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Socio-economic impact classification of alien taxa (SEICAT)

Sven Bacher[1,2] | **Tim M. Blackburn**[3,4,5] | **Franz Essl**[6] | **Piero Genovesi**[7] | **Jaakko Heikkilä**[8] | **Jonathan M. Jeschke**[9,10,11] | **Glyn Jones**[12] | **Reuben Keller**[13] | **Marc Kenis**[14] | **Christoph Kueffer**[2,15] | **Angeliki F. Martinou**[16] | **Wolfgang Nentwig**[17] | **Jan Pergl**[18] | **Petr Pyšek**[18,19] | **Wolfgang Rabitsch**[20] | **David M. Richardson**[2] | **Helen E. Roy**[21] | **Wolf-Christian Saul**[9,10,11] | **Riccardo Scalera**[22] | **Montserrat Vilà**[23] | **John R. U. Wilson**[2,24] | **Sabrina Kumschick**[2,24]

[1]Department of Biology, University of Fribourg, Fribourg, Switzerland

[2]Centre for Invasion Biology, Department of Botany & Zoology, Stellenbosch University, Matieland, South Africa

[3]Department of Genetics, Evolution & Environment, Centre for Biodiversity and Environment Research, UCL, London, UK

[4]Institute of Zoology, Zoological Society of London, Regent's Park, London, UK

[5]School of Biological Sciences and the Environment Institute, University of Adelaide, North Terrace, SA, Australia

[6]Division of Conservation Biology, Vegetation and Landscape Ecology, Faculty Centre of Biodiversity, University of Vienna, Vienna, Austria

[7]Institute for Environmental Protection and Research, and Chair IUCN SSC Invasive Species Specialist Group, Rome, Italy

[8]Natural Resources Institute Finland (Luke), Economics and Society, Helsinki, Finland

[9]Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany

[10]Department of Biology, Chemistry, Pharmacy, Institute of Biology, Freie Universität Berlin, Berlin, Germany

[11]Berlin-Brandenburg Institute of Advanced Biodiversity Research (BBIB), Berlin, Germany

[12]The Food and Environment Research Agency, Sand Hutton, UK

[13]Institute of Environmental Sustainability, Loyola University Chicago, Chicago, IL, USA

[14]CABI, Delémont, Switzerland

[15]Institute of Integrative Biology, ETH Zurich, Zurich, Switzerland

[16]Joint Services Health Unit, RAF Akrotiri, Akrotiri, Cyprus

[17]Institute of Ecology and Evolution, University of Bern, Bern, Switzerland

[18]Department of Invasion Ecology, Institute of Botany, The Czech Academy of Sciences, Průhonice, Czech Republic

[19]Department of Ecology, Faculty of Science, Charles University, Prague, Czech Republic

[20]Environment Agency Austria, Vienna, Austria

[21]Centre for Ecology & Hydrology, Benson Lane, Wallingford, UK

[22]IUCN/SSC Invasive Species Specialist Group, Rome, Italy

[23]Estación Biológica de Doñana (EBD-CSIC), Sevilla, Spain

[24]South African National Biodiversity Institute, Cape Town office, Claremont, South Africa

Correspondence
Sven Bacher
Email: sven.bacher@unifr.ch

Abstract

1. Many alien taxa are known to cause socio-economic impacts by affecting the different constituents of human well-being (security; material and non-material assets; health; social, spiritual and cultural relations; freedom of choice and action). Attempts to quantify socio-economic impacts in monetary terms are unlikely to provide a useful basis for evaluating and comparing impacts of alien taxa because

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they are notoriously difficult to measure and important aspects of human well-being are ignored.

2. Here, we propose a novel standardised method for classifying alien taxa in terms of the magnitude of their impacts on human well-being, based on the capability approach from welfare economics. The core characteristic of this approach is that it uses changes in peoples' activities as a common metric for evaluating impacts on well-being.
3. Impacts are assigned to one of five levels, from Minimal Concern to Massive, according to semi-quantitative scenarios that describe the severity of the impacts. Taxa are then classified according to the highest level of deleterious impact that they have been recorded to cause on any constituent of human well-being. The scheme also includes categories for taxa that are not evaluated, have no alien population, or are data deficient, and a method for assigning uncertainty to all the classifications. To demonstrate the utility of the system, we classified impacts of amphibians globally. These showed a variety of impacts on human well-being, with the cane toad (*Rhinella marina*) scoring Major impacts. For most species, however, no studies reporting impacts on human well-being were found, i.e. these species were data deficient.
4. The classification provides a consistent procedure for translating the broad range of measures and types of impact into ranked levels of socio-economic impact, assigns alien taxa on the basis of the best available evidence of their documented deleterious impacts, and is applicable across taxa and at a range of spatial scales. The system was designed to align closely with the Environmental Impact Classification for Alien Taxa (EICAT) and the Red List, both of which have been adopted by the International Union of Nature Conservation (IUCN), and could therefore be readily integrated into international practices and policies.

KEYWORDS
alien species, capability approach, human well-being, impacts, socio-economy

1 | INTRODUCTION

Biological invasions are a major driver of global change and can cause high costs to recipient environments and socio-economies (Bellard, Cassey, & Blackburn, 2016; MEA, 2005; Pimentel, Zuniga, & Morrison, 2005). However, the impacts caused by alien species vary markedly between species and contexts (Kumschick, Bacher, et al., 2015; Kumschick, Gaertner, et al., 2015; Pyšek et al., 2012; Ricciardi & Cohen, 2007), and there is substantial debate as to their severity and scale (Davis et al., 2011; Simberloff et al., 2011, 2013). A challenge for invasion science is to provide transparent and comparable measures of impact based on clear and explicit definitions (Hulme et al., 2013; Jeschke et al., 2014). What has largely been missing from the invasion science toolbox is a standard method for quantifying impacts using a common metric so that they can be compared across impact types, regions or species (Nentwig, Kühnel, & Bacher, 2010). Such a method is essential to ensure that the documentation of impacts of alien taxa is objective, transparent and can underpin efforts to prioritise species for policy and management. In this context, prioritisation is defined as the process of ranking alien taxa for determining their relative impacts, both environmental and socio-economic, and implementing necessary management actions (McGeoch et al., 2016). As such, the adoption of this method may contribute to key global policy measures aimed at addressing the problems associated with biological invasions, such as the Convention on Biological Diversity's (CBD) Strategic Plan for Biodiversity 2020 and associated Aichi Target 9 for biological invasions (UNEP, 2011).

A pragmatic solution for comparing diverse environmental impacts was recently developed: the Environmental Impact Classification for Alien Taxa (EICAT) (Blackburn et al., 2014; Hawkins et al., 2015). EICAT translates impacts caused through a broad range of mechanisms into five ranked levels of impact from "Minimal Concern" to "Massive." As these are measured in the same metric (impact on native biodiversity from individuals to communities), the magnitude of different impacts can be directly, consistently and transparently compared. EICAT is receiving increasing international support and has recently been adopted by the IUCN (https://portals.iucn.org/congress/motion/014; accessed 20 April 2017).

Environmental impact classification for alien taxa focuses on environmental impacts only. However, alien species are also known to have socio-economic impacts which should also be accounted for in any management decision (Crowley, Hinchliffe, & McDonald, 2017). This suggests the urgent need to develop a system to assess the full socio-economic impacts of alien taxa. Such a system may also help differentiate social and environmental impacts despite the obvious interconnections between humans and their environments (Crowley et al., 2017) and to address synergies and trade-offs between these impact types.

In Europe, more alien taxa are documented as causing socio-economic than ecological impacts, probably because the former are more readily perceived and are immediately reported by concerned people (Vilà et al., 2010). Although there is some correlation between environmental and socio-economic impacts across species (Kumschick, Bacher, et al., 2015), socio-economic impacts cannot reliably be inferred from their impact on the environment, e.g. the tiger mosquito (*Aedes albopictus*) probably has a relatively low impact on biodiversity, but clearly a very high impact on human health. However, no robust and unified solution is available for comparing socio-economic impacts among alien taxa. Most attempts to quantify and compare these involve utilitarian approaches of monetising their costs (Born, Rauschmayer, & Bräuer, 2005; Reinhardt, Herle, Bastiansen, & Streit, 2003; Zavaleta, 2000). This seems an obvious route for quantifying socio-economic impacts. Yet it is unlikely that monetising impacts will provide a useful basis for comparison because converting all impacts into monetary costs is difficult, if not impossible (Hoagland & Jin, 2006). For example, the most comprehensive attempt to quantify the costs of alien taxa in the European Union came up with a total estimate of 12.5 billion Euros/year (Kettunen et al., 2009). The authors were careful to emphasise that this is a minimum estimate because many species and impacts were excluded. Moreover, monetary estimates of socio-economic costs vary considerably depending on the accounting method used (Born et al., 2005). In particular, such values are often derived solely from management costs and research (Scalera, 2010). While costs associated with management can often be readily calculated (e.g. pesticide costs, human labour), they do not allow a straightforward assessment of a species' impacts before or without control, and they are highly context-dependent (e.g. wages may vary widely between different countries). Furthermore, socio-economic impacts of alien taxa can be more appropriately reduced by technology or adaptive behaviour in affluent countries as opposed to poor countries where alien taxa can, in extreme cases, lead to the collapse of socio-economic sectors, thereby causing irreversible societal changes. Utilitarian approaches have difficulties in capturing such context dependence. But more importantly, many aspects of human life that alien taxa could impact upon (e.g. health, security, culture) are usually not included when monetising impacts.

To capture the full socio-economic impacts of an alien taxon, dimensions that go beyond monetary costs must be considered (Turnhout, Waterton, Neves, & Buizer, 2013). This is why it seems most promising to concentrate on changes in peoples' well-being as described by how they are being impacted by changes in their environment (including the influence of alien taxa). It has been shown that human well-being is context-dependent and should not be assessed solely in terms of wealth (Diener & Seligman, 2004). Moreover, it depends to a large extent on peoples' position relative to their opportunities (capabilities) rather than on absolute values (Diener & Seligman, 2004). Pejchar and Mooney (2009) suggested that the most appropriate measure of socio-economic impact of alien taxa should take into account the number of people affected and the magnitude of the impact on their lives, i.e. on their well-being.

Previous attempts to unify socio-economic impacts in a comparable metric other than money (e.g. GISS: Nentwig et al., 2010; Harmonia+: D'hondt et al., 2015) are based on variable descriptions of different impact scenarios. This makes comparisons between categories of socio-economic impacts difficult. We propose a novel standardised system based on human well-being for classifying alien taxa in terms of their socio-economic impacts. This system aims to be a practical tool that can: (1) be used to identify the magnitude of socio-economic impacts of alien taxa; (2) considers the context dependency of impacts, thereby facilitating comparisons of impacts among regions and taxa; (3) facilitates predictions of potential future impacts of the species in the target region and elsewhere; and (4) aids in the prioritisation of alien taxa and relevant introduction pathways for management actions. The proposed Socio-Economic Impact Classification for Alien Taxa (SEICAT) has the same key properties as (and is thus complementary to) the EICAT scheme (Blackburn et al., 2014). Like EICAT, SEICAT focuses on deleterious impacts, and classifies species on the basis of the best available evidence of their most severe documented impacts in regions to which they have been introduced. The goal of SEICAT is not to weigh deleterious against beneficial impacts to determine the net value of an introduction of an alien taxon, but rather to highlight potential consequences. It provides a consistent procedure for translating the broad range of impact types and measures into ranked levels of socio-economic impact, and is applicable across taxa and at various spatial scales.

2 | THEORETICAL BACKGROUND AND THE NEED FOR A PRAGMATIC APPROACH

Many multidimensional indices of well-being have been developed, most of them for assessments of poverty (Decancq & Lugo, 2013). However, as far as we know, none specifically assess changes to human well-being via changes in the environment. Our framework is based on the capability approach to assess human well-being in welfare economics and social sciences (Robeyns, 2011; Sen, 1999). This approach has become a paradigm in human development policy. It has inspired, among other things, the creation of the human development index of the United Nations (Anand, 1994), and has been identified as a promising approach for evaluating effects of environmental changes on society (Hicks et al., 2016).

The core characteristic of this approach is its focus on what people are able to do and to be in their life, i.e. on their general capabilities. Examples include peoples' opportunities to be educated, and their ability to move around and enjoy supportive social relationships (Robeyns, 2011). A person's set of capabilities is determined by environmental factors, economic settings, and social context (Figure 1a). Of the given opportunities (capabilities), people choose a set of activities to engage in (their realised activities) according to their personal and cultural preferences. The capabilities are strongly linked to peoples' well-being (Sen, 1999).

Alien taxa can influence peoples' capabilities and realised activities via changes in environmental factors, economic settings, or the social context (Figure 1b). Thereby, different constituents of human well-being may be affected: security; material and immaterial assets; health; and social, spiritual and cultural relations (Table 1; Narayan, Chambers, Shah, & Petesch, 2000, Pejchar & Mooney, 2009). These constituents are analogous to the impact mechanisms in EICAT (Blackburn et al., 2014). The overarching premise for all constituents is the freedom of choice and action, i.e. the opportunity to be able to achieve what a person values doing and being. For example, the introduction of a new crop into a region where many people are undernourished can enlarge the capabilities of people by improving their health and access to material assets; this enables them to invest more time into preferred activities. In contrast, introduction of crop pests generally reduces the capability set of people because people would have to spend more resources (material and immaterial assets, e.g. time, money) to compensate for the losses, switch to less preferred crops that are not attacked by the pest, causing losses which may prevent e.g. their ability to send children to school. Such impacts would be perceived as detrimental.

Moreover, an alien taxon can affect not only the whole set of potential activities directly, but can also influence the activities that are actually realised. For example, stinging alien animals (e.g. wasps, mosquitoes, jellyfish) can make areas unsuitable for outdoor activities by threatening human health (thereby reducing the capability set), but they can also indirectly (by threatening human safety) reduce the frequency of outdoor activities at sites where there are no aliens because of the fear of getting stung (thereby reducing the realised activities within the available capability set).

3 | QUANTIFYING THE IMPACT OF ALIEN TAXA ON HUMAN WELL-BEING

In practice, we cannot measure the complete set of peoples' capabilities and how they have been changed by an alien taxon, because many opportunities are not realised and thus remain unrecognised. However, what is ultimately important for human well-being is how much the realised activities of people have changed (Robeyns, 2005). Focusing on the magnitude of changes in realised activities due to alien taxa facilitates the comparison of their impacts on well-being at various spatial scales and in societies with different backgrounds.

We define an activity as any human endeavour that is, or could be, affected in its entirety by an alien taxon. This includes agriculture, hunting, recreation, industry, tourism, and so on. Defining activities is critical to the use of SEICAT, and will inevitably be different across different regions. A relatively straightforward possible consideration is to choose activities according to the nature of the impact of an alien taxon such that all people in the focal region participating in the activity can be considered as being potentially affected. In some regions, agriculture might be a relatively minor activity, and so it can be considered as a single activity affected in its entirety by the alien taxon. In other regions it might be necessary to consider different types of agriculture (e.g. cereal, market vegetables, livestock) as separate activities. It should also be remembered that people engage in multiple activities at a time and through time.

Impact assessments should always refer to a well-defined area (focal region); this may be a country, continent or some other geographically restricted area in which the alien taxon occurs (Blackburn et al., 2014). Within this region, SEICAT users may choose to weigh activities differently to account for different values placed upon them by society. This can ensure that, for example, the total loss of an activity

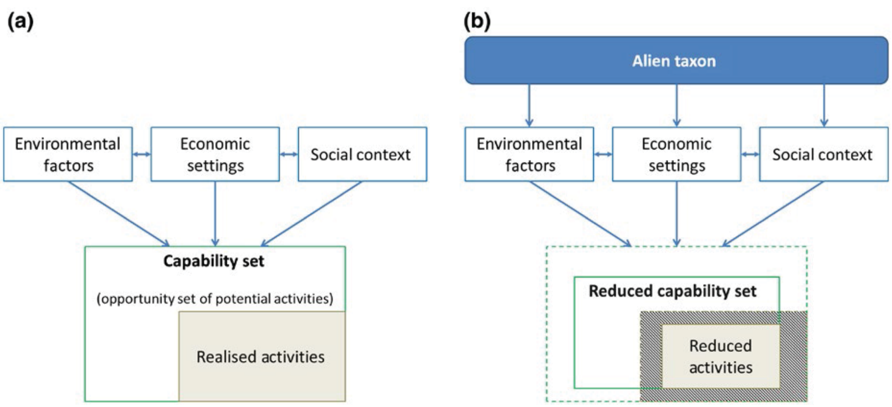

FIGURE 1 (a) A person's capability set depends on environmental factors, economic settings (goods & services), and the social context. From this set, people select the activities they want to achieve (realised activities). (b) Alien taxa can reduce peoples' opportunities via changes in environmental factors, economic settings or the social context. Socio-Economic Impact Classification for Alien Taxa (SEICAT) defines negative impacts as losses in realised activities attributable to an alien taxon (black hatched area)

TABLE 1 Constituents of human well-being and examples of their subcategories (after MEA, 2005). The overarching premise for all constituents is the freedom of choice and action, i.e. the opportunity to be able to achieve what a person values doing and being

Constituents of human well-being	Examples
Safety	Personal safety
	Secure resource access
	Security from disasters
Material and immaterial assets	Adequate livelihoods
	Sufficient nutritious food
	Shelter
	Access to goods
Health	Strength
	Feeling well
	Access to clean air and water
Social, spiritual and cultural relations	Social, spiritual and cultural practice
	Mutual respect
	Friendship

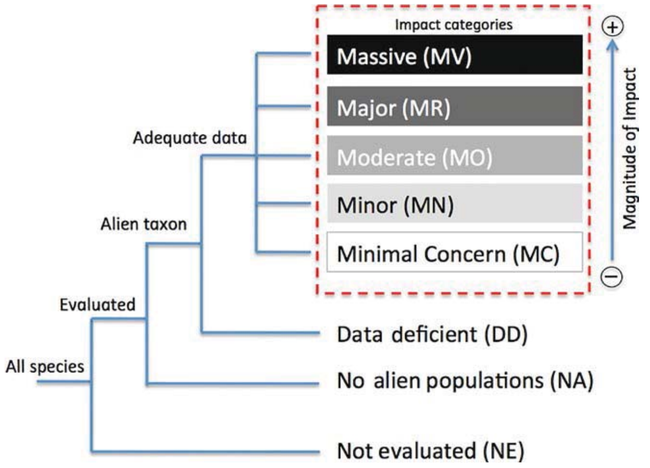

FIGURE 2 Socio-Economic Impact Classification of Alien Taxa (SEICAT) (after Blackburn et al., 2014; Hawkins et al., 2015). Detailed descriptions of the classes are given in Table 2

engaged in by very few people could be appropriately assessed against a less severe impact that affects many people. More details about these and other practical considerations involved in implementing SEICAT are described in the Supporting Information.

We define eight categories into which alien taxa can be classified according to the magnitude of changes in peoples' realised activities (Figure 2), detailed definitions of which are given in Table 2. This classification is analogous to the IUCN Red List and EICAT schemes (Blackburn et al., 2014; Hawkins et al., 2015; Mace et al., 2008). Five of the categories follow a sequential series of impact levels described by semi-quantitative scenarios. These were designed so that each step change in category reflects an increase in the order of magnitude of the particular impact; a new level of social organization is involved at each step. The remaining categories are not evaluated (NE; for taxa that have not yet been assessed), no alien population (NA; for taxa that have no known alien population), and data deficient (DD; alien taxa for which there is no information on impacts).

Alien taxa can have impacts on activities through effects on any of the constituents of human well-being (Table 1), similar to environmental impacts being potentially caused through several mechanisms in EICAT. During an assessment, all available evidence is gathered on socio-economic impacts of an alien taxon in its introduced range. For the final classification of the alien taxon, the highest deleterious impact level through any of the constituents of human well-being on an activity is reported.

4 | REPORTING

Since the proposed impact classification regards the whole socio-economic system as one entity determining human well-being, the maximum score found in any of the activities assessed is decisive for the final outcome (analogous to EICAT; Blackburn et al., 2014). It is, however, recommended that the magnitude of impacts on all activities affected by the alien taxon be reported to allow other ways of summarising the results, e.g. as systematic reviews, or frequency distribution of SEICAT scores. It should also be reported which constituents of well-being are affected by each impact. Furthermore, different activities might be of interest to different stakeholders involved in decisions made regarding the management of alien taxa. Since the (perceived) impact of a species can change over time (Strayer, Eviner, Jeschke, & Pace, 2006), we suggest reporting the current maximum impact score and the maximum score ever achieved in history (Hawkins et al., 2015). The latter is a proxy of the potential maximum impact the species can achieve. It should be noted that some alien taxa have positive impacts on human well-being and can increase peoples' capabilities which would become apparent through an increase in selected activities (e.g. Pienkowski, Williams, McLaren, Wilson, & Hockley, 2015). These positive impacts need to be taken into account when making management decisions, but are not scored in SEICAT. However, SEICAT could provide a framework for scoring such positive impacts on human well-being.

5 | PROPERTIES OF THE CLASSIFICATION

Socio-Economic Impact Classification for Alien Taxa provides a common metric for all detrimental effects caused by alien taxa on socio-economy. In contrast to other schemes that rely on monetary values, it assesses the entire spectrum of possible impacts on human well-being and social structures. SEICAT provides a process for translating the broad range of impact measures into ranked levels according to observed changes in peoples' activities. It therefore allows distinction between taxa with different magnitudes of impact and provides a framework for comparing

TABLE 2 Description of Socio-Economic Impact Classification of Alien Taxa (SEICAT) according to observed changes in peoples' activities

Impact classification	Description
Minimal concern (MC)	No deleterious impacts reported despite availability of relevant studies with regard to its impact on human well-being. Taxa that have been evaluated under the SEICAT process but for which impacts have not been assessed in any study should not be classified in this category, but rather should be classified as data deficient
Minor (MN)	Negative effect on peoples' well-being, such that the alien taxon makes it difficult for people to participate in their normal activities. Individual people in an activity suffer in at least one constituent of well-being (i.e. security; material and non-material assets; health; social, spiritual and cultural relations). Reductions of well-being can be detected through e.g. income loss, health problems, higher effort or expenses to participate in activities, increased difficulty in accessing goods, disruption of social activities, induction of fear, but no change in activity size is reported, i.e. the number of people participating in that activity remains the same
Moderate (MO)	Negative effects on well-being leading to changes in activity size, fewer people participating in an activity, but the activity is still carried out. Reductions in activity size can be due to various reasons, e.g. moving the activity to regions without the alien taxon or to other parts of the area less invaded by the alien taxon; partial abandonment of an activity without replacement by other activities; or switch to other activities while staying in the same area invaded by the alien taxon. Also, spatial displacement, abandonment or switch of activities does not increase human well-being compared to levels before the alien taxon invaded the region (no increase in opportunities due to the alien taxon)
Major (MR)	Local disappearance of an activity from all or part of the area invaded by the alien taxon. Collapse of the specific social activity, switch to other activities, or abandonment of activity without replacement, or emigration from region. Change is likely to be reversible within a decade after removal or control of the alien taxon. "Local disappearance" does not necessarily imply the disappearance of activities from the entire region assessed, but refers to the typical spatial scale over which social communities in the region are characterised (e.g. a human settlement)
Massive (MV)	Local disappearance of an activity from all or part of the area invaded by the alien taxon. Change is likely to be permanent and irreversible for at least a decade after removal of the alien taxon, due to fundamental structural changes of socio-economic community or environmental conditions ("regime shift")
Data deficient (DD)	There is no information to classify the taxon with respect to its impact, or insufficient time has elapsed since introduction for impacts to have become apparent

impacts among taxa, mechanisms, particular introduction/invasion events and regions. Analogous to EICAT, SEICAT can be used to flag species with high potential impacts. However, the context-dependency of impacts should be considered when transferring impacts from one region to another (see Supporting Information).

The classification is dynamic and should be based on the best available evidence. Hence, species can move between impact categories as new data become available, for example if the quality of evidence improves, socio-economic or environmental conditions change, an invasion proceeds or is successfully managed. The classification can handle the lack of knowledge on some components of well-being, because it uses the maximum known impact. It thus identifies knowledge gaps and helps focus research to improve impact classification over time (see Supporting Information). The SEICAT protocol can be applied to assess impacts at a range of spatial scales, allowing national, continental, and global categorisation of impacts. It can therefore inform national or global assessment schemes in which species are assigned to management lists depending on their impacts (see Supporting Information). Finally, SEICAT considers only impacts on human well-being, but in combination with EICAT it is possible to assess environmental and socio-economic impacts in concert, thus evaluating the complete spectrum of deleterious impacts of alien taxa.

6 | CONGRUENCY OF SEICAT AND EICAT

The properties of SEICAT align with those of EICAT, mostly due to their structural similarity. The assessment units in EICAT are the native species in the local communities, and the irreversible loss of a native species from the local community is regarded as a Massive environmental impact. Similarly, the assessment units in SEICAT are human activities. Consequently, the complete irreversible loss of an activity (e.g. cereal farming) caused by an alien taxon from a local social community (e.g. a human settlement) is considered as a Massive impact on human well-being. In EICAT, impacts accumulate through different impact mechanisms, whereas in SEICAT impacts accrue at the level of constituents of human well-being (Table 1). Combining the two classification schemes for a complete assessment of negative effects on the recipient systems can inform evidence-based listing processes (e.g. Kumschick, Blackburn, & Richardson, 2016). For example, alien taxa that score high in both schemes can be identified and prioritised for management actions. Also, different stakeholder groups might weigh environmental and socio-economic impacts differently allowing them to use different weights for EICAT and SEICAT scores according to their needs or beliefs. Both SEICAT and EICAT follow a similar approach to that used in the widely adopted Red Listing approach of the IUCN, which paves the way for integration with existing management and policy procedures.

7 | APPLICATION

To illustrate the applicability and usefulness of SEICAT, we assessed all alien amphibians globally (104 species; Measey et al., 2016). In addition, to the references found by Measey et al. (2016), we supplemented their literature search focussing only on socio-economic impacts. We used the scientific species name as a search term in databases such as Google Scholar, ISI Web of Knowledge and databases specific to amphibians and alien species, manually filtering through the sources identified by reading titles and (if applicable) abstracts. We then looked for references in the resulting sources until no further records of impact were found. Suitable data for socio-economic impacts was found in 20 articles/reports for 44 impacts involving 7 species (Table S1). Impacts covered almost all impact classes: the cane toad, *Rhinella marina*, was the only species scoring MR, affecting several constituents of human well-being but most importantly leading to abandonment of certain cultural practices in Aboriginal communities in Australia due to the loss of totem species (Van Dam, Walden, & Begg, 2002). However, these impacts were considered to be reversible after control of the toad and thus we currently did not classify these as MV. The Asian common toad, *Duttaphrynus melanostictus*, has been reported to have caused death of a child in Timor after eating a toad meal; however no further changes in social activities were reported (Trainor, 2009). This consequently resulted in a classification as MO (fewer people participating in activities). We acknowledge that the death caused by an alien taxon might lead to a change in the activities of other people, but such changes are rarely reported. A major reason for the lack of reporting is probably that impacts through e.g. food poisoning caused by eating toxic animals and plants can be easily avoided and are therefore not causes of major concern for human well-being in most regions despite their potentially severe consequences. This is in contrast to risks that cannot be directly controlled, e.g. exposure to allergenic pollen produced by an alien plant. Such less controllable risks can have much more far-reaching impacts on human well-being and affect larger parts of societies. Three species were classified as MN: the coqui frog, *Eleutherodactylus coqui*, is widely reported to have large socio-economic impacts due to noise pollution, but the only impact on human activities which was reported was a decline in property trade due to increased real-estate prices in affected areas in Hawaii (Kaiser & Burnett, 2006). Thus, houses are still being sold and traded, but the activity of property trade is not doing as well when the frog is present. Also, human health might be affected by the noise levels, but reports were lacking. A congener of the coqui frog, *Eleutherodactylus planirostris*, affects the nursery trade as plant shipments need to be treated. However, no other effects on trade were reported, and the activity did not seem to be reduced, but was just more onerous (Olson, Beard, & Pitt, 2012). Various minor impacts were also reported for *Osteopilus septentrionalis* (Johnson, 2007; see Table S1). In the case of *Hyla meridionalis*, it was reported that they cause a "deafening noise" (assuming this is not meant literally), without mention of any impacts on e.g. human health or activities being negatively affected in any specific way (Cheylan, 1983); therefore, this was classified as MC. The African clawed frog, *Xenopus leavis*, was classified as data deficient (DD) because the only impact reports were from the native range where it can affect fisheries. A further 98 species for which no studies on their impacts were found were also classified as DD (Table S1), and all other amphibians had no record of alien populations and were consequently classified as NA (not listed).

Most classifications (with the exception of *E. coqui*) were of low confidence due to the nature of the reports, which were mainly based on anecdotal observations and statements from affected people, but better quality studies are lacking. It is expected that such reports currently constitute the main evidence of impacts on human well-being until more systematic socio-economic studies that focus on changes in human activities due to alien taxa are done. General guidelines on how to conduct such studies are available (Palmer-Fry et al., 2017; Woodhouse, de Lange, & Milner-Gulland, 2016) and we hope that the publication of SEICAT triggers research in this direction. However, even with low quality data and in the presence of large uncertainties, SEICAT allowed a clear, meaningful, and transparent ranking of the species, with the cane toad causing the highest impact on human well-being, followed by the Asian common toad (whose impacts can be largely avoided), while other amphibians caused only minor or negligible impacts.

Comparing SEICAT and EICAT scores for amphibians for which both classifications are available (Table 3) shows that the scores are identical in only one species and that in general there is no good correlation between both scores. In most species, the EICAT scores were higher than the SEICAT scores, indicating that amphibians might tend to have stronger impacts on the environment than on human well-being (assuming that EICAT and SEICAT classifications can be considered as equivalent). However, because some species have larger environmental impacts and others higher impacts on human well-being it is not possible to forecast socio-economic impact from environmental impacts accurately (a simple regression

TABLE 3 Socio-economic (this paper) and environmental impact (Kumschick et al., 2017) classification of alien amphibians

	SEICAT	Confidence	EICAT	Confidence
Rhinella marina	MR	Low	MR	High
Duttaphrynus melanostictus	MO	Low	MR	Low
Eleutherodactylus coqui	MN	High	MO	High
Eleutherodactylus planirostris	MN	Low	MC	Medium
Hyla meridionalis	MC	Low	MO	Low
Osteopilus septentrionalis	MN	Low	MO	Low

SEICAT, socio-economic impact classification of alien taxa; EICAT, environmental impact classification for alien taxa; MR, major; MO, moderate; MN, minor; MC, minimal concern.

model assuming no correlation between the two scores actually fits better than a model assuming a linear relationship). It is currently not well understood which species have high or low impacts and which are more likely to affect the environment or socio-economy, but classification systems such as SEICAT and EICAT could be used to link such patterns to traits to understand and forecast species with different types of impact.

8 | CONCLUSION AND OUTLOOK

Considerable progress has been made recently on the quantification and classification of environmental impacts of alien taxa (e.g. Blackburn et al., 2014; Hawkins et al., 2015; Kumschick, Bacher, et al., 2015; Kumschick, Gaertner, et al., 2015) but assessing their effects on human well-being remains a challenge. Possible exceptions are purely economic pests such as agricultural pests (Simberloff et al., 2013) or species affecting human health (Rabitsch, Essl, & Schindler, 2017). There is a general demand for socio-economic impacts to be included in the decision making process on the legal regulation of alien taxa in trade, e.g. under the new EU Regulation (1143/2014) on invasive alien species, when justification for prioritising species is needed. Additionally, changes in SEICAT assessments over time (similar to the Red List Index of Invasive Alien Species from the Biodiversity Indicators Partnership; https://www.bipindicators.net/indicators/red-list-index/red-list-index-impacts-of-invasive-alien-species) could be used for developing an indicator of trends in socio-economic impacts, which is of crucial importance to guide policy and management decisions (Latombe et al., 2017; Rabitsch et al., 2016). Furthermore, socio-economic analyses can engage the public in ways that information on environmental impacts does not (Genovesi, Carboneras, Vilà, & Walton, 2014; Simberloff et al., 2013), thereby clarifying the framing of alien species problems (Woodford et al., 2016).

The global assessment of socio-economic impacts of alien amphibians shows that it is possible to differentiate between alien species with different levels of impacts meaningfully, even in the presence of uncertainty. The assessment also reveals that many impact descriptions are of low quality leading to classifications with low certainty and that for some suspected impact mechanisms information is not reported (e.g. presumed health effects due to noise). Furthermore, for the majority of species, no socio-economic assessments were reported, and they have to be classified as DD for the moment. The current classification, although useful, is dynamic and should therefore be seen as a starting point; species' classifications might change in the future as more and better data become available. As is the case with other classifications (e.g. Red List, EICAT), SEICAT classifications should therefore be regularly revised and updated.

In summary, SEICAT can aid policy makers creating policies for alien taxa and allocating funds to prevention and control programmes (Scalera, 2010) as well as research activities (e.g. by identifying knowledge gaps, traits of species with high impacts etc.). Assessments can also be used as transparent and consistent indicators to raise awareness on alien taxa and to strengthen public support for policy measures (Smeets & Weterings, 1999).

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AUTHORS' CONTRIBUTIONS

S.B. and S.K. conceived the ideas and designed methodology, S.K. classified the amphibians, S.B. wrote the first draft of the paper, and all authors contributed to ideas and critically reviewed and edited the manuscript and gave final approval for publication.

COMPETING INTERESTS

The authors have declared that no competing interests exist.

DATA ACCESSIBILITY

Data deposited in the Dryad Digital repository http://datadryad.org/resource/doi:10.5061/dryad.4g622. (Bacher et al., 2017).

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