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Speaking their language – development of a multilingual decision-support tool for communicating invasive species risks to decision makers and stakeholders

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Abstract :

Environmental changes due to non-native species introductions and translocations are a global concern. Whilst understanding the causes of bioinvasions is important, there is need for decision-support tools that facilitate effective communication of the potential risks of invasive non-native species to stakeholders. Decision-support tools have been developed mostly in English language only, which increases linguistic uncertainty associated with risk assessments undertaken by assessors not of English mother tongue and who need to communicate outcomes to local stakeholders. To reduce language-based uncertainty, the 'ecology-of-language' paradigm was applied when developing the Aquatic Species Invasiveness Screening Kit (AS-ISK), a decision-support tool that offers 32 languages in which to carry out screenings and communicate outcomes to stakeholders. Topics discussed include uncertainty related to language-specific issues encountered during the AS-ISK translation and the potential benefits of a multilingual decision-support tool for reducing linguistic uncertainty and enhancing communication between scientists, environmental managers, policy and decision makers.

Keywords : ecology of languages, Aquatic Species Invasiveness Screening Kit, alien species, risk identification, global applicability

1. Introduction

Over the last 100 years, the world has undergone considerable environmental and societal change, driven in large part by advances in technology, and an important role of science is to communicate the implications of these changes to the wider society. Decision-support tools play an increasingly important role in communicating risks to decision makers and, more widely, to stakeholders (Barnhart et al., 2018), and this is especially true for identifying potentially invasive species (Copp et al., 2009, 2016a, 2016b; Drolet et al., 2016). Human-driven environmental changes due to non-native species (NNS) introductions and translocations began much earlier but took on greater impetus in the mid-1800s through the activities of the so-called ‘acclimation societies’, and more recently through increased global trade, transport and tourism (Chapman et al., 2017). [Note that the term ‘non-native’ is used here instead of ‘alien’ to avoid the xenophobic associations with the latter term (Warren, 2007; Rémy and Beck, 2008).]

To quantify and address the risks associated with these NNS introductions and their consequences, assessment protocols in ecological/environmental risk analysis were adapted from those used in the nuclear industry (Cardwell, 1989). A characteristic common to all risk assessments is uncertainty (Copp et al., 2005a, 2016a), which is a key factor that shapes environmental and climate-change policy at within-national and international levels (Mehta et al., 2019). The underlying principles of risk analysis are shared with many disciplines, including the assessment of financial risks (Treasury, 2004). Most often discussed in NNS risk analysis are the uncertainties associated with the responses to risk assessment questions due to a lack or scarcity of information. However, less addressed are the linguistic uncertainties associated with the interpretation of the questions by assessors (Carey and Burgman, 2008; Ibabe and Sporer, 2004).

Linguistic uncertainty originates in how the questions are formulated (Turbé et al., 2017) and also in the assessor’s personal interpretation and use of invasion biology terminology, with some terms (e.g. ‘invasive’) having a myriad of definitions (Copp et al., 2005a; Verbrugge et al., 2016). This was highlighted in the description of the Canadian Marine Invasiveness Screening Tool, CMIST (Drolet et al., 2016: p. 281): “Uncertainty may arise from the quality of information used or its interpretation (judgement subjectivity, *sensu* Regan et al., 2002) or the interpretation of the language used in assessment tool questions or expert surveys (linguistic uncertainty, *sensu* Regan et al., 2002), resulting in both intra- and inter-assessor/expert uncertainty. Few studies have addressed these issues directly (Kumschick and Richardson, 2013).” Referring to Box 1 in Leung et al. (2012), Vilà et al. (2019) classified uncertainties as: linguistic (associated with the communication of guidance in the use of the risk analysis protocol), stochastic (due to unknown variations of the invasion process), and epistemic (associated with the level of knowledge about the NNS and/or invaded ecosystem). Aligned with this is the interpretation of the term ‘risk’ (Hamilton et al., 2007: p. 163), which relates to perception that “Science “determines risks” and the population “perceives risks””. This adds an additional level of uncertainty in communicating risk to stakeholders (Hamilton et al., 2007; Tang and Rundblad, 2017).

Use of common definitions in NNS risk analysis can have policy- and management-related benefits (Barnhart et al., 2018), but decision-support tools used to inform decisions have been prevented from being more widely adopted due to paradigm obstacles relating to a lack of communication between technical experts and the stakeholders (Rogers and Fiering, 1986). For example, regional scientists and managers in China are sufficiently familiar with the invasiveness of NNS within a local context because they spend much time in the field, but back in their offices they struggle with English-language risk analysis protocols. This is one of the main reasons why China is lagging behind in the incorporation of risk toolkits and schemes into NNS management strategies (Li et al., 2020). This may also be true of some countries in Europe (Copp et al., 2005a) – an issue identified by Piria et al. (2017). As such, a greater awareness is needed from scientists and policy makers on how conceptual and linguistic disputes can affect the assumptions, implications and consequences of NNS research, especially with respect to risk assessment, management and biological invasion processes (Verbrugge et al., 2016).

Terminological uncertainties in risk assessment are amplified when the assessor carries out their evaluation in a language other than their mother tongue (Matthews et al., 2017). [Note that the terms ‘mother tongue’ and ‘native language’ are used here to refer to the initial, post-natal language or languages acquired at first speech.] This is prevalent in multilingual work environments (*sensu* Kramsch and Whiteside, 2008), which are increasingly dominated by the English language – this is known as the ‘diffusion-of-English’ paradigm (Phillipson and Skutnabb-Kangas, 1996). This linguistic uncertainty may be compounded by the influence that culture can have on the cognitive processes involved in probability assessment (Phillips and Wright, 1977) and the communication of risks to the general public (Tang and Rundblad, 2017). One means of reducing linguistic uncertainty is to provide risk assessors with the option of carrying out screenings in their native tongue, thus promoting local languages, which is in line with the ‘ecology-of-language’ paradigm defined by Haugen (1972: p. 57) as “the study of interactions between any given language and its environment”.

A basic assumption of most risk assessment schemes is that uncertainty comprises variability and incertitude, but the contribution of language is often overlooked despite it being an integral source of uncertainty in those assessments (Carey and Burgman, 2008). Furthermore, both verbal and written forms of communication are often open to interpretation, with assessors arriving at different interpretations, judgments, understanding and resulting conclusions, even when exact language is used (Verbrugge et al., 2016). These discrepancies can occur even amongst speakers of the same mother tongue (e.g. Doupnik and Richter, 2003) due to interpersonal understanding of terms (Regan et al., 2002) and to differences in geographical context (Matthews et al., 2017). And despite any symbolic competence displayed by non-native English speakers in completing risk assessments

(Kramsch and Whiteside, 2008), the diffusion-of-English approach to risk-scheme formulation has a serious knock-on (i.e. secondary, indirect or cumulative) effect when risk assessment outcomes (i.e. risks and uncertainties) are converted into lay-persons' terms for communication to stakeholders and the general public (Wei, 2018) – this is equally important to policy and decision makers for the formulation of legislation and incorporation of policy into management strategies.

The issue of language policy (diffusion-of-English *vs* ecology-of-language) is directly relevant to environmental and ecological decision making involved in the global struggle to avoid and/or mitigate the impacts of biological invasions on native biodiversity, ecosystem function and ecosystem services. Linguistic uncertainty can arise in this science-to-policy-to-management implementation process due to the vague, ambiguous and context-dependent nature of language (Carey and Burgman, 2008; Lu, 2019; McGeoch et al., 2012). This includes neologisms (i.e. newly-defined terms such as 'invasivity', 'invasibility' and 'invasiveness') and changes to the precise meaning of words over time (Regan et al., 2002; Wei, 2018), e.g. the 'conflation' (i.e. merging) of terms or concepts (Leung et al., 2012), and the perceived meaning of terms such as 'risk' (Hamilton et al., 2007). Language policies must also consider the representations and categories specified by various scientific communities, such as in social *vs* biological sciences (Rémy and Beck, 2008; Tassin and Kull, 2012). Given that the purpose of NNS risk analysis schemes is to inform decision makers of the potential risks of a NNS being invasive, linguistic uncertainty is an important consideration in the identification, assessment, management and communication of NNS risks.

The recent release of the Aquatic Species Invasiveness Screening Kit (AS-ISK) v2.1 (currently in its v2.2, available at: www.cefas.co.uk/nns/tools/) represents a major departure from the predominantly diffusion-of-English approach in NNS risk analysis in that its development follows the alternative, ecology-of-language paradigm. The AS-ISK is a next-generation adaptation of the Pheloung et al. (1999) Weed Risk Assessment (WRA) screening tool with which to identify potentially invasive aquatic species using any one of several languages to carry out assessments. Such a reversal of this diffusion-of-English trend serves to reduce the language-related uncertainty in the risk screening process whilst contributing to global linguistic diversity (Phillipson and Skutnabb-Kangas, 1996). A multilingual screening toolkit is also expected to enhance clarity and quality in the communication (in mother tongue) of NNS assessment outcomes (i.e. assessment questions, responses, justification) to stakeholders, which is consistent with information accessibility within the European Union (EEC, 1958; Ammon, 2006).

To examine the contribution that the multilingual AS-ISK makes to address the underlying issues associated with linguistic uncertainty in NNS risk analysis, the objectives of the present study were to: 1) provide an overview of electronic decision-support tools and their language options; 2) describe the development of the AS-ISK from its WRA origins to its current multilingual version; 3) critically assess issues encountered in the translation process pertaining to linguistic uncertainty, including differences within and between languages due to cultural and societal factors; and 4) summarise the benefits of a multilingual decision-support tool with regard to reduced linguistic uncertainty and enhanced communication of assessment outcomes to stakeholders.

2. Electronic decision-support tools

There are more than 70 risk screening (or identification) tools and full risk assessment schemes available (Srėbalienė et al., 2019). Amongst the risk screening tools are the Australian WRA and its direct descendants, the freshwater Fish Invasiveness Screening Kit (FISK) and the 'sister' -ISK toolkits for marine fish, marine invertebrates, freshwater invertebrates, and amphibians (Copp, 2013; Copp et al., 2005b). There are also the Invasive Species Environmental Impact Assessment (ISEIA: Branquart, 2009), Harmonia^{+} and Pandora^{+} (D'hondt et al., 2015), and the CMIST (Drolet et al., 2016). At present, most NNS risk analysis schemes and assessment toolkits, whether electronic or paper-based, are entirely in English, with some available in one or two other languages.

Amongst the available decision-support tools, the Toolkit for Best Prevention and Management Practices of Invasive Alien Species (Wittenberg and Cock, 2001) was made available in English, French and Spanish. The Toolkit for the Economic Analysis of Invasive Species (Emerton and Howard, 2008) offers English and French, whereas the Toolkit for Developing Legal and Institutional Frameworks for Invasive Alien Species (Shine, 2008) is available in English and Portuguese. The Trinational Risk Assessment Guidelines of the Commission for Environmental Cooperation (Mendoza et al., 2009) offers English and Spanish, and, more recently, the CMIST was made available in both French and English (MPO, 2015). For native speakers of languages other than English and a few other languages, use of a second language has been necessary in virtually all steps of the NNS risk analysis process, which involves risk identification (screening), full (comprehensive) risk assessment, risk management, and risk communication (Copp et al., 2005a, 2005b).

The first widely-used electronic screening toolkit was the WRA, which despite its development for Australia was applied to risk assessment areas across six geographies: New Zealand, Hawaii, Hawaii and Pacific Islands, Czechia, Bonin Islands, and Florida (Gordon et al., 2008). Prior to the WRA's adaptation for other geographical areas (e.g. Gordon et al., 2012), the WRA was first adapted into the FISK to identify potentially invasive freshwater fishes (Copp et al., 2005c, 2009b). Following the release of FISK v1 in 2005 (Copp et al., 2005c), this decision-support tool was presented at a NNS risk screening workshop at Notre Dame University (Indiana, USA) in April 2008 (Simons and De Poorter, 2009), where Roberto Mendoza (a co-author of this article) proposed to translate FISK to create a Spanish (*español mexicano*) language version. This resulted in S-FISK (Copp et al., 2008), which was released in 2011 along with the other -ISK toolkits (Copp et al., 2005b, 2005c). At the American Fisheries Society annual meeting in Ottawa, Canada (www.afs-oc.org/about-us/afs-ottawa-2008/), Jeffrey E. Hill (University of Florida) commented on the 'temperate zone' focus of the FISK v1 and proposed a revision to make the toolkit applicable to warmer climates. Supported by a grant from the US Department of Agriculture (USDA, 2010), the questions and guidance of FISK v1 were revised, resulting in FISK v2 (Copp, 2013; Lawson et al., 2013), to ensure that it would be applicable to a wide range of climatic zones, and in particular semi-tropical and tropical areas of Florida. This wider climatic applicability of FISK v2 led to a doubling of the geographical applications worldwide, i.e. from eleven risk assessment areas where FISK v1 had been used to 25 where FISK v2 was applied (Vilizzi et al., 2019).

During the same period (2006–2008), the -ISK toolkits were included within the 'Screening module' of the European Non-native Species in Aquaculture Risk Analysis Scheme (ENSARS) – a modular scheme developed for NNS assessments under the 2007 Regulation 'concerning the use of alien and locally-absent species in aquaculture' (European Union, 2007). For aquatic species not assessable with the existing -ISK toolkits (Copp, 2013), a series of generic screening questions was adapted from these -ISK toolkits to create a taxon-generic screening tool (Copp et al., 2016a). In the meantime, further requests were received in 2010 for alternative languages, including French (E. Mazaubert, pers. comm.) and Castilian Spanish (E.D. Dana Sánchez, pers. comm.).

Consistent with the trend in NNS risk analysis at that time towards taxonomically-generic schemes, the questions of the ENSARS generic screening tool were subsequently incorporated into the FISK v2 architecture to create AS-ISK v1 (Copp et al., 2016b). As with the WRA and the FISK, the AS-ISK consists of 49 basic questions that examine the biogeography and biological aspects of the species being screened, resulting in a Basic Risk Assessment (BRA) score. An additional six Climate Change Assessment (CCA) questions ask the assessor to determine how future climatic conditions are likely to affect the BRA score with regard to the risks of the species' introduction, establishment, dispersal and impact, resulting in a (combined) BRA+CCA score. To aid assessors in completing their screenings, each question is accompanied by guidance. In order to achieve a valid AS-ISK risk outcome, the assessor is required to provide a response, a confidence level for the response, and a justification against each question. In developing AS-ISK v1, an important consideration was to ensure that this new decision-support tool would be compliant with the 'minimum standards' (Roy et al., 2018) for risk assessments under the Regulation on the prevention and management of the introduction and spread of invasive alien species (European Union, 2014). Additionally, with a mind towards an ecology-of-language approach, thus endeavouring to reduce 'language-based uncertainty' (Carey and Burgman, 2008), the AS-ISK v1 was released with five language options: English, French, Italian, Spanish and Turkish (Copp et al., 2016b), and later expanded with the release of v1.2 to include (simplified) Chinese.

3. Methods

In the preparation for development of AS-ISK v2 (a much-enhanced version relative to v1.x that involved almost complete re-coding and the inclusion of an additional eleven taxonomic groups of aquatic organisms to the existing 16), comments and suggestions received from users of AS-ISK v1.x were compiled and incorporated, as appropriate, into the English-language guidance template, in order to enhance the clarity of the guidance provided within AS-ISK. These modifications were then incorporated, in translated form, into the 29 languages of the graphical user interface (GUI) of the AS-ISK v2, with an additional language later included in AS-ISK v2.01, and another two languages in AS-ISK v2.1. Development of the multilingual GUI in AS-ISK v2.x followed the approach outlined in Green et al. (2007), with the extent of language support being the most advanced allowed by the Visual Basic for Application (VBA) code for Excel™ in which the program (including its predecessor -ISK toolkits) is written. This includes support of right-to-left languages (i.e. Arabic, Hebrew, Persian and Urdu), which led to the re-design of the source database spread-sheet of assessments and the output report template, and of double-byte-character-set languages (i.e. Chinese, Japanese and Korean) (Figure 1). In the latest release AS-ISK v2.2, the output report is also made available in pdf and mhtml formats (other than as a spread sheet) to facilitate even further communication and accessibility of assessment outcomes to stakeholders.

To construct the library (or database) of language options for incorporation into the AS-ISK v2.x architecture, fellow scientists were invited to act as 'author-translators' in the construction of a language library to be integrated into the toolkit (Supplementary Table S1). In some cases, these were persons who had requested their native language be included as a language option in AS-ISK to facilitate their current and future use of this new decision-support tool in a global trial of the AS-ISK as a contribution to one of the terms of reference of the Working Group on Introductions and Transfers of Marine Organisms (ICES, 2019). Criteria for an invitation to act as an author-translator were taxonomic expertise with aquatic species and invasion biology, and/or current or previous risk-screening experience with either FISK or AS-ISK v1. In most cases (74% of the author-translators), translations were elaborated by a minimum of two author-translators, and in some cases this included a non-biologist with linguistic expertise in order to reduce the likelihood of mistranslation into another language (e.g. the English questions and guidance).

The author-translators, usually more than one (Supplementary Table S1), were asked to provide translations of the: questions, revised guidance text, and GUI text. To achieve this, three spread sheets (in English) were provided to the author-translators (Figure 1): (i) a Header spread-sheet containing each language-specific template for the database of screenings including the keywords for the risk screening context; (ii) a Q&A spread-sheet containing each language-specific template for the question text and guidance; and (iii) a Strings spread-sheet containing each language-specific groups of templates for the various GUI features, run-time messages and lookup responses to the questions.

The resulting collective translations were then incorporated into AS-ISK v2.x and tested thoroughly for consistency in terminology.

During the translation process, and in line with the linguistic testing approach in the context of software localisation (Quaid, 2017), the following challenges were encountered and discussed with the author-translators as part of the on-going communication process:

1) For some of the languages with grammatical gender (https://en.wikipedia.org/wiki/Grammatical_gender), a slight rewording of the original English text (although not affecting its overall meaning) was required with particular reference to the responses to questions (other than ‘Yes’ and ‘No’) and related confidence levels (i.e. ‘Low’, ‘Medium’, ‘High’, ‘Very high’). This was the case of Croatian-Serbian and related languages, Italian and Polish.
2) For agglutinative languages (https://en.wikipedia.org/wiki/Agglutinative_language) such as Turkish additional attention was paid to ensure that the root of the keyword was preserved.
3) In those (few) cases where no substantial difference between two words in a certain language was present, either a different translation was ‘enforced’ (i.e. by use of the ‘closest synonym’ available in that language) due to VBA programming requirements (e.g. ‘decrease’ *vs* ‘lower’, ‘increase’ *vs* ‘higher’), or the same word was used (i.e. ‘certainty’ *vs* ‘confidence’).

4. Results and discussion

4.1 Issues with linguistic uncertainty

The current release of AS-ISK v2.2 (i.e. with enhanced report output capabilities) offers users a total of 32 languages, which may be used in some 164 countries worldwide (Figure 2): English, Albanian, Arabic, Bulgarian, Croatian-Serbian and related languages, Chinese (simplified), Czech, Dutch, Filipino, French, Georgian, German, Greek, Hebrew, Hungarian, Italian, Japanese, Korean, Macedonian, Persian, Polish, Portuguese, Romanian, Russian, Slovak, Slovenian, Spanish, Swedish, Thai, Turkish, Urdu, and Vietnamese. This represents the first-ever, multilingual decision-support tool for screening NNS, and perhaps for any form of risk assessment, that promotes the ecology-of-language paradigm. As such, AS-ISK serves the dual purpose of contributing to linguistic diversity (Phillipson and Skutnabb-Kangas, 1996) and reducing language-based uncertainty (Carey and Burgman, 2008). Indeed, the languages available to assessors in AS-ISK will serve to avoid the ‘linguistic short circuit’ (*sensu* Bortolus, 2012), which often forces local environmental managers and other stakeholders to use English-only decision-support tools in learning about local systems and making management decisions to protect natural resources, potentially affecting the accuracy of those decisions.

Given the reciprocity between language and environment, three principal themes are involved in language–environment interactions: language evolution, language environment, and language endangerment (Hornberger, 2002). All three of these ecology-of-language themes are relevant to NNS risk analysis in general, as they impact on linguistic uncertainty, which the multilingual AS-ISK was developed to reduce. Firstly, scientific terminology in all languages undergoes continual language evolution, as new phrases or terms are defined to add clarity to new (or revised) concepts and thus to our understanding of natural and artificial environments. This language evolution is especially notable in recent decades with the increasing awareness of the potential impacts imposed by future climate conditions on the natural world, with increased uncertainty potentially introduced due to differences in personal interpretations of what climate change means (not only temperature increases, but also changes in e.g. precipitation, river discharge regimes). Assessors carrying out risk screenings in their mother tongue are more likely to be aware of recently-evolved local terminology than that in a foreign language. Secondly, the need to communicate NNS risk outcomes to stakeholders forces scientists into the language environment of government agencies, academic/educational bodies, non-governmental organisations, and the general public (e.g. for public support of outcomes, participation in management and citizen science on biological invasions). All of these can (and do) operate within their own 'linguistic ecosystem', which assessors will understand better in their mother tongue than in a foreign language. And thirdly, the dispersal-of-English trend in risk analysis is driving language endangerment due to "inadequate [linguistic] environmental support for them [the non-English languages] *vis-à-vis* other languages in the eco-system" (Hornberger, 2002: p. 36). A decline in a language (e.g. lack of evolution leading to endangerment) reduces a scientist's ability to communicate NNS risks to stakeholders in their mother tongue, requiring the use of English terminology and the associated increase in linguistic uncertainty.

Linguistic uncertainty is particularly relevant in the context of risk analysis, which involves subjective judgments and decisions by stakeholders who may be susceptible to various forces that have little relation to data or facts (Carey and Burgman, 2008), with linguistic uncertainty potentially having a substantial contribution to the overall uncertainty associated with the analysis (Van der Bles et al., 2019). Indeed, language introduces uncertainty through the subjective interpretations involved in risk analysis, even when detailed guidelines are provided (Budescu et al., 2014). The issues surrounding uncertainty (linguistic, epistemic and psychological) that affect decisions may be viewed in a four-component framework (Latombe et al., 2019): (i) circumscription, (ii) quantification, (iii) understanding of the causal mechanisms behind the phenomenon, and (iv) understanding of the mechanisms through which the phenomenon has consequences. Of these, linguistic uncertainties are the easiest to avoid or mitigate, so particular care should be taken in the use of terminology (Latombe et al., 2019).

4.2 *Differences within and between languages*

The creation of AS-ISK as a multilingual decision-support tool has effectively been a study of environmental interactions between any given language and its user. Those interactions combine the various factors that make up national culture, including geography, history, climate, religion and language (Phillips and Wright, 1977). Indeed, the aforementioned authors found experimental support for their hypotheses that discriminations in degrees of uncertainty would be more refined in native-English speakers (who have a 'probabilistic' world-view) than in native-Chinese speakers (who have a 'fatalistic' world-view), and that numerical assessments of probabilities would hold greater meaning for native-English speakers than for native-Chinese speakers (e.g. Lau and Ranyard, 2005). Such a 'probabilistic' view is not necessarily limited to native-English speakers, given that 'probability' derives from Aristotelian bi-valued logic, which had a profound influence on most western cultures. Conversely, the indigenous Chinese philosophy of Yin-Yang is based on a perspective that accepts co-existence in contradictions (Kosko, 1993). In contrast to the interpretation of uncertainty, more recent research into Chinese *vs* English native speaker interpretations of 'probability' in accountancy found that "native culture and language are not significant factors in explaining differences between accounting students in their interpretation of 'in context' verbal probability expressions" (Salleh et al., 2011: p. 67).

The English questions and guidance, which are quite explicit, were point-by-point translated into simplified Chinese. Therefore, there should be little misinterpretation from the original context by assessors, who have a general biological knowledge base. However, responses to the questions could differ between Chinese and English assessors due to differences in Eastern and Western cultures, as the Chinese tend to have lower levels of probabilistic thinking (see above). The experience of the Chinese co-authors (HW and SL) is that Chinese assessors can respond "Yes" or "No" to questions for which sufficient evidence is available, but they feel uncomfortable in providing a confidence level for those responses. Also, in the assessment of NNS that generate considerable economic benefits, adverse impacts could be underestimated by the assessors, despite their intention to be objective, when they consider that the assessment outcome might lead to a potential negative impact on that species' use in aquaculture. Whereas, the assessors are likely to have provided objective evaluations of non-economic NNS. For Qs 10–17 in AS-ISK (see Copp et al., 2016b), the risks of NNS might be accepted by Chinese assessors if they have generated huge economic benefits and local studies of adverse impacts have received little or no study – this reflects the philosophy 'acceptation of contradictory', which might result in differences between native English and Chinese assessors in the interpretation of uncertainty.

Within a given language (e.g. English, German, Spanish), these national cultural factors combine to create separate, unique national cultures that affect how risks and uncertainties are expressed and understood (Phillips and Wright, 1977). This was evident in the initial translation of FISK into

Spanish, which was undertaken in Mexico, resulting in the use of Mexican Spanish rather than Castilian Spanish. Colleagues from Spain who used S-FISK commented on what they considered to be unusual terminology and sentence composition of the questions and guidance in S-FISK. For AS-ISK v2, this issue was resolved by Spanish and Mexican colleagues collaborating in the translation to create a generic 'hispanic' language option listed under 'Spanish'.

Similar to the S-FISK issue (i.e. Mexican *vs* Castilian Spanish), one of the difficulties encountered by the Portuguese author-translators of AS-ISK was with the Orthographic Agreement (see Washington, 2018) ratified by countries where Portuguese is a primary or official language (mainly Portugal, Brazil, Angola, Mozambique, East-Timor). Similar to English (e.g. UK *vs* USA) and French (France *vs* Québec), there were differences in the correct forms of writing and spelling in each of the signatory countries of the Orthographic Agreement. Major changes have thus been made in European Portuguese and, in many cases, the Brazilian form and spelling has been 'enforced' by treaty ratification and national legislation. This is particularly difficult for many people who still write in the 'old' correct form (e.g 'project' was *projecto* instead of *projeto*; as was *correcto* instead of *correto*). Some difficulties were also encountered with Romanian, a Daco-Romanian member of the Romance language family. Biological terms that derive from Latin or Greek are sometimes difficult to translate from English into Romanian, often requiring two or three Romanian words, as well as several synonyms in order to avoid that the translation imposes a different meaning on the original English term (e.g. 'invasional meltdown'). In the case of French, 'Québecois' French has diverged from the French spoken in France such that films produced in Québecois are screened in France with French sub-titles (G.H. Copp, pers. observation).

The AS-ISK translation into Croatian, Serbian and related languages of the former state of Yugoslavia encountered a situation similar to that of the Castilian *vs* Mexican Spanish in S-FISK. The translation into Croatian, Serbian and other related languages revealed differences, albeit slight in some cases, between these languages in terms of grammar but also word usage. As such, there are multiple versions of translated commands, even within one of these countries, which may cause confusion to users (Barić, 2011).

To maintain consistency of the translation of an English word or sentence structure, sometimes the sentence structure and writing style can be different from that of a local language, such as Thai. In English, some words have multiple meanings or have different roles in a sentence (e.g. noun, verb, adjective), and two terms can have the same (or virtually the same) meaning, and this can result in inconsistent word usage in a translated language, such as in Thai. This issue has been addressed in Section 3 *Methods* (see item 3). In case of an English word having no direct translation into another language, such as Thai, several additional words in the translated language were required to communicate the sentence's intended message, which in some cases created inconsistencies in sentence structure. Similarly, spaces between words and within a sentence may differ from English in which a single space separates every word. Thus, in Thai, double or triple spaces are often used to separate compound words, and additional double spaces are used between ideas. Although this may have linguistic implications, it does not affect the strings of text to be displayed by VBA, which can even consist of spaces only.

4.3 Terminology, culture, interpretation, and cognition

The above-mentioned issues suggest that, in the case of an AS-ISK language option elaborated by a lone author-translator, his/her own knowledge on invasion ecology and ability to interpret and translate the original English questions and guidance may affect the efficiency of AS-ISK relative to language options elaborated by more than one author-translator. This is due to the absence of inter-personal variability in translation and interpretation, e.g. related to regional and local conditions within that language's geographical range (Wei, 2018). The difficulties of understanding the nuances in meaning and use of invasion biology terms, and scientific terms in general, are particularly acute for scientists attempting to evaluate and communicate information in a language other than their mother tongue, hindering the use of up-to-date scientific knowledge by field practitioners and policy makers for local environmental issues (Amano et al., 2016; Mehta et al., 2019). The difficulties associated with nuances in meaning are also apparent in the terminology used to express uncertainty, which is not easily translated into another language, e.g. English to German (Doupnik and Richter, 2003). For example, in Table 1 of their article (*ibid.*), which lists various translation issues, 'unlikely' in German would be *aller Wahrscheinlichkeit nach nicht*, which translates literally into 'in all likelihood not'.

Further linguistic issues arise where no exact (appropriate) translation exists for an English scientific term, so scientists may still prefer to use the English term within their native language text to avoid the uncertainty potentially associated with inexact translations of the English term (Wei, 2018) – this was the case in the translation of AS-ISK v2.x with e.g. the Korean language that preserved the original English word 'threshold'. This is most frequently associated with terms that are first coined in an English-language article. Most new or revised scientific terms are coined in English-language articles (often from English-speaking countries or culture systems). When these terms are introduced into other regions/countries, they would be incorporated into that local cultural system (Mehta et al., 2019), and in the process may 'import' nuances in the meaning of the term relative to its original definition. For example, in Chinese, 'invasion' refers to enemies/criminals invading someone's country/home, which carries a pejorative connotation; whereas, the more neutral terms of 'non-native' and 'alien' refer simply to things or people that originate from outside a region or country. In English, 'invasion' still carries, to a lesser extent, a military-associated connotation. Both language and cognition are affected by social culture, education, and effectively the environmental setting, and as such cognitive bias can affect the certainty of risk assessment. This is especially true with qualitative methods, but linguistic uncertainty due to cognitive subjectivity (a.k.a. 'epistemological subjectivity': Solli and da Silva, 2018) also occurs with quantitative approaches (Leung et al., 2012). This language-culture-environment-education complex can influence the communication by scientists of NNS risks to policy and decision makers, especially in cases of 'trans-languaging' where English terms are re-appropriated in other languages, potentially with entirely different meanings (Wei, 2018).

Another issue arises in references made to policy and/or legislation from outside of the region/country where a risk analysis protocol is being used. For example, the guidance associated with AS-ISK question '53' (*Under the predicted future climatic conditions, what is the likely magnitude of future potential impacts on biodiversity and/or ecological integrity/status?*) refers to the EU's 'Water Framework Directive and/or the Marine Strategy Framework Directive', which might be difficult to understand for assessor/policy-makers in different countries or regions outside of Europe (see Copp et al., 2016b). This can exacerbate linguistic uncertainties, which can be reduced through improved guidelines and adequate training of assessors (Vilà et al., 2019). To this end, by way of example, the simplified Chinese translation of AS-ISK guidance replaces mention of these two EU directives with reference to similar regulations in China. Such improvements to AS-ISK's guidance in the translation process will facilitate the potential communication of NNS risks to local stakeholders, managers, policy and decision makers in their own countries. As such, this is consistent with the concept of respecting 'the diversity of culture/ecology of language'.

4.4 Benefits of a multilingual decision-support tool and future developments

A central motivation for the creation of AS-ISK as a multilingual decision-support tool was the need to communicate scientific evidence into a language understood by stakeholders, in particular policy and decision makers (Bernabo, 1995; Young et al., 2014). The political process behind policy making relies upon the communication of risk-based decisions to the general public (Russell and Gruber, 1987; Wardekker et al., 2008) and stakeholders (Matthews et al., 2017; Young et al., 2014). Scientists may perceive the decision-making process as being based primarily on scientific evidence, but this may only be a small component. This perception is changing, as scientists dealing with NNS risk analysis become increasingly aware of the importance of scientific evidence in risk-based decision making for policy and environmental management. To enhance the communication of NNS risks to the wider public, the decision-making process behind policy and management needs to be transparent, with views exchanged and discussed with scientists in order to identify and pursue the most policy-relevant, but evidence-based, way forward for managing the environment (Young et al., 2014). Furthermore, although international cooperation and communication is facilitated through the use of a common language, within-country (or region) communication should ideally be in that country's (or region's) local language to facilitate buy-in from managers and policy makers at local and regional levels (Piria et al., 2017), and to benefit from local-language evidence sources. Moreover, appropriate environmental management is best achieved using all available current knowledge, regardless of the language in which it is written, relevant to a system or environmental issue. However, review studies often investigate the information presented in the English language only (e.g. Kettenring and Reinhardt Adams, 2011; Lowry et al., 2013; Mačić et al., 2018). As noted by Crowther et al. (2010: p. 3143): “This will reduce the number of studies needed to review, especially if there is difficulty in translating a study. This may be acceptable for many reviews, but in some areas there may be many important studies published in other languages. Consequently, excluding studies on the basis of language must be done with care. For example, Chagas disease [i.e. parasite *Trypanosoma cruzi*] is endemic in Latin America, and a systematic review of transfusion-transmitted Chagas disease limited to English-only publications will exclude potentially important studies”.

Indeed, to ignore scientific documents published in languages other than English can be expected to bias our understanding of the systems under study. For example, in a Google Scholar survey carried out in 16 languages, Amano et al. (2016) found that 35.6% of 75,513 scientific documents published in 2014 on biodiversity conservation were in a language other than English. Here, a simultaneous translation of these non-English documents in a common ‘scientific’ language, such as English, would make this library of information available to risk assessors not conversant in that language (e.g. Fisheries Research Board of Canada translation series). The alternative approach is to include scientists with the required linguistic skills in the studies that require an understanding of, and expertise in, the existing non-English scientific literature. Such an approach is of interest with species for which information in English is lacking about their native range but of interest to other areas where that species may be a concern as a future bioinvader (e.g. Copp et al. 2009a; Tarkan et al., 2016; Vilizzi et al., 2019; Rohtla et al., 2020). The variety of ecosystems and languages across the globe is difficult to accommodate in any one risk screening/assessment tool and AS-ISK currently does not offer language options for some regions characterised by exceptionally high biodiversity (e.g. Indian sub-continent and south eastern areas of Asia including Indonesia) (Figure 2).

Beyond linguistic uncertainty, the consistency of risk assessment outcomes appears to be dependent more on the characteristics of the risk protocol than on those of the NNS (González-Moreno et al., 2019). Improvements to risk protocols to achieve more consistent outcomes include the structure and clarity of language used to formulate assessment questions (Turbé et al., 2017), since confidence tends to be higher with targeted choice questions, such as those used in AS-ISK, than broad, open-ended questions (Ibabe and Sporer, 2004). Further research is needed to understand better the effects that knowledge, variability, decision and linguistic uncertainty have on the environmental decision-making process and the quality of decisions made (Ascough et al., 2008). But even where these uncertainties can be minimised, the outcome of the risk analysis process must be interpreted in a transparent manner and communicated in a language that is accessible to the stakeholders in order to foster appropriate decisions and management recommendations (Matthews et al., 2017).

Transparency is a key feature of the AS-ISK by way of its report-generating function, which provides stakeholders with the questions, guidance, assessor responses and justifications in the chosen language. Improvement of the language content in AS-ISK can be made by contacting the corresponding lead author-translator with the proposed enhancements (see Supplementary Table S1). Following consideration by the author-translator concerned to ensure the modification is a more accurate translation of the English original, the agreed change can be made by the AS-ISK programmer (L. Vilizzi) for inclusion in the next AS-ISK release(s). The latter can also include contribution of any additional languages not yet supported by the toolkit.

In conclusion, this new, multilingual decision-support tool is expected to contribute to increased confidence in risk screenings through reduced linguistic uncertainty for assessors of non-English mother tongue. More importantly, for stakeholders responsible for NNS policy, legislation and the development and implementation of NNS management, the availability of risk screening reports (of assessor responses, confidence rankings, justifications and overall risk score outcomes) in their native language is expected to increase transparency and therefore stakeholder confidence in the evidence provided to them, thus facilitating their efforts to prevent further spread and/or the introduction of high-risk aquatic NNS. A benefit of the many language options available to users of AS-ISK is the enhanced communication of NNS risks within and amongst non-English speaking countries – this is expected to facilitate international collaboration and information transfer among countries to prevent the entry or dispersal of high-risk species, and implement their eradication at an early stage as part of a rapid-response strategy. Considering this expectation, it would be thus interesting to assess the use of AS-ISK, and the effects of its use in terms of policy and management, a few years following its release. Although linguistic uncertainty associated with risk assessment outcomes can be reduced by a multilingual toolkit, the lack of information on NNS is still the main constraint on increased assessment confidence. This suggests that more efforts should be made to encourage public science, scientific research, and international information exchange (Piria et al. 2017).

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Software and data availability

The AS-ISK v2.2 is available as free download at: www.cefas.co.uk/nns/tools/.

Author contributions

G.H. Copp and L. Vilizzi were both responsible for the conceptualisation, methodology, analysis and investigation and visualisation aspects of the study, with G.H. Copp additionally involved in supervision and project administration and L. Vilizzi in software development and validation. All authors contributed to the writing of the original draft and the reviewing and editing of the final version of the manuscript, with P. Goulletquer also contributing to the methodology and R. Mendoza to the conceptualisation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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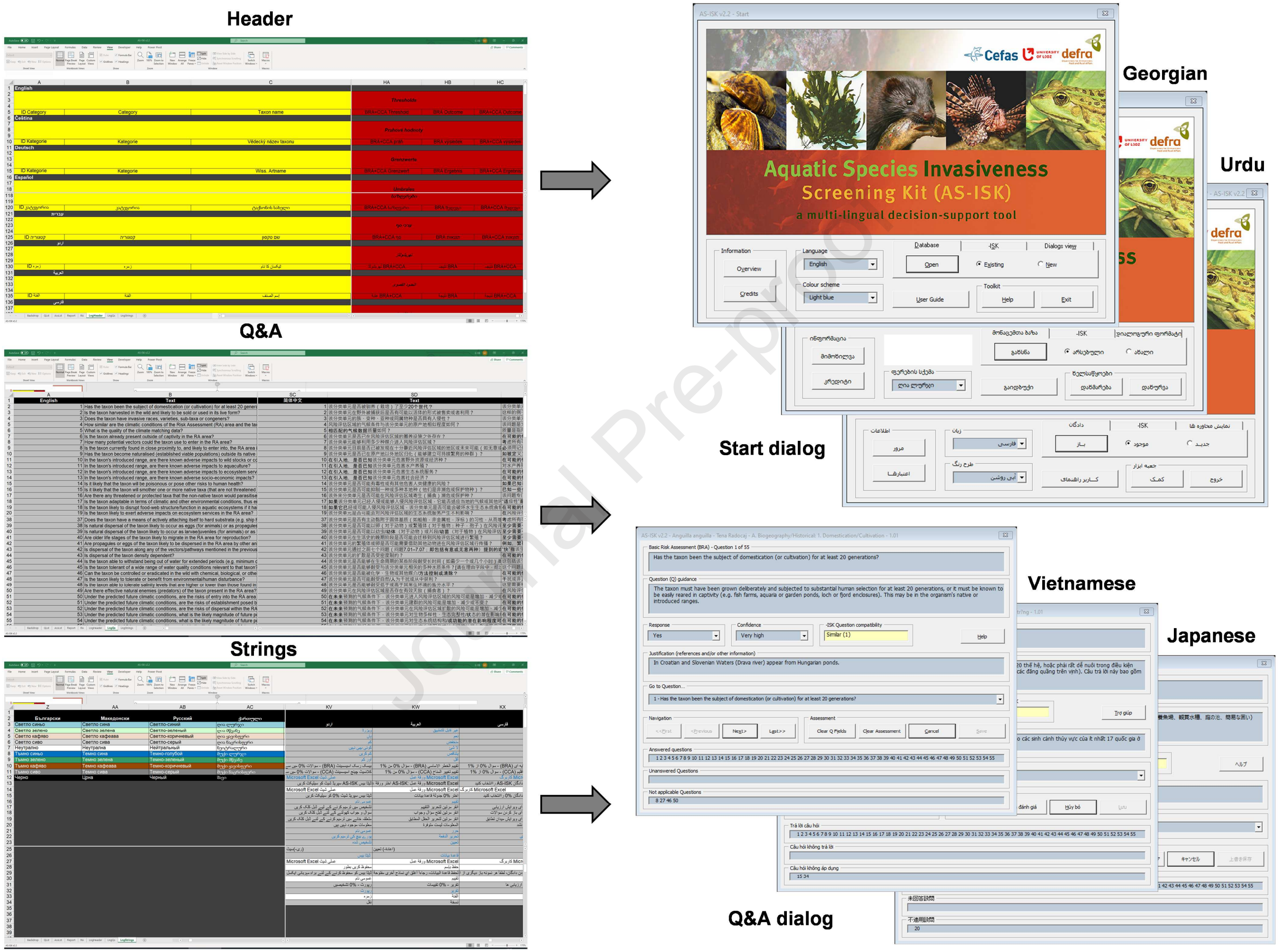
Figure captions

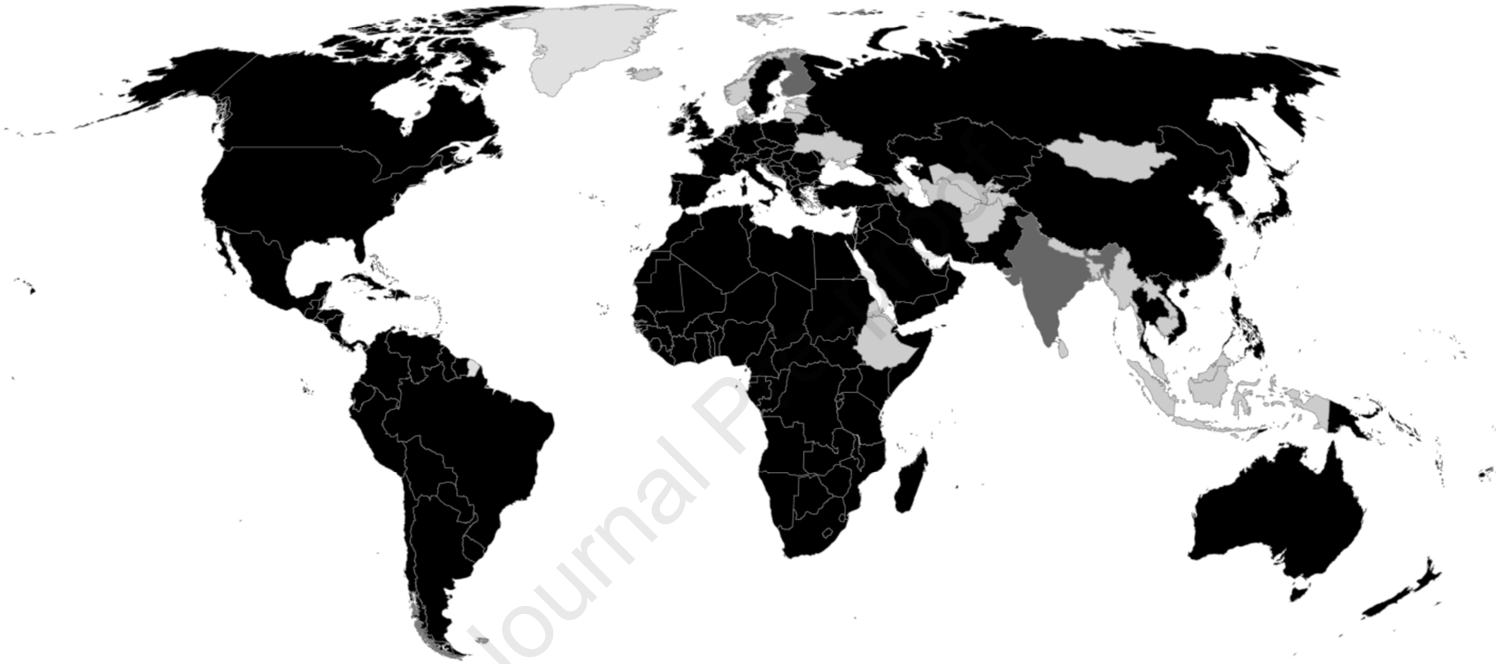
Figure 1 Process schematic for the development of the multilingual AS-ISK v2.x. The three spreadsheets Header, Q&A and Strings provide the multi-language input for the dialogs (Start and Q&A displayed for illustrative purposes with four examples of languages out of the 31 languages other than English supported) making up the graphical user interface of AS-ISK v2.x.

Figure 2 Map of the 164 (84.1%; in black) of the 195 worldwide countries/political entities where the multilingual AS-ISK v2.2 may be used in the official language, the two (1.0%; in dark grey) where the language is still an official but 'secondary' (Finland, India), and the remaining 29 (14.9%; in light grey) for which the language option is not (yet) available. Note that education in an 'official' national language may not necessarily be available to all citizens of that country, so official language status is used here as an estimator of potential usage.

947 **Figures**



948 **Fig. 1**



949 **Fig. 2**

The authors declare no conflict of interest.