

Development and application of a multilingual electronic decision-support tool for risk screening non-native terrestrial animals under current and future climate conditions

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Abstract

Electronic decision-support tools are becoming an essential component of government strategies to tackle non-native species invasions. This study describes the development and application of a multilingual electronic decision-support tool for screening terrestrial animals under current and future climate

conditions: the Terrestrial Animal Species Invasiveness Screening Kit (TAS-ISK). As an adaptation of the widely employed Aquatic Species Invasiveness Screening Kit (AS-ISK), the TAS-ISK question template inherits from the original Weed Risk Assessment (WRA) and related WRA-type toolkits and complies with the 'minimum requirements' for use with the recent European Regulation on invasive alien species of concern. The TAS-ISK consists of 49 basic questions on the species' biogeographical/historical traits and its biological/ecological interactions, and of 6 additional questions to predict how climate change is likely to influence the risks of introduction, establishment, dispersal and impact of the screened species. Following a description of the main features of this decision-support tool as a turnkey software application and of its graphical user interface with support for 32 languages, sample screenings are provided in different risk assessment areas for one representative species of each of the main taxonomic groups of terrestrial animals supported by the toolkit: mammals, birds, reptiles, amphibians, annelids, insects, molluscs, nematodes, and platyhelminths. The highest-scoring species were the red earthworm *Lumbricus rubellus* for the Aegean region of Turkey and the New Zealand flatworm *Arthurdendyus triangulatus* for Croatia. It is anticipated that adoption of this toolkit will mirror that of the worldwide employed AS-ISK, hence allowing to share information and inform decisions for the prevention of entry and/or dispersal of (high-risk) non-native terrestrial animal species – a crucial step to implement early-stage control and eradication measures as part of rapid-response strategies to counteract biological invasions.

Keywords

AS-ISK, biological invasions, decision-makers, turnkey application, TAS-ISK, WRA

Introduction

The steady increase in recent times in the number of invasive non-native species worldwide and its implications for wildlife conservation emphasise the importance of developing user-friendly decision-support tools for scientists to inform decision-makers about the prioritisation of management actions in response to non-native species' impacts (Dana et al. 2014; González-Moreno et al. 2019). The identification and assessment of hazards is a crucial aspect of environmental risk analysis, which consists of three steps: risk screening (identification), risk assessment, and risk communication and management (Canter 1993; UK Defra 2003; Booy et al. 2017; Robertson et al. 2021). In the risk analysis process applied to non-native species, risk screening identifies which non-native species are likely to be invasive in a given risk assessment area. This facilitates the development of policy and management procedures for that risk assessment area to prevent and/or mitigate the impacts of biological invasions (Copp et al. 2016a). In particular, risk screening of non-native species assists decision-makers in the allocation of resources to predict which species pose an elevated threat to native species and ecosystems and therefore require full (follow-up) risk assessment. This involves detailed examination of the likelihood and magnitude of risks of introduction, establishment, dispersal and impacts of a non-native species (Copp et al. 2005, 2016a; Baker et al. 2008; Mumford et al. 2010). To this end, it is crucial to distinguish between risk screening and risk assessment: this distinction is often overlooked in environmental risk analysis, where decision-support tools are often compared and evaluated together

(e.g. González-Moreno et al. 2019; Marcot et al. 2019; see also Hill et al. 2020). In this regard, the present study will focus on the first step of the risk analysis process, i.e. the risk screening, and this will include discussion of any related decision-support tools.

Decision-support tools have been developed for screening aquatic and terrestrial non-native species as well as pathogens (Pheloung et al. 1999; Copp et al. 2005, 2009, 2016b, 2021; D'hondt et al. 2015; Drolet et al. 2016). Amongst the most widely applied is the Weed Risk Assessment (WRA) for terrestrial plants (Pheloung et al. 1999) and its adaptations to various biogeographic regions and to the screening of aquatic plants (Gordon et al. 2008). The WRA question template formed the basis to create the Fish Invasiveness Screening Kit (FISK) for freshwater fish (Copp et al. 2005; Vilizzi et al. 2019) and its 'sister' -ISK toolkits for other aquatic organisms (Copp 2013). More recently, the -ISK toolkits were combined into the taxon-generic Aquatic Species Invasiveness Screening Kit (AS-ISK) to screen freshwater, brackish and marine aquatic organisms under current and future climate conditions (Copp et al. 2016b; Vilizzi et al. 2021). Other risk screening tools include *Harmonia+* and *Pandora+* (D'hondt et al. 2015) for plants, animals and their pathogens, and the Canadian Marine Invasive Screening Tool (CMIST: Drolet et al. 2016) for marine organisms.

A common feature of these risk screening tools is their availability in spreadsheet format, but with the AS-ISK only being designed as a 'turnkey' application (Copp et al. 2016b). This is contrary to the 'automated workbook' format of the other toolkits, which can make their usage time-consuming, if not counter-intuitive, to the end user. For this reason, the recent development of the AS-ISK as a user-friendly, dialog-driven electronic decision-support tool (Copp et al. 2016b) has resulted not only in a shortening of the risk screening process and, possibly, the follow-up decision-making (Matthies et al. 2007) but has also ensured exchangeability and seamless deployment of data and information across users (Copp et al. 2021). A 'fully fledged' electronic decision-support tool such as the AS-ISK, however, is currently available only for the screening of aquatic organisms. In contrast, for terrestrial organisms the (semi-automated) spreadsheet-based WRA (and its various adaptations: Gordon et al. 2008) is the only available tool for screening weeds (Dana et al. 2014). At the same time, most decision-support tools have been developed mainly in English (see Copp et al. 2021). This limitation increases the linguistic uncertainty associated with risk screenings undertaken by non-native English assessors (scientists) who ultimately need to communicate the risk outcomes to decision-makers in the country's native/official language. To meet these requirements, the 32 languages available to users of the AS-ISK are meant to enhance communication of non-native species' risks to local authorities and within/amongst non-English-speaking countries (Copp et al. 2021).

Despite the successful adoption and implementation of the WRA-type toolkits worldwide (Gordon et al. 2008; Vilizzi et al. 2019, 2021), there is currently no similar decision-support tool for screening terrestrial animals, as exemplified by the recent use of the AS-ISK as a 'surrogate' for screening terrestrial reptiles (Kopecký et al. 2019). To address this gap, this paper describes the development and application of a 'sibling' toolkit to the AS-ISK that will allow to share information and inform decision-makers about the prevention of entry and/or dispersal of (high-risk) non-native terrestrial animal species – a crucial step to implement early-stage control and eradication measures as part

of rapid-response strategies to counteract biological invasions (Piria et al. 2017; Copp et al. 2021). The aims of this study were threefold: (i) to develop a turnkey application based on the AS-ISK template to produce the Terrestrial Animal Species Invasiveness Screening Kit (TAS-ISK) and describe the main elements of the toolkit's interface and functionality (including some additional features introduced since the release of AS-ISK v1: Copp et al. 2016b); (ii) to review the questions and guidance for aquatic species in the AS-ISK template for adaptation to non-native terrestrial animal species in the TAS-ISK; and (iii) to implement a trial screening of the TAS-ISK on one representative species for each of the main terrestrial animal taxonomic groups supported by this new toolkit.

Methodology

Toolkit features

As an 'offshoot' of the AS-ISK, the TAS-ISK is also designed to comply with the 'minimum standards' for screening non-native species under EC Regulation No. 1143/2014 on the prevention and management of the introduction and spread of invasive alien species (EU 2014). The TAS-ISK consists of 55 questions (Qs). The first 49 Qs comprise the Basic Risk Assessment (BRA) and address the biogeography/invasion history and biology/ecology of the screened species. The last 6 Qs include the Climate Change Assessment (CCA) and require the assessor to predict how predicted (future) climatic conditions are likely to affect the BRA with respect to risks of introduction, establishment, dispersal and impact. The BRA questions consist of two sections with eight categories: Section A Biogeography/Invasion History including Categories Domestication/Cultivation, Climate, distribution and introduction risk, and Invasive elsewhere; Section B Biology/Ecology, including Categories Undesirable (or persistence) traits, Resource exploitation, Reproduction, Dispersal mechanisms, and Tolerance attributes. The CCA questions comprise Section C (and Category) Climate change (see Suppl. material 1: Table S1).

To achieve a valid screening, the assessor must provide for each question a response, a level of confidence for the response (see below), and a justification based on literature sources. The outcomes are a BRA score, which ranges from -20 to 68, and a (composite) BRA+CCA score, which ranges from -32 to 80 (i.e. after adding or subtracting up to 12 points to the BRA score or leaving it unchanged in case of a CCA score equal to 0). Confidence levels in the responses to questions are ranked using a 1–4 scale (1 = low; 2 = medium; 3 = high; 4 = very high) as per the Intergovernmental Panel on Climate Change (see Copp et al. 2016a). Based on the confidence level (CL) allocated to each response, a confidence factor (CF) is obtained as:

$$CF = \sum(CL_{Q_i}) / (4 \times 55) \quad (i = 1, \dots, 55)$$

where CL_{Q_i} is the CL for Q_i , 4 is the maximum achievable value for confidence (i.e. very high: see above) and 55 is the total number of questions comprising the TAS-ISK questionnaire. The CF ranges from a minimum of 0.25 (i.e. all 55 Qs with a

confidence level equal to 1) to a maximum of 1 (i.e. all 55 Qs with a confidence level equal to 4). For the CF, the CF_{Total} , CF_{BRA} and CF_{CCA} (based on all 55 Qs, on the 49 Qs comprising the BRA, and on the 6 Qs comprising the CCA, respectively) are computed. For further details about implementation of the overall risk screening process, see Vilizzi et al. (2022).

Toolkit development

Questions and related guidance of the AS-ISK v2.3.x template (noting that this toolkit is now available in its release v2.3.2: www.cefas.co.uk/nns/tools) were critically reviewed for application to terrestrial animal taxa. Following modification to the relevant questions and related guidance for adaptation to terrestrial animals, the resulting template was finalised by a consensus meeting to improve clarity, conciseness and accuracy in the text of both questions and guidance. The final template was then circulated amongst the author-translators (see below) for translation into the corresponding native language of the parts of text modified relative to the original AS-ISK template.

Similar to the AS-ISK, the TAS-ISK is designed as a ‘turnkey application’ (*sensu* Walkenbach 2007). This represents the most advanced level of Excel VBA software development as it allows complete distinction (separation) between graphical user interface, business logic, and data access/storage tiers. This is ensured by separating the data (i.e. the spreadsheet) and the graphical user interface (consisting of tightly controlled dialogs) from the underlying code. All these features offer major benefits: (i) for the end user, by allowing the assessor to work seamlessly on the database spreadsheet(s) located on the local computer or accessible from a network (e.g. under a ‘cloud system’); and (ii) for the developer, by facilitating provision of feedback and support by software updates that will replace previous releases of the toolkit whilst ensuring full backward compatibility in data access. The TAS-ISK graphical user interface is available in 32 languages, which allows it to be used in some 161 countries worldwide (see also Copp et al. 2021): English, Albanian, Arabic, Bulgarian, Chinese (simplified), Croatian, 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, Vietnamese. This extent of language support is the most advanced allowed by the Excel VBA code (Walkenbach 2007), as it includes support of right-to-left languages (i.e. Arabic, Hebrew, Persian, Urdu) and double-byte-character-set languages (i.e. Chinese, Japanese, Korean).

The TAS-ISK is available for download at www.cefas.co.uk/nns/tools in its release v2.3.2. This first release number of the toolkit mirrors that of the latest version of the AS-ISK (see above), with which the TAS-ISK, as already emphasised, shares most of the underlying code. The TAS-ISK allows the screening of nine taxonomic groups of terrestrial animals (classification mainly after Zoological Record indexing service: <https://www.ebsco.com/products/research-databases/zoological-record>): Mammals, Birds, Reptiles, Amphibians, Annelids, Insects, Molluscs, Nematodes, Platyhelminths, Other arthropods, Other eukaryote taxa.

Trial screenings

Trial screenings were conducted for one representative taxon (hereafter, for simplicity ‘species’) of each of the main taxonomic groups of terrestrial animals (i.e. except for ‘Other arthropods’ and ‘Other eukaryote taxa’). In total, eight experts (= assessors) were involved in the resulting nine screenings, with seven species screened each by a single assessor, one species screened by two joint assessors and another species screened by three joint assessors. One assessor screened two species and another assessor four species (Table 1). Notably, each assessor chose the non-native species for screening in which they were more knowledgeable in terms of its environmental biology and risk assessment area.

Each species was categorised *a priori* into non-invasive or invasive based on a search made of: (i) the Centre for Agriculture and Bioscience International Invasive Species Compendium (CABI ISC: www.cabi.org/); (ii) the Global Invasive Species Database (GISD: www.iucngisd.org/); and (iii) the Invasive and Exotic Species of North America list (IESNA: www.invasive.org/). If the species was not categorised as invasive in any (or all) of the previous three databases, a Google Scholar (literature) search was performed to check whether at least one peer-reviewed reference was found that ‘demonstrates’ (hence, not ‘assumes’) invasiveness/impact. The latter was then taken as ‘sufficient evidence’ for categorising the species as invasive; whereas, if no evidence was found in this last step, then the species was categorised as non-invasive (see also Vilizzi et al. 2022).

As a result of the *a priori* categorisation, there were eight species categorised *a priori* as invasive: the aoudad/Barbary sheep *Ammotragus lervia* (Mammals), the common pheasant *Phasianus colchicus* (Birds), the common house gecko *Hemidactylus frenatus* (Reptiles), the red earthworm *Lumbricus rubellus* (Annelids), the western corn rootworm *Diabrotica virgifera virgifera* (Insects), the Spanish slug *Arion vulgaris* (Molluscs),

Table 1. Taxa evaluated with the Terrestrial Animal Species Invasiveness Screening Kit (TAS-ISK) for their potential risk of invasiveness in different risk assessment areas. For each species, the *a priori* categorisation outcome into Non-invasive and Invasive is provided (after Vilizzi et al. 2022).

Taxonomic group	Taxon name	Common name	Assessor(s)	Risk assessment area	<i>A priori</i> categorisation
Mammals	<i>Ammotragus lervia</i>	aoudad/Barbary sheep	NS, TR, MP	Europe	Invasive
Birds	<i>Phasianus colchicus</i>	common pheasant	TR	Croatia	Invasive
Reptiles	<i>Hemidactylus frenatus</i>	common house gecko	BS, MP	Pannonian region of Hungary	Invasive
Amphibians	<i>Bombina variegata</i>	yellow-bellied toad	OC	Anatolia (Turkey)	Non-invasive
Annelids	<i>Lumbricus rubellus</i>	red earthworm	NK	Aegean region of Turkey	Invasive
Insects	<i>Diabrotica virgifera virgifera</i>	western corn rootworm	DL	Croatia	Invasive
Molluscs	<i>Arion vulgaris</i>	Spanish slug	IŠ	Croatia	Invasive
Nematodes	<i>Ditylenchus destructor</i>	potato rot nematode	MP	Croatia	Invasive
Platyhelminths	<i>Arthurdendyus triangulatus</i>	New Zealand flatworm	MP	Croatia	Invasive

the potato rot nematode *Ditylenchus destructor* (Nematodes), and the New Zealand flatworm *Arthurdendyus triangulatus* (Platyhelminths). The only species categorised *a priori* as non-invasive was the yellow-bellied toad *Bombina variegata* (Amphibians). For seven species the risk assessment area was Europe or part of it, and for two species it was Anatolia and Aegean regions of Turkey in Asia (Table 2).

Differences in CF between components (BRA, BRA+CCA) were tested with permutational ANOVA. Analysis was implemented in PERMANOVA+ for PRIMER v7, with normalisation of the data and using a Bray-Curtis dissimilarity measure, 9999 permutations of the raw data, and with statistical effects evaluated at $\alpha = 0.05$.

Results

Toolkit development

Modification of the original AS-ISK questionnaire (template) for adaptation to terrestrial animals resulted in changes only to the text for one question, only to the guidance for 14 questions, and to both text and guidance for 10 questions. This resulted in 25 questions being modified out of the 55 in total (i.e. 45.5%), with changes to the text involving all Sections and Categories therein except for the six climate change questions for which only a minor removal of text from the guidance to Q53 was sufficient. In particular: for Domestication/Cultivation, changes involved the guidance for Qs 1 and 2; for Climate, distribution and introduction risk, only the guidance for Q8; for Invasive elsewhere, the text and guidance for Q11 and guidance for Q13; for Undesirable (or persistence) traits, the text and guidance for Qs 15 and 23, text for Q18, and guidance for Qs 19, 22 and 24; for Resource exploitation, the guidance for Q26; for Reproduction, the guidance for Qs 28, 32 and 34; for Dispersal mechanisms, the text and guidance for Qs 36–39 and guidance for Q41; for Tolerance attributes, the text and guidance for Qs 44, 45 and 48 and guidance for Q47; for Climate change, the guidance for Q53 (Suppl. material 1: Table S1).

The graphical user interface of the TAS-ISK consists of six ‘dialogs’ (i.e. user interface elements that enable communication and interaction between the user and the software program). Below, a concise description of the dialogs is provided (for a full description see the User Guide downloadable with the toolkit):

- **Start** – TAS-ISK requires a spreadsheet (Database tab) and offers the options of opening either an Existing or a New spreadsheet. The user can select to carry out the screening in any of the 32 available Language options, noting that the toolkit will open by default in the language of the Excel version installed on the local computer. The Colour scheme of choice (seven options) can also be selected. Two new features (relative to AS-ISK v1) are the Background (tab) shading (light to dark) and the size of the Dialogs view (tab), which automatically resize to adapt to low-resolution screens.
- **Main Assessment Workspace** – This is the core dialog (launched from Start) where all screening-related data information is displayed and data manipulations can

be performed (i.e. Wizard, Assessment, Thresholds, Report, Utilities tabs). As a new feature (relative to AS-ISK v1), the Report tab offers the option to generate the report for the screened species in Excel spreadsheet format, PDF or MHTML.

- **Wizard** – This new dialog (relative to AS-ISK v1) allows the assessor to generate the basic template quickly for one or (usually) more screenings as part of the risk screening of several species for the risk assessment area under study.
- **New/Edit** – In this dialog, the assessor provides all details of the screened species, either by creating a new screening, editing an existent screening, or batch-editing multiple screenings.
- **Replicate** – In this dialog, replication of a screening selected from the Main Assessment Workspace is generally performed as part of the risk screening of several species for the risk assessment area under study.
- **Q&A** – In this dialog, the screening for the species selected from the Main Assessment Workspace is carried out by responding to the 55 questions, ranking the level of confidence/certainty associated with the response, and providing references and/or other information as justification for each question-related response.

Trial screenings

The highest scoring (*a priori* invasive) species were *Lumbricus rubellus* for the Aegean region of Turkey and *Arthurdendyus triangulatus* for Croatia (Table 2). Both species were recognised as ‘invasive elsewhere’ and obtained the highest score amongst all screened species for the Biology/Ecology section, with *Arthurdendyus triangulatus* also achieving the highest possible increase (+12 points) for the CCA. The other *a priori* invasive species *Arion vulgaris*, *Diabrotica virgifera virgifera*, *Ditylenchus destructor* and *Phasianus colchicus*, all screened for Croatia, and *Ammotragus lervia*, screened for Europe, obtained BRA scores ≥ 22 . These species have been recognised as invasive elsewhere and gained overall high scores for their Undesirable (or persistence) traits. The CCA increased the BRA score for *Ammotragus lervia*, *Diabrotica virgifera virgifera* and *Ditylenchus destructor*, but decreased that of *Arion vulgaris*. At the same time, there was no change in outcome score relative to the BRA (cf. BRA+CCA) for *Phasianus colchicus*. For *Hemidactylus frenatus* screened for the Pannonian region of Hungary, there was a substantial increase in the BRA+CCA relative to the BRA score. Finally, the *a priori* non-invasive *Bombina variegata* screened for Anatolia (Turkey) obtained the lowest outcome score of all species (Table 2). The TAS-ISK combined report for the nine screened species is provided as Suppl. material 2.

The highest confidence factor in responses for the BRA was found for *Diabrotica virgifera virgifera* and *Ditylenchus destructor*, and for the CCA for *Ammotragus lervia* and *Arion vulgaris*. *Bombina variegata* and *Phasianus colchicus* had confidence factors for both components below 0.60 (Table 2). The mean CF_{Total} was 0.697 ± 0.034 SE, the mean CF_{BRA} 0.699 ± 0.036 SE, and the mean CF_{CCA} 0.672 ± 0.043 SE, and there were no differences in CF between BRA and CCA ($F^{MC} = 0.002$, $P^{MC} = 0.970$; MC = Monte Carlo permutational value, best for small sample sizes).

Table 2. Scoring output for the terrestrial animal taxa screened with the TAS-ISK (see Table 1). BRA = Basic Risk Assessment; CCA = Climate Change Assessment. See also Suppl. material 1: Table S1.

Section/Category	<i>Anmotragus lervia</i>	<i>Phasianus colchicus</i>	<i>Hemidactylus frenatus</i>	<i>Bombina variegata</i>	<i>Lumbricus rubellus</i>	<i>Diabrotica virgifera virgifera</i>	<i>Ariion vulgaris</i>	<i>Ditylenchus destructor</i>	<i>Arthurdendynus triangulatus</i>
A. Biogeography/Historical	12	15.5	9	5	24	21	15	19	17
1. Domestication/ Cultivation	2	4	4	2	4	2	0	0	-2
2. Climate, distribution and introduction risk	1	1	2	1	2	1	1	1	1
3. Invasive elsewhere	9	10.5	3	2	18	18	14	18	18
B. Biology/Ecology	17	12	15	3	24	9	7	12	19
4. Undesirable (or persistence) traits	8	8	5	3	6	9	4	7	5
5. Resource exploitation	5	5	7	0	5	0	0	7	2
6. Reproduction	1	5	1	1	6	-3	6	-2	4
7. Dispersal mechanisms	-2	-2	2	-3	4	0	-1	-1	2
8. Tolerance attributes	5	-4	0	2	3	3	-2	1	6
BRA Score	29	27.5	24	8	48	30	22	31	36
C. Climate change	4	0	8	2	6	4	-10	2	12
BRA+CCA Score	33	27.5	32	10	54	34	12	33	48
Confidence									
BRA	0.76	0.57	0.59	0.59	0.61	0.82	0.79	0.81	0.78
CCA	0.92	0.58	0.71	0.50	0.54	0.71	0.79	0.63	0.67
Total (BRA+CCA)	0.77	0.57	0.61	0.58	0.60	0.81	0.79	0.79	0.76

Discussion

Toolkit development

The successful employment of the WRA-type toolkits for screening weeds (cf. WRA and its derivatives) and aquatic organisms (cf. WRA, -ISK toolkits and AS-ISK) is testified by the vast number of applications worldwide (Gordon et al. 2008; Vilizzi et al. 2019, 2021, 2022). An additional value of these risk screening applications is the high degree of accuracy (cf. discriminatory power *sensu* Hosmer et al. 2013) achieved in the classification of low-to-medium- and high-risk species for a variety of risk assessment areas in different climates and biogeographic regions and, since the development of the AS-ISK, under both current and predicted future climate conditions (Vilizzi et al. 2019, 2021, 2022).

The advantages of a multilingual decision-support toolkit have been described in detail in Copp et al. (2021). In the case of the screening of terrestrial animals with the TAS-ISK, the same benefits are expected in terms of enhanced communication of species-specific risk outcomes between assessors (scientists) and decision-makers by providing screening reports in the native language. This has already been exemplified by some of the AS-ISK applications conducted in the native language of the country's risk assessment area (Vilizzi et al. 2021), including publication and discussion of the corresponding risk outcomes also in the native language (i.e. Moghaddas et al. 2020; IAVH 2021; Li et al. 2021; Wei et al. 2021b).

Trial screenings

The risk outcomes for the nine non-native terrestrial animal species screened with the TAS-ISK highlighted which species are likely to pose the greatest threat of invasiveness (e.g. *Lumbricus rubellus* and *Arthurdendyus triangulatus*), hence should be prioritised for full (follow-up) risk assessment and potentially targeted by prevention measures and related management strategies (Copp et al. 2016a). Confidence in the BRA questions was similar to that in the CCA questions, which reflected the large availability of literature resources for the screened species and the overall knowledge/expertise by the assessors in both the screened species and related risk assessment areas.

Lumbricus rubellus was the highest scoring of the species screened – a finding that is likely to apply to risk assessment areas with warm-temperate and continental climate other than Anatolia (Tiunov et al. 2006). *Lumbricus rubellus* has been introduced in many continents outside its native range in Western Europe, but it is considered invasive only in North America and New Zealand (Greiner et al. 2012; Kim et al. 2015). The species' native distribution is still unclear, as it may originate from the Pyrenees, with its native range extending across France, southern Germany, Austria, Hungary and Romania (Gates 1972). The uncertainty about the origin of *L. rubellus* is to be ascribed to the extensive agricultural and fishing activities that have occurred over the last 2000 years involving the unintentional transport of this species in the soil (i.e. by transportation of plants rooted in soil contaminated with different life stages of this species) and as fish

bait (Keller et al. 2007; Crumsey et al. 2014). *Lumbricus rubellus* is harmful in forest ecosystems (Crumsey et al. 2014) and its introduction may change soil structure and chemistry, nutrient dynamics, microbial community content, and even plant community composition (Greiner et al. 2012). Furthermore, the species' hermaphroditism, tolerance of low pH (3.0–7.7) and resistance to low temperatures are all traits that increase the chance for its successful colonisation of novel environments (Tiunov et al. 2006; Wironen and Moore 2006; Kopp et al. 2012). Climate change appears to increase the competitiveness of *L. rubellus* because of its high tolerance of a wide range of temperatures, though not of a reduction in soil water content (Singh et al. 2019).

The second highest scoring species *Arthurdendyus triangulatus* is not yet found in Croatia (the risk assessment area in this study). The species' high risk of invasiveness confirms recent findings using a different risk assessment tool (Thunnissen et al. 2022) and justifies its inclusion in the Invasive Alien Species of Union Concern C/2019/5360 (European Commission 2019). *Arthurdendyus triangulatus* is a free-living terrestrial flatworm native to New Zealand introduced mainly by trade in containerised plants to the British Isles and the Faroe Islands (Murchie and Gordon 2013). This species is considered harmful mainly due to its predation on earthworms with consequent reduction of soil fertility and earthworm-feeding wildlife (Thunnissen et al. 2022). Based on the Köppen-Geiger climate classification system (Peel et al. 2007), *A. triangulatus* could become established in the northern part of Europe including The Netherlands, Denmark, Sweden and also Iceland due to its tolerance of the *Cfb*-type (warm-temperate, fully humid, warm summer) climate (Boag and Yeates 2001; Thunnissen et al. 2022). As this species prefers *Cs*-type (i.e. warm-temperate) climate conditions (typical of its native range on the South Island of New Zealand), it is very likely to establish in Croatia, where a similar climate is present. Although *A. triangulatus* is expected to become less widespread in the U.K. due to climate change (Hulme 2017), in Croatia it may considerably increase its establishment success as winter temperatures in New Zealand are milder compared to other areas of similar latitude (Sturman and Wanner 2001).

The two agricultural pests *Ditylenchus destructor* (not yet present in Croatia) and *Diabrotica virgifera virgifera* (already introduced to Croatia) gained similarly high BRA and BRA+CCA scores. *Ditylenchus destructor* and *D. virgifera virgifera* may cause severe crop damage resulting in financial losses and management expenditures (Tinsley et al. 2013; Benjamin et al. 2018). *Ditylenchus destructor* is a harmful endoparasite of roots and underground-modified plant parts in Europe and North America and is characterised by behavioural plasticity (Spencer et al. 2009; EFSA Panel on Plant Health 2016). Economically, it is the most important pest of the potato *Solanum tuberosum*, although it acts also as a pest of the sweet potato *Bulbous iris*, cultivated mushrooms, garlic *Allium sativum*, and several other cultivated plants (EFSA Panel on Plant Health 2016; Dobosz et al. 2020). Although the impact of *D. destructor* on crops in Europe is negligible due to precautionary measures, in Australia this species is regarded as posing a potentially high risk of invasiveness (Singh et al. 2015; EFSA PLH Panel 2016). Plants for potting are a pathway for the introduction and spread of *D. destructor*, which may cause severe impacts on their intended use. Climate conditions in Europe are favourable to the completion of the species' life cycle, and all of its developmental stages can overwinter successfully

throughout Europe (EFSA Panel on Plant Health 2016). *Diabrotica virgifera virgifera* was introduced by at least five independent events from northern USA into Europe (Ciosi et al. 2008), where it is currently successfully established, including in the risk assessment area of Croatia (Lemic et al. 2015). This species is a major pest of corn *Zea mays* but may also affect alternative host species such as soybean *Glycine max* or crops of pumpkin *Cucurbita* sp. (Manole et al. 2017a, b). *Diabrotica virgifera virgifera* poses a challenge to management actions because of its invasive nature and adaptability (Toepfer and Kuhlmann 2006; Toth et al. 2020). Climate is one of the most critical environmental factors for the species' colonisation success (Aragón et al. 2010; Dupin et al. 2011), and as a result of climate change the future distribution of this species may extend northward with the resulting risk of outbreaks at higher latitudes (Aragón and Lobo 2012).

Ammotragus lervia is native to North Africa and established in Croatia, Czechia, Italy and Spain following intentional introductions for hunting purposes (Šprem et al. 2020). *Phasianus colchicus*, partly native to Europe, has a long history of introductions and re-introductions with populations established across the continent (Ashrafzadeh et al. 2021). Both *A. lervia* and *P. colchicus* are highly adaptable and plastic in their use of available food resources, resulting in their distribution expanding rapidly (Hoodless et al. 2001; Šprem et al. 2020). *Phasianus colchicus* is already widespread across Europe including the risk assessment area (Croatia), where it may be favoured by proximity to human-affected land cover (i.e. agriculture, orchards and plantation forests; Ashoori et al. 2018). It has been observed that populations of *P. colchicus* in Croatia have been declining for the past 30 years. However, intended population reinforcements with captive-bred individuals may have negatively affected population size by outbreeding depression, introduction and fast spread of diseases and parasites from birds introduced from foreign sources (Ashrafzadeh et al. 2021). As a result, it seems that further population expansion of this species is not to be expected under current conditions. Also, the distributional range of *P. colchicus* already covers a variety of climate conditions and habitats (Ashoori et al. 2018); hence, further benefits in terms of range expansion under climate change conditions in the risk assessment area remain low. On the contrary, the intense desertification process that is taking place in Mediterranean regions (cf. south-east Spain) as a result of lowered rainfall regimes and increased mean annual temperatures, may result in substantial habitat changes that may favour the expansion of a desert caprid such as *A. lervia* (Acevedo et al. 2007). Thus, particularly in the Mediterranean region of European countries, the threat posed by *A. lervia* population expansion under future climate conditions may become higher.

The native distributional range of *Arion vulgaris* is still uncertain as this species is thought to be native to the Iberian Peninsula (Zemanova et al. 2016) and southern France (Zajac et al. 2020). *Arion vulgaris* has extended its distributional range to several European countries (Zemanova et al. 2016) and is classified as one of the 100 most invasive terrestrial invertebrate species in Europe (Vilà et al. 2009). *Arion vulgaris* may pose severe damage to agriculture and horticulture, is responsible for the defoliation of wild plants and trees and has also caused severe impacts in terms of decline in abundance and also disappearance of its congener red slug *A. rufus* as a result of hybridisation (Zemanova et al. 2017). However, mitochondrial diversity of *A. vulgaris* is lower than that of its congeners with a weak association of genetic struc-

turing amongst geographically distant populations in Europe, which suggests a human contribution to the species' ongoing expansion (Zemanova et al. 2016). Based on predicted future temperature increase scenarios for Europe, the broad range of suitable areas for the establishment of *A. vulgaris* may slightly decrease (Zemanova et al. 2018).

There is still no evidence of established populations in Europe of *Hemidactylus frenatus*, which is native to Southeast Asia, although specimens have been recorded in Italy and Portugal as hitchhikers (Weterings and Vetter 2018). This species has been classified as highly invasive in tropical regions of America, Africa, Asia and Australasia (Lei and Booth 2014) due to its competition for food and space with native geckos and transmission of endo- and ecto-parasitic mites (Dame and Petren 2006; Diaz et al. 2020). Recently, several adult specimens of *H. frenatus* were found in Hungary (B. Szajbert, unpublished data) but it was assumed that this species cannot overwinter outdoors due to its intolerance to the low winter temperatures present in the Pannonian region (Lei and Booth 2014). However, it was recently noted that *H. frenatus* captured in winter has cold tolerances 1–2 °C lower than those captured in summer, suggesting that tropical invaders can adjust their temperature tolerance downwards via phenotypic plasticity (Lapwong et al. 2021). Such changes may allow tropical invaders to expand their geographic range into colder regions of their non-native ranges (Lapwong et al. 2021). This could increase the probability of establishment of *H. frenatus* in the Pannonian region of Hungary under future climate change conditions (Rödder et al. 2008).

The lowest scoring species *Bombina variegata* is protected under the EU Habitat Directive and has been classified as 'Least concern' in the IUCN Red List of Threatened Species since 2004 (Kuzmin et al. 2009). The Atlantic and continental populations of *B. variegata* are classified as in 'bad' condition and others in 'poor' condition, with only a Greek lineage of this species being reported as self-sustaining on a long-term basis and classified as in 'good' condition (https://eunis.eea.europa.eu/species/638#threat_status). The *B. variegata* lineage (subspecies *B. variegata scabra*) originating from Greece (Sotiropoulos 2020) has recently extended its distributional range to Kurtkaya-Enez (Edirne) in Turkey, where it has established self-sustaining populations (Bülbul et al. 2016). According to the Köppen-Geiger climate system, areas with suitable climate conditions will increase in the risk assessment area of Anatolia (Rubel and Kottek 2010), thereby favouring the dispersal of *B. variegata*. This species has been introduced to Great Britain and Northern Ireland (Roy et al. 2020), where no detrimental impacts have been observed. The lowest score amongst the screened species obtained by *B. variegata* in this study is a further indicator of the applicability and reliability of the newly released TAS-ISK.

Conclusions

Given the current dearth of risk screening applications for non-native terrestrial animals (but see Baiwy et al. 2015; Schaffner and Ries 2019; Ries et al. 2021; Thunnissen et al. 2022), it is anticipated that the availability of the TAS-ISK as a multilingual turnkey application will allow for a 'quantum leap' in this field of research in conservation biology. Accordingly, prospective applications of this newly released decision-support tool

may focus on: (i) lists of potentially invasive non-native species (both extant and horizon) for selected risk assessment areas, which would allow for local ‘calibration’ (i.e. setting of a threshold to distinguish between low-to-medium and high-risk species) (e.g. Clarke et al. 2020; Interesova et al. 2020; Killi et al. 2020; Uyan et al. 2020; Li et al. 2021; Moghaddas et al. 2021; Radočaj et al. 2021; Ruykys et al. 2021; Wei et al. 2021a, b), (ii) global (meta-analytical) studies for setting taxonomic group and/or climate-specific thresholds (e.g. Tarkan et al. 2021; Vilizzi et al. 2021), and (iii) individual non-native and (potentially) invasive species regarded as ‘high priority’ in terms of e.g. importation/commercial exploitation/evaluation of existing impacts for a specific risk assessment area (e.g. Castellanos-Galindo et al. 2018; Suresh et al. 2019; Baduy et al. 2020; Zięba et al. 2020; Haubrock et al. 2021; Kumar et al. 2021; Yoğurtçuoğlu et al. 2021).

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References

- Acevedo P, Cassinello J, Hortal J, Gortázar C (2007) Invasive exotic aoudad (*Ammotragus lervia*) as a major threat to native Iberian ibex (*Capra pyrenaica*): A habitat suitability model approach. *Diversity and Distributions* 13(5): 587–597. <https://doi.org/10.1111/j.1472-4642.2007.00374.x>
- Aragón P, Lobo JM (2012) Predicted effect of climate change on the invasibility and distribution of the Western corn root-worm. *Agricultural and Forest Entomology* 14(1): 13–18. <https://doi.org/10.1111/j.1461-9563.2011.00532.x>
- Aragón P, Baselga A, Lobo JM (2010) Global estimation of invasion risk zones for the western corn rootworm *Diabrotica virgifera virgifera*: Integrating distribution models and physiological thresholds to assess climatic favourability. *Journal of Applied Ecology* 47(5): 1026–1035. <https://doi.org/10.1111/j.1365-2664.2010.01847.x>
- Ashoori A, Kafash A, Varasteh Moradi H, Yousefi M, Kamyab H, Behdarvand N, Mohammadi S (2018) Habitat modeling of the common pheasant *Phasianus colchicus* (Galliformes: Phasianidae) in a highly modified landscape: application of species distribution models in the study of a poorly documented bird in Iran. *The European Zoological Journal* 85(1): 372–380. <https://doi.org/10.1080/24750263.2018.1510994>
- Ashrafzadeh MR, Khosravi R, Fernandes C, Aguayo C, Bagi Z, Lavadinović VM, Szendrei L, Beuković D, Mihalik B, Kusza S (2021) Assessing the origin, genetic structure and demographic history of the common pheasant (*Phasianus colchicus*) in the introduced European range. *Scientific Reports* 11(1): e21721. <https://doi.org/10.1038/s41598-021-00567-1>
- Baduy F, Saraiva JL, Ribeiro F, Canario AV, Guerreiro PM (2020) Distribution and risk assessment of potential invasiveness of *Australoheros facetus* (Jenyns, 1842) in Portugal. *Fishes* 5(1): e3. <https://doi.org/10.3390/fishes5010003>

- Baiwy E, Schockert V, Branquart E (2015) Risk analysis of the Fox squirrel, *Sciurus niger*. Risk analysis report of non-native organisms in Belgium. Cellule interdépartementale sur les Espèces invasives (CiEi), DGO3, SPW / Editions, updated version, 34 pp.
- Baker RHA, Black R, Copp GH, Haysom KA, Hulme PE, Thomas MB, Brown A, Brown M, Cannon RJC, Ellis J, Ellis M, Ferris R, Graves P, Gozlan RE, Holt J, Howe L, Knight JD, MacLeod A, Moore NP, Mumford JD, Murphy ST, Parrott D, Sansford CE, Smith GC, St-Hilaire S, Ward NL (2008) The UK risk assessment scheme for all non-native species. In: Rabitsch W, Essl F, Klingenstein F (Eds) Biological Invasions – from Ecology to Conservation. Neobiota 7: 46–57.
- Benjamin EO, Grabenweger G, Strasser H, Wessler J (2018) The socioeconomic benefits of biological control of western corn rootworm *Diabrotica virgifera virgifera* and wireworms *Agriotes* spp. in maize and potatoes for selected European countries. Journal of Plant Diseases and Protection 125(3): 273–285. <https://doi.org/10.1007/s41348-018-0156-6>
- Boag B, Yeates GW (2001) The potential impact of the New Zealand flatworm, a predator of earthworms, in western Europe. Ecological Applications 11(5): 1276–1286. [https://doi.org/10.1890/1051-0761\(2001\)011\[1276:TPIOTN\]2.0.CO;2](https://doi.org/10.1890/1051-0761(2001)011[1276:TPIOTN]2.0.CO;2)
- Booy O, Mill AC, Roy HE, Hiley A, Moore N, Robertson P, Baker S, Brazier M, Bue M, Bullcock R, Campbell S, Eyre D, Foster F, Hatton-Ellis M, Long J, Macadam C, Morrison-Bell C, Mumford J, Newman J, Parrott D, Payne R, Renals T, Rodgers E, Spencer M, Stebbing P, Sutton-Croft M, Walker KJ, Ward A, Whittaker S, Wyn G (2017) Risk management to prioritise the eradication of new and emerging invasive non-native species. Biological Invasions 19(8): 2401–2417. <https://doi.org/10.1007/s10530-017-1451-z>
- Bülbül U, Kurnaz M, Eroğlu Aİ, Szymura JM, Koç H, Kutrup B (2016) First record of *Bombina variegata* (L., 1758) (Anura: Bombinatoridae) from Turkey. Turkish Journal of Zoology 40: 630–636. <https://doi.org/10.3906/zoo-1508-40>
- Canter LW (1993) Pragmatic suggestions for incorporating risk assessment principles in EIA studies. Environment and Progress 15: 125–138.
- Castellanos-Galindo G, Moreno X, Robertson R (2018) Risks to eastern Pacific marine ecosystems from sea-cage mariculture of alien Cobia. Management of Biological Invasions 9(3): 323–327. <https://doi.org/10.3391/mbi.2018.9.3.14>
- Ciosi M, Miller NJ, Kim KS, Giordano R, Estoup A, Guillemaud T (2008) Invasion of Europe by the western corn rootworm, *Diabrotica virgifera virgifera*: Multiple transatlantic introductions with various reductions of genetic diversity. Molecular Ecology 17(16): 3614–3627. <https://doi.org/10.1111/j.1365-294X.2008.03866.x>
- Clarke SA, Vilizzi L, Lee L, Wood LE, Cowie WJ, Burt JA, Mamiit RJ, Hassina A, Davison PI, Fenwick GV, Harmer R, Skóra ME, Kozic S, Aislabie LR, Kennerley A, Le Quesne WJE, Copp GH, Stebbing PD (2020) Identifying potentially invasive non-native marine and brackish water species for the Arabian Gulf and Sea of Oman. Global Change Biology 26(4): 2081–2092. <https://doi.org/10.1111/gcb.14964>
- Copp GH (2013) The Fish Invasiveness Screening Kit (FISK) for non-native freshwater fishes – a summary of current applications. Risk Analysis 33(8): 1394–1396. <https://doi.org/10.1111/risa.12095>

- Copp GH, Garthwaite R, Gozlan RE (2005) Risk identification and assessment of non-native freshwater fishes: concepts and perspectives on protocols for the UK, Cefas Science Technical Report No. 129, Cefas, Lowestoft, 36 pp.
- Copp GH, Vilizzi L, Mumford J, Fenwick GM, Godard MJ, Gozlan RE (2009) Calibration of FISK, an invasiveness screening tool for non-native freshwater fishes. *Risk Analysis* 29(3): 457–467. <https://doi.org/10.1111/j.1539-6924.2008.01159.x>
- Copp GH, Russell IC, Peeler EJ, Gherardi F, Tricarico E, MacLeod A, Cowx IG, Nunn AD, Occhipinti Ambrogi A, Savini D, Mumford JD, Britton JR (2016a) European Non-native Species in Aquaculture Risk Analysis Scheme – a summary of assessment protocols and decision making tools for use of alien species in aquaculture. *Fisheries Management and Ecology* 23(1): 1–11. <https://doi.org/10.1111/fme.12074>
- Copp GH, Vilizzi L, Tidbury H, Stebbing PD, Tarkan AS, Miossec L, Goulletquer P (2016b) Development of a generic decision-support tool for identifying potentially invasive aquatic taxa: AS-ISK. *Management of Biological Invasions* 7(4): 343–350. <https://doi.org/10.3391/mbi.2016.7.4.04>
- Copp GH, Vilizzi L, Wei H, Li S, Piria M, Al-Faisal AJ, Almeida D, Atrique U, Al-Wazzan Z, Bakiu R, Bašić T, Bui TD, Canning-Clode J, Castro N, Chaichana R, Çoker T, Dashinov D, Ekmekçi FG, Erős T, Ferincz Á, Ferreira T, Giannetto D, Gilles Jr AS, Głowacki Ł, Goulletquer P, Interesova E, Iqbal S, Jakubčinová K, Kanongdate K, Kim JE, Kopecký O, Kostov V, Koutsikos N, Kozic S, Kristan P, Kurita Y, Lee HG, Leuven RSEW, Lipinskaya T, Lukas J, Marchini A, González-Martínez AI, Masson L, Memedemin D, Moghaddas SD, Monteiro J, Mumladze L, Naddafi R, Năvodaru I, Olsson KH, Onikura N, Paganelli D, Pavia Jr RT, Perdikaris C, Pickholtz R, Pietraszewski D, Povž M, Preda C, Ristovska M, Rosíková K, Santos JM, Semenchenko V, Senanan W, Simonović P, Smeti E, Števoe B, Švolíková K, Ta KAT, Tarkan AS, Top N, Tricarico E, Uzunova E, Vardakas L, Verreycken H, Zięba G, Mendoza R (2021) Speaking their language – Development of a multilingual decision-support tool for communicating invasive species risks to decision makers and stakeholders. *Environmental Modelling & Software* 135: e104900. <https://doi.org/10.1016/j.envsoft.2020.104900>
- Crumsey JM, Le Moine JM, Vogel CS, Nadelhoffer KJ (2014) Historical patterns of exotic earthworm distributions inform contemporary associations with soil physical and chemical factors across a northern temperate forest. *Soil Biology and Biochemistry* 68: 503–514. <https://doi.org/10.1016/j.soilbio.2013.10.029>
- D'hondt B, Vanderhoeven S, Roelandt S, Mayer F, Versteirt V, Adriaens T, Ducheyne E, San Martin G, Grégoire J-C, Stiers I, Quoilin S, Cigar J, Heughebaert A, Branquart E (2015) Harmonia* and Pandora*: Risk screening tools for potentially invasive plants, animals and their pathogens. *Biological Invasions* 17(6): 1869–1883. <https://doi.org/10.1007/s10530-015-0843-1>
- Dame EA, Petren K (2006) Behavioural mechanisms of invasion and displacement in Pacific island geckos (*Hemidactylus*). *Animal Behaviour* 71(5): 1165–1173. <https://doi.org/10.1016/j.anbehav.2005.10.009>
- Dana E, Jeschke J, García-de-Lomas J (2014) Decision tools for managing biological invasions: Existing biases and future needs. *Oryx* 48(1): 56–63. <https://doi.org/10.1017/S0030605312001263>

- Defra UK (2003) Guidelines for Environmental Risk Assessment and Management. <http://www.defra.gov.uk/environment/risk/eramguide/02.htm>
- Díaz JA, Torres RA, Paternina LE, Santana DJ, Miranda RJ (2020) Traveling with an invader: ectoparasitic mites of *Hemidactylus frenatus* (Squamata: Gekkonidae) in Colombia. *Cuadernos de Herpetología* 34(1): 79–82. [https://doi.org/10.31017/CdH.2020.\(2019-027\)](https://doi.org/10.31017/CdH.2020.(2019-027))
- Dobosz R, Rybarczyk-Mydłowska K, Winiszewska G (2020) Occurrence of *Ditylenchus destructor* Thorne, 1945 on a sand dune of the Baltic Sea. *Journal of Plant Protection Research* 60: 31–40.
- Drolet D, DiBacco C, Locke A, McKenzie CH, McKindsey CW, Moore AM, Webb JL, Theriault TW (2016) Evaluation of a new screening-level risk assessment tool applied to non-indigenous marine invertebrates in Canadian coastal waters. *Biological Invasions* 18(1): 279–294. <https://doi.org/10.1007/s10530-015-1008-y>
- Dupin M, Reynaud P, Jarošík V, Baker R, Brunel S, Eyre D, Pergl J, Makowski D (2011) Effects of the training dataset characteristics on the performance of nine species distribution models: Application to *Diabrotica virgifera virgifera*. *PLoS ONE* 6(6): e20957. <https://doi.org/10.1371/journal.pone.0020957>
- EFSA Panel on Plant Health (PLH), Jeger M, Bragard C, Caffier D, Candresse T, Chatzivassiliou E, Dehnen-Schmutz K, Gilioli G, Grégoire J-C, Jaques Miret JA, MacLeod A, Navajas Navarro M, Niere B, Parnell S, Potting R, Rafoss T, Rossi V, Van Bruggen A, Van Der Werf W, West J, Winter S, Mosbach-Schulz O, Urek G (2016) Scientific opinion on the risk to plant health of *Ditylenchus destructor* for the EU territory. *EFSA Journal* 14: e04602. <https://doi.org/10.2903/j.efsa.2016.4602>
- EU (2014) Regulation (EU) 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species. *Official Journal of the European Union*, L 317: 35–55. <http://eur-lex.europa.eu/legalcontent/EN/TXT/?qid=1417443504720&uri=CELEX:32014R1143>
- European Commission (2019) Commission Implementing Regulation (EU) 2019/1262 of 25 July 2019 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern C/2019/5360. *Official Journal of the European Union*, L 199(1): 1–4.
- Gates GE (1972) Burmese earthworms—An introduction to the systematics and biology of megadrile oligochaetes with special reference to southeast Asia. *Transactions of the American Philosophical Society* 62(pt. 7): 1–326. <https://doi.org/10.2307/1006214>
- González-Moreno P, Lazzaro L, Vilà M, Preda C, Adriaens T, Bacher S, Brundu G, Copp GH, Essl F, García-Berthou E, Katsanevakis S, Moen TL, Lucy FE, Nentwig W, Roy HE, Srebalienė G, Talgø V, Vanderhoeven S, Andjelković A, Arbačiauskas K, Auger-Rozenberg M-A, Bae M-J, Bariche M, Boets P, Boeiro M, Borges PA, Canning-Clode J, Cardigos F, Chartosia N, Cottier-Cook EJ, Crocetta F, D'hondt B, Foggi B, Follak S, Gallardo B, Gammelmo Ø, Giakoumi S, Giuliani C, Guillaume F, Jelaska LŠ, Jeschke JM, Jover M, Juárez-Escario A, Kalogirou S, Kočić A, Kytinou E, Lavery C, Lozano V, Maceda-Veiga A, Marchante E, Marchante H, Martinou AF, Meyer S, Minchin D, Montero-Castaño A, Morais MC, Morales-Rodriguez C, Muhthassim N, Nagy ZÁ, Ogris N, Onen H, Pergl J, Puntilla R, Rabitsch W, Ramburn TT, Rego C, Reichenbach F, Romeralo C, Saul W-C, Schrader

- G, Sheehan R, Simonović P, Skolka M, Soares AO, Sundheim L, Tarkan AS, Tomov R, Tricarico E, Tsiamis K, Uludağ A, van Valkenburg J, Verreycken H, Vettrai AM, Vilar L, Wiig Ø, Witzell J, Zanetta A, Kenis M (2019) Consistency of impact assessment protocols for non-native species. *NeoBiota* 44: 1–25. <https://doi.org/10.3897/neobiota.44.31650>
- Gordon DR, Onderdonk DA, Fox AM, Stocker RK (2008) Consistent accuracy of the Australian weed risk assessment system across varied geographies. *Diversity and Distributions* 14(2): 234–242. <https://doi.org/10.1111/j.1472-4642.2007.00460.x>
- Greiner HG, Kashian DR, Tieggs SD (2012) Impacts of invasive Asian (*Amyntas bilgendorfi*) and European (*Lumbricus rubellus*) earthworms in a North American temperate deciduous forest. *Biological Invasions* 14(10): 2017–2027. <https://doi.org/10.1007/s10530-012-0208-y>
- Haubrock PJ, Copp GH, Johović I, Balzani P, Inghilesi AF, Nocita A, Tricarico E (2021) North American channel catfish, *Ictalurus punctatus*: A neglected but potentially invasive freshwater fish species. *Biological Invasions* 23(5): 1563–1576. <https://doi.org/10.1007/s10530-021-02459-x>
- Hill JE, Copp GH, Hardin S, Lawson KM, Lawson Jr LL, 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>
- Hoodless AN, Draycott RAH, Ludiman MN, Robertson PA (2001) Spring foraging behaviour and diet of released pheasants (*Phasianus colchicus*) in the United Kingdom. *Game and Wildlife Science* 18: 375–386.
- Hosmer Jr DW, Lemeshow S, Sturdivant RX (2013) Applied logistic regression. John Wiley & Sons, Hoboken, 511 pp. <https://doi.org/10.1002/9781118548387>
- Hulme PE (2017) Climate change and biological invasions: Evidence, expectations, and response options. *Biological Reviews* 92(3): 1297–1313. <https://doi.org/10.1111/brv.12282>
- IAVH (2021) El pez basa, panga o pangasius, *Pangasianodon hypophthalmus* (Sauvage, 1878) (Siluriformes: Pangasiidae) en Colombia. Instituto de Investigación de Recurso Biológicos Alexander von Humboldt, Ministerio de Ambiente y Desarrollo Sostenible. Bogotá, D. C., Colombia. <http://repository.humboldt.org.co/bitstream/handle/20.500.11761/35863/El%20pez%20pasa%2c%20panga%20o%20pangasius%20en%20Colombia%20112021.pdf?sequence=4&isAllowed=y>
- Interesova E, Vilizzi L, Copp GH (2020) Risk screening of the potential invasiveness of non-native freshwater fishes in the River Ob basin (West Siberian Plain, Russia). *Regional Environmental Change* 20(2): e64. <https://doi.org/10.1007/s10113-020-01644-3>
- Keller RP, Cox AN, Van Loon C, Lodge DM, Herborg L-M, Rothlisberger J (2007) From bait shops to the forest floor: Earthworm use and disposal by anglers. *American Midland Naturalist* 158(2): 321–328. [https://doi.org/10.1674/0003-0031\(2007\)158\[321:FBSTTF\]2.0.CO;2](https://doi.org/10.1674/0003-0031(2007)158[321:FBSTTF]2.0.CO;2)
- Killi N, Tarkan AS, Kozic S, Copp GH, Davison PI, Vilizzi L (2020) Risk screening of the potential invasiveness of non-native jellyfishes in the Mediterranean Sea. *Marine Pollution Bulletin* 150: e110728. <https://doi.org/10.1016/j.marpolbul.2019.110728>
- Kim Y-N, Robinson B, Boyer S, Zhong H-T, Dickinson N (2015) Interactions of native and introduced earthworms with soils and plant rhizospheres in production landscapes of New Zealand. *Applied Soil Ecology* 96: 141–150. <https://doi.org/10.1016/j.apsoil.2015.07.008>

- Kopecký O, Bílková A, Hamatová V, Kňazovická D, Konrádová L, Kunzová B, Slaměníková J, Slanina O, Šmídová T, Zemancová T (2019) Potential invasion risk of pet traded lizards, snakes, crocodiles, and tuatara in the EU on the basis of a Risk Assessment Model (RAM) and Aquatic Species Invasiveness Screening Kit (AS-ISK). *Diversity (Basel)* 11(9): 164. <https://doi.org/10.3390/d11090164>
- Kopp KC, Wolff K, Jokela J (2012) Natural range expansion and human-assisted introduction leave different genetic signatures in a hermaphroditic freshwater snail. *Evolutionary Ecology* 26(3): 483–498. <https://doi.org/10.1007/s10682-011-9504-8>
- Kumar L, Kumari K, Gogoi P, Manna RK, Madayi RC, Salim SM, Muttanahalli Eregowda V, Raghavan SV, Das BK (2021) Risk analysis of non-native three-spot cichlid, *Amphilophus trimaculatus*, in the River Cauvery (India). *Fisheries Management and Ecology* 28(2): 158–166. <https://doi.org/10.1111/fme.12467>
- Kuzmin S, Denoël M, Anthony B, Andreone F, Schmidt B, Ogradowczyk A, Ogińska M, Vogrin M, Cogalniceanu D, Kovács T, Kiss I, Puky M, Vörös J, Tarkhishvili D, Ananjeva N (2009) *Bombina variegata*. The IUCN Red List of Threatened Species 2009: e.T54451A11148290. <https://doi.org/10.2305/IUCN.UK.2009.RLTS.T54451A11148290.en>
- Lapwong Y, Dejtardol A, Webb JK (2021) Shifts in thermal tolerance of the invasive Asian house gecko (*Hemidactylus frenatus*) across native and introduced ranges. *Biological Invasions* 23(4): 989–996. <https://doi.org/10.1007/s10530-020-02441-z>
- Lei J, Booth DT (2014) Temperature, field activity and post-feeding metabolic response in the Asian house gecko, *Hemidactylus frenatus*. *Journal of Thermal Biology* 45: 175–180. <https://doi.org/10.1016/j.jtherbio.2014.09.006>
- Lemic D, Mikac KM, Ivkovic SA, Bažok R (2015) The Temporal and Spatial Invasion Genetics of the Western Corn Rootworm (Coleoptera: Chrysomelidae) in Southern Europe. *PLoS ONE* 10(9): e0138796. <https://doi.org/10.1371/journal.pone.0138796>
- Li XJ, Tang WQ, Zhao YH (2021) Risk analysis of fish invasion in Haihe River Basin caused by the central route of the South-to-North Water Diversion Project. *Shengwu Duoyangxing* 29(10): 1336–1347. <https://doi.org/10.17520/biods.2021130>
- Manole T, Chireceanu C, Teodoru A (2017a) Current status of *Diabrotica virgifera virgifera* LeConte, 1868 (Coleoptera: Chrysomelidae) in Romania. *Acta Zoologica Bulgarica* (Suppl. 9): 143–148. <http://www.acta-zoologica-bulgarica.eu/downloads/acta-zoologica-bulgarica/2017/supplement-9-143-148.pdf>
- Manole T, Chireceanu C, Teodoru A (2017b) The broadening of distribution of the invasive species *Diabrotica virgifera virgifera* Leconte in the area of Muntenia region under specific climatic and trophic conditions. *Scientific Papers - Series A. Agronomy (Basel)* 60: 495–499. <http://agronomyjournal.usamv.ro/pdf/2017/vol2017.pdf>
- Marcot BG, Hoff MH, Martin CD, Jewell SD, Givens CE (2019) A decision support system for identifying potentially invasive and injurious freshwater fishes. *Management of Biological Invasions* 10(2): 200–226. <https://doi.org/10.3391/mbi.2019.10.2.01>
- Matthies M, Giupponi C, Ostendorf B (2007) Environmental decision support systems: Current issues, methods and tools. *Environmental Modelling & Software* 22(2): 123–127. <https://doi.org/10.1016/j.envsoft.2005.09.005>

- Moghaddas SD, Abdoli A, Kiabi BH, Rahmani H (2020) Risk assessment of the potential invasiveness of *Coptodon zillii* (Gervais, 1848) in Anzali Wetland using AS-ISK. Environmental Sciences 18(2): 255–270. [In Persian] <https://doi.org/10.29252/envs.18.2.255>
- Moghaddas SD, Abdoli A, Kiabi BH, Rahmani H, Vilizzi L, Copp GH (2021) Identifying invasive fish species threats to RAMSAR wetland sites in the Caspian Sea region—A case study of the Anzali Wetland Complex (Iran). Fisheries Management and Ecology 28L(1): 28–39. <https://doi.org/10.1111/fme.12453>
- Mumford JD, Booy O, Baker RHA, Rees M, Copp GH, Black K, Holt J, Leach AW, Hartley M (2010) Non-native species risk assessment in Great Britain. In: Evans A (Ed.) What Makes an Alien Invasive? Risk and Policy Responses. Aspects of Applied Biology, 104, Association of Applied Biologists, 49–54.
- Murchie AK, Gordon AW (2013) The impact of the ‘New Zealand flatworm’, *Arthurdendyus triangulatus*, on earthworm populations in the field. Biological Invasions 15(3): 569–586. <https://doi.org/10.1007/s10530-012-0309-7>
- Peel MC, Finlayson BL, McMahon TA (2007) Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences 11(5): 1633–1644. <https://doi.org/10.5194/hess-11-1633-2007>
- Pheloung PC, Williams PA, Halloy SR (1999) A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. Journal of Environmental Management 57(4): 239–251. <https://doi.org/10.1006/jema.1999.0297>
- Piria M, Copp GH, Dick JT, Duplić A, Groom Q, Jelić D, Lucy FE, Roy HE, Sarat E, Simonović P, Tomljanović T, Tricarico E, Weinlander M, Adámek Z, Bedolfe S, Coughlan NE, Davis E, Dobrzycka-Krahel A, Grgić Z, Kırankaya ŞG, Ekmekçi FG, Lajtner J, Lukas JAY, Koutsikos N, Mennen GJ, Mitić B, Pastorino P, Ruokonen TJ, Skóra ME, Smith ERC, Šprem N, Tarkan AS, Treer T, Vardakas L, Vehanen T, Vilizzi L, Zanella D, Cafrey JM (2017) Tackling invasive alien species in Europe II: Threats and opportunities until 2020. Management of Biological Invasions 8(3): 273–286. <https://doi.org/10.3391/mbi.2017.8.3.02>
- Radočaj T, Špelić I, Vilizzi L, Povž M, Piria M (2021) Identifying threats from introduced and translocated non-native freshwater fishes in Croatia and Slovenia under current and future climatic conditions. Global Ecology and Conservation 27: e01520. <https://doi.org/10.1016/j.gecco.2021.e01520>
- Ries C, Schneider N, Vitali F, Weigand A (2021) First records and distribution of the invasive alien hornet *Vespa velutina nigrithorax* du Buysson, 1905 (Hymenoptera: Vespidae) in Luxembourg. Bulletin (Societe des Naturalistes Luxembourgeois) 123: 181–193. https://www.snl.lu/publications/bulletin/SNL_2021_123_181_193.pdf
- Robertson PA, Mill AC, Adriaens T, Moore N, Vanderhoeven S, Essl F, Booy O (2021) Risk Management Assessment Improves the Cost-Effectiveness of Invasive Species Prioritisation. Biology (Basel) 10(12): e1320. <https://doi.org/10.3390/biology10121320>
- Rödder D, Solé M, Böhme W (2008) Predicting the potential distributions of two alien invasive Housegeckos (Gekkonidae: *Hemidactylus frenatus*, *Hemidactylus mabouia*). North-Western Journal of Zoology 4: 236–246.

- Roy H, Rorke S, Wong LJ, Pagad S (2020) Global Register of Introduced and Invasive Species - Great Britain. Version 1.7. Invasive Species Specialist Group ISSG.
- Rubel F, Kottek M (2010) Observed and projected climate shifts 1901–2100 depicted by world maps of the Köppen-Geiger climate classification. *Meteorologische Zeitschrift* (Berlin) 19(2): 135–141. <https://doi.org/10.1127/0941-2948/2010/0430>
- Ruykys L, Ta KAT, Bui TD, Vilizzi L, Copp GH (2021) Risk screening of the potential invasiveness of non-native aquatic species in Vietnam. *Biological Invasions* 23(7): 2047–2060. <https://doi.org/10.1007/s10530-020-02430-2>
- Schaffner F, Ries C (2019) First evidence and distribution of the invasive alien mosquito *Aedes japonicus* (Theobald, 1901) in Luxembourg. *Bulletin (Societe des Naturalistes Luxembourgeois)* 121: 169–183. https://www.snl.lu/publications/bulletin/SNL_2019_121_169_183.pdf
- Singh SK, Ash GJ, Hodda M (2015) Keeping ‘one step ahead’ of invasive species: Using an integrated framework to screen and target species for detailed biosecurity risk assessment. *Biological Invasions* 17(4): 1069–1086. <https://doi.org/10.1007/s10530-014-0776-0>
- Singh J, Schädler M, Demetrio W, Brown GG, Eisenhauer N (2019) Climate change effects on earthworms - a review. *Soil Organisms* 91: 114–138.
- Sotiropoulos K (2020) The Amphibians. In: Pafilis P (Ed.) *The fauna of Greece. Biology and management of wild fauna*. Broken Hills Publishers Ltd, Nicosia, Cyprus, 579–623. [in Greek]
- Spencer JL, Hibbard BE, Moeser J, Onstad DW (2009) Behaviour and ecology of the western corn rootworm (*Diabrotica virgifera virgifera* LeConte). *Agricultural and Forest Entomology* 11(1): 9–27. <https://doi.org/10.1111/j.1461-9563.2008.00399.x>
- Šprem N, Gančević P, Safner T, Jerina K, Cassinello J (2020) Barbary sheep *Ammotragus lervia* (Pallas, 1777). In: Hackländer K, Zachos FE (Eds) *Handbook of the Mammals of Europe*. Springer, Cham, 1–14. https://doi.org/10.1007/978-3-319-65038-8_35-1
- Sturman A, Wanner H (2001) A comparative review of the weather and climate of the Southern Alps of New Zealand and the European Alps. *Mountain Research and Development* 21(4): 359–369. [https://doi.org/10.1659/0276-4741\(2001\)021\[0359:ACROTW\]2.0.CO;2](https://doi.org/10.1659/0276-4741(2001)021[0359:ACROTW]2.0.CO;2)
- Suresh VR, Ekka A, Biswas DK, Sahu SK, Yousuf A, Das S (2019) Vermiculated sailfin catfish, *Pterygoplichthys disjunctivus* (Actinopterygii: Siluriformes: Loricariidae): invasion, biology, and initial impacts in east Kolkata Wetlands, India. *Acta Ichthyologica et Piscatoria* 49(3): 221–233. <https://doi.org/10.3750/AIEP/02551>
- Tarkan AS, Tricarico E, Vilizzi L, Bilge G, Ekmekçi FG, Filiz H, Giannetto D, İlhan A, Killi N, Kirankaya ŞG, Koutsikos N, Kozic S, Kurtul I, Lazzaro L, Marchini A, Occhipinti-Ambrogi A, Perdikaris C, Piria M, Pompei L, Sari H, Smeti E, Stasolla G, Top N, Tsiamis K, Vardakas L, Yapici S, Yoğurtçuoğlu B, Copp GH (2021) Risk of invasiveness of non-native aquatic species in the eastern Mediterranean region under current and projected climate conditions. *The European Zoological Journal* 88(1): 1130–1143. <https://doi.org/10.1080/24750263.2021.1980624>
- Thunnissen NW, de Waart SA, Collas FPL, Jongejans E, Jan Hendriks A, van der Velde G, Leuven RSEW (2022) Risk screening and management of alien terrestrial planarians in The Netherlands. *Management of Biological Invasions* 13(1): 81–100. <https://doi.org/10.3391/mbi.2022.13.1.05>

- Tinsley NA, Estes RE, Gray ME (2013) Validation of a nested error component model to estimate damage caused by corn rootworm larvae. *Journal of Applied Entomology* 137(3): 161–169. <https://doi.org/10.1111/j.1439-0418.2012.01736.x>
- Tiunov AV, Hale CM, Holdsworth AR, Vsevolodova-Perel TS (2006) Invasion patterns of Lumbricidae into the previously earthworm-free areas of northeastern Europe and the western Great Lakes region of North America. In: Hendrit PF (Ed.) *Biological Invasions Belowground: Earthworms as Invasive Species*. Springer, Dordrecht, 22–34. https://doi.org/10.1007/978-1-4020-5429-7_4
- Toepfer S, Kuhlmann U (2006) Constructing life-tables for the invasive maize pest *Diabrotica virgifera virgifera* (Col.; Chrysomelidae) in Europe. *Journal of Applied Entomology* 130(4): 193–205. <https://doi.org/10.1111/j.1439-0418.2006.01060.x>
- Toth S, Szalai M, Kiss J, Toepfer S (2020) Missing temporal effects of soil insecticides and entomopathogenic nematodes in reducing the maize pest *Diabrotica virgifera virgifera*. *Journal of Pest Science* 93(2): 767–781. <https://doi.org/10.1007/s10340-019-01185-7>
- Uyan U, Oh C-W, Tarkan AS, Top N, Copp GH, Vilizzi L (2020) Risk screening of the potential invasiveness of non-native marine fishes in South Korea. *Marine Pollution Bulletin* 153: e111018. <https://doi.org/10.1016/j.marpolbul.2020.111018>
- Vilà M, Basnou C, Gollasch S, Josefsson M, Pergl J, Scalera R (2009) One hundred of the most invasive alien species in Europe. *Handbook of Alien Species in Europe. Invading Nature - Springer Series in Invasion Ecology, Vol 3*. Springer, Dordrecht, 265–268. https://doi.org/10.1007/978-1-4020-8280-1_12
- Vilizzi L, Copp GH, Adamovich B, Almeida D, Chan J, Davison PI, Dembski S, Ekmekçi FG, Ferincz A, Forneck SC, Hill JE, Kim J-E, Koutsikos N, Leuven RSEW, Luna SA, Magalhães F, Marr SM, Mendoza R, Mourão CF, Neal JW, Onikura N, Perdikaris C, Piria M, Poulet N, Puntila R, Range IL, Simonović P, Ribeiro F, Tarkan AS, Troca DFA, Vardakas L, Verreycken H, Vintsek L, Weyl OLF, Yeo DCJ, Zeng Y (2019) A global review and meta-analysis of applications of the freshwater Fish Invasiveness Screening Kit. *Reviews in Fish Biology and Fisheries* 29(3): 529–568. <https://doi.org/10.1007/s11160-019-09562-2>
- Vilizzi L, Copp GH, Hill JE, Adamovich B, Aislabie L, Akin D, Al-Faisal AJ, Almeida D, Azmai MNA, Bakiu R, Bellati A, Bernier R, Bies JM, Bilge G, Branco P, Bui TD, Canning-Clode J, Cardoso Ramos HA, Castellanos-Galindo GA, Castro N, Chaichana R, Chainho P, Chan J, Cunico AM, Curd A, Dangchana P, Dashinov D, Davison PI, de Camargo MP, Dodd JA, Durland Donahou AL, Edsman L, Ekmekçi FG, Elphinstone-Davis J, Erős T, Evangelista C, Fenwick G, Ferincz Á, Ferreira T, Feunteun E, Filiz H, Forneck SC, Gajduchenko HS, Gama Monteiro J, Gestoso I, Giannetto D, Gilles AS, Gizzi Jr F, Glamuzina B, Glamuzina L, Goldsmit J, Gollasch S, Goulletquer P, Grabowska J, Harmer R, Haubrock PJ, He D, Hean JW, Herczeg G, Howland KL, İlhan A, Interesova E, Jakubčinová K, Jelmert A, Johnsen SI, Kakareko T, Kanongdate K, Killi N, Kim J-E, Kirankaya ŞG, Kňazovická D, Kopecký O, Kostov V, Koutsikos N, Kozic S, Kuljanishvili T, Kumar B, Kumar L, Kurita Y, Kurtul I, Lazzaro L, Lee L, Lehtiniemi M, Leonardi G, Leuven RSEW, Li S, Lipinskaya T, Liu F, Lloyd L, Lorenzoni M, Luna SA, Lyons TJ, Magellan K, Malmstrøm M, Marchini A, Marr SM, Masson G, Masson L, McKenzie CH, Memedemin D, Mendoza R, Minchin D, Miossec L, Moghaddas SD, Moshobane MC, Mumladze L, Na-

- ddafi R, Najafi-Majd E, Năstase A, Năvodaru I, Neal JW, Nienhuis S, Nimtim M, Nolan ET, Occhipinti-Ambrogi A, Ojaveer H, Olenin S, Olsson K, Onikura N, O'Shaughnessy K, Paganelli D, Parretti P, Patoka J, Pavia RTB, Pellitteri-Rosa Jr D, Pelletier-Rousseau M, Peralta EM, Perdikaris C, Pietraszewski D, Piria M, Pitois S, Pompei L, Poulet N, Preda C, Puntila-Dodd R, Qashqaei AT, Radočaj T, Rahmani H, Raj S, Reeves D, Ristovska M, Rizevsky V, Robertson DR, Robertson P, Ruykys L, Saba AO, Santos JM, Sarı HM, Segurado P, Semenchenko V, Senanan W, Simard N, Simonović P, Skóra ME, Slovák Švolíková K, Smeti E, Šmídová T, Špelić I, Srébalienė G, Stasolla G, Stebbing P, Števoe B, Suresh VR, Szajbert B, Ta KAT, Tarkan AS, Tempesti J, Therriault TW, Tidbury HJ, Top-Karakuş N, Tricarico E, Troca DFA, Tsiamis K, Tuckett QM, Tutman P, Uyan U, Uzunova E, Vardakas L, Velle G, Verreycken H, Vintsek L, Wei H, Weiperth A, Weyl OLF, Winter ER, Włodarczyk R, Wood LE, Yang R, Yapıcı S, Yeo SSB, Yoğurtçuoğlu B, Yunnice ALE, Zhu Y, Zięba G, Žitňanová K, Clarke S (2021) A global-scale screening of non-native aquatic organisms to identify potentially invasive species under current and future climate conditions. *Science of the Total Environment* 788: e147868. <https://doi.org/10.1016/j.scitotenv.2021.147868>
- Vilizzi L, Hill JE, Piria M, Copp GH (2022) A protocol for screening potentially invasive non-native species using Weed Risk Assessment-type decision-support toolkits. *Science of the Total Environment* 832: e154966. <https://doi.org/10.1016/j.scitotenv.2022.154966>
- Walkenbach J (2007) Excel 2007 bible. John Wiley and Sons Inc., New York, 912 pp.
- Wei H, Chaichana R, Vilizzi L, Daengchana P, Liu F, Nimtim M, Zhu Y, Li S, Hu Y, Copp GH (2021a) Do non-native ornamental fishes pose a similar level of invasion risk in neighbouring regions of similar current and future climate? Implications for conservation and management. *Aquatic Conservation* 31(8): 2041–2057. <https://doi.org/10.1002/aqc.3609>
- Wei H, Liu C, Hu Y, Wang X, Mu X, Gu D, Xu M, Fang M (2021b) (in press) Invasiveness identification using Aquatic Species Invasiveness Screening Kit of non-native ornamental fish in China: A case study of non-native Loricariidae species. *Journal of Ecology and Rural Environment*. <https://kns.cnki.net/kcms/detail/32.1766.X.20211015.1941.001.html> [In Chinese with an English abstract]
- Weterings R, Vetter KC (2018) Invasive house geckos (*Hemidactylus* spp.): Their current, potential and future distribution. *Current Zoology* 64(5): 559–573. <https://doi.org/10.1093/cz/zox052>
- Wironen M, Moore TR (2006) Exotic earthworm invasion increases soil carbon and nitrogen in an old-growth forest in southern Quebec. *Canadian Journal of Forest Research* 36(4): 845–854. <https://doi.org/10.1139/x06-016>
- Yoğurtçuoğlu B, Bucak T, Ekmekçi FG, Kaya C, Tarkan AS (2021) Mapping the establishment and invasiveness potential of rainbow trout (*Oncorhynchus mykiss*) in Turkey: With special emphasis on the conservation of native salmonids. *Frontiers in Ecology and Evolution* 8: e599881. <https://doi.org/10.3389/fevo.2020.599881>
- Zajac KS, Hatteland BA, Feldmeyer B, Pfenninger M, Filipiak A, Noble LR, Lachowska-Cierlik D (2020) A comprehensive phylogeographic study of *Arion vulgaris* Moquin-Tandon,

- 1855 (Gastropoda: Pulmonata: Arionidae) in Europe. *Organisms, Diversity & Evolution* 20(1): 37–50. <https://doi.org/10.1007/s13127-019-00417-z>
- Zemanova MA, Knop E, Heckel G (2016) Phylogeographic past and invasive presence of *Arion* pest slugs in Europe. *Molecular Ecology* 25(22): 5747–5764. <https://doi.org/10.1111/mec.13860>
- Zemanova MA, Knop E, Heckel G (2017) Introgressive replacement of natives by invading *Arion* pest slugs. *Scientific Reports* 7(1): e14908. <https://doi.org/10.1038/s41598-017-14619-y>
- Zemanova MA, Broennimann O, Guisan A, Knop E, Heckel G (2018) Slimy invasion: Climatic niche and current and future biogeography of *Arion* slug invaders. *Diversity and Distributions* 24(11): 1627–1640. <https://doi.org/10.1111/ddi.12789>
- Zięba G, Vilizzi L, Copp GH (2020) How likely is *Lepomis gibbosus* to become invasive in Poland under conditions of climate warming? *Acta Ichthyologica et Piscatoria* 50: 37–51. <https://doi.org/10.3750/AIEP/02390>

Supplementary material I

Table S1

Authors: Lorenzo Vilizzi, Marina Piria, Dariusz Pietraszewski, Oldřich Kopecký, Ivan Špelić, Tena Radočaj, Nikica Šprem, Kieu Anh T. Ta, Ali Serhan Tarkan, Andrés Weiperth, Baran Yoğurtçuoğlu, Onur Candan, Gábor Herczeg, Nurçin Killi, Darija Lemić, Bettina Szajbert, David Almeida, Zainab Al-Wazzan, Usman Atique, Rigers Bakiu, Ratcha Chaichana, Dimitriy Dashinov, Árpád Ferincz, Guillaume Flieller, Allan S. Gilles Jr, Philippe Goulletquer, Elena Interesova, Sonia Iqbal, Akihiko Koyama, Petra Kristan, Shan Li, Juliane Lukas, Seyed Daryoush Moghaddas, João G. Monteiro, Levan Mumladze, Karin H. Olsson, Daniele Paganelli, Costas Perdikaris, Renanel Pickholtz, Cristina Preda, Milica Ristovska, Kristína Slovák Švolíková, Barbora Števo, Eliza Uzunova, Leonidas Vardakas, Hugo Verreycken, Hui Wei, Grzegorz Zięba

Data type: docx file

Explanation note: List of the 55 questions (Qs) making up the Terrestrial Animal Species Invasiveness Screening Kit (TAS-ISK v2.3.1). Sector codes (in parentheses): C = Commercial; E = Environmental; S = Species or population nuisance traits. Changes of questions relative to AS-ISK v2.3.1: G = Guidance; Q = Question (text). For each Q, the corresponding Question (text), Guidance and choice of Response (with coding as displayed in report and score) are indicated.

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Supplementary material 2

Combined TAS-ISK report

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Data type: pdf file

Explanation note: Combined TAS-ISK report including the nine screenings for the sample terrestrial animal species.

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