

In the black: Information harmonisation and educational potential amongst international databases for invasive alien species designated as of Union Concern



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ABSTRACT

Since 2016, the European Union (EU) has required Member States to prevent, control and eradicate selected invasive alien species (IAS) designated as Species of Union Concern. To improve these conservation efforts, online information systems are used to convey IAS information to the wider public, often as a means to bolster community-based environmental monitoring. Despite this, both the conformity and quality of information presented amongst online databases remain poorly understood. Here, we assess the harmonisation and educational potential of four major IAS databases (i.e., conformity of information and information quality, respectively): CABI, EASIN, GISD and NOBANIS. All databases were interrogated for information concerning 49 IAS of Union Concern. For each species, information presented within the evaluated databases was scored in relation to several key topics: morphological identification; EU distribution; detrimental impacts; control options; and the use of source material citations. Overall, scores differed significantly among databases and thus lacked harmonisation, whereby CABI ranked significantly highest based on the combined scores for all topics. In addition, CABI ranked highest for the individual topics of species identification, impacts, control options, and for the use of citations. EASIN ranked highest for species distribution data. NOBANIS consistently ranked as the lowest scoring database across all topics. For each topic, the highest scoring databases achieved scores indicative of detailed or highly detailed information, which suggests a high educational potential for the information portrayed. Nevertheless, the extent of harmonisation and quality of information presented amongst online databases should be improved. This is especially pertinent if online databases are to contribute to public participatory monitoring initiatives for IAS detection.

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1. Introduction

Biological invasions are major drivers of biodiversity loss and the detrimental alteration of normal ecosystem functioning worldwide, which has resulted in wide-ranging negative consequences for the sustainability of ecosystem services, human health, and food security (Ricciardi and MacIsaac 2011; Cardinale et al., 2012). Although the ecological impacts of invaders are not correlated with their invasiveness, i.e. establishment and spread (Ricciardi and Cohen 2007), once established in a new region, many invasive alien species (IAS) can quickly proliferate and be extremely difficult to eradicate or control (Booy et al., 2017; Coughlan et al., 2018). In addition, while the financial and social costs of IAS can be difficult to quantify (Hanley and Roberts 2019), IAS present a variety of negative socio-economic impacts, including the loss of natural capital, increased management costs, devaluation of property, and reduced opportunities for recreational activities (Oreska and Aldridge 2011; Hussner et al., 2017; Zipp et al., 2019). In Europe, for example, the total annual costs of IAS have been estimated at approximately 12.5 billion EUR, but may exceed 20 billion EUR (Kettunen et al., 2008). Therefore, biological invasions by IAS are considered to be fundamentally analogous to natural disasters, and require similar management strategies and resource commitments to mitigate impacts (Ricciardi et al., 2011).

Globally, despite billions of dollars spent on controlling biological invasions, it is not always clear whether efforts are effective, or particularly cost-effective (McConnachie et al., 2016). Prevention of initial introduction and the secondary spread of IAS is considered the most cost-effective management option (Hussner et al., 2017), and unsuccessful spread-prevention measures can result in costly pest management programmes (Hulme et al., 2016). However, the cost of inaction, both economic and socio-economic, can be greater (Hanley and Roberts 2019). Consequently, management of IAS has become a priority issue in both international and domestic law and domestic policy, such as the European Union (EU) IAS Regulation 1143/2014, New Zealand Biosecurity Strategy, and Great Britain Non-Native Species Strategy (EU 2014; GBNNSS 2015; PGNZ 2016). In particular, the EU Regulation no. 1143 has provided the basis for improved spread-prevention, control and eradication of selected IAS designated as Species of Union Concern. Since August 2019, this list has grown to encompass 66 IAS. In effect, for these 'black-listed' species, trade, transport, cultivation/breeding, release and ownership is now prohibited within EU territories.

Public perception has become a key element of conservation policies, including IAS management strategies (Davis et al., 2018), as community support is often essential for policy success (Crowley et al., 2017; Melero 2017). Furthermore, recent efforts have sought to counter invasion science denialism that can misinform and mislead the public and policy makers (Cuthbert et al., 2020). Nevertheless, there often remains limited public, political, and stakeholder awareness or risk perception of major global conservation challenges that are directly or indirectly associated with IAS impacts (Reid et al., 2013; Robinson et al., 2017). Accordingly, there is an urgent requirement to enhance public knowledge of IAS issues and relevant national and international IAS policy. Traditionally, conventional media have facilitated the dissemination of knowledge to the general public (Nisbet and Scheufele 2009). In recent years, however, online resources in the form of network-based databases have become an increasingly popular method of IAS information sharing and as a mechanism to bolster community-based environmental monitoring, especially concerning the cataloguing of species occurrence, distribution and impact records (Gatto et al., 2013). In general, these networks tend to be established and maintained by academic groups, governmental, non-government and non-profit agencies, or consortia of the same. Although some databases act as detailed data repositories to help expedite further research or biodiversity conservation efforts amongst stakeholder groups (e.g. species occurrence records), many were constructed to improve public IAS education (Simpson et al., 2009). However, these databases are often data deficient and lack common conformity for information (i.e. harmonisation of information) (Simpson et al., 2009; Gatto et al., 2013). Further, the educational potential (i.e. information quality) of online databases remains largely unknown. In addition, there remains a lack of guidelines and standardisation criteria for data in relation to collection (including metadata), format, accessibility, interoperability and long-term preservation (Groom et al., 2017). Deficient IAS data, poor harmonisation and low educational potential may lead to reduced public engagement and inaccurate public participatory based monitoring of IAS (i.e. citizen science), which can decrease participation in conservation activities such as IAS early-warning systems, and result in unreliable or misleading data, respectively.

The provision of online IAS databases has coincided with a dramatic escalation in citizen science participation, which actively engages non-professionals in scientific research across a range of ecological and environmental disciplines in participatory based monitoring of nature (Dickinson et al., 2012; Theobald et al., 2015; Lewenstein 2016). As a combination of both research and education, citizen science has facilitated direct and credible engagement between scientists, practitioners, policy makers and the general public. Importantly, while acting as a mechanism for educational outreach, public engagement and conservation advancement, the integration of ordinary citizens within the scientific process has expedited and enhanced opportunities for gathering data, and address large-scale data limitations for basic and applied science (Theobald et al., 2015; Lewenstein 2016; Burgess et al., 2017; McKinley et al., 2017). Moreover, increased communication and public engagement is considered to be particularly important for IAS pathway control in relation to the disruption of IAS introduction and spread, via early warning systems, rapid action, and effective biosecurity protocols (Caffrey et al., 2014; Essl et al., 2015; Piria et al., 2017). In particular, early detection and a rapid response are key components for the successful implementation of EU Regulation no. 1143 following the appearance of a Species of Union Concern within an EU Member State (EU 2014). Given that

citizen science participatory monitoring initiatives can be conducted across a range of spatial and temporal scales (Dickinson et al., 2012; McKinley et al., 2017), which often exceed the data collection abilities of mainstream biodiversity research groups, public engagement can be harnessed to support early detection of IAS of Union Concern. Accordingly, online IAS databases can act as a resource to support conservation efforts which aim to increase IAS awareness and identification, and are especially useful for members of the public who seek further information following a suspected sighting of an IAS of Union Concern. Arguably, the European Commission has been especially reliant on the use of online databases to convey information to the public, having appointed the European Alien Invasive Species Information Network (EASIN) to act as the primary, publicly available information system for IAS of Union Concern. Although information concerning IAS of Union Concern can be sourced from a variety of different online databases, the level of data harmonisation amongst IAS databases, and the educational potential of information portrayed, remain largely unknown.

Here, we assess the harmonisation and educational potential of four major international IAS databases: the Invasive Species Compendium of the Centre for Agriculture and Bioscience International (CABI), the EASIN, the Global Invasive Species Database (GISD), and the European Network on Invasive Alien Species (NOBANIS) (see Table 1). However, although NOBANIS is an available online resource, the database has not been updated in recent years as it no longer receives active funding support. Nevertheless, these four databases were chosen for evaluation as they are specifically designed to provide information on the topic of IAS at a European and global scale, with both animal and plant species being listed. Databases were interrogated for information concerning 49 of the current 66 IAS of EU Concern. For each species, information presented within the evaluated databases was scored in relation to several key topics, i.e. morphological identification, EU distribution, detrimental impacts, control options, and the use of source material citations. These topics were considered essential to enable non-specialist users to identify possible IAS of Union Concern, and to convey an understanding of why these species have been assigned this designation. Although 66 species are currently designated as of Union Concern, since 17 of these are relatively new appointments (≤ 3 months at the time of evaluation), we have opted to assess database information for the preceding 49 species.

2. Methods

To assess database harmonisation and educational potential, selected databases were evaluated for content portrayed in relation to: 1) species 'identification'; 2) EU 'distribution'; 3) ecological and/or economic 'impacts'; 4) 'control' options; and 5), the citation of relevant 'source material' for further information. A five-point scale was constructed to facilitate comparative assessment amongst databases. For each topic, the scale was composed of five possible scores (1–5), which enumerated a basic description of the information presented within the database, i.e. 1 = none given, 2 = little, 3 = some, 4 = detailed, and 5 = highly detailed. These basic descriptions corresponded to a series of detailed definitions for each of the five topics assessed, which denote the extent of information required to be portrayed within the dataset to allocate a score to a topic, i.e. the educational potential of the data (see Table 2).

A single individual assessor (LL) interrogated all databases using the five-point assessment scale (Table 2). Crucially, although the assessor was familiar with the concept of IAS, and had participated in a number of citizen science surveys of flora and fauna, the individual was not an expert in the identification of IAS. A lack of familiarity was considered essential to reduce

Table 1

Brief overview of database parameters. Time of last update can vary for individual species within each database.

Name	Abbr.	Declared purpose of database	Information developers	Date of creation	Last updated	Date of assessment
Invasive Species Compendium of the Centre for Agriculture and Bioscience International	CABI	To provide: "an encyclopaedic resource that draws together scientific information on all aspects of invasive species"	Content is provided by experts, edited by CABI's scientific staff, peer-reviewed, and enhanced with data from specialist organizations.	≥ 2001	≤ 2019	November 2019
European Alien Invasive Species Information Network (Brochure)	EASIN Brochure	To provide: "brief, non-technical and informal summaries"	Ecosystem LTD. under contract for the European Commission.	2017	2017	November 2019
European Alien Invasive Species Information Network (Factsheet)	EASIN Factsheet	To provide: "scientific information and identification tools to facilitate invasive alien species detection and reporting"	European Commission - Joint Research Centre.	≥ 2012	≤ 2019	November 2019
Global Invasive Species Database	GISD	To provide: "increased public awareness about invasive species and to facilitate effective prevention and management activities by disseminating specialist's knowledge and experience to a broad global audience"	Content is created or reviewed by experts.	≥ 2004	≤ 2015	November 2019
European Network on Invasive Alien Species	NOBANIS	To provide: "tools for implementing the precautionary approach against the unintentional dispersal of invasive alien species"	Information voluntarily provided and reviewed by scientific experts.	≥ 2010	≤ 2015	November 2019

Table 2

Scale describing the allotted score and associated basic description for a defined level of information content presented for European Union (EU) invasive alien species (IAS) of Union Concern within online IAS databases across five discrete topics: 1) species 'identification'; 2) EU 'distribution'; 3) ecological and/or economic 'impacts'; 4) 'control' options; and 5), the citation of relevant 'source material' for further information.

Score	Description	Identification (ID)	Distribution	Impact	Control	Source Material
1	None given	None given.	None given.	None given.	None given.	None given.
2	Little	Basic description, and/or visual ID not possible.	Identify presence or absence within the EU.	Confirmation as to the existence of ecological and/or economic impacts.	Confirmation as to the existence of control measures.	Use of basic non-original sources only.
3	Some	Basic description, and/or visual ID may be possible.	Identify presence or absence within all EU Member States.	Basic description of ecological and/or economic impacts.	Basic description of measures required to limit spread and/or reduce populations.	Use of detailed non-original sources, and/or 1–3 original sources.
4	Detailed	Detailed description, and/or visual ID likely possible.	Identify presence or absence within all Member States, and identify distribution in ≥ 1 Member State.	Detailed description of ecological and/or economic impacts.	Detailed description of measures required to limit spread and/or reduce populations.	Use of detailed non-original sources, and/or 3–5 original sources.
5	Highly detailed	Highly detailed description, and/or positive visual ID possible.	Identify all Member State level distributions.	Detailed description of ecological and/or economic impacts for ≥ 1 Member State. Specific examples and/or source material presented.	Detailed description of measures required to limit spread and/or reduce populations. Specific examples and/or source material presented.	Use of detailed non-original sources, and/or multiple (>5) original sources.

potential unconscious bias during database assessment, especially in relation to the determination of species identification. Further, the assessor was interviewed as per their choice of selected scores and asked to rescore 12 randomly selected species in the presence of the interviewer to insure fair and unbiased allocation of scores, whilst verbally confirming their rationale for score allocation. The assessor's approach to be evenly and unbiasedly applied across the unique parameters of all datasets. As EASIN is a platform that encompasses multiple IAS information resources, this database was scored first in relation to the downloadable brochure describing IAS designated as Union Concern (https://ec.europa.eu/environment/nature/pdf/IAS_brochure_species.pdf). EASIN was then separately scored in respect to the interactive Information Factsheets (<https://easin.jrc.ec.europa.eu/easin/CitizenScience/Factsheets>), which allow users to search and view IAS profiles online. For both assessments of EASIN, species distribution scores are based on a related European Commission report by Tsiamis et al. (2017), 'Baseline Distribution of Invasive Alien Species of Union Concern', rather than limited distribution information presented in the brochure or factsheets, as the highly detailed report is freely available for download from the EASIN website. All databases were accessed in November 2019.

2.1. Statistical analysis

We tested for differences in scores among data sources (5 levels: CABI, EASIN [brochure and factsheet], GISD and NOBANIS) and taxonomic groupings (2 levels: animals and plants), and their two-way interaction, using ordered logistic regression models. The presence of a significant interaction would indicate that score differences among data sources were dependent on taxonomic groupings. This approach fits a proportional odds logistic regression model to an ordered factor response, which in this case comprised scores from data sources that were determined on an ordinal scale. We fit these models using the *polr* function of the 'MASS' package in R v4.0.2 (Venables and Ripley 2002; R Core Team, 2020). We fit six different proportional odds logistic regression models, first for the product of scores across all the five categories (identification, distribution, impact, control and source material), and second for scores in each of those five categories separately. Parallel regression assumptions were tested using the *brant* function of the 'brant' package (Brant 1990). To compute overall effect sizes, the *Anova* function in the 'car' package was used, with type III sums of squares given the presence of an interaction term (Fox and Weisberg 2019). Tukey comparisons were used *post hoc* to compare data sources pairwise using the *glht* function of the 'multcomp' package (Hothorn et al., 2008). We considered significance at a *p*-value of 0.05.

3. Results

Total scores differed significantly among sources (Table 3). Median total scores were ordered: CABI (800) > EASIN (factsheet) (135) > EASIN (brochure) (40) = GISD (40) > NOBANIS (1) (Fig. 1A). CABI scores were significantly greater than all other sources (all *p* < 0.001), and EASIN (factsheet) was significantly higher compared to EASIN (brochure), GISD and NOBANIS (all *p* < 0.05). In turn, NOBANIS was significantly lowest overall (all *p* < 0.001). Median scores were statistically similar between animals (105) and plants (135) (Fig. 1B; Table 3). However, although non-significant (Table 3), median scores trended towards being higher for plants rather than animals in the EASIN (factsheet) and GISD databases (Fig. 1C).

Individual topics were also consistently significantly different among sources, but not between taxonomic groups or their interaction with sources (Table 3). For species identification information, median scores were ordered CABI (4) = EASIN

Table 3

Analysis of deviance results considering ordinal regression models for different topics (and corresponding totals, i.e., products). Significant predictor terms are shown in bold.

Topics	Predictor	χ^2	df	P
Total	Source	165.37	4	< 0.001
	Taxon	0.45	1	0.50
	Source:Taxon	0.76	4	0.94
Identification	Source	164.70	4	< 0.001
	Taxon	0.52	1	0.47
	Source:Taxon	5.77	4	0.22
Distribution	Source	322.39	4	< 0.001
	Taxon	0.00	1	1.00
	Source:Taxon	0.65	4	0.96
Impact	Source	152.22	4	< 0.001
	Taxon	0.34	1	0.56
	Source:Taxon	2.93	4	0.57
Control	Source	210.33	4	< 0.001
	Taxon	0.00	1	1.00
	Source:Taxon	6.83	4	0.15
Source material	Source	224.63	4	< 0.001
	Taxon	0.01	1	1.00
	Source:Taxon	1.67	4	0.80

(factsheet) (4) > EASIN (brochure) (2) = GISD (2) > NOBANIS (1) (Fig. 2A). Median scores for plants and animals were each 3. Contrastingly, in relation to distributional information, score source medians were greatest for the two EASIN datasets (both 5), followed by CABI (2) > GISD (1) = NOBANIS (1) (Fig. 2B). Median animal and plant scores were equal (both 2).

CABI had the highest median score for the impact information topic (4), followed by EASIN (factsheet) (3) > EASIN (brochure) (2) > GISD (1) = NOBANIS (1) (Fig. 2C). Animal median impact scores (2) were lower than plants here (3), yet non-significantly. For control information, scores were ordered as CABI (5) > EASIN (brochure) (2) = GISD (2) > EASIN (factsheet) (1) = NOBANIS (1) (Fig. 2D), whilst animal and plant scores were similar (both 2). With regards to source material (i.e. use of citations), CABI again exhibited the highest median score (5), followed by EASIN (factsheet) (3) > GISD (2) > EASIN (brochure) (1) = NOBANIS (1) (Fig. 2E). Animal and plant source material were similar (both medians = 3).

4. Discussion

Engagement and educational advancement of key stakeholder groups, along with appropriate policy development and implementation, have emerged as essential areas for IAS mitigation and biodiversity conservation (Caffrey et al., 2014; Theobald et al., 2015; Piria et al., 2017). In an era of misinformation, interactive online databases represent a means to convey factual information with a high educational potential (i.e., high information quality). In this study, the assessed IAS databases show little harmonisation of information concerning IAS of Union Concern (i.e., limited conformity of information). Although all species of interest are included in CABI and both EASIN databases, only 27 and 12 IAS of Union Concern are listed in GISD and NOBANIS, respectively. A lack of inclusion for these species is concerning given their increased importance from an EU perspective, especially in the case of NOBANIS, which is a European-orientated database, although it no longer receives funding support. Overall, CABI had the highest education potential per topic, except in relation to the EU distribution of the assessed species. In this case, the availability of a highly detailed species distribution report (i.e. Tsiamis et al., 2017) bolstered both EASIN datasets. Nevertheless, the overall educational potential of all databases can be further improved. For example, while CABI ranked highest for the topic of IAS control options (CABI median = 5), 12 of the assessed species scored ≤ 4 (i.e. 24.5%). However, in some instances, low scores appear to reflect knowledge gaps concerning the management of a number of these species. Nevertheless, no single database currently provides for a complete and thorough overview of the assessed IAS of Union Concern. As EASIN is the European Commission's official online mechanism to disseminate information for these black-listed IAS, it is recommended that action be taken to further increase the educational potential of this database. Further, as separate information sources are provided by the EASIN online platform, we suggest that essential information presented within the downloadable brochure, the interactive information factsheets, and the detailed species distribution report (i.e. Tsiamis et al., 2017), be amalgamated into a single searchable database. Whilst various national-level databases are used by the public as sources of IAS information, these platforms frequently reference the international databases assessed by the present study as supporting or further sources of IAS information. In addition, given that national-level databases also frequently reference agency reports and primary peer-reviewed literature as sources of further information, in our opinion, we believe it is reasonable to assume that ordinary members of the public will prefer to source additional information from larger online databases rather than detailed scientific reports. Further, in many cases, the public will not have access to much of the primary literature as it is locked behind journal pay-walls. In particular, EASIN is the European Commission's official platform for the provision of publicly available information concerning Species of Union Concern. Therefore, in our opinion, it is not unreasonable to presume that the general public within EU Member States will use this database when seeking information. Nevertheless, national-level databases offer additional and original information, through the provision of content

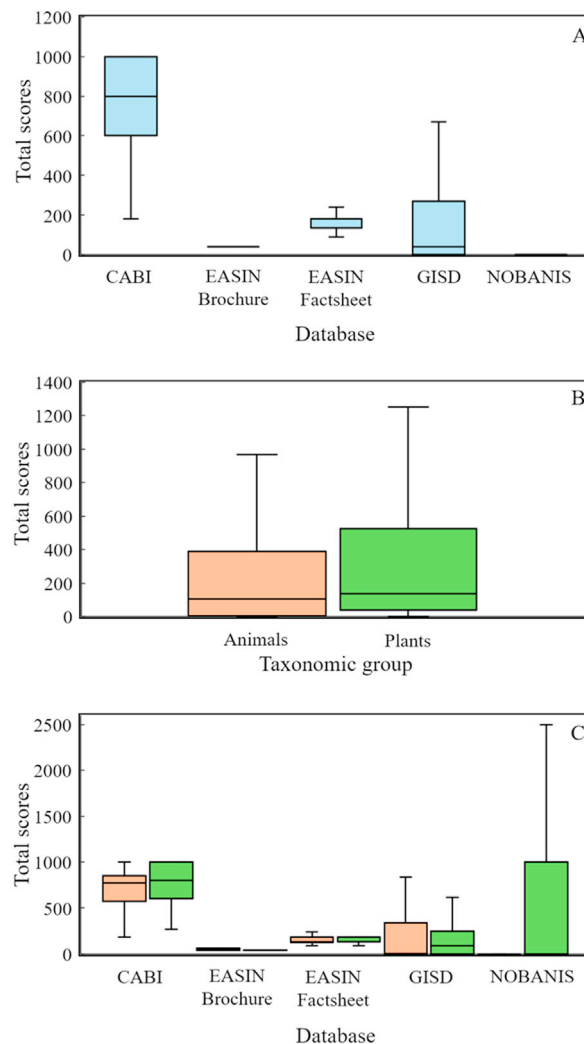


Fig. 1. Total median scores achieved by online databases for harmonisation of information provided for 49 invasive alien species of Union Concern. Total database scores were determined from the product of scores attained across five discrete assessment topics for each species (see Table 2). Total median scores, with interquartile ranges, and maximum and minimum values are shown for: (A) amongst databases; (B) between the major taxonomic groups of animals and plants; and (C), amongst the major taxonomic groups in relation to source database.

by national experts, national risk assessments and management experience, and such national-level data may be used as an information source within the focal international databases. Finally, our results need to be caveated in the context of the scores being allocated by a single individual assessor, while this does not diminish the experience of this assessor, the potential for unconscious bias remains.

With increased societal awareness of environmental and conservation issues in recent decades, including those associated with IAS, the level of public participation in conservation-based activities has generally increased (Bickford et al., 2012; Humair et al., 2014). Despite this, proactive engagement often remains relatively low amongst public, political, and stakeholder groups (Reid et al., 2013; Robinson et al., 2017). To increase collective community IAS awareness, conservation values, and accomplish the societal or cultural behavioural changes needed to mitigate IAS spread, the EU has recognised that a comprehensive information system is needed to underpin EU policy on IAS (EC 2008; Gatto et al., 2013). Despite this, substantial communication gaps still exist (Humair et al., 2014; Kemp et al., 2017), which is arguably further confounded by the lack of database harmonisation and poor educational potential of portrayed data (Groom et al., 2017). As the availability of accurate and detailed information concerning the distribution, pathways of introduction, and impacts of IAS is considered necessary to improve public awareness of, and proactive participation in IAS management programmes as conservation initiatives (Katsanevakis and Roy 2015; Groom et al., 2017), provision of high quality IAS information should be considered a priority issue for effective IAS management. In addition, management plans for long-term preservation will need to be

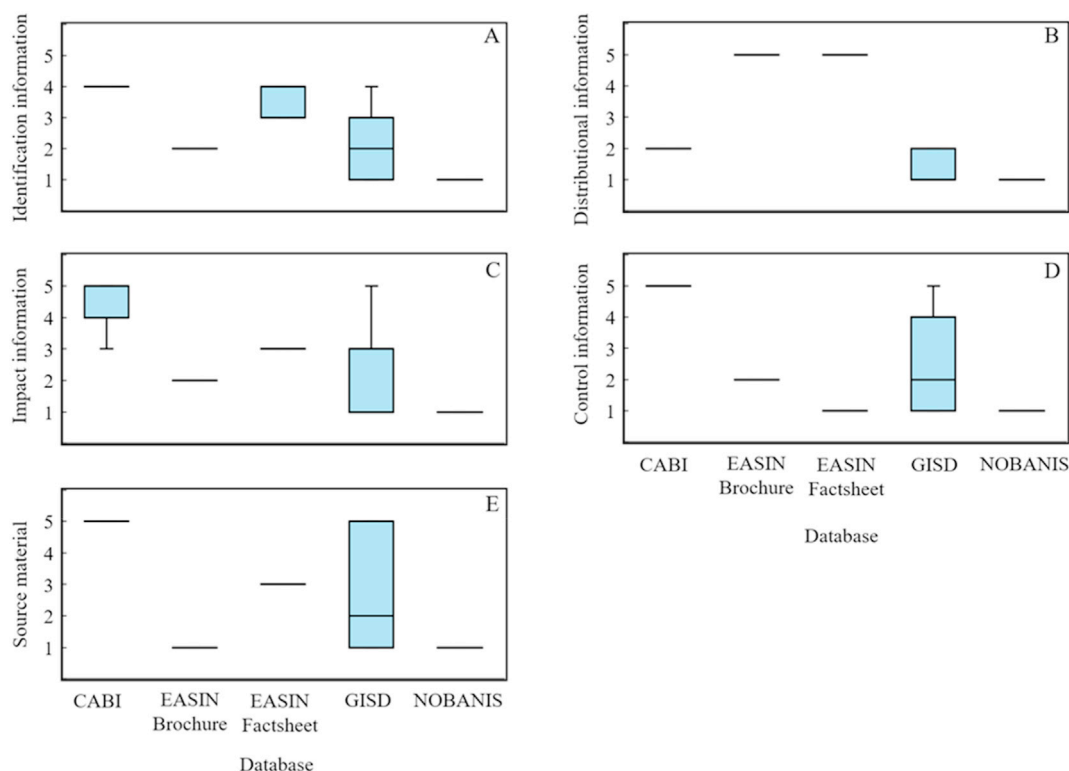


Fig. 2. Median scores achieved by online databases in relation to five discrete topics used to establish the educational potential of information provided for 49 invasive alien species of Union Concern (see Table 2). Median scores, with interquartile ranges, and maximum and minimum values are shown for: (A) species 'identification'; (B) EU 'distribution'; (C) ecological and/or economic 'impacts'; (D) control options; and (E), the citation of relevant 'source material' for further information.

developed, i.e. databases should not be reliant on a single time-limited funding source, while metadata should be made available for download to enable further analysis, e.g. species distribution records (Michener 2006; Groom et al., 2017).

In addition to informing the public, IAS databases can support improved biosecurity efforts. In particular, citizen science based participatory monitoring initiatives represents an excellent mechanism for improved data collection, cost-effective passive surveillance and early-warning systems through community-based environmental monitoring, whereby research and management of biological invasions can be greatly improved, e.g. better IAS prevention and early detection (Bickford et al., 2012; Gatto et al., 2013). However, poor quality databases could lead to the proliferation of inaccurate or misleading information, including false reporting of IAS of Union Concern, reducing opportunities for improved and targeted IAS management. Additionally, now that media outlets are increasingly influencing the general public on topical environmental issues, it is ever more important to have factual emphatically based information readily available to the public for guidance (e.g. Cunningham et al., 2020). As the expansion of citizen science projects has been greatly advanced by new developments in information science technologies (Dickinson et al., 2012), in addition to the use of an online platform, the European Commission could consider the development of an official smart-device web application (app) to portray the information contained within a high educational potential database. Portable hand-held smart-devices are now widely used within EU territories, and a web application could be used to increase dissemination of high educational potential information for IAS of Union Concern. This is particularly the case as navigation of webpages for the assessed online databases can be difficult, with decreased functionality and resolution issues for webpages when displayed on the relatively smaller screen sizes of portable hand-held devices (LL pers. obs.). Further, the use of a smart-device application could increase engagement of children and young adults. Youth-orientated citizen science projects could facilitate improved biodiversity awareness, encourage greater participation in current conservation actions, and enhance their capacity and willingness to contribute to future conservation activities (Ballard et al., 2017). Moreover, especially if databases can become immediately accessible on multiple platforms, delivering high quality information to individuals located in field settings could potentially aid improved reporting of suspected sighting of Species of Union Concern. Nevertheless, until harmonisation and educational potential of on-line databases are further improved, government agencies, conservation initiatives and educational bodies should not solely rely on IAS databases as a means of disseminating information to the public, especially in lieu of such bodies providing factual and educationally high-value information directly to communities through other mechanisms, e.g. agency websites, posters,

pamphlets. Overall, increased resolution, currency and availability of key information regarding Species of Union Concern could help mitigate the spread and proliferation of environmentally and economically costly invasive species.

Declaration of competing interest

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

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