rank species on both the east and west coasts, and thus there will be differences between experts depending

on their level of risk tolerance and areas of concern (e.g. aquaculture versus ecosystems). The differences between experts and potential biases of experts further outline difficulties with assigning a threshold to determine high risk species.

Finally, participants discussed the possibility of using heat matrices to depict the risk posed by each species as a means of not setting a specific threshold (defining a threshold is not necessary as per the Terms of Reference). The risk matrices created for each ecoregion (see Appendix 5) show both the likelihood of invasion and the impact of invasion for each species that was assessed. Higher risk species will fall towards the upper right quadrant, and therefore those are the species that will require attention from management, or are worth following up on (see Appendix 5).

Participants of the meeting came to consensus and decided that Science was responsible for providing the list of species, for placing species in a matrix with an accompanying explanation of each species' adjusted score, and for explaining why each species is placed where they are. Science will create three heat matrices, one for each ecoregion currently assessed: Gulf of St. Lawrence, Scotian Shelf, and Strait of Georgia.

## OBJECTIVE 3: PROVIDE SCIENCE ADVICE REGARDING THE SUITABILITY OF CMIST FOR OTHER TAXA

CMIST was initially used to rank marine invertebrate NIS, as most of the current knowledge and information of NIS in marine ecoregions is focused on marine invertebrate species. Because CMIST is targeted at the invasion process and not a specific species, it should be straightforward enough to apply the tool to other taxa. Further, CMIST and its questions are robust, and preliminary results in applying CMIST to freshwater fish in British Columbia have been promising to date (T. Therriault, pers. comm.).

The researchers stressed that proper training on the tool should be provided across all sectors to ensure its correct usage, and to ensure that results are consistent. In addition, participants agreed that, in the future, the CMIST guidance document should include some guidance for specific taxa (e.g. migratory fish) to ensure its robustness across all taxa. The current version of this guidance document can be found in Appendix 6.

## DRAFTING OF THE SCIENCE ADVISORY REPORT

On the third day of the meeting (6 February 2015), participants began to draft the Science Advisory Report (SAR) (DFO 2015). Participants discussed and proposed key findings and additions to include in the SAR. The SAR was finalized and published in July 2015.

## CONCLUDING REMARKS

Meeting participants felt that the Working Papers presented at the meeting presented sound scientific analyses on marine screening-level risk assessment protocols for aquatic non-indigenous species. The reviewers' comments will be incorporated into the Working Papers, which will subsequently be submitted for peer-review and published in the primary literature. Although the Science Advisory Report (SAR) was not completed at the meeting, it was agreed by meeting participants that the science leads and meeting chairperson would coordinate completion of a draft SAR consistent with views expressed in the meeting on the Working Papers, and circulate as a revised draft SAR by email for subsequent review and approval by meeting participants (completed, DFO 2015). Comments provided by meeting participants on the circulated draft SAR were addressed, and incorporated as necessary. Sincere efforts were made in this science peer review process to acknowledge and address all comments and

concerns raised by meeting participants provided they were appropriate and within the confines of acceptable peer review practice. The Science Advisory Report received consensus following the meeting.

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## APPENDIX 1: TERMS OF REFERENCE

### Marine Screening-Level Risk Assessment Protocol for Aquatic Non-Indigenous Species

### National Peer Review – Maritimes Region

**4-6 February 2015**
**Dartmouth, NS**

Chairperson: Eddy Kennedy

### Context

Fisheries and Oceans Canada's (DFO) aquatic invasive species program has been tasked by the Office of the Auditor General and an internal evaluation to establish a scientifically defensible and relatively quick protocol to screen and prioritize high risk aquatic non-indigenous species (NIS). Such a protocol would benefit DFO Science in providing timely advice on risk posed by NIS newly introduced to Canadian ecosystems, including application in Rapid Response frameworks for NIS. The national ranking of aquatic NIS, based on the biological risk they pose to Canadian aquatic ecosystems, is necessary to prioritize the allocation of funds and other resources for national and regional aquatic NIS activities.

DFO's Ecosystem and Fisheries Management (EFM), also a client for this process, has requested science advice to support the development of a national regulatory proposal to address aquatic NIS. Specifically, they have requested: 1) a protocol to identify and prioritize high risk aquatic NIS, and 2) a list of high risk aquatic NIS including NIS not yet present and already established in Canadian waters and whose transport to "non-infected" areas should be limited.

As a result, DFO's Centre of Expertise for Aquatic Risk Assessment (CEARA) initiated the review and development of screening-level risk assessment (SLRA) prioritization tools for aquatic NIS and associated ecosystems. These tools will allow the ranking of aquatic NIS that can inform national prioritization of NIS. As well, they can be used as biological screening tools for aquatic NIS to determine (in a short time frame) if more detailed-level risk assessment or if risk management evaluations are required based on existing information.

A national Canadian Science Advisory Secretariat (CSAS) science advisory process was initiated in 2011 to provide science advice on SLRA prioritization tools for freshwater and marine NIS. This process will consist of at least 3 peer-review meetings. The first (Part 1) was held in Montreal, Québec on November 22-24, 2011. For Part 1, participants compared SLRA protocols and developed a framework for a new SLRA tool for aquatic NIS, referred to as the Montreal Rapid Assessment Tool (i.e., MRAT). It was concluded that different SLRA protocols may be required for freshwater vs. marine NIS taxa and ecosystems and, hence, prioritization using a single protocol was not pursued following this initial review. Part 2 was held in Burlington, Ontario on March 19-21, 2013, where SLRA protocols were evaluated for and applied to 3 freshwater NIS taxa, namely fish, molluscs and plants, currently in trade within Canada. Part 3 will be held in Halifax, NS on February 4-6, 2015, at the Bedford Institute of Oceanography to review and evaluate (i) the performance of a newly developed marine SLRA tool (i.e., Canadian Marine Invasive Screening Tool, CMIST) to predict the risk associated with NIS already established in 3 Canadian ecoregions (Strait of Georgia, Gulf of St. Lawrence, and Scotian Shelf); (ii) the statistical optimisation methods to enhance CMIST predictability and performance in predicting risk associated with NIS already established in 3 Canadian ecoregions, and (iii) the performance of CMIST in assessing the risk of NIS not yet established in the same 3 Canadian ecoregions. To date, CMIST has been developed, tested and optimized for marine invertebrate

NIS only. Future work will be required to assess its applicability to prioritize other high risk NIS taxa (e.g., marine fish and algae).

## Objectives

Based on the papers presented at the meeting, meeting participants will be asked to fulfill the following objectives:

1. Review the marine SLRA tool (CMIST), as well as the optimisation methods, developed for screening marine invertebrates and provide science advice on the application of the tool as a scientifically defensible and relatively quick protocol to screen and prioritize marine invertebrate NIS that are:
    - already present in Canada, and
    - not yet introduced to Canada.
2. If CMIST is deemed appropriate in fulfilling Objective 1 and based on the testing of CMIST to date, provide a prioritised list of higher risk marine invertebrate species of those that were assessed as well as details of why they are higher risk:
    - already present in Canada, and
    - not yet introduced to Canada.
3. Provide Science advice on the suitability of CMIST for marine NIS in other taxa (e.g., fish and marine plants).

## Background Papers and Working Papers

- Drolet, D., C. DiBacco, A. Locke, C.H. McKenzie, C.W. McKindsey, A.M. Moore, J. Webb, and T.W. Therriault (in review). An evaluation of two screening-level risk assessment tools for non-indigenous marine invertebrates in Canadian coastal waters (includes CMIST performance for marine invertebrates not yet introduced in the 3 Canadian ecoregions).
- Drolet, D., C. DiBacco, A. Locke, C.H. McKenzie, C.W. McKindsey, and T.W. Therriault (submitted). Optimizing screening protocols for non-indigenous species: are currently used tools over-parameterized?
- CMIST Guidance (Tool questions and guidance for scoring system).

## Expected Publications

- Science Advisory Report(s)
- Proceedings

## Participation

- Fisheries and Oceans Canada (DFO) Science, Ecosystem and Fisheries Management, Policy and Economics
- Experts from other federal and provincial government departments
- Academics

## References


DFO. 2014. Science advice for screening-level risk assessment protocols for nonindigenous freshwater organisms in trade in Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/009.

DFO. 2012. Proceedings of the Meeting on Screening-Level Risk Assessment Prioritization Protocols for Aquatic Non-Indigenous Species. November 22-24, 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2011/068.

DFO. 2014. Proceedings of the National Peer Review of Screening-Level Risk Assessment Protocols for Freshwater Non-indigenous Species; March 19-21, 2013. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2014/004.

Mandrak, N.E., Cudmore, B., and Chapman, P.M. 2012. National detailed-level risk assessment guidelines: assessing the biological risk of aquatic invasive species in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/092. vi + 15 p

Mandrak, N.E., Gantz, C., Jones, L.A., Marson, D., and Cudmore, B. 2013. Evaluation of five freshwater screening-level risk assessment protocols and application to non-indigenous organisms in trade in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/122 v+137 p.

Schroeder, B., Mandrak, N.E., and Cudmore, B.C. 2014. Application of a Freshwater Mollusc Risk Assessment to Non-indigenous Organisms in Trade in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/060.

## APPENDIX 2: LIST OF PARTICIPANTS

### Marine Screening-Level Risk Assessment Protocol for Marine Non-Indigenous Species

### National Peer Review – Maritimes Region

**4-6 February 2015**
**Dartmouth, NS**

Chairperson: Eddy Kennedy

| Name | Affiliation |
|---|---|
| Craig, Mark | DFO Maritimes / Policy and Economics |
| DiBacco, Claudio | DFO Maritimes / Coastal Ecosystem Science |
| Drolet, Dave | DFO NCR |
| Herborg, Matthias | BC Ministry of Environment |
| Howland, Kim | DFO C&A / Science |
| Kennedy, Eddy | DFO Maritimes / Coastal Ecosystem Science |
| Kling, Ashley | DFO NCR / Fish Population Science |
| Koop, Anthony | USDA-APHIS, NC, USA |
| Landry, Thomas | DFO Gulf / Science |
| LeBlanc, Jason | NS Dept. Fisheries & Aquaculture / Inland Fisheries |
| Lemieux, Stephanie | DFO NCR / Strategic Policy |
| Liew, Doreen | DFO Maritimes / Policy and Economics |
| Locke, Andrea | DFO Gulf / Oceans |
| McKenzie, Cynthia | DFO Newfoundland |
| McKindsey, Chris | DFO Québec / Ocean & Environmental Science |
| Moore, Andrea | DFO Maritimes (Contractor) |
| Pilgrim, Brooks | DFO Newfoundland / Policy and Economics |
| Rees, Bobbi | Government of Newfoundland & Labrador |
| Richter, Julie | DFO NCR / Fisheries Protection Program |
| Scriven, Danielle | DFO Maritimes / Coastal Ecosystem Science |
| Sephton, Dawn | DFO Maritimes / Coastal Ecosystem Science |
| Therriault, Thomas | DFO Pacific |
| Webb, Janis | DFO Pacific (Contractor) |
| Wilson, Claire | Canadian Food Inspection Agency (CFIA) |

## APPENDIX 3: MEETING AGENDA

**Marine Screening-Level Risk Assessment Protocol for Marine Non-Indigenous Species**

**National Peer Review – Maritimes Region**

**4-6 February 2015**
**Dartmouth, NS**

Chairperson: Eddy Kennedy

4 February 2015 – Wednesday

| Time | Topic | Presenter |
|---|---|---|
| 9:00-9:30 | Welcome and Introduction<br>– Review of Terms of Reference, Agenda | Eddy Kennedy |
| 9:30-9:45 | Review of Canadian Science Advisory Secretariat (CSAS) process, policies and guidelines | Tom Therriault |
| 9:45-10:30 | Review of CMIST | David Drolet |
| 10:30-10:45 | Break | |
| 10:45-12:00 | Questions and Discussion<br>CMIST – ToR 1a | All |
| 12:00-1:00 | Lunch (not provided) | |
| 1:00-2:00 | Review of CMIST application to invertebrate species not currently in Canada | Tom Therriault, Claudio DiBacco |
| 2:00-3:00 | Questions and Discussion<br>ToR 1b | All |
| 3:00-3:15 | Break | |
| 3:15-5:00 | Identification of key points for Science Advisory Report ToR 1 CMIST | Eddy Kennedy |

6 February 2015 – Thursday

| Time | Topic | Presenter |
|---|---|---|
| 9:00-9:30 | Opening – Review of Day 1 | Eddy Kennedy |
| 9:30-10:30 | Review of CMIST Optimization | David Drolet |
| 10:30-10:45 | Break | |
| 10:45-11:30 | Questions and Discussion | |
| 11:30-12:00 | Identification of key points for Science Advisory Report ToR 1 Optimization | |
| 12:00-1:00 | Lunch (not provided) | |
| 1:00-3:00 | Identify list of higher risk marine invertebrate species ToR 2 | All |
| 3:00-3:15 | Break | |
| 3:15-4:00 | Discussion of the suitability of CMIST for marine NIS in other taxa ToR 3 | All |
| 4:00-5:00 | Identification of key points for Science Advisory Report ToR 2 and 3 | Eddy Kennedy |

6 February 2015 – Friday

| Time | Topic | Presenter |
|---|---|---|
| 8:30-9:00 | Review of Results of Day 1 and 2 | Eddy Kennedy |
| 9:00-10:30 | Drafting of Science Advisory Report | All |
| 10:30-10:45 | Break | |
| 10:45-11:45 | Drafting of Science Advisory Report | All |
| 11:45-12:00 | Closing and Next Steps | Eddy Kennedy |

# APPENDIX 4: CMIST RAT QUESTIONS

Questions of CMIST and description of potential scores. From Drolet et al., 2015a.

| # | Question | Score: 1 (Low) | Score: 2 (Moderate) | Score: 3 (High) |
|---|---|---|---|---|
| 1 | **Present status**: Is the species established in the assessment area? | No | Observed but not reported as established | Yes |
| 2 | **Rate of introduction**: How frequently and in what numbers is the species expected to arrive into the assessment area? | Infrequently in low numbers of individuals | Frequently in low numbers or infrequently in high numbers | Frequently in high numbers |
| 3 | **Survival**: How much of the assessment area offers suitable habitat for the species? | Negligible proportion of the assessment area | Moderate proportion of the assessment area | Most of the assessment area |
| 4 | **Survival**: How much of the assessment area offers suitable environmental conditions for the species to survive? | Negligible proportion of the assessment area | Moderate proportion of the assessment area | Most of the assessment area |
| 5 | **Establishment**: Are the species' reproductive requirements available in the assessment area? | Almost never | Sometimes | Almost always |
| 6 | **Establishment**: To what extent could natural control agents slow the species' population growth in the assessment area? | Likely to severely restrict population growth | Could slow population growth | Unlikely to affect population growth |
| 7 | **Spread**: What is the range of the species' potential natural dispersal in the assessment area? | Very limited range | Moderate rage | Wide range |
| 8 | **Spread**: What is the range of the species' potential dispersal in the assessment area from anthropogenic mechanisms? | Very limited range | Moderate rage | Wide range |
| 9 | **Impact**: What level of impact could the species have on population growth of other species in the assessment area? | Low or no impact | High impact in few areas or moderate impact in many areas | High impact in many areas |
| 10 | **Impact**: What level of impact could the species have on communities in the assessment area? | Low or no impact | High impact in few areas or moderate impact in many areas | High impact in many areas |
| 11 | **Impact**: What level of impact could the species have on habitat in the assessment area? | Low or no impact | High impact in few areas or moderate impact in many areas | High impact in many areas |
| 12 | **Impact**: What level of impact could the species have on ecosystem function in the assessment area? | Low or no impact | High impact in few areas or moderate impact in many areas | High impact in many areas |
| 13 | **Impact**: What level of impact could the species' associated diseases, parasites, or travellers have on other species in the assessment area? | Low or no impact | High impact in few areas or moderate impact in many areas | High impact in many areas |
| 14 | **Impact**: What level of genetic impact could the species have on other species in the assessment area? | Low or no impact | High impact in few areas or moderate impact in many areas | High impact in many areas |
| 15 | **Impact**: What level of impact could the species have on at-risk or depleted species in the assessment area? | Low or no impact | High impact in few areas or moderate impact in many areas | High impact in many areas |
| 16 | **Impact**: What level of impact could the species have on aquaculture and commercially fished species in the assessment area? | Low or no impact | High impact in few areas or moderate impact in many areas | High impact in many areas |
| 17 | **Impact**: Is the species known or generally considered to be invasive anywhere in the world? | No | No, but has traits related to invasiveness | Yes |

## APPENDIX 5: HEAT MATRICES TO IDENTIFY HIGHER RISK MARINE INVERTEBRATE SPECIES IN THREE CANADIAN ECOREGIONS: GULF OF ST. LAWRENCE, SCOTIAN SHELF, AND STRAIT OF GEORGIA (DFO, 2015)

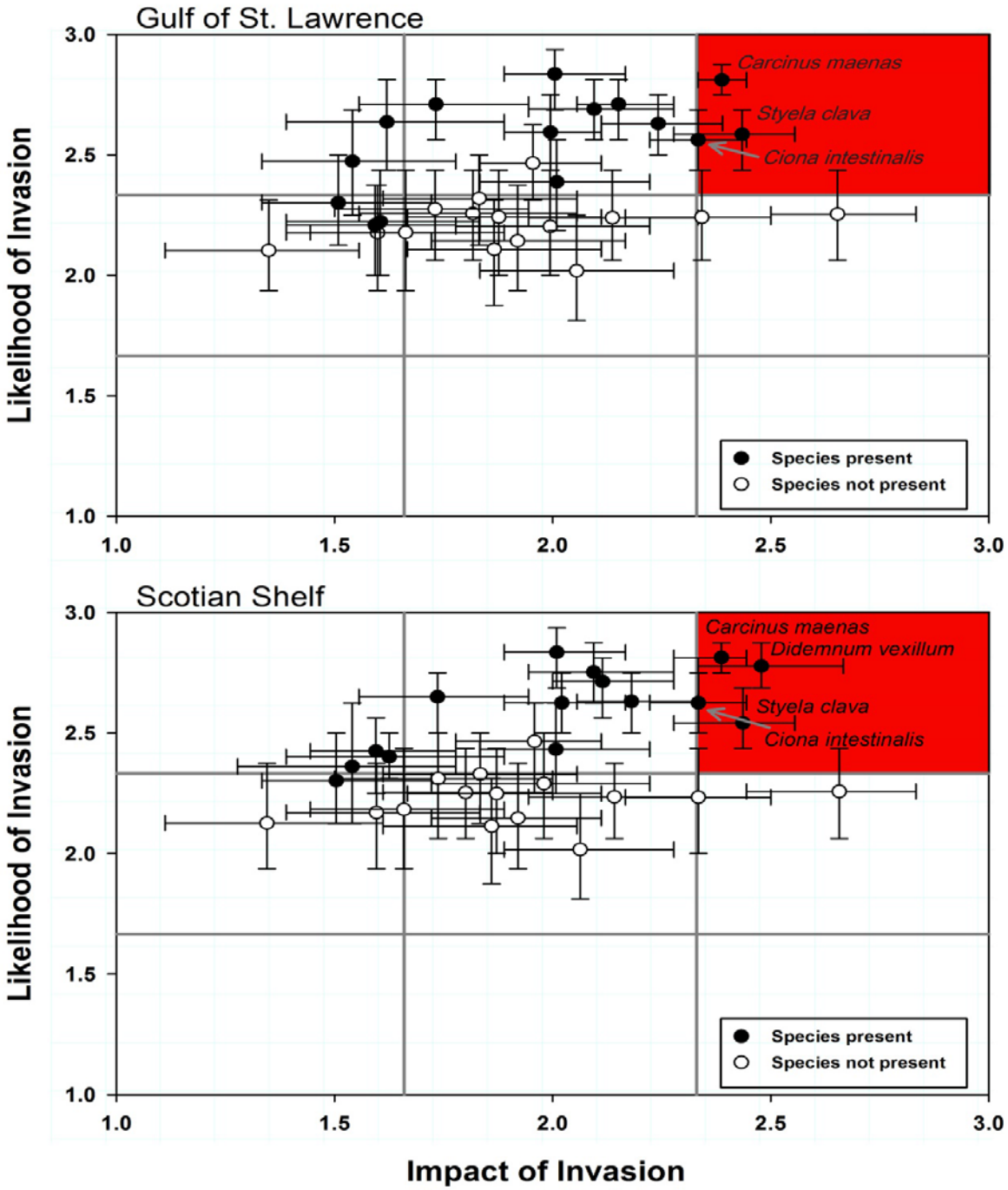


*Figure 1. Heat matrix employed to identify higher risk marine invertebrate species (this was Figure 5 in Working Paper 2 discussed at the meeting). For each ecoregion, marine species that had high likelihood of invasion and impact scores generated using CMIST are in the upper right hand corner of each plot (highlighted in red). CMIST scores have been adjusted for assessor uncertainty. Error bars represent upper and lower 95% confidence limits.*

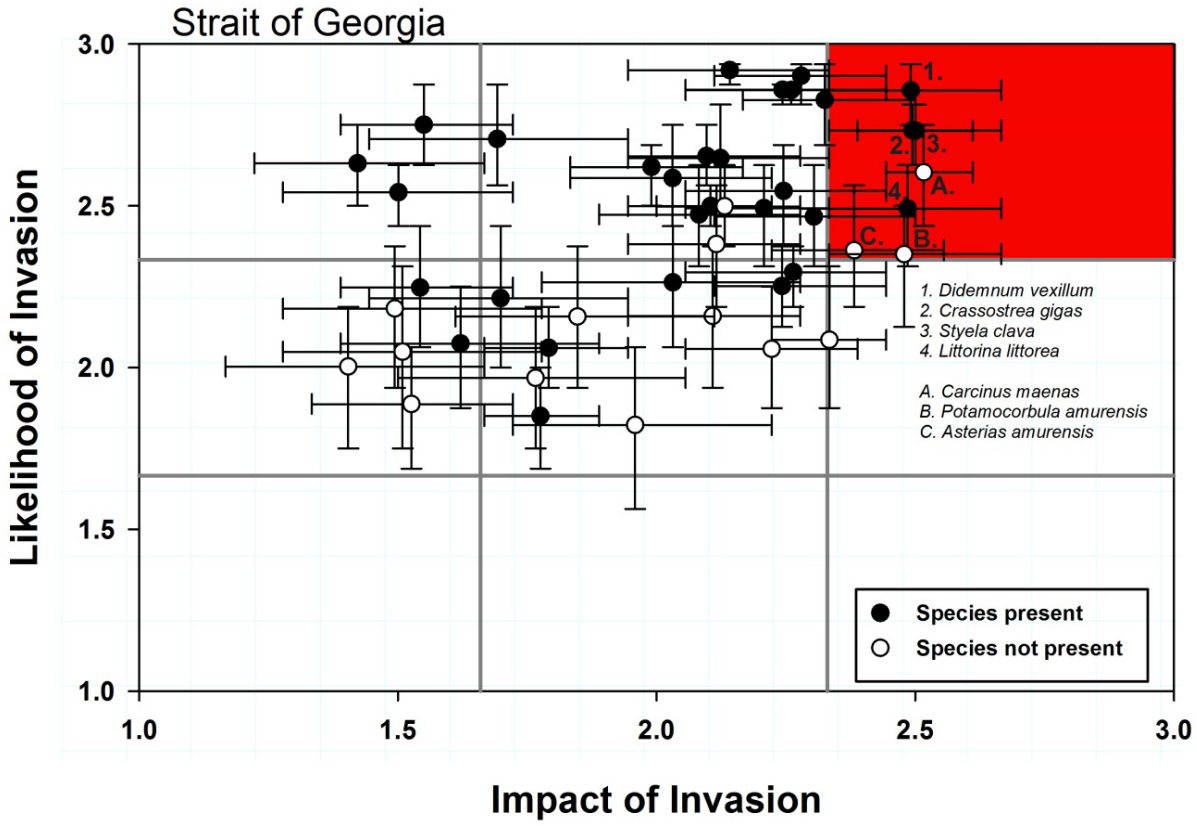


*Figure 1. (continued)*

# APPENDIX 6: CANADIAN MARINE INVASIVE SCREENING TOOL MANUAL

Fisheries and Oceans Canada

December 2015

## INTRODUCTION

The Canadian Marine Invasive Screening Tool (CMIST) is a peer-reviewed screening-level risk assessment tool for marine invasive species (Drolet et al. 2015). It is a short questionnaire that follows the invasion process from arrival to impact and is designed so an informed assessor can evaluate one species in an assessment area in approximately one day using easily accessible information from internet databases, primary literature, and grey literature. Species can be those with an invasion history in an area or those that are candidates for future invasions.

CMIST is score-based and incorporates both likelihood and impact of invasion as well as uncertainty. Questions are general to make CMIST broadly applicable to different taxa, different assessment areas, and different project goals. To date, CMIST has been tested with molluscs, tunicates, crustaceans, and polychaetes introduced or at risk of introduction to three Canadian marine ecoregions (DFO 2009). CMIST has also been successfully applied to non-indigenous freshwater fish in British Columbia with adapted guidelines (T. Therriault, pers. comm.). Upon completion, CMIST produces a risk score adjusted for the assessor's uncertainty which, combined with information collected during the assessment, can be used to assist in management decisions. For example, in 2015, CMIST assessments were used to identify high risk invaders in three Canadian marine ecoregions (DFO 2015a). Completed assessments submitted from assessors within and outside Fisheries and Oceans Canada (DFO) are reviewed for accuracy and completeness then housed online in the searchable CMIST database.

This manual contains best practices for using CMIST and should be read in full before proceeding with an assessment to achieve consistent results. For more in-depth background information, refer to Drolet et al. (2015).

## PRE-ASSESSMENT PREPARATION

Before starting an assessment, save a copy of the template as an Excel Macro-Enabled Workbook (.xlsm) and rename the file to indicate the species, assessment area, assessor, and date as in the example below. A separate file should be created for each assessment involving a new species–assessment area combination.

> Example file name for assessor Jane Doe assessing *Ciona intestinalis* in the Scotian Shelf ecoregion on November 12, 2015:
> **CMIST_Cintestinalis_ScotianShelf_JD_112015.xlsm**

Consideration should also be given to the species and assessment area of the assessment as well as the assessor.

### Species

Although CMIST was designed for and tested with marine invertebrates, its theoretical basis and general questions makes it suitable for other organisms. Assessors should always use their best judgement when interpreting questions, answers, and guidance for the selected species, which will likely not have species or taxon-specific examples.

Prior to assessment, background information on the selected species that pertains to CMIST questions should be collated from available resources and quickly reviewed. If there is little known about the species, information on other species in the genus (or higher taxonomic level) should be obtained and used as complementary resources. A lack of species-specific information would be expected to increase uncertainty.

## Assessment area

The assessment area can be any size or scope but must be defined since most CMIST questions use this assessment area as a context for answers (see Appendix A for questions, answers, and guidance). It is up to the assessor to determine (and document) the scale used for their assessment.

Prior to assessment, background information should be collated on the assessment area from available resources and quickly reviewed. Pertinent information includes both physical characteristics (e.g., bottom types, habitats, temperature range, and salinity range) and biological components (e.g., species at risk, aquaculture species, commercially fished species, and species of special interest).

## Assessor

All CMIST questions are semi-quantitative and require interpretation and judgement to answer based on available information as well as the assessor's expert opinion. An assessor should therefore have good general knowledge on invasive species and, ideally, the assessment area and species being assessed. A less-knowledgeable assessor would be expected to have higher uncertainty, especially for species with little available information.

Prior to assessment, assessors should review background information on the species and assessment area and familiarize themselves with CMIST questions, answers, guidance, and glossary.

## USING CMIST

CMIST is available for download as a macro-enabled Excel workbook. **Macros must be enabled to obtain the final adjusted risk score**. The workbook is divided into three sections for completion by the assessor: 1) Assessment information, 2) CMIST Assessment and 3) References. Guidance, glossary, and an example assessment are also provided in separate worksheets.

## 1. Assessment Information

This section contains general information about the species, the assessment area, and the assessor. If you submit your assessment for inclusion in the CMIST database, you must complete all information labelled with an asterisk. Contact information including address, phone, and email is for communication purposes only and will not be made publicly available.

## 2. CMIST Assessment

This section contains the questionnaire and final risk scores for CMIST. The assessor should answer questions by entering risk scores, uncertainty scores, and rationales in the designated cells. When all risk scores and uncertainty scores have been entered, raw risk scores will automatically be displayed at the top of the sheet. To obtain the risk score adjusted for uncertainty, press the "Calculate adjusted risk score" button. The adjusted risk score and lower and upper confidence limits will then be displayed. See below for guidance on specific sections.

### Questions

CMIST has 17 questions that follow the invasion process: arrival (Q1 and Q2), survival (Q3 and Q4), establishment (Q5 and Q6), spread (Q7 and Q8), and impact (Q9–Q17). The first 8 questions relate to the likelihood of invasion and the next 9 questions relate to the impact of invasion.

Many terms used in CMIST questions (e.g., population growth, invasive, community) have different definitions depending on perspective and context. Such terms and their intent in the CMIST context are defined in the glossary.

**Answers**

Each question has three possible answers (1–3). Answers differ between questions and should be considered carefully in conjunction with the risk score guidance before entering a score.

**Risk score guidance**

This section provides specific guidance on interpreting each question and answer and may include the following: the intent of the question, broad examples of when to select each answer, and additional considerations or explanations. Examples are non-exhaustive, and assessors should consider all relevant factors.

**Risk score**

Risk scores of low (1), moderate (2), and high (3) are entered based on the interpretation of the question, answers, and risk score guidance in the context of available information for the species. When information is not readily available or is of poor quality or when there is conflicting information, assessors should use their best judgement to decide on a score and adjust the uncertainty score accordingly. In the absence of any information on a species, information from similar species in the same genus (or higher taxonomic level) should be used.

**Uncertainty score**

Uncertainty scores are determined based on the availability and quality of information and the level of expertise of the assessor as follows:

1 – Low certainty – Little to no reliable information is available AND the assessor has no experience with the species.

2 – Moderate certainty – Some reliable information is available. If information is incomplete, it is supplemented with information on or experience with similar species in a similar environment.

3 – High certainty – A considerable amount of reliable information is available OR the assessor has first-hand experience with the species and the assessment area.

**Rationale**

The rationale is a short summary of the reasoning behind both the risk score and uncertainty score for each question, including relevant information and sources. Rationales can include direct quotes from databases or literature or a paraphrased summary or an expert reasoning. Short yes or no statements are less valuable and should be avoided. All sources should be listed in annotated form, with full references listed in the References sheet.

**Raw scores**

Raw scores for likelihood of invasion, impact of invasion, and mean risk score are calculated using individual question risk scores only (not uncertainty scores) as follows:

Likelihood of invasion: mean Q1 to Q8, range 1–3

Impact of invasion: mean Q9 to Q17, range 1–3

Mean risk score: Likelihood of invasion x Impact of invasion, range 1–9

Raw scores are calculated automatically when relevant information is entered and are updated automatically when changes are made.

### Adjusted score

The adjusted risk score is calculated by incorporating the uncertainty scores with the risk scores in a Monte Carlo simulation (see Drolet et al. 2015 for detailed explanation). To obtain the adjusted risk scores in CMIST, press the “Calculate adjusted risk score” button after all risk scores and uncertainty scores have been entered. Once the button has been pressed, any changes to risk or uncertainty scores for questions will automatically be reflected. Because this method uses random numbers, if the button is pressed again, the adjusted risk score will be recalculated with new random numbers and may generate a slightly different score and confidence limits.

We recommend using the adjusted risk score because it allows uncertainty to be quantified and incorporated into the risk score. However, raw risk scores may also be used in conjunction with question-specific uncertainty and rationales depending on the needs and objectives of the assessor or managers. Adjusted risk scores should always be reported with their confidence limits.

## 3. References

This section is a list of the resources used in the rationales on the CMIST Assessment sheet. Websites and publications should be listed separately in this sheet in the indicated columns in a consistent format. If additional resources were used during the assessment but not used specifically in the rationales (e.g., models, environmental data, and ancillary information), include them in the Additional Resources column. There is no prescribed format for references, but the information should be complete enough to guide others to the resource. References listed here may be included as suggested resources for future assessments in a given assessment area.

## LITERATURE CITED

Drolet D, DiBacco C, Locke A, McKenzie CH, McKindsey CW, Moore AM, Webb JL, Therriault TW (2015) Evaluation of a new screening-level risk assessment tool applied to non-indigenous marine invertebrates in Canadian coastal waters. Biological Invasions DOI: 10.1007/s10530-015-1008-y

DFO (2009) Development of a framework and principles for the biogeographic classification of Canadian marine areas. DFO Canadian Science Advisory Secretariat Science Advisory Report 2009/056, p 17

## APPENDIX A: CMIST QUESTIONS, ANSWERS, AND GUIDANCE

### Question 1

Is the species established in the assessment area?

### Answers

1 – No

2 – Present but not established

3 – Yes

### Guidance

This question is meant to differentiate species that are not present in the assessment area (1) from species that are established in the assessment area (3). Species that are present in the assessment area but not established would score 2.

### Question 2

How frequently and in what numbers is the *species* expected to arrive into the *assessment area*?

### Answers

1 – Infrequently in low numbers

2 – Frequently in low numbers OR infrequently in high numbers

3 – Frequently in high numbers

### Guidance

Consider initial arrival into the assessment area by primary vectors only. Do not consider secondary spread (anthropogenic or natural) within the assessment area by species that are already present.

Consider all primary anthropogenic and natural vectors for transport into the assessment area (e.g., ballast water, hull fouling, aquaculture, rafting, and natural dispersal from outside the assessment area).

### Question 3

How much of the assessment area offers suitable habitat for the species?

### Answers

1 – Negligible proportion of the assessment area

2 – Moderate proportion of the assessment area

3 – Most of the assessment area

### Guidance

This question is meant to differentiate habitat specialists (1) from habitat generalists (3). Species that fall between these extremes would score 2.

First consider the species' broad habitat zone (e.g., intertidal, subtidal, benthic, and pelagic). Then consider the proportion of that zone within the assessment area that offers suitable habitat for the species.

Consider suitable anthropogenic habitat (e.g., docks and aquaculture sites) as well as natural habitat.

**Question 4**

How much of the *assessment area* offers suitable environmental conditions for the *species* to survive?

**Answers**

1 – Negligible proportion of the assessment area

2 – Moderate proportion of the assessment area

3 – Most of the assessment area

**Guidance**

This question is meant to differentiate species with very poor environmental match for survival (1) from those with a very good environmental match (3). Species that fall between these extremes would score 2.

Consider environmental conditions (e.g., temperature, salinity, and turbidity) in its suitable habitat (see Question 3).

Consider the most tolerant life stage at any time of year.

Consider survival only, not reproduction.

**Question 5**

Are the *species*' reproductive requirements available in the *assessment area*?

**Answers**

1 – Almost never

2 – Sometimes

3 – Almost always

**Guidance**

This question is meant to differentiate species that face severe constraints in reproduction in the assessment area and are very unlikely to reproduce in a typical year (1) from those that face few constraints in reproduction in the assessment area and are very likely to reproduce every year (3). Species that fall between these extremes would score 2.

Consider any constraint (e.g., temperature, salinity, and stage-specific habitat) in the species' ontogenetic development (e.g., spawning, fertilization, and propagule dispersal) that may affect its ability to reproduce successfully in otherwise suitable habitat (see Question 3).

**Question 6**

To what extent could natural control agents slow the *species*' *population growth* in the *assessment area*?

**Answers**

1 – Likely to severely restrict population growth
2 – Could slow population growth
3 – Unlikely to slow population growth

**Guidance**

This question is meant to differentiate species with known, *effective* natural control agents in the assessment area (1) from those with no known, effective natural control agents in the assessment area (3). Species with known—but not necessarily effective—natural control agents in the assessment area would score 2.

Consider presence and incidence of known natural control agents (e.g., predators, competitors, disease, and disturbance) in the species' suitable habitat (see Question 3) and to what extent they could slow the species' population growth.

**Question 7**

What is the range of the *species*' potential natural dispersal in the *assessment area*?

**Answers**

1 – Very limited range

2 – Moderate range

3 – Wide range

**Guidance**

This question is meant to differentiate species that face severe constraints in natural dispersal (e.g., short larval planktonic stage and sessile adults) (1) from those that face few constraints (e.g., long larval planktonic stage, motile adults) (3). Species that fall between these extremes would score 2.

Consider the natural dispersal vectors (e.g., currents, rafting, and migration) for all life stages.

Consider any constraints on natural dispersal vectors in the assessment area.

**Question 8**

What is the range of the *species*' potential dispersal in the *assessment area* from anthropogenic mechanisms?

**Answers**

1 – Very limited range

2 – Moderate range

3 – Wide range

**Guidance**

This question is meant to differentiate species likely to have little to no contact with anthropogenic mechanisms of dispersal in the assessment area (1) from those that are likely to have contact with anthropogenic mechanisms that could disperse them over large distances (e.g., among embayments) (3). Species that have contact with anthropogenic mechanisms that could disperse them over short distances (e.g., among sites in an embayment) would score a 2.

Consider anthropogenic dispersal vectors (e.g., ballast, hull fouling, and aquaculture) for all life stages.

**Question 9**

What level of impact could the *species* have on *population growth* of *other species* in the *assessment area*?

**Answers**

1 – Low or no impact

2 – High impact in few areas OR moderate impact in many areas

3 – High impact in many areas

**Guidance**

Only consider impacts in the species' suitable habitat (see Question 3).

Consider positive and negative impacts (i.e. population increase or decrease).

Consider impacts to indigenous and non-indigenous populations.

Consider ecological impacts on aquaculture and commercially fished species, not economic impacts on the industry itself.

**Question 10**

What level of impact could the *species* have on *communities* in the *assessment area*?

**Answers**

1 – Low or no impact

2 – High impact in few areas OR moderate impact in many areas

3 – High impact in many areas

**Guidance**

Only consider impacts in the species' suitable habitat (see Question 3).

Consider positive and negative impacts.

Consider impacts to indigenous and non-indigenous populations.

**Question 11**

What level of impact could the *species* have on *habitat* in the *assessment area*?

**Answers**

1 – Low or no impact

2 – High impact in few areas OR moderate impact in many areas

3 – High impact in many areas

**Guidance**

Only consider impacts in the species' suitable habitat (see Question 3) and not on associated communities.

Consider habitat engineering (e.g., reef-building organisms) and habitat destruction (e.g., bioturbating organisms).

**Question 12**

What level of impact could the *species* have on *ecosystem* function in the *assessment area*?

**Answers**

1 – Low or no impact

2 – High impact in few areas OR moderate impact in many areas

3 – High impact in many areas

**Guidance**

Only consider impacts in the species' suitable habitat (see Question 3).

Consider changes (positive or negative) to the physical, chemical, and biological processes that would normally maintain the ecosystem.

**Question 13**

What level of impact could the *species*' associated diseases, parasites, or travellers have on *other species* in the *assessment area*?

**Answers**

1 – Low or no impact

2 – High impact in few areas OR moderate impact in many areas

3 – High impact in many areas

**Guidance**

Only consider impacts in the species' suitable habitat (see Question 3).

**Question 14**

What level of genetic impact could the *species* have on *other species* in the *assessment area*?

**Answers**

1 – Low or no impact

2 – High impact in few areas OR moderate impact in many areas

3 – High impact in many areas

**Guidance**

Only consider impacts in the species' suitable habitat (see Question 3).

Consider indigenous and non-indigenous species in the assessment area.

Consider hybridization (among species hybridization and supplementation of genetic material between strains or varieties of a species) as well as other genetic impacts.

**Question 15**

What level of impact could the *species* have on at-risk or depleted species in the *assessment area*?

**Answers**

1 – Low or no impact

2 – High impact in few areas OR moderate impact in many areas

3 – High impact in many areas

**Guidance**

Consider all possible impacts on species in the assessment area that are depleted, of extra value, or recognized as being at risk.

**Question 16**

What level of impact could the *species* have on aquaculture and commercially fished species in the *assessment area*?

**Answers**

1 – Low or no impact

2 – High impact in few areas OR moderate impact in many areas

3 – High impact in many areas

**Guidance**

Consider ecological impacts on aquaculture and commercially fished species in aquaculture operations and the wild, but not economic impacts on the industry itself.

**Question 17**

Is the species known or generally considered to be invasive anywhere in the world?

**Answers**

1 – No

2 – No, but has traits related to invasiveness

3 – Yes

**Guidance**

This question is meant to differentiate species that are not invasive and not likely to be invasive based on their life history traits (1) from those that are known or generally considered to be invasive (3). An introduced species that is not generally considered to be invasive but that has traits related to invasiveness would score a 2.

An introduced species can be non-invasive.

## APPENDIX B: GLOSSARY

**assessment area:** an area of any size as pre-defined by the user for the purposes of the assessment

**community*:** any group of organisms belonging to a number of different species that co-occur in the same habitat or area and interact through trophic and spatial relationships; typically characterized by reference to one or more dominant species

**ecosystem*:** a community of organisms and their physical environment interacting as an ecological unit

**effective:** producing the intended result (e.g., slowed population growth by a predator)

**established*:** growing and reproducing successfully in a given area

**habitat:** the locality, site, and particular type of local environment occupied by an organism

**invasive**[†]**:** a non-indigenous species that spreads rapidly, causing environmental or economic damage (definition often used by managers)

**other species:** any species that is not the subject of the assessment

**population growth*:** change in population size with time as a net result of natality, mortality, immigration, and emigration

**species:** the subject of the assessment

**suitable habitat:** the portion of the habitat zone within the assessment area in which the species could live

* Adapted from Lincoln, R., Boxshall, G. and Clark, P. 1998. A Dictionary of Ecology, Evolution and Systematics, Second Edition. Cambridge University Press, Cambridge, U.K.

[†] Adapted from Simberloff, D, Rejmánek, M. (editors). 2011. Encyclopedia of biological invasions. University of California Press, 792 pp. ISBN: 9780520264212