MARINE SCREENING-LEVEL RISK ASSESSMENT TOOL FOR AQUATIC NON-INDIGENOUS SPECIES

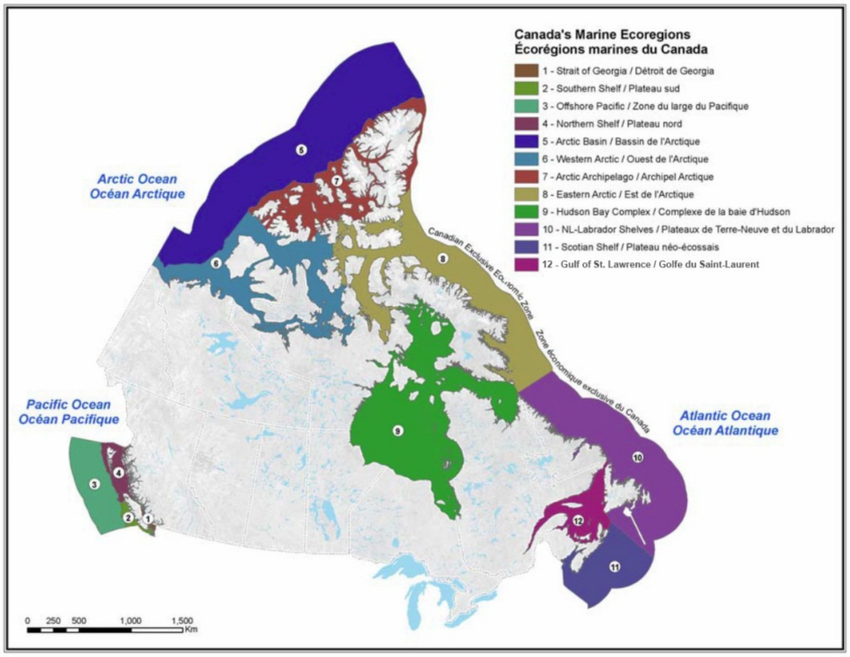

Figure 1. Recommended Canadian marine ecoregions (DFO 2009). Three ecoregions employed to test screening-level risk assessment protocols for marine non-indigenous invertebrate species included the Gulf of St. Lawrence, Scotian Shelf and Strait of Georgia (see legend).

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). DFO's Ecosystem and Fisheries Management (EFM), also a client for this process, has requested science advice to support national regulations 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 already introduced as well as others not reported in Canadian waters, whose transport to "non-infected" areas should be limited.

A national Canadian Science Advisory Secretariat (CSAS) science advisory process was initiated in 2011 to provide science advice on screening level risk assessment (SLRA) prioritization tools for freshwater and marine NIS. Part 1 was held in Montréal, Quebec from 22 to 24 November 2011, where participants compared SLRA protocols and developed a framework for a new SLRA tool for aquatic NIS, referred to as the Montreal Rapid Assessment Tool (Montreal-RAT). In Part 2, held in Burlington, Ontario from 19 to 21 March 2013, SLRA protocols were evaluated for, and applied to, three freshwater NIS taxa.

Part 3 reviewed a newly developed marine SLRA tool (Canadian Marine Invasive Screening Tool, CMIST) to predict the risk associated with NIS invertebrates already introduced and others not reported in three Canadian ecoregions (Gulf of St. Lawrence, Scotian Shelf, and Strait of Georgia).

This Science Advisory Report is from the February 4-6, 2015 national peer review meeting on the Marine Screening-Level Risk Assessment Protocol for Aquatic Non-Indigenous Species. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Biological risk assessment tools can be used to identify high risk aquatic invasive species. Screening-level risk assessment (SLRA) tools can be applied relatively quickly (days), using available information, to determine biological and ecological risk associated with species already introduced in the assessment area as well as those of new or potential introductions to that area.
- Screening-level risk assessment tools that are score-based can be used to create a relative ranking to prioritize species-specific risk and the allocation of resources to mitigate or manage invasions. To address DFO objectives, SLRA tools should include both elements of invasion risk: likelihood and impact of invasion.
- A new SLRA tool, the Canadian Marine Invasive Screening Tool (CMIST), was developed and tested on marine invertebrate species in three Canadian ecoregions: Gulf of St. Lawrence, Scotian Shelf and Strait of Georgia (Figure 1). CMIST is score-based and incorporates both likelihood and impact of invasion. In addition, novel methods for incorporating uncertainty into risk scores and for optimizing tool performance were developed and evaluated for CMIST.
- The performance of CMIST was evaluated concurrently with the Marine Invertebrate Invasiveness Scoring Kit (MI-ISK), the only other marine invertebrate SLRA tool. In total, 60 species-ecoregion combinations for species already introduced were assessed by two assessors using both tools, and outputs were compared to expert knowledge of species-ecoregion invasion outcomes. For species not reported from these three Canadian ecoregions, 45 species-ecoregion combinations were assessed using both tools to estimate invasion risk.
- Overall, CMIST performed better than MI-ISK: its scores were more strongly correlated with expert knowledge and inter-assessor variability was lower. Further, CMIST clearly distinguishes between the two elements of invasion risk (likelihood of invasion and impact of invasion) and has fewer questions to score. Thus, CMIST was considered a scientifically defensible and practical tool to screen and prioritize marine invertebrates, both for those already introduced and those not reported in Canadian marine ecoregions.
- Optimization procedures suggested that CMIST was over-parameterized, similar to many other risk assessment tools. Adjusting the weights of questions contributing to the overall risk score and removing specific questions improved model performance, defined as greater agreement with expert knowledge. However, consensus at the peer review meeting was not to employ these optimization procedures since a relatively small dataset was used for testing and all questions had value for DFO-specific objectives. Future applications of CMIST may benefit from reducing the number or relative weighting of questions depending on specific assessment objectives.
- CMIST provided a ranked list of assessed species (including species introduced and species not reported from each ecoregion). Higher risk marine invertebrate species could be identified using these relative rankings (Figure 2).
- High risk marine invertebrate species also were identified using a heat matrix that summarized likelihood of invasion and impact of invasion in conjunction with overall risk scores. Marine species-ecoregion combinations with high likelihood and impact scores generated using CMIST included 8 species already introduced and 3 species not reported from specific ecoregions (Figure 3).
- CMIST questions are generalized to the invasion process and resulting impacts, therefore this tool could be applied to other taxa. It was recognized that the CMIST guidance document should be updated periodically as additional taxa are evaluated to ensure consistency in the application of the tool among taxa and ecosystems.

INTRODUCTION

A major challenge for invasion biologists is identifying high risk NIS whether their introductions are intentional or unintentional, as is the case with many marine invasions. For non-indigenous species (NIS), risk represents both the likelihood of invasion and the predicted impacts (consequences) of that invasion. The goal is to determine which species are most likely to complete the invasion process (introduction, survival, establishment and spread) and have negative impacts in an invaded area. Thus, to better inform management and policy decisions, risk assessment tools for NIS are necessary.

Screening-level risk assessment (SLRA) tools generally consist of a series of questions that can be answered relatively quickly (days) to determine if a species is a threat (high risk) or not (low risk) based on available information. These assessments can be used to evaluate both species already established in the assessment area and potential future introductions to that area. Tools that generate scores have an additional advantage since they create a relative ranking of species-specific risk and can help prioritize 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. However, they should be evaluated and calibrated before implementation. Validated SLRA tools can be used to quickly identify risk associated with newly reported NIS (e.g., within a Rapid Response Plan), to inform monitoring programs that target early detection of high risk species, and to identify high risk species for regulatory actions.

Here, a new SLRA tool, the Canadian Marine Invasive Screening Tool (CMIST), was evaluated on a number of performance criteria using non-indigenous marine invertebrate species from three Canadian marine ecoregions (Figure 1). The performance of CMIST was evaluated concurrently with the Marine Invertebrate Invasiveness Scoring Kit (MI-ISK), the only other marine invertebrate screening-level risk assessment tool. The risk scores generated from each tool were compared to expert knowledge and evaluations of risk posed by each species-ecoregion combination. Since these screening-level risk assessment tools are ultimately designed to identify the potential risk posed by species not already present in an area, they also were applied to a selection of species not reported in each specific ecoregion.

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

Part 1 was held in Montréal, Quebec (22-24 November 2011) where participants reviewed and compared existing SLRA protocols and developed a framework for a new SLRA tool for aquatic NIS, hereafter the Montreal Rapid Assessment Tool (Montreal-RAT). Participants at this meeting had specific recommendations for advancing this process including: 1) test this newly developed tool for freshwater and marine taxa and systems; 2) compare results of the Montreal-RAT with the full Alberta-RAT (version 3); and 3) compare results of the Montreal-RAT to other peer-reviewed approaches (e.g., FISK, FI-ISK, MISK, MI-ISK). Given limited funding, it was decided that potential SLRA tools would be evaluated on select freshwater taxa (i.e., fish, molluscs, algae) and marine invertebrates initially, with the intention to revisit the possibility of identifying a national tool once these assessments were completed.

Part 2 was held in Burlington, Ontario (19-21 March 2013) where screening-level risk assessment protocols were evaluated for, and applied to, three freshwater non-indigenous taxa (fish, molluscs, algae) currently in trade within Canada (DFO 2014a, b).

Part 3 (this Science Advisory Report) was held in Halifax, Nova Scotia (4-6 February 2015) to review and evaluate:

(i) the performance of a newly developed marine SLRA tool (CMIST) to predict and rank the relative risk associated with non-indigenous marine invertebrate species already introduced to three Canadian marine ecoregions (Gulf of St. Lawrence, Scotian Shelf, and Strait of Georgia);
(ii) statistical optimization procedures to enhance CMIST performance and predictability of risk; and
(iii) the performance of CMIST in assessing the risk of NIS not reported in the same three Canadian marine ecoregions. To date, CMIST has been developed, tested, and optimized for non-indigenous marine invertebrate taxa, but since this tool was developed from the theoretical basis of invasion dynamics, its suitability for other aquatic NIS taxa (e.g., fish, marine plants) was also considered during this meeting.

ASSESSMENT

The newly developed SLRA tool, CMIST, is based on a series of questions related to the sequence of events in the invasion process including potential ecological impacts. This tool explicitly distinguishes two risk components: likelihood of invasion and impact of invasion. CMIST questions, including the scoring rubric, are included in the Table A1 (see Appendix). The mean likelihood of invasion score was multiplied by the mean impact of invasion score to obtain CMIST risk scores. Further, this tool explicitly captures assessor uncertainty for each question and uses it to adjust risk scores. Uncertainty can be documented in different ways, but for this analysis uncertainty distributions were generated for each score-uncertainty combination and applied to each question score using Monte Carlo simulations. Uncertainty was explicitly included in final CMIST adjusted risk scores since they were more highly correlated with expert opinion scores. This adjusted score is a valuable output because (i) it incorporates uncertainty and makes scores more comparable between species already introduced in assessment areas and others not reported, and (ii) it provides managers with a single score to aid in decision making. Further, since the output is score-based it can be used to assess and prioritize the relative risk posed by assessed species.

The performance of CMIST was evaluated concurrently with MI-ISK. Both tools are score-based, but with different questions and scoring systems; CMIST questions are specific to the invasion sequence and potential impacts, while MI-ISK questions pertain more to species survival and potential invasiveness. Tool performance was evaluated for accuracy (relative to expert knowledge of species-ecoregion invasion outcomes) and precision (relative similarity among assessor scores). In total, 60 species-ecoregion combinations for species already introduced were assessed by two assessors using both tools and outputs compared to expert knowledge. In addition, 45 species-ecoregion combinations for species not yet reported were assessed by two assessors using both tools to assess invasion risk.

Overall, CMIST performed better than MI-ISK; its scores were more strongly correlated with expert knowledge and inter-assessor variability was lower. Further, CMIST clearly distinguishes between the two elements of invasion risk (likelihood and impact of invasion) and has fewer questions to score making it relatively efficient to apply, though it still may be considered over-parameterized (see optimization discussion below). Thus, CMIST was considered a scientifically defensible protocol to screen and prioritize marine invertebrates already introduced or not yet reported in Canadian marine ecoregions.

To implement this tool effectively, it is essential that the accompanying guidance document be followed as it provides context for how to answer and score each question and how to interpret the results. This will ensure consistency over time when assessors change and when additional species-ecoregion combinations are scored. To ensure further consistency over time, tool outputs should be re-evaluated in response to significant changes in either information quality or quantity (e.g., new information that could affect CMIST scoring of a particular question(s), such as environmental conditions in the assessment area or new information on a specific invader). Species-ecoregion combinations with less information and higher uncertainty will require reassessment more frequently. Finally, even though assessments can be conducted at various spatial scales depending on specific objectives, ecoregion-level assessments conducted here appear to provide sufficient balance for many management purposes.

While risk assessment tools generally provide managers with reliable information for decision making (e.g., recommendations that a proposed species introduction should be allowed or rejected), the results are affected by several sources of uncertainty that can influence the contribution of a question(s) in the overall risk determination. For example, a question that is scored the same for all species-ecoregion combinations does little to separate higher risk invaders from lower risk ones. Further, there is growing evidence that risk assessment tools are over-parameterized and consequently that tools used currently could benefit from a detailed evaluation of the value of specific questions. Statistically it is possible to evaluate the contribution of each question and remove those that don’t improve performance. Careful selection of questions and relative weighting of questions, based on overall performance and additional considerations (e.g., organizational mandate), could benefit risk assessment tools, including CMIST, and their application.

In this analysis, optimization procedures provided evidence that CMIST was over-parameterized, like many other risk assessment tools. Adjusting the weights of specific questions and removing questions improved model performance and made the tool more efficient (i.e., fewer questions to answer). However, it was noted that optimization procedures were based on a relatively small dataset that did not include outputs from all DFO ecoregions and that all questions had value for DFO-specific objectives (including output that may be useful for socio-economic risk assessment and cost-benefit analyses). Thus, although future applications of CMIST may benefit from reducing the number or relative weighting of questions depending on specific objectives of the assessment, for this science advisory report it was decided not to use the optimization procedures with CMIST (i.e., all questions were retained with equal weighting).

One CMIST question (Question 1, Table A1) is scored specifically with respect to the status of the species within the assessment area. Thus, by design, species that have been introduced score higher than those that have not been reported. Although this might result in a small difference in the overall risk score between species already present and those not reported, it more accurately reflects the actual risk posed between these two groups of species. Thus, all questions were retained in the analyses presented herein.

Ranking of Marine Invertebrate Species Tested using CMIST

As a score-based tool, CMIST provides a ranked (prioritized) list where lower scores represent lower risk species and those with higher scores represent higher risk ones (Figure 2). The species considered here that have existing detailed-level risk assessments completed already (see species names highlighted with asterisks in Figure 2) have been identified on the relative risk gradient to provide context for those species that lack detailed assessments. One can infer that species with similar scores to previously identified high risk species (from the detailed assessments) also could be considered high risk. The available data did not allow for the identification of scientifically-defensible threshold values to separate high, medium, and low risk species.

Another way that species’ risk can be visualized is by using a heat matrix that plots the likelihood of invasion against impact of invasion (Figure 3). Since CMIST provides these two scores, they can easily be represented on such a matrix. Without *a priori* information on risk tolerance, and hence thresholds for the heat map, species considered high risk here are those that ranked high for both likelihood of invasion and impact of invasion (i.e., upper right corner of the 3-by-3 heat matrix). However, species not in this box might be considered higher risk under alternative risk tolerances and thresholds. Higher risk marine invertebrate species identified in the heat matrix included 8 species already introduced and 3 species not reported in three Canadian ecoregions considered here (Table 1; Figure 3). For these high risk species-ecoregion combinations, a summary table has been generated for managers to capture key elements related to likelihood and impact of invasion (see Comments in Table 1).

Suitability of CMIST for NIS of Other Taxa

When this process began the overarching objective was to develop a single, national SLRA tool that would be applicable to taxa in marine and freshwater ecosystems. Although CMIST was developed, refined, and evaluated using marine invertebrate species (due to existing data and knowledge about these invasions) its theoretical basis is integrally linked to the invasion process and resulting impacts. Thus, it should be broadly applicable to other taxa in both marine and freshwater ecosystems. Further, since no CMIST questions are taxon-specific, they should not limit its application to other taxa. It was noted that CMIST is being applied to freshwater fish species in British Columbia (preliminary analyses suggest it is working well) so cross-taxa performance could be evaluated in the near future. To ensure standardization and consistency for use with other taxa, the guidance document that accompanies the tool should be updated periodically as additional taxa are scored.

Sources of Uncertainty

Uncertainty in risk assessments may arise from the quality or quantity of information available, from the interpretation of information (judgement subjectivity), or from interpretation of the language used in questions or expert surveys (linguistic uncertainty), resulting in both intra- and inter-assessor and expert uncertainty. Although all tools would benefit from abundant, high-quality information, this may be lacking for a number of potential invasive species. However, it should be noted that invasions remain dynamic and outcomes have the potential to be more or less severe than predicted from any risk tool.

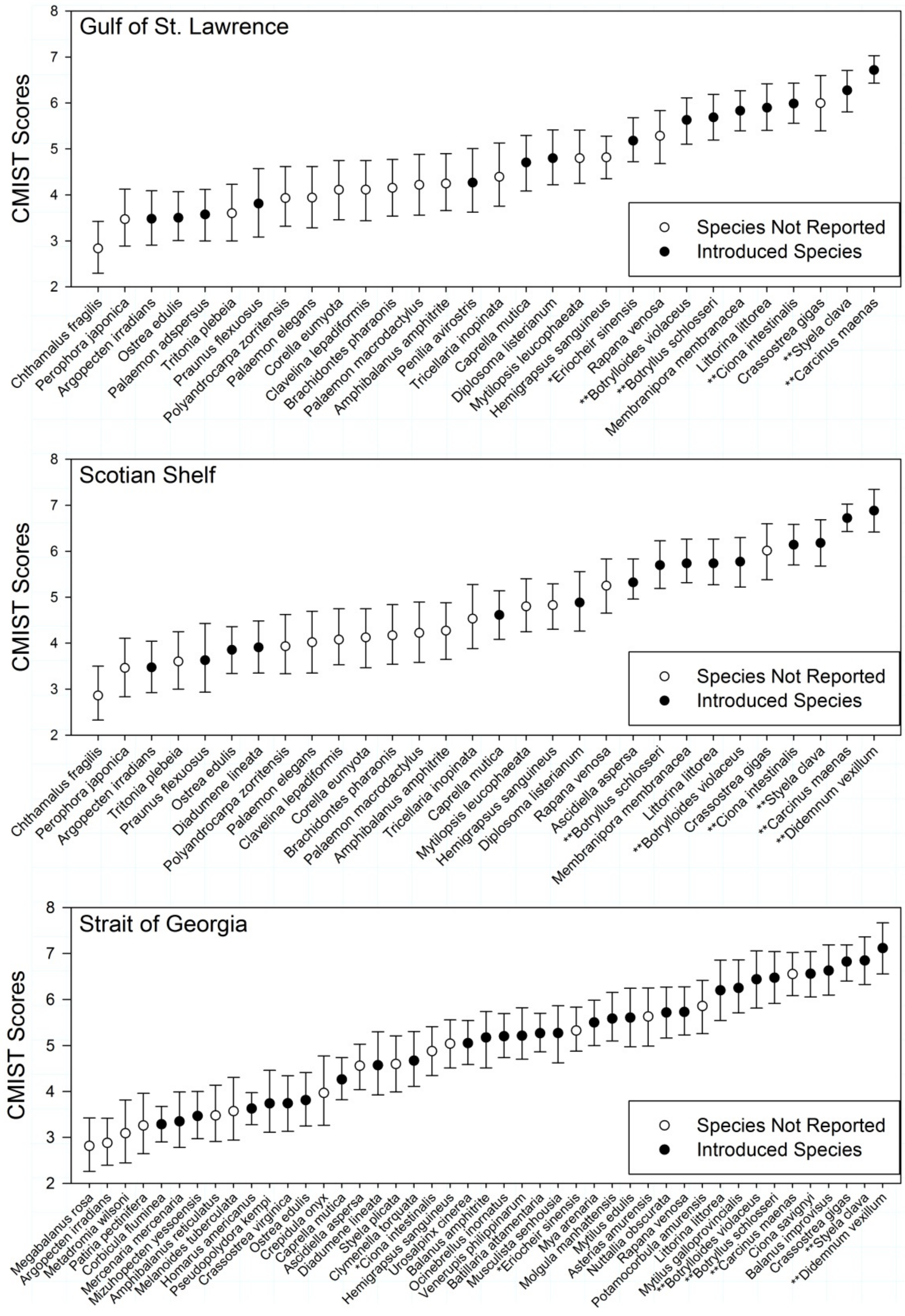

*Figure 2. Ranked CMIST scores for introduced marine invertebrate species (closed symbols) and species not reported (open symbols) in three Canadian marine ecoregions. CMIST scores have been adjusted for assessor uncertainty. Species with existing detailed-level risk assessments are indicated by asterisks (**High risk; *Moderate risk) next to species names. Error bars represent upper and lower 95% confidence limits.*

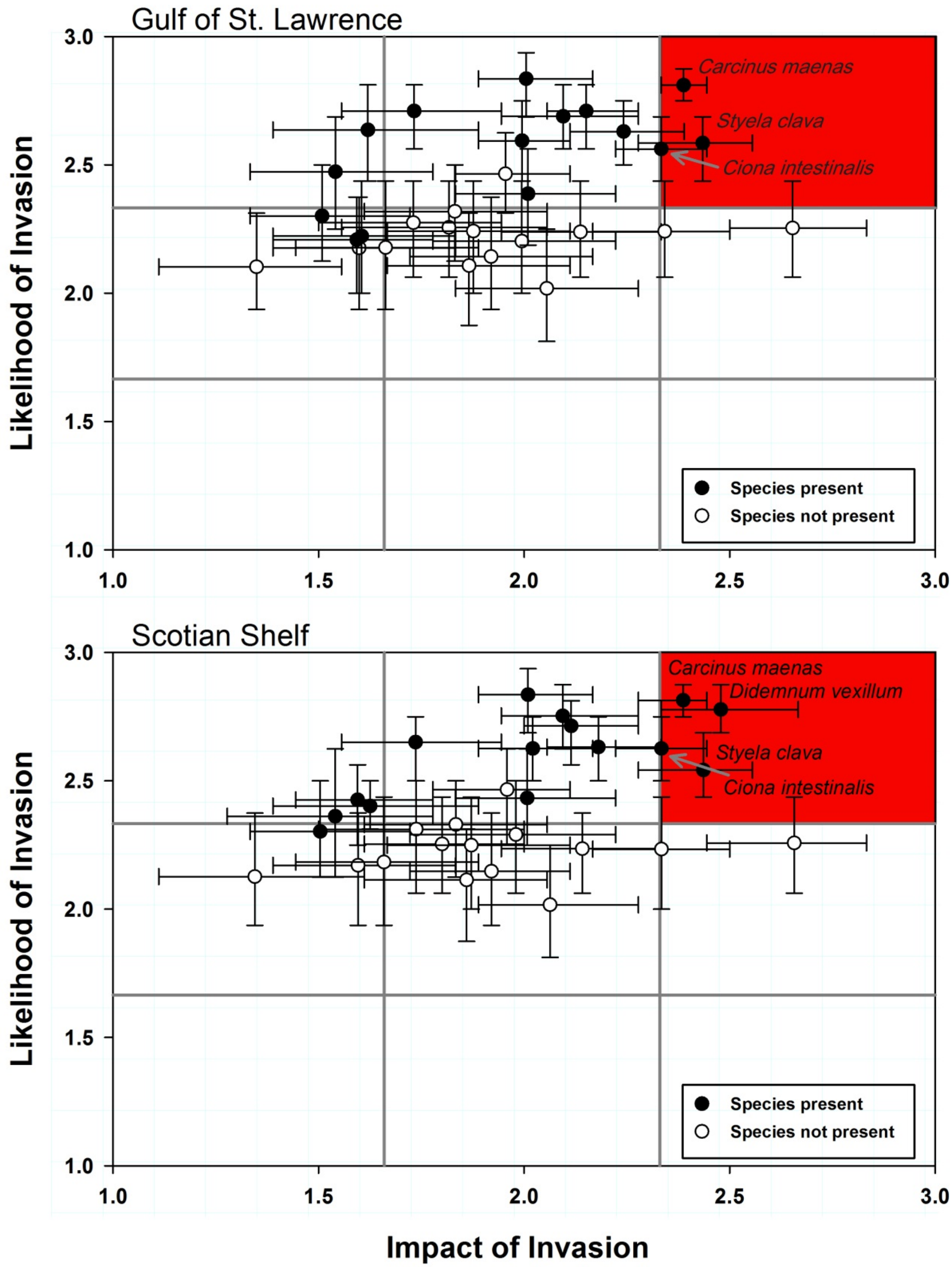

Figure 3. Heat matrix employed to identify higher risk marine invertebrate species. For each ecoregion, marine species that had high likelihood of invasion and impact scores generated using CMIST are in the upper right hand corner of each plot (highlighted in red). CMIST scores have been adjusted for assessor uncertainty. Error bars represent upper and lower 95% confidence limits.

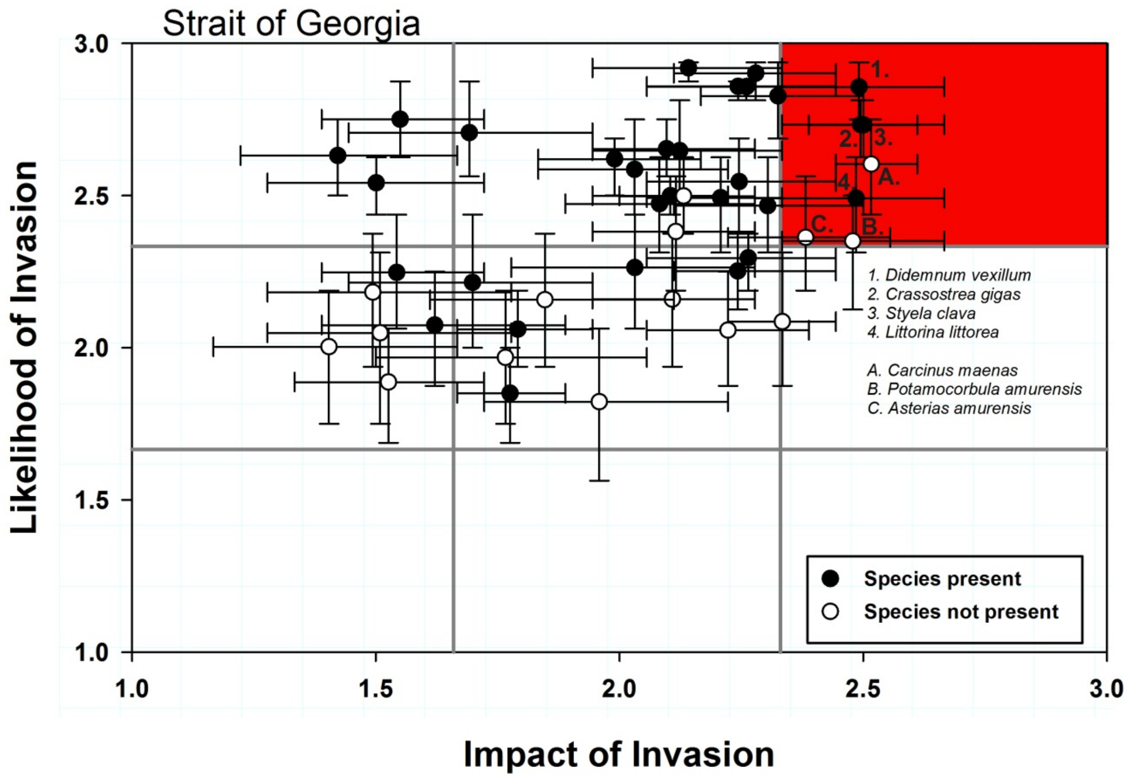

Figure 3. (continued)

Table 1. List of high risk non-indigenous marine invertebrate species (as identified in Figure 3) evaluated in three Canadian marine ecoregions (Gulf of St. Lawrence, GoSL; Scotian Shelf, SS; Strait of Georgia, SoG). CMIST scores (adjusted) are presented for species already introduced (unshaded cells) and not yet reported (shaded cells) in each ecoregion. Numbers in parentheses are upper and lower 95% confidence limits, respectively. NA and NI represent species either not assessed or not identified as high risk for specific ecoregions, respectively.

Species Name	Common Name	Scores	GoSL	SS	SoG	Comments
Asterias amurensis	Northern Pacific seastar	CMIST SLRA	NA	NA	5.63 (4.99, 6.25)	
		Likelihood of Invasion			2.36 (2.18, 2.56)	Strongest contributors to likelihood score were suitable environmental conditions for survival, ability to reproduce, and wide range for natural and anthropogenic dispersal.
		Impact of Invasion			2.38 (2.22, 2.56)	Strongest contributors to impact score were impacts on population growth, communities, and aquaculture/commercially fished species and known invasiveness.
Carcinus maenas	European Green Crab	CMIST SLRA	6.71 (6.43, 7.03)	6.72 (6.43, 7.03)	6.55 (6.08, 7.02)	
		Likelihood of Invasion	2.81 (2.75, 2.88)	2.81 (2.75, 2.88)	2.60 (2.44, 2.75)	Strongest contributors to likelihood score were presence in ecoregion (SS and GoSL), suitable habitat and environmental conditions for survival, ability to reproduce, and wide range for natural and anthropogenic dispersal.
		Impact of Invasion	2.39 (2.33, 2.44)	2.39 (2.28, 2.44)	2.52 (2.44, 2.61)	Strongest contributors to impact score were impacts on population growth, communities, and aquaculture/commercially fished species (SoG) and known invasiveness.

Species Name	Common Name	Scores	GoSL	SS	SoG	Comments
Ciona intestinalis	Vase Tunicate	CMIST SLRA	5.98 (5.56, 6.43)	6.14 (5.70, 6.58)	NI	
		Likelihood of Invasion	2.56 (2.44, 2.69)	2.63 (2.50, 2.75)		Strongest contributors to likelihood score were presence in ecoregion, suitable environmental conditions for survival (SS), ability to reproduce, and wide range for anthropogenic dispersal.
		Impact of Invasion	2.33 (2.22, 2.44)	2.33 (2.22, 2.44)		Strongest contributors to impact score were impacts on habitats and aquaculture/commercially fished species and known invasiveness.
Crassostrea gigas	Pacific oyster	CMIST SLRA	NI	NI	6.82 (6.40, 7.19)	
		Likelihood of Invasion			2.73 (2.63, 2.81)	Strongest contributors to likelihood score were presence in ecoregion, suitable habitat and environmental conditions for survival, lack of effective natural control agents, and wide range for anthropogenic dispersal.
		Impact of Invasion			2.50 (2.39, 2.61)	Strongest contributors to impact score were impacts on population growth, communities, and habitats and known invasiveness.
Didemnum vexillum	Colonial tunicate	CMIST SLRA	NA	6.88 (6.42, 7.35)	7.12 (6.56, 7.67)	
		Likelihood of Invasion		2.78 (2.69, 2.88)	2.86 (2.75, 2.94)	Strongest contributors to likelihood score were presence in ecoregion (SoG), rate of introduction (SoG), suitable habitat and environmental conditions for survival, ability to reproduce in ecoregion, lack of effective natural control agents, and wide range for natural (SS) and anthropogenic dispersal.

Species Name	Common Name	Scores	GoSL	SS	SoG	Comments
		Impact of Invasion		2.48 (2.33, 2.67)	2.49 (2.33, 2.67)	Strongest contributors to impact score were impacts on population growth, communities, habitats, ecosystem function and aquaculture/commercially fished species (SoG) and known invasiveness.
Littorina littorea	Common periwinkle	CMIST SLRA	NI	NI	6.20 (5.54, 6.85)	
		Likelihood of Invasion			2.49 (2.31, 2.63)	Strongest contributors to likelihood score were suitable habitat and environmental conditions for survival and wide range for natural and anthropogenic dispersal.
		Impact of Invasion			2.49 (2.28, 2.67)	Strongest contributors to impact score were impacts on habitats and ecosystem function, impacts of diseases, parasites, or travelers, and known invasiveness.
Potamocorbula amurensis	Asian clam	CMIST SLRA	NA	NA	5.86 (5.26, 6.42)	
		Likelihood of Invasion			2.35 (2.13, 2.50)	Strongest contributors to likelihood score were suitable environmental conditions for survival, ability to reproduce, and wide range for natural and anthropogenic dispersal.
		Impact of Invasion			2.48 (2.33, 2.67)	Strongest contributors to impact score were impacts on population growth, communities, and aquaculture/commercially fished species and known invasiveness.

Species Name	Common Name	Scores	GoSL	SS	SoG	Comments
Styela clava	Clubbed tunicate	CMIST SLRA	6.27 (5.81, 6.71)	6.18 (5.68, 6.69)	6.85 (6.33, 7.36)	
		Likelihood of Invasion	2.59 (2.44, 2.69)	2.54 (2.44, 2.69)	2.73 (2.63, 2.81)	Strongest contributors to likelihood score were presence in ecoregion, suitable habitat (SoG) and environmental conditions for survival, ability to reproduce, lack of effective natural control agents (GoSL and SoG), and wide range for anthropogenic dispersal.
		Impact of Invasion	2.43 (2.28, 2.56)	2.44 (2.28, 2.56)	2.49 (2.33, 2.67)	Strongest contributors to impact score were impacts on population growth, communities (SoG), habitats (GoSL and SS), and aquaculture/commercially fished species (GoSL and SS) and known invasiveness.

CONCLUSIONS AND ADVICE

The comparison of marine invertebrate screening-level risk assessment tools in this study revealed that CMIST, designed around the invasion cycle and its resulting impacts, performed better (accuracy and precision) than MI-ISK and is recommended as the preferred screening-level risk assessment tool. Further, it can be used as a prioritization tool since it provides a relative ranking of the risk posed by assessed species. Though not explicitly tested, CMIST appears suitable for taxa other than marine invertebrates based on discussions and considerations at this meeting.

Though there was evidence that CMIST, like other risk assessment tools, might be over-parameterized and could benefit from optimization procedures described here, it is recommended that the full set of CMIST questions be retained and scored (along with the associated uncertainty).

Higher risk species already present in an ecoregion as determined by CMIST scores included: *Didemnum vexillum, Crassostrea gigas, Styela clava* and *Littorina littorea* in the Strait of Georgia; *Carcinus maenas, Ciona intestinalis* and *Styela clava* in the Gulf of St Lawrence; *Carcinus maenas, Ciona intestinalis, Didemnum vexillum and Styela clava* in the Scotian Shelf.

Higher risk species not yet reported in an ecoregion included: *Asterias amurensis, Carcinus maenas* and *Potamocorbula amurensis* in the Strait of Georgia. None were identified for the Gulf of St. Lawrence or Scotian Shelf ecoregions.

Assessors using CMIST documented their rationale and support for each question scored and their level of uncertainty. This ancillary information is extremely valuable for future ecological or socio-economic assessments as it provides additional context to assessors. Thus, it is recommended that a searchable, accessible database for supporting information (answers to questions indicating rationale for scoring and uncertainty) be established to enable archiving and aid in future assessments.

Managers also highlighted the value of some of the ancillary information beyond the overall risk score and the likelihood of invasion and impact of invasion scores and uncertainty, especially for higher risk species. Thus, it is recommended that an additional template be established to provide a quick summary for managers. Given limited time and resources such information may be used in place of a more detailed-level risk assessment.

OTHER CONSIDERATIONS AND NEXT STEPS

The CMIST guidance document provides the basis for answering and scoring each of the questions, but additional information should be added to the front of this document to ensure the overall context is retained. This would include elements like the spatial and temporal bounds of the assessment. Further, as a living document, the guidance should be updated periodically as additional information is made available (e.g., when additional taxa are scored).

To ensure continued standardization of tool outputs among assessors, especially those working in different ecoregions or with other taxa, training materials should be developed. Further, some validation mechanism (i.e., peer-review) should be developed for individual assessments to ensure the tool is used as intended and tool outputs are meaningful.

To effectively implement the tool requires knowledge of the assessment area in addition to species-specific information collected from the literature. Background ecoregion assessments containing information about key characteristics of the environment would be helpful in providing a consistent baseline against which species are being scored.

There was consensus among meeting participants that marine and freshwater assessors should work towards the initial goal of a unified national SLRA protocol, which would allow for cross taxonomic group comparison and prioritization of high risk aquatic NIS in Canada and in specific ecoregions.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 4-6, 2015 national peer review meeting on the Marine Screening-Level Risk Assessment Protocol for Aquatic Non-Indigenous Species. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2014a. 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.

DFO. 2014b. 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. 2009. Development of a Framework and Principles for the Biogeographic Classification of Canadian Marine Areas. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/056.

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

Table A1. CMIST questions and descriptions of potential scores (reproduced from Drolet et al., in review).

		Score		
	Question	1 (Low)	2 (Moderate)	3 (High)
Present status				
1	Is the species established in the assessment area?	No	Observed but not reported as established	Yes
Rate of introduction				
2	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
Survival				
3	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	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
Establishment				
5	Are the species' reproductive requirements available in the assessment area?	Almost never	Sometimes	Almost always
6	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
Spread				
7	What is the range of the species' potential natural dispersal in the assessment area?	Very limited range	Moderate rage	Wide range

	Question	Score		
		1 (Low)	2 (Moderate)	3 (High)
8	What is the range of the species' potential dispersal in the assessment area from anthropogenic mechanisms?	Very limited range	Moderate rage	Wide range
Impact				
9	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	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	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	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	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	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	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	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	Is the species known or generally considered to be invasive anywhere in the world?	No	No, but has traits related to invasiveness	Yes

THIS REPORT IS AVAILABLE FROM THE:

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