

**TECHNICAL
COMMENT**

Addressing a critique of the TEASI framework for invasive species risk assessment

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Abstract

We address criticism that the Transport, Establishment, Abundance, Spread, Impact (TEASI) framework does not facilitate objective mapping of risk assessment methods nor defines best practice. We explain why TEASI is appropriate for mapping, despite inherent challenges, and how TEASI offers considerations for best practices, rather than suggesting one best practice.

Keywords

Colonisation, exotic, habitat suitability, life history trait, non-indigenous, policy, propagule pressure, risk analysis, species distribution, uncertainty.

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Our review of alien species risk assessments (RA) (Leung *et al.* 2012) aimed to synthesise the diverse approaches applied in this field to establish a logical framework for best practices. We believe the TEASI framework that makes explicit the consideration of Transport, Establishment, Abundance, Spread and Impact aspects of biological invasions helps integrate the main ideas underlying risk assessment and identifies important open questions. Barry (2013) provided a thoughtful review of our study and while he found much to commend in our approach, he indicated two main criticisms: (1) the mapping process in the article was subjective and TEASI does not encapsulate all the reviewed RAs and (2) we are not explicit in defining *the* best practice. We address each criticism.

First, although quantitative approaches were relatively easy to map onto the TEASI framework, scoring-based approaches were more difficult and more subjective. Importantly, subjective does not mean arbitrary. For instance, mapping RA questions such as ‘propagules dispersed by wind’ onto the Spread component in TEASI and identifying it as a species trait is arguably logical. However, the rationale for how answers were combined was less clear for scoring approaches. For instance, many simply summed binary yes/no answers across all components, so we agree that they ‘would need to be radically redefined’ to map onto TEASI as many do not consider model structure. Barry (2013) further notes that the scoring

approaches ‘are abstract while the TEASI model is process-based and explicit’. This is certainly true but if the ‘abstract’ risks do not (at least imperfectly) map onto the set of real processes underlying invasions, we question whether they can be predictive. Thus, we argue that scoring-based approaches can and should be considered in the context of a process-based framework, but we acknowledge that this is challenging. We view this difficulty in mapping model structure as a limitation of existing scoring methodology rather than of the process-based TEASI model. We pose the questions: do the scoring model structures make sense in terms of invasion processes? How? If they do not, in the future, should they? Note, we do not deny the value of scoring RAs; they will remain important in addressing biological invasions, given limited time, data and resources.

In addition, Barry (2013) argues that TEASI equations were too highly structured and prescriptive. Although we could have just listed factors thought to be relevant for invasion risk, this would be less valuable. Models are useful, in part, exactly because they are highly structured, presenting a clear picture of how we believe factors relate to one another and to invasion risk, and where we disagree with other models. Alternative formulations are possible, but it would be useful to consider their consequences. For instance, scoring approaches sometimes only sum the vector types in Transport. The consequence is that all vectors types are implicitly mod-

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elled as having equal transport capability and vector numbers – factors explicitly considered in TEASI. We stand by the rationale underlying our formulations and the utility of explicitly considering model components, structure and dependencies, while acknowledging that alternative formulations may be necessary (e.g. due to data limitations).

Second, we emphasise that we proposed a '*framework for best practices*' and do not suggest that there is a *single* best approach for risk assessment. Our view in the TEASI framework is that best practices involve, among other issues, considering the major relevant invasion processes from Transport to Impact, use of ecological theory, and consideration of uncertainty. In some cases, certain invasion steps will not be needed, such as for deliberate introductions where the Transport component can be taken as given; here, adaptation of TEASI would be straightforward. In contrast, many RAs do not address Impact, which ultimately should be assessed. Our aim was not to negate the relevance of previous efforts, but to synthesise and build upon them, and we recognise that modification may be needed for particular systems. Nevertheless, we highlight that most existing models only describe part of the picture and perhaps provide an incomplete view of invasion risk. By explicitly modelling components, structure and dependencies, we provide, for the consideration of managers and researchers, guidance for estimating and combining (most) relevant processes.

Finally, we agree that further research is needed and dedicated much of the manuscript to identifying open questions. We highlighted that there have been a number of ways to combine TEASI components, and that the ramifications have generally remained unexplored. We suggested exploration of the relative importance of subcomponents, derivation of rules for excluding subcomponents, and comparison of performance between quantitative and qualitative models, among others. We identified useful future modifications of TEASI (e.g. analogous models for multiple species or pathway risk assessments). Clearly, much work remains to be done. Together, through discussion and collaboration, we may move towards more rational means of assessing the potential risk of alien species.

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