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1 **Socio-economic impact classification of alien taxa (SEICAT)**

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49 SB and SK conceived the ideas and designed methodology, SK classified the amphibians, SB wrote the
50 first draft of the paper, and all authors contributed to ideas and critically reviewed and edited the
51 manuscript and gave final approval for publication.

52 **Competing Interests**

53 The authors have declared that no competing interests exist.

54

55 **Abstract**

56 1. Many alien taxa are known to cause socio-economic impacts by affecting the different constituents
57 of human well-being (security; material and immaterial assets; health; social, spiritual and cultural
58 relations; freedom of choice and action). Attempts to quantify socio-economic impacts in monetary
59 terms are unlikely to provide a useful basis for evaluating and comparing impacts of alien taxa
60 because they are notoriously difficult to measure and important aspects of human well-being are
61 ignored.

62 2. Here we propose a novel standardised method for classifying alien taxa in terms of the magnitude
63 of their impacts on human well-being, based on the capability approach from welfare economics. The
64 core characteristic of this approach is that it uses changes in peoples' activities as a common metric
65 for evaluating impacts on well-being.

66 3. Impacts are assigned to one of five levels, from Minimal Concern to Massive, according to semi-
67 quantitative scenarios that describe the severity of the impacts. Taxa are then classified according to
68 the highest level of deleterious impact that they have been recorded to cause on any constituent of
69 human well-being. The scheme also includes categories for taxa that are Not Evaluated, have No
70 Alien Population, or are Data Deficient, and a method for assigning uncertainty to all the
71 classifications. To demonstrate the utility of the system, we classified impacts of amphibians globally.
72 These showed a variety of impacts on human well-being, with the cane toad (*Rhinella marina*)
73 scoring Major impacts. For most species, however, no studies reporting impacts on human well-being
74 were found, i.e. these species were Data Deficient.

75 4. The classification provides a consistent procedure for translating the broad range of measures and
76 types of impact into ranked levels of socio-economic impact, assigns alien taxa on the basis of the
77 best available evidence of their documented deleterious impacts, and is applicable across taxa and at
78 a range of spatial scales. The system was designed to align closely with the Environmental Impact

79 Classification for Alien Taxa (EICAT) and the Red List, both of which have been adopted by the
80 International Union of Nature Conservation (IUCN), and could therefore be readily integrated into
81 international practices and policies.

82 **Key words:** alien species, impacts, human well-being, capability approach, socio-economy

83 *Introduction*

84 Biological invasions are a major driver of global change and can cause high costs to recipient
85 environments and socio-economies (Pimentel et al. 2005; MEA 2005; Bellard et al. 2016). However,
86 the impacts caused by alien species vary markedly between species and contexts (Ricciardi & Cohen
87 2007; Pyšek et al. 2012; Kumschick et al. 2015a,b), and there is substantial debate as to their severity
88 and scale (Davis et al. 2011, Simberloff et al. 2011, 2013). A challenge for invasion science is to
89 provide transparent and comparable measures of impact based on clear and explicit definitions
90 (Hulme et al. 2013, Jeschke et al. 2014). What has largely been missing from the invasion science
91 toolbox is a standard method for quantifying impacts using a common metric so that they can be
92 compared across impact types, regions or species (Nentwig et al. 2010). Such a method is essential to
93 ensure that the documentation of impacts of alien taxa is objective, transparent and can underpin
94 efforts to prioritise species for policy and management. In this context, prioritisation is defined as the
95 process of ranking alien taxa for the purpose of determining their relative impacts, both
96 environmental and socio-economic, and implementing necessary management actions (McGeoch et
97 al. 2016). As such, the adoption of this method may contribute to key global policy measures aimed
98 at addressing the problems associated with biological invasions, such as the Convention on Biological
99 Diversity's (CBD) Strategic Plan for Biodiversity 2020 and associated Aichi Target 9 for biological
100 invasions (UNEP, 2011).

101

102 A pragmatic solution for comparing diverse environmental impacts was recently developed: the
103 Environmental Impact Classification for Alien Taxa, or EICAT (Blackburn et al. 2014; Hawkins et al.
104 2015). EICAT translates impacts caused through a broad range of mechanisms into five ranked levels
105 of impact from “Minimal Concern” to “Massive”. As these are measured in the same metric (impact
106 on native biodiversity from individuals to communities), the magnitude of different impacts can be
107 directly, consistently and transparently compared. EICAT is receiving increasing international support

108 and has recently been adopted by the IUCN (<https://portals.iucn.org/congress/motion/014>; accessed
109 20 April 2017).

110

111 EICAT focuses on environmental impacts only. However, alien species are also known to have socio-
112 economic impacts which should also be accounted for in any management decision (Crowley et al.
113 2017). This suggests the urgent need to develop a system to assess the full socio-economic impacts
114 of alien taxa. Such a system may also help differentiate social and environmental impacts despite the
115 obvious interconnections between humans and their environments (Crowley et al. 2017) and to
116 address synergies and trade-offs between these impact types.

117

118 In Europe, more alien taxa are documented as causing socio-economic than ecological impacts,
119 probably because the former are more readily perceived and are immediately reported by concerned
120 people (Vilà et al. 2010). Although there is some correlation between environmental and socio-
121 economic impacts across species (Kumschick et al. 2015b), socio-economic impacts cannot reliably be
122 inferred from their impact on the environment, e.g. the tiger mosquito (*Aedes albopictus*) probably
123 has a relatively low impact on biodiversity, but clearly a very high impact on human health. However,
124 no robust and unified solution is available for comparing socio-economic impacts among alien taxa.
125 Most attempts to quantify and compare these involve utilitarian approaches of monetising their
126 costs (Zavaleta 2000; Reinhard et al. 2003, Born et al. 2005). This seems an obvious route for
127 quantifying socio-economic impacts. Yet it is unlikely that monetising impacts will provide a useful
128 basis for comparison because converting all impacts into monetary costs is difficult, if not impossible
129 (Hoagland & Jin 2006). For example, the most comprehensive attempt to quantify the costs of alien
130 taxa in the European Union came up with a total estimate of 12.5 billion Euros/year (Kettunen et al.
131 2010). The authors were careful to emphasise that this is a minimum estimate because many species
132 and impacts were excluded. Moreover, monetary estimates of socio-economic costs vary

133 considerably depending on the accounting method used (Born et al. 2005). In particular, such values
134 are often derived solely from management costs and research (Scalera 2010). While costs associated
135 with management can often be readily calculated (e.g. pesticide costs, human labour), they do not
136 allow a straightforward assessment of a species' impacts before or without control, and they are
137 highly context-dependent (e.g. wages may vary widely between different countries). Furthermore,
138 socio-economic impacts of alien taxa can be more appropriately reduced by technology or adaptive
139 behaviour in affluent countries as opposed to poor countries where alien taxa can, in extreme cases,
140 lead to the collapse of socio-economic sectors, thereby causing irreversible societal changes.
141 Utilitarian approaches have difficulties in capturing such context dependence. But more importantly,
142 many aspects of human life that alien taxa could impact upon (e.g. health, security, culture) are
143 usually not included when monetising impacts.

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

154 Previous attempts to unify socio-economic impacts in a comparable metric other than money (e.g.
155 GISS: Nentwig et al. 2010; Harmonia+: D'hondt et al. 2015) are based on variable descriptions of
156 different impact scenarios. This makes comparisons between categories of socio-economic impacts
157 difficult. We propose a novel standardised system based on human well-being for classifying alien
158 taxa in terms of their socio-economic impacts. This system aims to be a practical tool that can: (i) be

159 used to identify the magnitude of socio-economic impacts of alien taxa; (ii) considers the context
160 dependency of impacts, thereby facilitating comparisons of impacts among regions and taxa; (iii)
161 facilitates predictions of potential future impacts of the species in the target region and elsewhere;
162 and (iv) aids in the prioritisation of alien taxa and relevant introduction pathways for management
163 actions. The proposed Socio-Economic Impact Classification for Alien Taxa (SEICAT) has the same key
164 properties as (and is thus complementary to) the EICAT scheme (Blackburn et al. 2014). Like EICAT,
165 SEICAT focuses on deleterious impacts, and classifies species on the basis of the best available
166 evidence of their most severe documented impacts in regions to which they have been introduced.
167 The goal of SEICAT, like other risk assessments, is not to weigh deleterious against beneficial impacts
168 to determine the net value of an introduction of an alien taxon, but rather to highlight potential
169 consequences. It provides a consistent procedure for translating the broad range of impact types and
170 measures into ranked levels of socio-economic impact, and is applicable across taxa and at various
171 spatial scales.

172

173 *Theoretical background and the need for a pragmatic approach*

174 Many multidimensional indices of well-being have been developed, most of them for assessments of
175 poverty (Decanq & Lugo 2013). However, as far as we know, none specifically assess changes to
176 human well-being via changes in the environment. Our framework is based on the capability
177 approach to assess human well-being in welfare economics and social sciences (Sen 1999, Robeyns
178 2011). This approach has become a paradigm in human development policy. It has inspired, among
179 other things, the creation of the Human Development Index (HDI) of the United Nations (Anand
180 1994), and has been identified as a promising approach for evaluating effects of environmental
181 changes on society (Hicks et al. 2016).

182 The core characteristic of this approach is its focus on what people are able to do and to be in their
183 life, i.e. on their general capabilities. Examples include peoples' opportunities to be educated, and

184 their ability to move around and enjoy supportive social relationships (Robeyns 2011). A people's set
185 of capabilities is determined by environmental factors, economic settings, and social context (Figure
186 1a). Of the given opportunities (capabilities), people choose a set of activities to engage in (their
187 realised activities) according to their personal and cultural preferences. The capabilities are strongly
188 linked to peoples' well-being (Sen 1999).

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

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

209

210 *Quantifying the impact of alien taxa on human well-being*

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

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

227 Impact assessments should always refer to a well-defined area (focal region); this may be a country,
228 continent or some other geographically restricted area in which the alien taxon occurs (Blackburn et
229 al. 2014). Within this region, SEICAT users may choose to weigh activities differently to account for
230 different values placed upon them by society. This can ensure that, for example, the total loss of an
231 activity engaged in by very few people could be appropriately assessed against a less severe impact
232 that affects many people. More details about these and other practical considerations involved in
233 implementing SEICAT are described in the Supporting Information.

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

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

249

250 *Reporting*

251 Since the proposed impact classification regards the whole socio-economic system as one entity
252 determining human well-being, the maximum score found in any of the activities assessed is decisive
253 for the final outcome (analogous to EICAT; Blackburn et al. 2014). It is, however, recommended that
254 the magnitude of impacts on all activities affected by the alien taxon be reported to allow other ways
255 of summarising the results, e.g. as systematic reviews, or frequency distribution of SEICAT scores. It
256 should also be reported which constituents of well-being are affected by each impact. Furthermore,
257 different activities might be of interest to different stakeholders involved in decisions made
258 regarding the management of alien taxa. Since the (perceived) impact of a species can change over

259 time (Strayer et al. 2006), we suggest reporting the current maximum impact score and the
260 maximum score ever achieved in history (Hawkins et al. 2015). The latter is a proxy of the potential
261 maximum impact the species can achieve. It should be noted that some alien taxa have positive
262 impacts on human well-being and can increase peoples' capabilities which would become apparent
263 through an increase in selected activities (e.g. Pienkowski et al. 2015). These positive impacts need to
264 be taken into account when making management decisions, but are not scored in SEICAT. However,
265 SEICAT could provide a framework for scoring such positive impacts on human well-being.

266

267 *Properties of the classification*

268 SEICAT provides a common metric for all detrimental effects caused by alien taxa on socio-economy.
269 In contrast to other schemes that rely on monetary values, it assesses the entire spectrum of possible
270 impacts on human well-being and social structures. SEICAT provides a process for translating the
271 broad range of impact measures into ranked levels according to observed changes in peoples'
272 activities. It therefore allows distinction between taxa with different magnitudes of impact and
273 provides a framework for comparing impacts among taxa, mechanisms, particular
274 introduction/invasion events and regions. Analogous to EICAT, SEICAT can be used to flag species
275 with high potential impacts. However, the context-dependency of impacts should be considered
276 when transferring impacts from one region to another (see Supporting Information).

277 The classification is dynamic and should be based on the best available evidence. Hence, species can
278 move between impact categories as new data become available, for example if the quality of
279 evidence improves, socio-economic or environmental conditions change, an invasion proceeds or is
280 successfully managed. The classification can handle the lack of knowledge on some components of
281 well-being, because it uses the maximum known impact. It thus identifies knowledge gaps and helps
282 focus research to improve impact classification over time (see Supporting Information). The SEICAT
283 protocol can be applied to assess impacts at a range of spatial scales, allowing national, continental,

284 and global categorisation of impacts. It can therefore inform national or global assessment schemes
285 in which species are assigned to management lists depending on their impacts (see Supporting
286 Information). Finally, SEICAT considers only impacts on human well-being, but in combination with
287 EICAT it is possible to assess environmental and socio-economic impacts in concert, thus evaluating
288 the complete spectrum of deleterious impacts of alien taxa.

289

290 *Congruency of SEICAT and EICAT*

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

306

307 *Application*

308 To illustrate the applicability and usefulness of SEICAT, we assessed all alien amphibians globally (104
309 species; Measey et al. 2016). In addition to the references found by Measey et al. (2016), we
310 supplemented their literature search focussing only on socio-economic impacts. We used the
311 scientific species name as a search term in databases such as Google scholar, ISI Web of Knowledge
312 and databases specific to amphibians and alien species, manually filtering through the sources
313 identified by reading titles and (if applicable) abstracts. We then looked for references in the
314 resulting sources until no further records of impact were found. Suitable data for socio-economic
315 impacts was found in 20 articles/reports for 44 impacts involving 7 species (Supporting Information
316 Table S1). Impacts covered almost all impact classes: the cane toad, *Rhinella marina*, was the only
317 species scoring MR, affecting several constituents of human well-being but most importantly leading
318 to abandonment of certain cultural practices in Aboriginal communities in Australia due to the loss of
319 totem species (van Dam et al. 2002). However, these impacts were considered to be reversible after
320 control of the toad and thus we currently did not classify these as MV. The Asian common toad,
321 *Duttaphrynus melanostictus*, has been reported to have caused death of a child in Timor after eating
322 a toad meal; however no further changes in social activities were reported (Trainor 2009). This
323 consequently resulted in a classification as MO (fewer people participating in activities). We
324 acknowledge that the death caused by an alien might lead to a change in the activities of other
325 people, but such changes are rarely reported. A major reason for the lack of reporting is probably
326 that impacts through e.g. food poisoning caused by eating toxic animals and plants can be easily
327 avoided and are therefore not causes of major concern for human well-being in most regions despite
328 their potentially severe consequences. This is in contrast to risks that cannot be directly controlled,
329 e.g. exposure to allergenic pollen produced by an alien plant. Such less controllable risks can have
330 much more far-reaching impacts on human well-being and affect larger parts of societies. Three
331 species were classified as MN: the coqui frog, *Eleutherodactylus coqui*, is widely reported to have
332 large socio-economic impacts due to noise pollution, but the only impact on human activities which

333 was reported was a decline in property trade due to increased real-estate prices in affected areas in
334 Hawaii (Kaiser & Burnett 2006). Thus, houses are still being sold and traded, but the activity of
335 property trade is not doing as well when the frog is present. Also, human health might be affected by
336 the noise levels, but reports were lacking. A congener of the coqui frog, *E. planirostris*, affects the
337 nursery trade as plant shipments need to be treated. However, no other effects on trade were
338 reported, and the activity did not seem to be reduced, but was just more onerous (Olson et al. 2012).
339 Various minor impacts were also reported for *Osteopilus septentrionalis* (Johnson 2007; see Table
340 S1). In the case of *Hyla meridionalis*, it was reported that they cause a “deafening noise” (assuming
341 this is not meant literally), without mention of any impacts on e.g. human health or activities being
342 negatively affected in any specific way (Cheylan 1983); therefore, this was classified as MC. The
343 African clawed frog, *Xenopus leavis*, was classified as data deficient (DD) because the only impact
344 reports were from the native range where it can affect fisheries. A further 98 species for which no
345 studies on their impacts were found were also classified as DD (Supporting Information Table S1),
346 and all other amphibians had no record of alien populations and were consequently classified as NA
347 (not listed).

348

349 Most classifications (with the exception of *E. coqui*) were of low confidence due to the nature of the
350 reports, which were mainly based on observations and statements from affected people, but better
351 quality studies are lacking. It is expected that such reports currently constitute the main evidence of
352 impacts on human well-being until more systematic socio-economic studies that focus on changes in
353 human activities due to alien taxa are done. General guidelines on how to conduct such studies are
354 available (Palmer-Fry et al. 2017, Woodhouse et al. 2016) and we hope that the publication of SEICAT
355 triggers research in this direction. However, even with low quality data and in the presence of large
356 uncertainties, SEICAT allowed a clear, meaningful, and transparent ranking of the species, with the
357 cane toad causing the highest impact on human well-being, followed by the Asian common toad

358 (whose impacts can be largely avoided), while other amphibians caused only minor or negligible
359 impacts.

360

361 Comparing SEICAT and EICAT scores for amphibians for which both classifications are available (Table
362 3) shows that the scores are identical in only one species and that in general there is no good
363 correlation between both scores. In most species, the EICAT scores were higher than the SEICAT
364 scores, indicating that amphibians might tend to have stronger impacts on the environment than on
365 human well-being (assuming that EICAT and SEICAT classifications can be considered as equivalent).
366 However, because some species have larger environmental impacts and others higher impacts on
367 human well-being it is not possible to forecast socio-economic impact from environmental impacts
368 accurately (a simple regression model assuming no correlation between the two scores actually fits
369 better than a model assuming a linear relationship). It is currently not well understood which species
370 have high or low impacts and which are more likely to affect the environment or socio-economy, but
371 classification systems such as SEICAT and EICAT could be used to link such patterns to traits to
372 understand and forecast species with different types of impact.

373

374 *Conclusion and outlook*

375 Considerable progress has been made recently on the quantification and classification of
376 environmental impacts of alien taxa (e.g. Blackburn et al. 2014; Hawkins et al. 2015; Kumschick et al.
377 2015a, b) but assessing their effects on human well-being remains a challenge. Possible exceptions
378 are purely economic pests such as agricultural pests (Simberloff et al. 2013) or species affecting
379 human health (Rabitsch et al. 2017). There is a general demand for socio-economic impacts to be
380 included in the decision making process on the legal regulation of alien species in trade, e.g. under
381 the new EU Regulation (1143/2014), when justification for prioritising species is needed. Additionally,
382 changes in SEICAT assessments over time (similar to the Red List Index of Invasive Alien Species from

383 the Biodiversity Indicators Partnership; <https://www.bipindicators.net/indicators/red-list-index/red->
384 [list-index-impacts-of-invasive-alien-species](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
385 socio-economic impacts, which is of crucial importance to guide policy and management decisions
386 (Latombe et al. 2017; Rabitsch et al. 2016). Furthermore, socio-economic analyses can engage the
387 public in ways that information on environmental impacts does not (Genovesi et al. 2014; Simberloff
388 et al. 2013), thereby clarifying the framing of alien species problems (Woodford et al. 2016).

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

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

404

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424 **Data Accessibility**

425 Data deposited in the Dryad repository: <http://datadryad.org/resource/doi:10.5061/dryad.4g622>.

426

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593	List of Supporting Information
594	SI1 Details of SEICAT application
595	SI2 Table S1 SEICAT Application to Amphibians
596	
597	

598 **Figure 1:** (a) A person's capability set depends on environmental factors, economic settings (goods &
599 services), and the social context. From this set, people select the activities they want to achieve
600 (realised activities). (b) Alien taxa can reduce peoples' opportunities via changes in environmental
601 factors, economic settings or the social context. SEICAT defines negative impacts as losses in realised
602 activities attributable to an alien taxon (black hatched area).

603

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

606 **Table 1:** Constituents of human well-being and examples of their subcategories (after MEA 2005).
 607 The overarching premise for all constituents is the freedom of choice and action, i.e. the opportunity
 608 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

609

610 **Table 2:** Description of socio-economic impact classification of alien taxa according to observed
 611 changes in peoples' activities.

Impact classification	Description
Minimal Concern MC	An alien taxon is considered to have impacts of Minimal Concern when it has been studied with regard to its impacts on human well-being, but no deleterious impacts have been reported. 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 species 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 immaterial 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 changes in activity size, 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,

	<p>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).</p>
Major MR	<p>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).</p>
Massive MV	<p>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”).</p>
Data Deficient DD	<p>There is inadequate information to classify the taxon with respect to its impact, or insufficient time has elapsed since introduction for impacts to have become apparent.</p>

612

613

614 **Table 3:** Socio-economic (this paper) and environmental impact (Kumschick et al. 2017) classification
 615 of alien amphibians.

	SEICAT	Confidence	EICAT	Confidence
<i>Rhinella marina</i>	MR	low	MR	high
<i>Duttaphrynus melanostictus</i>	MO	low	MR	low
<i>Eleutherodactylus coqui</i>	MN	high	MO	high
<i>Eleutherodactylus planirostris</i>	MN	low	MC	medium
<i>Hyla meridionalis</i>	MC	low	MO	low
<i>Osteopilus septentrionalis</i>	MN	low	MO	low

616

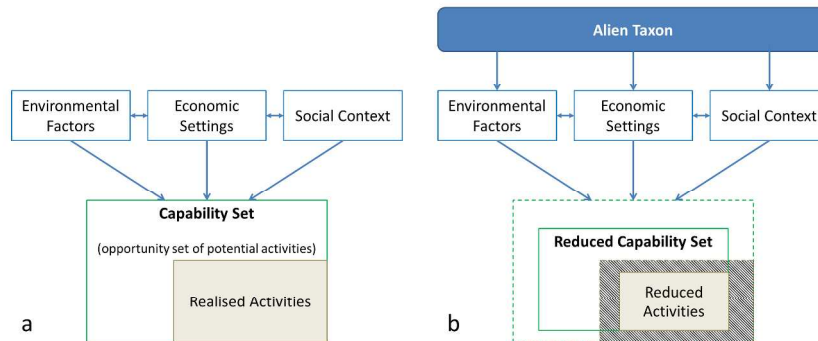


Figure 1: (a) A person's capability set depends on environmental factors, economic settings (goods & services), and the social context. From this set, people select the activities they want to achieve (realised activities). (b) Alien taxa can reduce peoples' opportunities via changes in environmental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

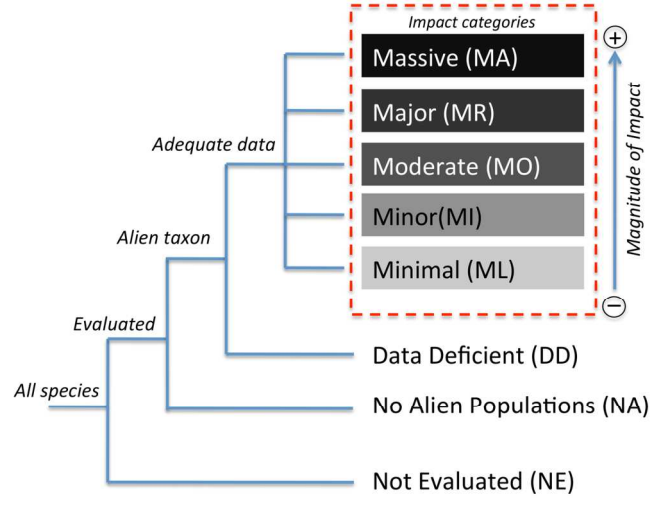


Figure 2: Socio-Economic Impact Classification of Alien Taxa SEICAT (after Blackburn et al. 2014; Hawkins et al. 2015). Detailed descriptions of the classes are given in Table 2.