

Revisiting the use of the invasive species concept: An empirical approach[†]

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Abstract Invasion science has not been developed without controversies. Two questions that are still unsolved are: what is an invasive species?, and are invasive species an inherent conservation problem? These questions have led to discussions about effects versus origins. In contrast to the definitional problems, a unified framework describing invasion as a step-by-step process has been widely accepted. I conducted a bibliographic search with two separate databases searching for (i) evidence of less use of controversial terms over time; (ii) how many articles defined ‘invasive species’; (iii) the criteria used to define a species as invasive; and (iv) in which stage of the invasion continuum were species labelled as invasive located. My results show that controversial terms are widely used, that authors rarely define ‘invasive species’ and, often, it is very complicated to determine which criterion they used. In addition, only a fraction of the species labelled as invasive could be classified as such according to the unified framework of invasion stages. This is not a merely semantic issue, because invasive is a strong and value-laden term that is used to guide environmental agendas. The uncritical use of a key concept could hamper research, complicate communication among peers and produce mixed results.

Key words: biological invasions, invasive species, normative use, unified framework.

INTRODUCTION

Biological Invasions Research (Richardson 2011b) is a hot research topic that has developed greatly in recent decades (Davis 2009; Richardson 2011a; Lockwood *et al.* 2013). As any other active field in ecology, it is not free of controversies, some of which are revived from time to time (Brown & Sax 2004; Davis *et al.* 2011a; Simberloff *et al.* 2011; Richardson & Ricciardi 2013; Valéry *et al.* 2013; Blondel *et al.* 2014; Simberloff & Vitule 2014). In particular, two central questions are widely discussed: What is an invasive species?, and are invasive species a major conservation issue?

The lack of a precise definition of ‘invasive species’ started with Elton’s (1958) seminal book, which did not define ‘invasive’. Several definitions were later proposed (Davis & Thompson 2000; Richardson *et al.* 2000; Pyšek *et al.* 2004; Valéry *et al.* 2008; Lockwood *et al.* 2013) and have so far coexisted. These different definitions have even been used interchangeably in different applications, and different authors have different opinions about the meaning of ‘invasive species’ (Hulme

& Weser 2011). Richardson *et al.* (2000) even suggested that authors should provide a definition of invasive species in their articles.

The parallel question of whether invasive species are an important conservation issue (Davis *et al.* 2011a) arose because the current conservation-oriented Biological Invasions Research arose from a non-conservational Biological Invasions Research (Davis 2005). Some authors have called for greater recognition of the conservation potential of non-natives (Schlaepfer *et al.* 2011), pleaded for a more nuanced debate (Shackelford *et al.* 2013) or pointed out the impracticality of such a term as ‘invader’ (Carey *et al.* 2012). In response, others have stated that origin matters (Simberloff *et al.* 2012; Paolucci *et al.* 2013; Hassan & Ricciardi 2014) and that Biological Invasions Research is far from being xenophobic (Simberloff 2003). In accordance with this, Blondel *et al.* (2014) and Simberloff (2012, 2013) pointed out that most ecologists nowadays have shifted from terms like ‘invasive’ or ‘invader’ (potentially pejorative) to less controversial and value-free terms such as non-native, alien or exotic. Accordingly, Richardson and Ricciardi (2013) wrote that recent criticisms to Biological Invasions Research (e.g. Valéry *et al.* 2013) are based on ‘a caricature or a parody of the discipline’ and not on Biological Invasions Research itself, in which most authors agree on concepts and definitions about invasive species.

A related issue often lost in these debates is that what some authors call invasive species are in fact invasive

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populations (Colautti & MacIsaac 2004; Davis 2009; Richardson & Pyšek 2012). Davis *et al.* (2001) called attention to the indiscriminate use of the term ‘invader’ to refer to any alien species in a region. Similarly, Lockwood *et al.* (2013; page 13) explicitly referred to the fact that ‘invasive’ should not be used as an all-encompassing label to describe any new population arriving at a site, even when some populations deserve this label. Davis (2009, page 5) distinguished between the normative use of a term (‘invader’, in his example) and the use of a term, which merely describes a behaviour (‘invasive’, in his example) and thus recommended that ‘invasive’ should not be used as a taxonomic label. This line of thinking is important because there is evidence that biological invasions are a very contextual problem (Ehrenfeld 2010; Pyšek & Richardson 2010), and that a species could have invasive populations in one site but not another (Kueffer *et al.* 2013).

There is less theoretical debate about how a biological invasion occurs (Blackburn *et al.* 2011). Irrespective of the number of stages or barriers in a given framework (Davis 2009), most authors agree that a biological invasion is a phenomenon in which a species (or population) passes from one stage to another. The final step is a successful biological invasion and the result is an invasive species (or population) (Blackburn *et al.* 2011). Such frameworks allow us to map the progression of any species in the invasion continuum (i.e. the progression through different stages in a given framework). Correctly locating a species within a framework is important because if the normative use of the term invasive species is common in the scientific literature, then it could overstate the severity of biological invasions.

In evaluating these controversies, it would be helpful to understand actual patterns of usage of terms by invasion biologists. Here, I describe the results of a bibliometric study of Biological Invasions Research, to determine: (i) whether the use of controversial terms has become less frequent through time; (ii) the number of studies that define ‘invasive species’; (iii) which criteria are used to classify a species as invasive; and (iv) in what stage of the invasion continuum were species labelled as ‘invasive’. I followed the terminology proposed by Blackburn *et al.* (2011) for invasive species (i.e. individuals dispersing, surviving and reproducing at multiple sites). Although this definition was proposed

for non-native species, I also included native species (Valéry *et al.* 2008), an exception recognized by Blackburn *et al.* (2011). In addition, I used the definition proposed by Ricciardi *et al.* (2013) for ‘impact’.

METHODS

Database construction

I constructed two different databases to perform the analysis. The first database (database I) was composed of all the articles published in the journal *Biological Invasions* in the period 1999–2012. The second database (database II) was composed of all the articles on *Biological Invasions Research* published in 21 international journals in the years 2011 and 2012 (see below for details).

To evaluate the use of seven specific terms commonly used in *Biological Invasions Research* (cf. Colautti & MacIsaac 2004) (objective 1), I used database I as a proxy for *Biological Invasions Research*. I chose the journal *Biological Invasions* because it is focused specifically on the subject of biological invasions, has a broad scope and has been published since the establishment of the debates considered in this research (starting in 2000, Davis & Thompson 2000; Richardson *et al.* 2000).

To perform the remaining analyses (objectives 2 to 4), I used database II. I chose the years 2011–2012 for the assessment because the debates surrounding the definition of ‘invasive species’ were firmly established (e.g. Kühn *et al.* 2011), and invasion biologists should have been prepared to recognize and avoid the pejorative use of the term. I searched in four invasion journals (*Biological Invasions*, *Diversity and Distribution*, *Aquatic Invasions and Neobiota*) and 17 other journals, which encompass all kinds of ecosystems worldwide (marine, freshwater and terrestrial), all kinds of topics, both applied and theoretical aspects of biological invasions, primary research, meta-analysis and reviews, field and laboratory trials and with a great variety of approaches, from local to global (Table 1). I selected these journals because many of the most influential articles in *Biological Invasions Research* were published there (Pyšek *et al.* 2006). Although other influential journals could have been analysed (e.g. *PNAS*, *BioScience*), the broad scope of my analysis prevented me from doing so.

I downloaded all kinds of articles related to *Biological Invasions Research* from these journals to make a first selection. I considered all kinds of papers except book reviews. I based my

Table 1. Journals reviewed to analyse the use of ‘invasive species’ (database II; see text for details)

Annual review of ecology, evolution and systematics	Ecological monographs	Journal of biogeography
Aquatic invasions	Ecology	Marine biology
Biological conservation	Ecology letters	Marine ecology progress Series
Biological invasions	Freshwater biology	Neobiota
Conservation biology	Frontiers in ecology and the environment	Oecologia
Diversity and distributions	Global change biology	Oikos
Ecological applications	Journal of applied ecology	Trends in ecology and evolution

search on titles, abstracts and keywords, looking for terms related directly or indirectly (e.g. Biotic Homogenization) to Biological Invasions Research. I ended the search on 23 November 2013. Given the vast nature of topics published in Biological Invasions Research (Richardson 2011a), I focused on papers working with invasive species: those in which authors called their study species an ‘invader’ or an ‘invasive species’, and those with a broader spectrum (i.e. review, meta-analysis) in which the authors worked with the concept of an invasive species (e.g. Blackburn *et al.* 2011). I call this the selection criterion. For all the articles in database II, I searched in the Title, Introduction and Methods sections for those that fulfilled the selection criterion described earlier. I avoided using abstracts and keywords to select articles to review because those two sections could be found in databases different from those for full papers (Day 2005), and this could bias the writing of those sections (e.g. ‘invasive species’ was a common keyword even when it barely appears in the article). Each article was treated separately, and the analyses were made with the information provided in the article without requesting further information from the corresponding authors.

Use of common terms in Biological Invasions Research through time

Using database I, I recorded the use (i.e. appearance in the article) of the following terms: ‘invasive species’, ‘invader’, ‘introduced species’, ‘exotic species’, ‘non-native species’, ‘alien species’ and ‘non-indigenous species’. I obtained the average use of each term through the period analysed.

Definitions

Using database II, I reviewed the Introduction and Methods sections looking for a definition of ‘invasive species’, in the authors’ own words and/or using existing definitions in the literature and recorded it (i.e. presence/absence). I searched through these sections instead of the whole article, because the context and statement of the problem, as well as the definitions, usually are given in the Introduction.

Assessment of criteria used to define invasive species

Given that there are several definitions of ‘invasive species’, I looked for the criterion used to classify a species as invasive. To do this, I first compiled different definitions of invasive species to find out what they had in common and determine the criteria associated with an ‘invasive species’. I selected nine well-known and widely cited definitions. Although I skipped some early definitions (e.g. Pyšek 1995), I focused on articles published since 2000, when the definition began to be contentious (Davis & Thompson 2000; Richardson *et al.* 2000). Based on this compilation, dominance, impact and spread emerged as the criteria most commonly associated with the concept of invasive species (Table 2). All nine definitions stated that, to be

considered as invasive, the species has to spread (even when this was not the principal criterion, as in Davis & Thompson 2000), which agrees with the unified framework proposed by Blackburn *et al.* (2011; later).

I reviewed the Introduction and Methods sections of the articles in database II that fulfilled the selection criterion to evaluate what concepts were used to classify a species or group of species as invasive (even when a definition was not provided). For this classification, I used a nine-class system. Based on the three main criteria identified (dominance, impact and spread) and their possible combinations, I obtained a seven-category classification scheme (Table 3). I also included as a class when authors called a species invasive because it is ‘invasive elsewhere’ or because another/other expert/s labelled the species as invasive. This class was included to recognize that ‘invasive species’ is sometimes used as an all-encompassing label, and because different experts think differently about the invasive status of a given species (Hulme & Weser 2011). When an article could not be assigned unambiguously to one of those previous categories, it was labelled as ‘others’ (Table 3).

Species within the unified framework (Blackburn *et al.* 2011)

According to Blackburn *et al.* (2011), any species (or population) could be allocated within their unified framework (see Table 1 in Blackburn *et al.* 2011). This framework provides a simple way to classify any given species into three broad categories within the invasion continuum (i.e. introduced, naturalized and invasive). Although this unified framework is recent, it is similar in essence to previous frameworks (see Blackburn *et al.* 2011 for details), and as stated earlier, all definitions studied consider spread as a requisite to consider a species as invasive (Table 2). Consequently, I consider it safe to compare the reviewed articles with the unified framework.

I used the information provided in the Introduction and Methods sections of the articles selected in database II to locate the species within the unified framework (see Table 4 for details). I also assigned the articles to two other categories: ‘Insufficient data’, for those articles describing studies conducted in natural or semi-natural environments in which species could not be unambiguously classified, and ‘others’, for those articles

Table 2. Definitions used to classify species as ‘invasive’: +, criterion used; –, criterion not used; +/- criterion implicit but not stated as necessary

Source	Spread	Dominance	Impact
Colautti & MacIsaac 2004	+	+	–
Davis & Thompson 2000	+	+/-	–
Davis 2009	+	+/-	+
Lockwood <i>et al.</i> 2013	+	+/-	+
Richardson <i>et al.</i> 2000	+	–	–
Richardson 2011a	+	+	–
Valéry <i>et al.</i> 2008	+	+/-	–

Table 3. Classification criteria to label a species as ‘invasive’

Category	Defining criterion	Example
Spread (S)	A species is invasive because it spreads across the terrain	‘...and only species that have spread considerable distances from parent populations are considered ‘invasive’ ^a
Dominance (D)	A species is invasive because it dominates the invaded community	‘...both native and introduced <i>Typha</i> species are capable of forming monospecific stands that allow few coexisting plants once established. Therefore, both <i>Typha</i> species are also sometimes considered invasive species...’ ^b
Impact (I)	A species is invasive because of its high population growth	‘...we gained estimates of the population growth rate (λ) and, thus, invasion potential’ ^c
	A species is invasive because it produces some impact	‘...invasive alien is an alien species whose introductions and/or spread threatens biological diversity...’ ^d
Invasive elsewhere	A species is invasive because it invades elsewhere	‘We also focused particular attention on those species listed by the USDA as invasive...’ ^e
	A species is invasive because of expert’s opinion	‘Several taxa of the genus <i>Fallopia</i> (Polygonaceae) originating from East Asia, are among the most troublesome invasive weeds worldwide...’ ^f
Others	When the criterion used to label a species as invasive is not clear	‘...that has become invasive on flower heads of the non-target native host plant...’ ^g ‘For many invaders...particularly if they have become widespread...’ ^h
Combinations		
S + D	A species is invasive because it spreads and has high population growth/dominates the invaded community	‘...((‘invasive’) the species needed to be abundant and regenerating outside the original plantations...’ ⁱ
S + I	A species is invasive because it spreads and produce impact	‘...categorized them as invasive if they were considered a widespread or noxious weed’ ^j
D + I	A species is invasive because it produces impact and has high population growth/dominates the invaded community	‘...invasive species establish and dominate areas (...) but also contribute to further declines of native species...’ ^k
S + D + I	A species is invasive because it spreads and has high population growth/dominates the invaded assemblage and produces impact	‘...to promote native species to invader status as a result of enhanced abundance, greater per-capita effects and colonization of new habitat within their native range’ ^l

^aGibson *et al.* 2011, ^bEichner 2012, ^cDavis *et al.* 2011b, ^dHulme & Weser 2011, ^eOreska & Aldridge 2011, ^fKrebs *et al.* 2011, ^gLouda *et al.* 2011, ^hD’Antonio *et al.* 2011, ⁱNuñez & Medley 2011, ^jPalacio-López & Gianoli 2011, ^kBauer 2012, ^lCarey *et al.* 2012.

that could not be unambiguously classified into the other four categories, or when the term invasive was used as a normative concept (Table 4).

RESULTS

Use of common words through time

To follow the use of each term through the years (Fig. 1), 1526 articles were reviewed. The term favoured by most authors was ‘invasive’, which was used in more than half of the papers published since the appearance of the journal *Biological Invasions* in 1999, and in 90% or more of the papers published since 2008. The terms ‘invader’, ‘introduced’ and ‘exotic’ were used variously between about 40–60% through the years. The use of ‘exotic’ declined slightly in recent years. The other three terms (‘alien’, ‘non-native’ and ‘non-indigenous’) were used far less frequently (about 10–40%).

Definitions and criteria

I downloaded 1092 papers for the construction of database II, 700 of which met the selection criteria and were used to answer the remaining questions. Only a fraction of the reviewed articles (13%) defined ‘invasive species’. Regarding the different criteria (spread, impact and dominance) used to consider a species as invasive, none of those were used more often than the others (Fig. 2). Most articles (about 66%) could not be unambiguously assigned to a specific criterion and were classified as ‘others’. The second most important category (about 18%) was ‘invasive elsewhere’. The other three categories, encompassing the three main criteria and their combinations fluctuated between about 0.30% and about 5.60% of the articles examined. Spread, the chief criterion in the unified framework and in all the definitions reviewed, was used only in about 4% of articles as a determining criterion. Impact was used as a criterion

Table 4. Classification scheme to place a species within the unified framework of Blackburn *et al.* (2011). Use of ‘introduced’, ‘naturalized’ and ‘invasive’ follows Blackburn *et al.* (2011)

Category	Classification criteria	Example
Introduced	Recently introduced species (≤ 15 years) and/or absence of reproduction	Verity <i>et al.</i> 2011
Naturalized	Self-sustaining populations (i.e. evidence of reproduction or presence of juveniles)	Warren <i>et al.</i> 2012
Invasive	Self-sustaining populations with evidence of spread Articles modelling the spread of a species, or a group of species Broad-spectrum articles considering a species as invasive based in its spread	Petty <i>et al.</i> 2012 Vink <i>et al.</i> 2011 Blackburn <i>et al.</i> 2011
Insufficient data	Insufficient data to differentiate ‘introduced’ from ‘naturalized’ (e.g. absence of reproductive structures or juveniles in the samples) Naturalized populations (i.e. presence of juveniles) without evidence of spread Absence of specific data (e.g. time since introduction, reproductive features and evidence of spread) that allow unambiguous classification in the invasion continuum	Siesa <i>et al.</i> 2011 Kowarik & von der Lippe. 2011 Hladysz <i>et al.</i> 2011
Others	Laboratory, greenhouse, microcosm or mesocosm studies involving an ‘invasive species’ Articles with more than one species, making infeasible the distinction between stages for each species, or articles where the terms (e.g. exotic, alien and invasive) were used interchangeably, making the distinction infeasible Theoretical or broad-spectrum articles in which ‘invasive’ is not defined or clearly specified Models where spread is not the main subject	Richards <i>et al.</i> 2012 Mercer <i>et al.</i> 2012 Liu <i>et al.</i> 2012 Thiele <i>et al.</i> 2011

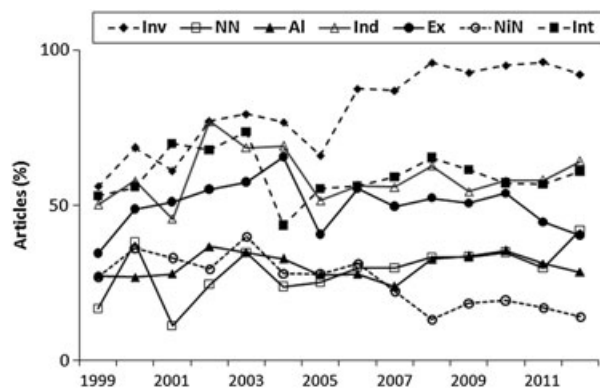


Fig. 1. Use of seven common terms in the journal *Biological Invasions* over time. Inv = invasive species; NN = nonnative species; AI = alien species; Ind = invader; Ex = exotic species; NiN = non-indigenous species; Int = introduced species.

in about 6% of the articles and dominance in about 2% of the articles.

Invasive species within the unified framework

Regarding my fourth question, most of the articles could not be unambiguously categorized using the unified framework and were labelled as ‘others’ (about 57%; Fig. 3). In many cases (about 19%), data contained in the articles were insufficient to classify them. Only 17%

of the papers ($n = 115$) provided enough data to categorize the species as invasive according to the unified framework (Fig. 3). Forty-one articles (about 6%) and 15 articles (about 2.5%), respectively, provided enough data to categorize the species as naturalized or introduced, respectively (Fig. 3).

DISCUSSION

Although the use of specific terminology within Biological Invasions Research has been discussed, this is the first attempt to quantify it rather than rely on the opinion of experts. My results show that value-laden terms (i.e. invasive, invader) are used more often than other options (i.e. exotic, non-native, alien and introduced). In addition, articles rarely define ‘invasive’, and in many cases, it is not possible to infer the criterion (i.e. spread, dominance and impact) that was used to label a species as ‘invasive’. Finally, based on the information provided in their articles, it is hard to place a species within the unified framework of Blackburn *et al.* (2011). Overall, the results show that the vague use of concepts remains the rule rather than the exception within Biological Invasions Research.

‘Invasive’ was the most widely used among the seven terms analysed and its use has increased in recent years. ‘Invader’, ‘introduced’ and ‘exotic’ were used similarly with slight variations between years. Other terms (‘non-native’, ‘non-indigenous’ and ‘alien’) were much

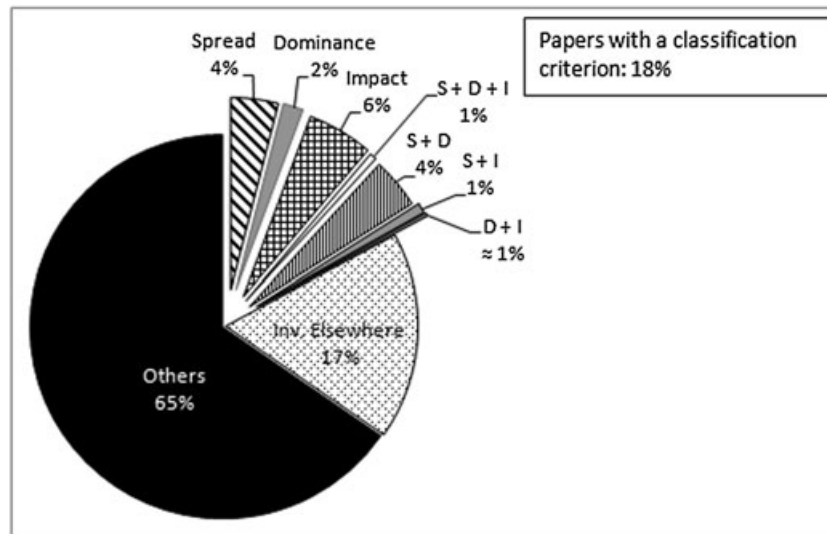


Fig. 2. Prevalence of different criteria used to classify a species as invasive. The names of some criteria are abbreviated; see Table 3 for full versions. D = Dominance I = Impact; S = Spread.

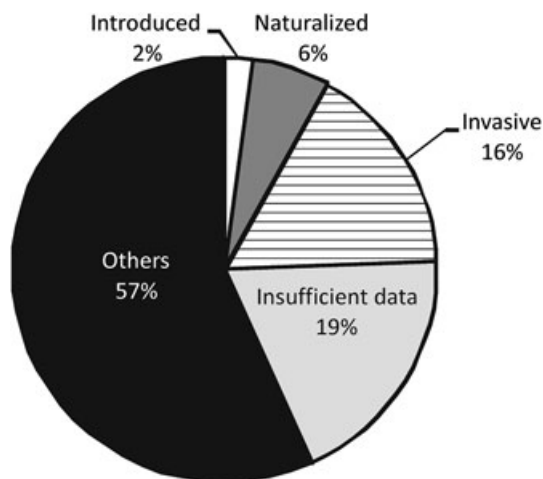


Fig. 3. Classification of species in articles from database II according to invasion stage in the unified framework of Blackburn *et al.* 2011 (see text for details).

less used through the years. These results contradict the assertion that authors have shifted to neutral terms, avoiding the use of pejorative terms.

Regarding the second question (i.e. how many articles define ‘invasive species?’), few of the articles reviewed in database II did it. Likewise, the criterion used to consider a species invasive was identified in few of the articles reviewed, and none of the criteria was predominant. Contrary to previous assertions, my results show that Biological Invasions Research has not moved to the use of the biogeographical criterion, because this criterion was used only by 4% of the articles reviewed. The single most important category was ‘invasive elsewhere’,

which contradicts the suggestion not to use ‘invasive’ as an all-encompassing label (Lockwood *et al.* 2013).

Many of the articles reviewed cannot be unambiguously assigned to any of the stages of an invasion (introduction, naturalization and spread) within the unified framework of Blackburn *et al.* (2011), and only some can be assigned to the invasive stage within this framework. This finding is consistent with the lack of definition of ‘invasive species’ and with the use of ‘invasive’ as an all-encompassing label. Admittedly, a simple definition covering all taxa would not be feasible. Certain rates of spread have been suggested for plant species (Richardson *et al.* 2000), but they could be meaningless for other groups. The same can be argued for other criteria, such as the number of years or generations needed for a species to become ‘naturalized’ or ‘invasive’. However, the absence of a universal definition cannot serve as a free pass to label any species as ‘invasive’ based on citation practices, experts’ opinions or a normative use of a concept (Davis 2009; Herrando-Pérez *et al.* 2014).

Hodges (2008) stated that there is no evidence that an ambiguous concept generates misuse throughout a research field. Overall, my results provide evidence that authors publishing within Biological Invasions Research neither define what an ‘invasive species’ is nor explain which criterion is used for a species to be considered ‘invasive’. In addition, my results show that classifying species into those categories can be arbitrary. Although meanings cannot be inferred from the selection of words made by authors, my results also show an increase, not a decrease, in the use of value-laden terms. For instance, the neutral neologism ‘Neobiota’ (Kühn *et al.* 2011) has faded into oblivion, with almost zero use, even in the journal *Neobiota*. Larson (2011) mentioned that

'invasion' is not a neutral term, and that instead, it usually conflates spread with impact and leads us to assume that invasive species are those that we have to do something about. Although it could be argued that authors use 'invasive' as a technical term without any connotation, the absence of definitions or guiding principles, as shown here, contradicts such an assumption. Humair *et al.* (2014) showed that ecologists working within Biological Invasions Research lack consistency in their use of basic concepts, as well as having an implicit bias against non-native species. In preparing this review, I have encountered many expressions that imply that native species are natural and desirable, while non-native ones (often referred as invasive) are not, something which has been repeatedly denied (e.g. Simberloff *et al.* 2011; Simberloff 2012, 2013).

Regarding flexibility in definitions, some authors (Colautti & MacIsaac 2004; Colautti & Richardson 2009) have argued in favour of a precise and objective lexicon, whereas others (e.g. Larson 2007; Hodges 2008) have argued that this approach is futile, impractical and even undesirable. Hodges (2008, 2014) suggested that prescriptive approaches to terminology are detrimental, rather than beneficial. Other authors (Davis 2009; Heger *et al.* 2013a, 2013b; Humair *et al.* 2014) have emphasized that providing a universal definition of 'invasive species' is not feasible. Consider for example a recent debate about invasive species. Valéry *et al.* (2013) provided a definition of 'biological invasion' as 'the appearance of a state of dominance of a species and the rapidity of changes observed'. Blondel *et al.* (2014) counter-argued that such definition is 'limited, self-created and non-widely accepted' and denied the logic behind it, which allows native species to become invasive. Without generally accepted definitions, confusion arises. For instance, this flexibility in the use of the language has led invasive species to become 'the second cause of biodiversity loss', based more on bold statements than on real data (Chew 2015).

Herrando-Pérez *et al.* (2014) described a 'silent rule' in scientific publications, in which key terms do not need to be defined and a reference in a previous article is an easy way to validate them. Davis (2009, 2011) mentioned that some assumptions within Biological Invasions Research (e.g. invasive species as a conservation problem) have reached the fact level and do not need further explanation. The metaphorical web (*sensu* Larson 2011) generated through Biological Invasions Research presents 'invasive species' as different from 'non-invasive species', while those with greatest spread are those with greatest impacts (but see Ricciardi & Cohen 2007). In addition, those with greater impact are those that deserve priority attention (Kuebbing & Simberloff 2015). Ultimately, it is the impact of an invasive species that defines it as a conservation problem. However, 'impact' is not usually defined (e.g. Gallardo *et al.* 2015), and the theory defines

it in such a way (e.g. Barney *et al.* 2013; Ricciardi *et al.* 2013; Simberloff *et al.* 2013) that makes it impossible for an invasive species not to produce impact. Regardless of whether it is the local extinction of a population or the increase in local diversity, it is called 'impact' if it refers to a non-native species and 'effect' if it refers to a native species (Chew & Carroll 2011). Clearly, the way we write about 'invasive species' tells many of our interpretation.

Given the society-oriented and conservation-oriented nature of Biological Invasions Research (Davis 2005), several authors have suggested that flexible language is better to communicate with the community and the stakeholders involved (Larson 2011; Humair *et al.* 2014). However, it is not clear how this confusing use of terms could help understanding among peers, and the potential for confusing use of the lexicon to jeopardize communication among peers is usually not considered (Herrando-Pérez *et al.* 2014). Those who advocate for a more flexible lexicon should state clearly how it favours communication among peers, because the example highlighted earlier suggests that misunderstandings are already occurring. Until a universal definition of 'invasive' appears, or until the temporal and spatial limits to define 'naturalized' or 'invasive' for different groups can be established, Biological Invasions Research could be greatly favoured by the use of common concepts, clearly stated and defined in every article (Colautti & Richardson 2009). Journals can also ask authors to define key concepts in their articles (e.g. invasion, invasive), or provide rules of thumb to avoid confusion or bias (e.g. Biological Conservation suggests the use of 'effect' instead of 'impact'). Nowadays, none of the four invasion journals reviewed in this research ask authors to define those concepts in their 'Instructions for authors'. The creation of a common repository of terms as proposed by Herrando-Pérez *et al.* (2014) can be a useful tool to advance in this direction.

Admittedly, nobody will hesitate to label as 'invasive' any new population of the zebra mussel (*Dreissena polymorpha*) outside its current introduced distributional range. It would be wise to deal with this new population quickly and preventively, because of the well-known uncertainty about every case of invasion. However, by no means, we should label it as 'invasive' if we do not want to be inconsistent with theory (Blackburn *et al.* 2011). This normative labelling has shown to be inefficient in practice (Carey *et al.* 2012). It is well known that Biological Invasions Research has several biases (Pyšek *et al.* 2008), and the same occurs with the impacts of invasive species (Hulme *et al.* 2014; Gallardo *et al.* 2015), mainly based on a small group of well-studied species, too widely generalized (Davis 2009). To answer questions as the limits of the different stages in an invasion process (Blackburn *et al.* 2011; Richardson & Pyšek 2012), the reasons behind different outcomes of each invasion (Kueffer *et al.* 2013), or even the way to approach

the ever-increasing arrival of new species (Larson 2007; Davis 2009; Larson 2011), we should start by setting a common language (Herrando-Pérez *et al.* 2014).

Finally, although this article discusses definitions, I am not proposing a definition of ‘invasive species’ because it is not needed. The unified framework of Blackburn *et al.* (2011) allows us to place any species (or population) in the invasion continuum, and provides a guide of specific terminology. To avoid annoying simplifications, it is reasonable to label the species according to this framework (or any other in the author’s preference). This is not only to avoid hampering Biological Invasions Research by giving the name ‘invasive’ to what is not invasive, but to allow more focus on the biological invasion phenomenon itself, rather than on the invasive species per se (Strayer 2009). Irrespective of the lexicon or significance of being non-native (Davis 2009; Davis *et al.* 2011a; Simberloff *et al.* 2011; Valéry *et al.* 2013), biological invasions are very complex, even when the species (or population) does not achieve an invasive status. Species introductions have increased at unprecedented rates in the past decades (Ricciardi 2007), and biotic homogenization is a widely recognized phenomenon (e.g. Baiser *et al.* 2012). There is increasing evidence that populations, not species, invade (Richardson & Pyšek 2012, Kueffer *et al.* 2013), that most populations of many invasive species have low densities (Hansen *et al.* 2013), and that even with highly studied invasive species, there is a small proportion of cases with evidence of impact (Kulhanek *et al.* 2011). The impact of a species (or population) does not depend on what we decide to call it, but does change the interpretation of those impacts (Larson 2011). While communication among peers can be hampered by this use of ‘invasive’, there is little evidence that a fear-related message mobilizes people into action (Larson 2011). It does not matter how many more cases of a given species producing some impact we present, it will be meaningless if we cannot place it correctly into a given framework. ‘Invasive species’ is a strong and connotative term, used to mobilize people and funds, and to set environmental agendas. Thus, it should not be used vaguely.

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