

Letter to Management of Biological Invasions**Comparing apples to oranges and other misrepresentations of the risk screening tools FISK and AS-ISK – a rebuttal of Marcot et al. (2019)**

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Citation: Hill JE, Copp GH, Hardin S, Lawson KM, Lawson LL Jr., Tuckett QM, Vilizzi L, Watson CA (2020) Comparing apples to oranges and other misrepresentations of the risk screening tools FISK and AS-ISK – a rebuttal of Marcot et al. (2019). *Management of Biological Invasions* 11(2): 325–341, <https://doi.org/10.3391/mbi.2020.11.2.10>

Received: 6 September 2019

Accepted: 22 October 2019

Published: 5 December 2019

Handling editor: Vadim E. Panov

Thematic editor: Matthew A. Barnes

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OPEN ACCESS**Abstract**

Marcot et al. (2019) recently described the risk analysis process by which the U.S. Fish and Wildlife Service (USFWS) chooses species for listing as injurious wildlife. They further compared the Fish Invasiveness Screening Kit (FISK) and the Aquatic Species Invasiveness Screening Kit (AS-ISK), generally unfavorably, with their process/components. We assert that FISK and AS-ISK were largely misrepresented. The USFWS process is a risk analysis framework, whereas FISK and AS-ISK are hazard identification/risk screening tools, addressing only the initial step of a risk analysis scheme. Thus, to avoid an apples-to-oranges comparison as done in that paper, FISK/AS-ISK should be compared to the equivalent USFWS tool, the Ecological Risk Screening Summaries (ERSS). The remaining issues that we address concerning FISK/AS-ISK include: (1) need for expert opinion, (2) subjective climate matching, (3) need for regional calibration, and (4) narrower range of information inputs; and concerning the ERSS process: (5) peer-review. Both systems clearly use expert opinion, the FISK/AS-ISK arguably in a more structured and transparent manner. Guidance for FISK/AS-ISK recommends a climate-matching program, but allows for use of Köppen-Geiger climate types or physiological tolerances, potentially increasing subjectivity in some cases but improving climate-match quality in others. Calibration of FISK/AS-ISK follows from the regional nature of invasiveness risk and the use of questions unrelated to climate that are tailored to the risk assessment (RA) area. Climate match is the only element that the ERSS applies specifically to the RA area. The FISK and AS-ISK actually use a much wider range of information than does the ERSS, a system based on invasion history and climate match only. The peer review of ERSS consisted of a five-member expert panel that evaluated the method, whereas the ERSS reports posted online are not peer reviewed. Conversely, FISK applications have resulted in 37 peer-reviewed journal articles, including assessments from over 70 experts in 45 countries. We welcome constructive criticism and improvement of these decision-support tools, but we are concerned that managers may dismiss well-established approaches in favor of a framework that possesses its own method-specific limitations. We recommend that managers evaluate risk-based approaches and adopt systems to support decisions and improve invasive species management.

Key words: aquatic species invasiveness screening kit, risk assessment, fish invasiveness screening kit, ERSS, injurious wildlife, fish

Introduction

Marcot et al. (2019) recently described the risk analysis process for non-native freshwater fishes used by the U.S. Fish and Wildlife Service (USFWS) for regulatory purposes within the United States of America. Risk analysis typically involves four components: risk (or hazard) identification (a.k.a. screening), comprehensive (full) risk assessment, risk management (regulatory and non-regulatory approaches to mitigate risk such as lists of extant and/or horizon species for regulation, rapid response and control/eradication protocols, best management practices, and educational programs), and risk communication and review (see Hill and Zajicek 2007; Copp et al. 2016a). Similarly, the Marcot et al. (2019) framework consists of: (1) a rapid screen called the Ecological Risk Screening Summary (ERSS); (2) a Bayesian secondary assessment called the Freshwater Fish Injurious Species Risk Assessment Model (FISRAM), which is used when the outcome of the ERSS is uncertain; (3) a set of criteria for regulatory listing as injurious wildlife (see Marcot et al. 2019 for a distinction between invasive and injurious); and (4) a rule-making process communicated through the official U.S. Federal Register (Figure 1). Brief examples of other risk assessment (RA) tools and schemes were included. However, the authors provided more specific description of, and comment on, the Fish Invasiveness Screening Kit (FISK; Copp et al. 2009; Lawson et al. 2013) and its successor, the taxon-generic Aquatic Species Invasiveness Screening Kit (AS-ISK; Copp et al. 2016b). Marcot et al. (2019) contrasted these screening tools with the USFWS process, which is effectively an apples-to-oranges comparison of a risk analysis framework with the FISK and AS-ISK risk identification tools (i.e. the first step in the risk analysis process). Despite their acknowledgment that FISK “has been shown to be a useful tool to judge potential invasiveness” (Marcot et al. 2019, p. 204), there are several inaccurate or misleading statements in their paper, and as such FISK and AS-ISK were largely misrepresented.

We argue that characterizing FISK and AS-ISK as “based on user defined, expert opinion responses to risk assessment and climate assessment questions and the ranking of the level of confidence of those opinions” (Marcot et al. 2019, p. 205) is an inadequate description of the methodology and theory behind these decision-support tools. At the same time, the contrast of FISK and AS-ISK (and other methods described) with the “more quantitative” ERSS/FISRAM may lead risk managers to dismiss the value of well-established approaches in favor of a process that has method-specific limitations as well as those inherent to all biological risk assessments. We briefly describe the FISK and AS-ISK tools and then rebut specific and general points brought up by Marcot et al. (2019).

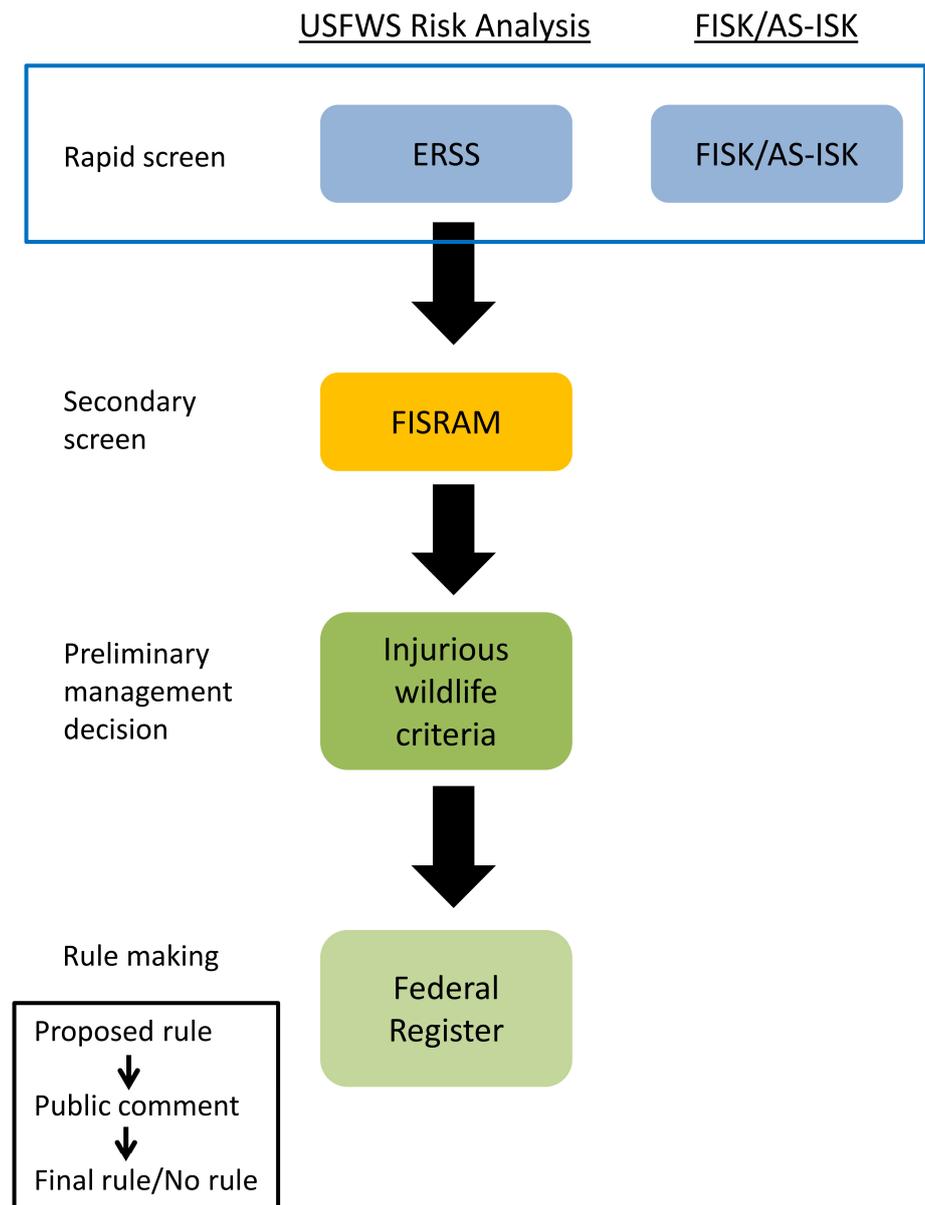


Figure 1. Flow diagram of the USFWS injurious wildlife listing process for a species with an “uncertain” outcome of the ERSS and relative comparison with the FISK/AS-ISK. A “low risk” outcome generally stops the process and a “high risk” outcome bypasses FISRAM. The ERSS and FISK/AS-ISK are both rapid risk screens and are the only equivalent components as indicated by the blue box outline. Information on the USFWS process from Marcot et al. (2019).

FISK and AS-ISK

These invasiveness screening kits are direct descendants of the Australian Weed Risk Assessment (WRA; Pheloung et al. 1999), which has proven highly successful and is used across the globe for evaluating risks of potentially invasive plants (Gordon et al. 2008a, 2012; Gassó et al. 2010; Kumschick and Richardson 2013), including in the USA (Daehler et al. 2004; Gordon et al. 2011; Koop et al. 2012). The WRA was first adapted for use with freshwater fishes in England and Wales (Copp et al. 2005, 2009), adapted for some other aquatic taxonomic groups (Copp 2013), and then updated and improved to FISK v2 in order to accommodate a wider range

of geographic regions, especially those with warmer climates (Lawson et al. 2013; see also Copp 2013 and Vilizzi et al. 2019). The original WRA structure of 49 questions was developed to capture key factors known to influence invasiveness in plants (Pheloung et al. 1999). This structure and scoring system was retained in FISK, but questions and scores were modified to reflect risks associated with freshwater fishes and complemented by a ranking of assessor confidence in each response (Copp et al. 2005, 2009; Lawson et al. 2013) – the same adaptation was implemented for the other aquatic taxonomic groups: freshwater invertebrates, marine fish, marine invertebrates, and amphibians (Copp 2013). Answers to questions provide a numerical score or modify the scores of other questions. Higher scores suggest higher risk. Calibration studies are common where the outcome scores for a group of species is subjected to statistical analysis to determine a score threshold that best differentiates species that are likely to pose a low or medium risk of being invasive and those likely to pose a high risk of being invasive (Vilizzi et al. 2019). In addition to an output of a score and estimated risk level, justification of answers allows a thorough and transparent evaluation of the risk factors that led to a particular output and the certainty ranking provides decision makers with the level of confidence (i.e. knowledge base) behind the responses (Copp et al. 2009; Lawson et al. 2013; Hill et al. 2014, 2017; Hill and Lawson 2015). Numerous applications of FISK are found in the literature, and a recent global review and meta-analysis provides a synthesis of the 1,973 FISK assessments carried out by 70+ experts on 372 taxa for 35 RA areas in 45 countries across the six inhabited continents (Vilizzi et al. 2019).

In developing the taxon-generic AS-ISK (Copp et al. 2016b), the FISK architecture was retained to house the questions from the generic risk screening module of the European Non-native Species in Aquaculture Risk Analysis Scheme (ENSARS: Copp et al. 2016a; Figure 2), which itself was derived from the WRA/FISK template. To construct AS-ISK, the ENSARS questions were complemented by the inclusion of a preamble (brief description of the assessed organism and its range), new questions that directly address the evaluation of socio-economic and ecosystem services impacts, and six additional questions that require the assessor to evaluate the likely effects that future climate conditions could have on the risks of introduction, establishment, dispersal and impact (Copp et al. 2016b). These developments rendered AS-ISK compliant with the “minimum standards” required for assessing the risk of non-native species under the 2014 EU Regulation on the prevention and management of the introduction and spread of invasive alien species (Roy et al. 2018). The FISK and AS-ISK tools are freely available online from the Centre for Environment, Fisheries and Aquaculture Science (Cefas 2019). A global review and meta-analysis of FISK applications has been published (Vilizzi et al. 2019), and a global trial and calibration of AS-ISK is currently under way, contributing to a

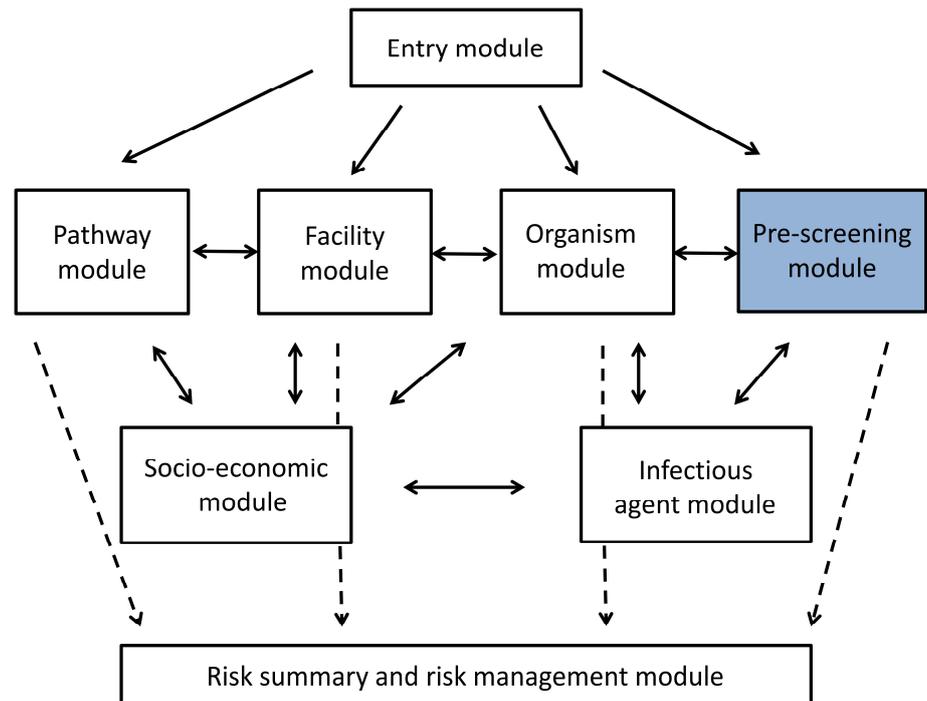


Figure 2. Schematic diagram of the modular European Non-native Species in Aquaculture Risk Analysis Scheme (ENSARS) for evaluating non-native species in aquaculture (redrawn from Copp et al. 2016a). The seven upper boxes represent risk assessment modules and the bottom box represents a summary and risk management module into which the risk assessment outcomes feed information. The Pre-screening module (blue) originally comprised six screening kits (FISK, FI-ISK, MFISK, MI-FISK, Amph-ISK, and Generic), which have since been replaced by AS-ISK (i.e. risk screening).

“term of reference” of the ICES working group on introductions and transfers of marine organisms (ICES 2016).

Rebuttal

Risk analysis vs risk screening

Comparing risk analysis with a rapid screening tool is illogical and unfair. The USFWS process is a risk analysis framework, which includes risk identification/screening, (further) risk assessment, risk management, and risk communication (Figure 1; Hill and Zajicek 2007; Roy et al. 2018; Marcot et al. 2019). Whereas, FISK and AS-ISK are risk screening tools (Copp et al. 2005, 2016b), designed to identify for decision/policy makers those species likely to pose a high risk of being (or becoming) invasive in the RA area and warrant additional (comprehensive) assessment (Copp et al. 2005, 2009; Lawson et al. 2013; Table 1; Figure 1). As such, FISK and AS-ISK should be directly compared to the ERSS only, being that both are decision-support tools that deal solely with risk screening/identification (Figure 1). Comparison with FISRAM is inappropriate. Direct comparison of equivalent tools is important for sorting out strengths and weaknesses and deciding on tool-specific uses in risk management. Unfortunately, the application of false equivalencies in (apples-to-oranges) comparisons of

Table 1. A comparison of the USFWS Ecological Risk Screening Summary (ERSS) (Marcot et al. 2019) with the Fish Invasiveness Screening Kit (FISK) and the Aquatic Species Invasiveness Screening Kit (AS-ISK).

	ERSS	FISK/AS-ISK
Risk screening?	Yes	Yes
Uses expert opinion?	Yes	Yes
Climate matching options	CLIMATCH/RAMP	<ul style="list-style-type: none"> • Climate matching software such as CLIMATCH • Köppen-Geiger climate classification • Physiological tolerances
Climate change assessment?	No	No/Yes
Calibration?	No	Region-specific
Information inputs	<ul style="list-style-type: none"> • Invasion history • Climate match 	<ul style="list-style-type: none"> • Invasion history • Climate match • Human use • Undesirable traits • Feeding impacts • Life history/reproduction • Dispersal mechanisms • Tolerance attributes
Multiple language options?	No	Yes ¹ /Yes
Peer review/publication (prior to Marcot et al. 2019)	<ul style="list-style-type: none"> • Method – Five invited reviewers; internal review • Products—internal review by two staff; external review “not needed” • Publication—USFWS websites 	Method/products/publication—anonymous peer-review and publication in journals; 37 publications of FISK applications
Published review/synthesis/meta-analysis?	No	Yes ²

¹ Spanish FISK (i.e. S-FISK), see Lawson et al. (2013) and Copp et al. (2016a); ² Vilizzi et al. (2019)

risk screening and assessment schemes developed for non-native species management is too common (e.g. Verbrugge et al. 2012; González-Moreno et al. 2019).

In practice, FISK has been used frequently in management as a component of an overall risk analysis scheme. For example, FISK is one of the taxon-specific, risk-identification tools included in the pre-screening module of the ENSARS (Copp et al. 2016a; Figure 2). Similarly, FISK is a common component of risk analysis efforts in the U.S. State of Florida, where it is frequently combined with literature reviews, research to fill data gaps, expert stakeholder panels, qualitative and quantitative assessment protocols, and review by agency subject-matter experts. These elements of risk assessment are combined as needed to support informed decision making and risk management (Hill and Lawson 2015; J.E. Hill *unpublished data*). Similarly, the FISK’s parent tool, the WRA, has also been used in Florida to assess potentially invasive plant species (Gordon et al. 2008b, 2011) and has specific policy and regulatory uses within Florida (Lieurance et al. 2016).

Use of expert opinion

In multiple sections, Marcot et al. (2019, p. 220) point out the use of expert opinion in FISK and AS-ISK and contrast this, for example, with the USFWS process that uses information on invasion history and quantitative

climate match as well as “repeatable quantification of risk probability outcomes rather than relying on subjective expert opinion.” Interestingly, Pheloung et al. (1999, p. 246) concluded that the WRA “model is much less variable than expert opinion and it enforces objectivity.” Specifically for FISK, Copp et al. (2005, 2009) considered that this tool, like the WRA, would improve risk identification because it is a more objective method than subjective assessor opinion. Expert opinion is restricted in the WRA and its derivatives to specific questions that require interpretation and, in its derivatives (FISK, AS-ISK), to the estimation (ranking) of certainty. For example, a question about maximum body size exceeding a threshold value requires no interpretation, whereas the potential for impacts of a specific feeding mode within the RA area requires well-informed, preferably evidence-based interpretation. Justification is required for responses to all FISK and AS-ISK questions, clearly distinguishing straightforward, factual responses from expert opinion; further, the assessor’s ranking of their confidence in the response provided, which is an improvement over the WRA, informs decision makers as to the level of certainty associated with each response and the overall risk screening outcome. Transparent justification responses and the use of trained, multiple assessors improves the objectivity of the risk screenings (Copp et al. 2009, 2016b; Lawson et al. 2013; González-Moreno et al. 2019; Vilizzi et al. 2019).

Regardless of risk screening or assessment method, the use of expert opinion is unavoidable in responding to the assessment questions, the weighting of important factors or scoring, data interpretation, and in identifying potential adverse impacts. Marcot et al. (2019) fail to acknowledge the extensive application of expert opinion in the ERSS, FISRAM, and injurious species listing processes (Table 1). For example, the ERSS requires expert opinion in evaluating invasion history, one of the two components of the method, as a subjective high, low, none documented, or uncertain (Hill et al. 2018). The standard operating procedure (SOP) manual distinguishes the invasion history categories primarily by the existence of scientific study documenting negative impacts (Table 2; Hoff 2016). The SOP acknowledges that the RA uses “structured, expert judgement” and that the method is “not completely automated,” requiring risk assessors to decide on categorization, using qualitative judgements on data quality and quantity (Hoff 2016, p. 32). Lack of data quality and quantity is a major source of bias in RA (Orr 2003). Invasion history and impacts are among the most uncertain and speculative data used in RA, even for many well-known species, requiring expert opinion to interpret the data or estimate the potential for impacts in the RA area (Leprieur et al. 2009; Hill et al. 2014, 2017).

Climate matching

Marcot et al. (2019, p. 207) state that a “shortcoming of FISK and AS-ISK is that neither does quantitative climate-matching,” and therefore “results of

Table 2. Categories, categorization criteria, and evidence criteria for invasion history in the U.S. Fish and Wildlife Service’s Ecological Risk Screen Summaries (Hoff 2016). Vague and potentially conflicting criteria make expert opinion a necessary component in categorization of invasion history.

Invasion history category	Categorization criteria	Evidence criteria for documentation
High	(1) species established, and (2) “one or more sources” document “negative impacts of introduction”	“clear, convincing, and scientifically credible, reliable, and defensible documentation”
Low	(1) species established, and (2) “studies conclude that there are no significant negative impacts of introduction”; or (3) “species has been transported beyond its native range due to substantial trade [millions of organisms] for substantial time [10 or more years] without [any] or very little evidence of establishment”	“scientifically defensible studies”
None documented	(1) species established, and (2) no “studies exist documenting negative impacts of introduction”	“scientifically credible studies”
Uncertain	(1) species not established, and (2) “no evidence of the species having ever been transported...has had no opportunity to become established or exhibit any negative impacts”; or (3) species is cryptogenic/unknown native range	No criteria given

their climate match analysis may be based on subjective evaluations by the risk assessors.” The guidance provided in both FISK and AS-ISK with the climate matching questions states specifically “a climate matching approach (e.g., Climex, GARP, Climatch) may be used ... If a climate matching model is not available, then make a “best estimate” through consultation of the Köppen-Geiger climate region system...or local expertise” (FISK v2.03; AS-ISK v2.0.1; Table 1). Although there is an increasing trend in the use of climate matching programs to answer the climate questions in FISK and AS-ISK, in many cases a simple comparison of Köppen-Geiger climate classes/types (Peel et al. 2007; Beck et al. 2018) is adequate (e.g. few fishes confined to class-D cold climate regions are likely to establish and prove invasive in class-A tropical regions). Moreover, considering that species may have greater physiological tolerance than evident in their natural and non-native ranges (Broennimann et al. 2007; Jiménez-Valverde et al. 2008), thermal tolerance data might be equal or superior to climate modeling in some cases (e.g., Lawson et al. 2015b). In all cases, the assessor is obliged to rank their confidence in their responses to the climate matching scores, and the use or not of a climate-matching program can be reflected in the confidence rank allocated (Lawson et al. 2013; Copp et al. 2016b). Further, both FISK and AS-ISK include a question on the quality of the climate matching data, and that response may increase or decrease the climate-matching score.

Calibration for regions

Marcot et al. (2019, p. 206) state that “subjective evaluations” of climate match are at least partly responsible for the need to calibrate FISK. Although climate is an important reason for calibrating FISK (e.g. Puntilla

et al. 2013; Lawson et al. 2015a; Dodd et al. 2019; see also Vilizzi et al. 2019), a variety of factors also influence FISK and AS-ISK score thresholds. Unlike the ERSS, which is used for the United States, FISK and AS-ISK combined have applications in 80+ countries across multiple biogeographic and climatic regions around the world (Vilizzi et al. 2019; L. Vilizzi, G.H., Copp et al. *unpublished data*). Vilizzi et al. (2019) found that for 27 species evaluated across Köppen-Geiger climate classes B, C, and D, FISK scores differed significantly, reflecting different levels of risk in these regions. Correspondingly, threshold values differed across Köppen-Geiger climate classes, though no climate-specific pattern occurred (Hill et al. 2017; Vilizzi et al. 2019). Answers to FISK and AS-ISK questions may pertain specifically to the RA area (Lawson et al. 2013), influenced by habitat or species present, in addition to climate. Clearly, invasiveness risk varies by region, and potentially even within the same climate type (e.g. Dodd et al. 2019), thus a regional calibration for a score threshold is needed (Table 1; Vilizzi et al. 2019), and in the case of aquatic organisms the ecoregion should be considered (Dodd et al. 2019).

Conversely, the ERSS has no provision for calibration (Table 1) and does not allow interpretation of invasion history across different climates, ecoregions, or habitats. Any history of establishment and any documented negative impact outside of the RA area are sufficient to yield a high invasion risk categorization (Table 2), even when considerable data to the contrary are available from within the risk assessment area. This inflexibility might be overcome if a high-risk ERSS outcome was treated as the output of a risk screen, which it is, namely identification of potential hazards and an approximation of relative risk, rather than a comprehensive assessment, which it is not. The high-risk determination from the ERSS is a conclusion that the species is high risk for the entire United States, with no process for concluding that the species is anything other than high risk. Further, high risk species from the ERSS are then considered for listing as injurious (Marcot et al. 2019, Figure 1), a blanket prohibition on importation despite a rather low threshold of evidence (Corn and Johnson 2013). This is in stark contrast with guidance on interpreting FISK and AS-ISK for which species scoring as high-risk are assessed further using different methods to determine actual risk category (Lawson et al. 2013; Copp et al. 2016b). The frequent inability to place species invasions into a relative context, with realistic predictions of range and likely types and magnitude of impacts within the risk assessment area follows directly from the SOP and hampers the effective application of the ERSS.

Information range used in FISK and AS-ISK compared to ERSS

Marcot et al. (2019, p. 208) describe the information used to complete the ERSS and state that of the other methods “none integrates the full array of factors pertaining to potential injuriousness of an introduced invasive

species.” Neither FISK nor AS-ISK requires the compilation of a lengthy review of assessed species, though AS-ISK does include brief descriptions of the species, its native and introduced ranges, and the reason for carrying out the risk screening (Copp et al. 2016b). However, both tools are in many ways focused, concise literature reviews, that is, reviews designed to acquire information with which to answer the 49 specific questions across a broad range of topics related to invasiveness potential. And in the AS-ISK, the assessor answers six additional questions to assess how future climate conditions are likely to affect the risks of the species introduction, establishment, dispersal and impacts (Copp et al. 2016b). Unlike AS-ISK, no such provision is provided in the ERSS by which the assessor(s) evaluates the potential impact of future climate conditions (i.e. “climate change”) on the ERSS risk rankings (Table 1), though their most recent climate-matching program has the capacity to estimate climate match to future conditions (USFWS 2019b).

The ERSS assessor compiles information on the species but uses only two categories of that information in the estimation of risk, invasion history and climate match (Table 1; Hoff 2016; Marcot et al. 2019). The process uses expert opinion to categorize history of invasiveness (combination of introduction, establishment, and impacts) as high, low, none documented, or uncertain, and quantitative thresholds to categorize climate match as high, medium, or low. The ERSS outcome is then determined using a two-way, qualitative matrix to return overall risk categories of high, low, or uncertain (Marcot et al. 2019). Invasion history and climate match are prominent in FISK and AS-ISK, but a much wider range of information directly influences the scoring, hence estimation of risk (Lawson et al. 2013; Copp et al. 2016b). Questions pertaining to human use, potential impacts in the RA area, physiology, dispersal, potential control, and other categories contribute to scoring in both FISK and AS-ISK (Table 1).

Although many FISK and AS-ISK applications have been calibration studies (Copp 2013; Vilizzi et al. 2019) for which no separate literature review (supplementary information) document was provided, there is an increasing trend in published applications of these decision-support tools that provide the “reports” that these tools generate for each species (e.g. Hill and Lawson 2015; Dodd et al. 2019). Similar to the “report” produced of FISK and AS-ISK assessments, past and ongoing applications of the -ISK toolkits in Florida often include a specific review document called a biological synopsis (Hardin and Hill 2012; Hill and Lawson 2015). This synopsis, which is presented in a standardized format developed by the Florida Fish and Wildlife Conservation Commission, contains information on the taxonomy, biology, ecology, invasion history, native and introduced ranges, pathways, control options, and current state and federal regulations. The biological synopsis format further contains sections specific to risk assessment where a combination of empirical information and expert

opinion is used to discuss potential habitat, distribution, and impacts within the RA area. These documents provide considerable information for the completion of screens and RAs along with much additional information pertinent to risk for assessors and managers (Hill and Lawson 2015). In comparison to limited review contained in the ERSS, a biological synopsis synthesizes available evidence, draws more heavily on the primary literature, and is considerably more thorough and detailed, reducing subjectivity. In contrast, an ERSS report “consists mainly of copying and pasting large amounts of quoted material from various websites and scientific journals” (Hoff 2016, p. 7) with a heavy reliance on online databases, which are known to contain inaccuracies (McGeoch et al. 2012).

Peer review of tool/process and products

Marcot et al. (2019) frequently mentioned that the elements of the USFWS process were peer reviewed to meet U.S. federal standards for influential science. The ERSS review by five experts specifically chosen by the USFWS (USFWS 2019a) was laudable but was not a review of anonymous experts refereed by a journal’s editors consistent with the gold standard of scientific peer-review (Table 1; Mayden 2012; D’Andrea and O’Dwyer 2017). Furthermore, the products of the ERSS, the species reports, are not peer-reviewed, being subject only to internal review by two additional biologists (Marcot et al. 2019). Despite an internal review, numerous inaccuracies and misinterpretations in ERSS reports have been pointed out (e.g. Federal Register 2016; Hill et al. 2018), resulting in the withdrawal of several ERSS reports from the USFWS website for revision. Critique of these shortcomings has resulted in a reply from the USFWS in the U.S. Federal Register that “because the ERSSs are rapid screens, we believe that having a good foundation for the process is sufficient, and a *detailed peer-review process of individual ERSSs is not required*” (emphasis added; Federal Register 2016, p. 67895).

Conversely, FISK and AS-ISK methods and output assessments have been the subject of frequent internal and external peer review (Table 1). The recent review and meta-analysis of FISK applications worldwide by Vilizzi et al. (2019) noted that the vast majority of FISK applications were published in the peer-reviewed literature. About 42% of applications included multiple independent assessors (Vilizzi et al. 2019). A growing trend is the explicit use of a project team member that acts as an internal reviewer to ensure consistency and accountability in the species assessments (responses, confidence rankings, and justifications) prior to peer review. For example, L. Vilizzi has acted as the internal reviewer of the assessments for all applications of FISK and AS-ISK for which he has performed the calibrations (see also Hill et al. 2014; Hill and Lawson 2015). Moreover, the use of FISK, and increasingly AS-ISK, by management agencies worldwide,

facilitated by AS-ISK's multiple language options assessors can use for assessments (Table 1), initially five languages (Copp et al. 2016b) but currently > 30 languages. These two factors provide another level of scrutiny and reduce linguistic-related uncertainty of the assessments (Carey and Burgman 2008). We welcome scientific critique of FISK and AS-ISK methods and assessment products. In this, we are following in the footsteps of assessors of non-native plants who developed and improved the WRA, subjecting their methods and results to peer review of the scientific and management communities and ultimately finding this system as a useful tool for weed risk assessment for regulatory and non-regulatory purposes (Pheloung et al. 1999; Daehler et al. 2004; Keller et al. 2007; Koop et al. 2012; Gordon et al. 2008a, 2011, 2012, 2016).

Management Implications

No RA scheme or decision-support tool is perfect (Orr 2003), and this includes all of those mentioned herein. The USFWS developed a risk analysis scheme that combines the ERSS, FISRAM, and injurious wildlife criteria specifically to designate fish and other non-native taxa as injurious, a specially-defined and narrow category unique to U.S. federal regulation that has its own set of primarily qualitative criteria (Marcot et al. 2019). Regulatory agencies and scientists outside of the USFWS will need to determine potential invasiveness or risk rather than injuriousness of fish or other species. What managers sorely need is objective information on various tools such as FISK, AS-ISK, ERSS or the Canadian Invasiveness Screening Tool (Drolet et al. 2016) that can be used to support policy and management decisions. Unfortunately, in presenting their scheme, Marcot et al. (2019) have misrepresented the FISK/AS-ISK family of WRA derivatives. This misrepresentation is of particular concern with regard to potential users who may not be familiar with risk screening toolkits and may dismiss it out of hand, hindering risk evaluation of potentially invasive fishes and other aquatic taxa internationally and in the U.S.

Despite limitations to the method and applications of the ERSS (Hill et al. 2017, 2018), neither Marcot et al. (2019) nor the supporting documentation online (Hoff 2016; USFWS 2019a) provide even a few caveats or cautions in the interpretation or use of the ERSS or other tools and products of the USFWS process. Clearly, the ERSS has limitations in the types of data used with a focus so strongly on documented invasion history and climate match (without caveat), interpretation and categorization of the data, thus placing species within risk categories across the expansive mosaic of geographic regions that make up the conterminous United States. A high-risk ERSS outcome is further considered to be an actionable and immediate precursor to injurious species categorization, yet the ERSS is a rapid screen rather than a comprehensive RA. Nevertheless, this

method (and FISRAM) is recommended to U.S. state agencies and other management entities despite no discussion of these and other issues in publication or online where managers can access the information and evaluate the effects on interpretation and usefulness for their own jurisdictions.

Considerable information is available in the literature as guidance for assessing risks of non-native fishes and other aquatic organisms. European Union agencies have placed emphasis on the use of methods that adhere to “minimum standards” for risk analysis when used to assess species for the 2014 EU Regulation on management of invasive species (Roy et al. 2018). Developed at the same time as these minimum standards, AS-ISK was the first (journal) published decision-support tool designed to comply fully with those standards (Copp et al. 2016b), though an EU-modified version of the Great Britain full RA scheme (NNSS 2019) was available online in 2015. Other protocols that most closely met the minimum standards (Roy et al. 2018) were the European Plant Protection Organization Decision-Support Scheme (EPPO 2011), Harmonia+ (D’hondt et al. 2015) and the ENSARS (Copp et al. 2016a).

The U.S. Department of Agriculture-Animal and Plant Health Inspection Service-Plant Protection and Quarantine uses a modified WRA (establishment and impact assessment, uncertainty assessment, and geographic potential), along with a logistic model as a secondary screening step, to evaluate potentially noxious weeds in the United States (Koop et al. 2012; USDA-APHIS-PPQ 2019). The U.S. Aquatic Nuisance Species Task Force developed the Generic Analysis as a comprehensive risk analysis framework for species and pathways (ANSTF 1996; Orr 2003). This method was used by U.S. federal agencies, including by the USFWS for injurious species assessment, until recently (Hill and Zajicek 2007; Hardin and Hill 2012). Florida’s state agencies have embraced the development of RA schemes, usually containing FISK or AS-ISK, to provide adequate information for invasive species decision making (e.g. Hill and Lawson 2015). Having more options for risk assessment, and using the scheme most fit for the intended purpose (Turbé et al. 2017), should benefit invasive species management because different methods may compensate for various biases and other shortcomings, thus providing a better estimate of risk than a single tool alone (e.g. Marr et al. 2017). Following Hill et al. (2018), we recommend that agencies evaluate risk-based approaches and adopt systems *in toto* or as adaptable packages to provide the appropriate level of information necessary to support decisions and improve invasive species management.

Acknowledgements

We thank Dr. Matthew Barnes for a thorough review and comments that improved the manuscript.

Funding Declaration

The participation of GHC was funded by Cefas’ Science Excellence fund. The other authors received no specific funding for this work.

Authors' Contribution

JEH, GHC, QMT, and LV – conceptualized the need for a rebuttal; JEH, SH, KML, and LLL – researched issues in Marcot et al. (2019) and online supporting documents; JEH – wrote original draft; JEH, GHC, SH, KML, LLL, QMT, LV, and CAW – reviewed and edited subsequent drafts.

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