Taming the terminological tempest in invasion science

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Abstract

Standardized terminology in science is important for clarity of interpretation and communication. In invasion science — a dynamic and quickly evolving discipline — the rapid proliferation of technical terminology has lacked a standardized framework for its language development. The result is a convoluted and inconsistent usage of terminology, with various discrepancies in descriptions of damages and interventions. A standardized framework is therefore needed for a clear, universally applicable, and consistent terminology to promote more effective communication across researchers, stakeholders, and policymakers. Inconsistencies in terminology stem from the exponential increase in scientific publications on the patterns and processes of biological invasions authored by experts from various disciplines and countries since the 1990s, as well as publications by legislators and policymakers focusing on practical applications, regulations, and management of resources. Aligning and standardizing terminology across stakeholders remains a prevailing challenge in invasion science. Here, we review and evaluate the multiple terms used in invasion science (e.g. 'non-native', 'alien', 'invasive' or 'invader', 'exotic', 'non-indigenous', 'naturalized, 'pest') to propose a more simplified and standardized terminology. The streamlined framework we propose and translate into 28 other languages is based on the terms (*i*) 'non-native', denoting species transported beyond their natural biogeographic range, (*ii*) 'established non-native', i.e. those non-native species that have established self-sustaining populations in their new location(s) in the wild, and (*iii*) 'invasive non-native' — populations of established non-native species that have recently spread or are spreading rapidly in their invaded range actively or passively with or without human mediation. We also highlight the importance of conceptualizing 'spread' for classifying invasiveness and 'impact' for management. Finally, we propose a protocol for classifying populations based on (1) dispersal mechanism, (2) species origin, (3) population status, and (4) impact. Collectively and without introducing new terminology, the framework that we present aims to facilitate effective communication and collaboration in invasion science and management of non-native species.

Key words: biological invasion, classification, communication, non-English language, non-native, polysemy, synonymy

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I. Introduction

Scientific disciplines often grapple with lexical and semantic ambiguities and inconsistencies that can confuse, misinterpret, and create barriers to effective interdisciplinary collaboration among scientists, as well as hinder engagement with practitioners, policymakers, educators, stakeholders, and society (Metzger & Zare, 1999; Regan et al., 2002). This problem spans many scientific fields, from ecology and taxonomy to physics, computer science, and social science (Boucher, 1985; Herrando-Pérez et al., 2012; Stroud et al., 2015; Kirk et al., 2018; Amador-Cruz et al., 2021; Roth et al., 2021; Bortolus & Schwindt, 2022; Macêdo et al., 2023). Over time, each discipline develops a unique technical lexicon (jargon) with the common challenge of establishing a clear, universally accepted terminology that enables accurate communication within its community and with other scientific or public domains (Montgomery, 1989; Hirst, 2003). While Hodges (2008) argued that "... [u]seful lexical reviews should focus on the development of ecological knowledge that is signalled by a wealth of terms and meanings, rather than critiquing the terms employed", relying on jargon can be detrimental to effective communication, especially among researchers from different backgrounds and disciplines (Orwell, 1968; Plavén-Sigray et al., 2017; Bullock et al., 2019, Martínez & Mammola, 2021). Judicious use of specialized terms permits effective and precise communication of ideas and concepts not available in the common language, but this is best achieved when jargon is unambiguous and approved by most scientists in a given field (Hirst, 2003).

Invasion science is a swiftly evolving discipline that encompasses a wide range of specialized fields. Despite its youth, the jargon of invasion science has many inconsistent definitions that hinder research progress, effective management, alignment with global-change science, and standardized communication (Colautti & MacIsaac, 2004; Ricciardi & Cohen, 2007; Lockwood et al., 2013). For example, Castro et al. (2023) found that ambiguous terminology in the field of invasion science hampers effective reporting of non-native taxa for regional checklists. Terms associated with the stages and impacts of biological invasions in particular are often polysemous (i.e. many meanings for a word, phrase or concept), leading to potential misunderstanding and limitations in scientific exchange and conservation practice (Colautti & MacIsaac, 2004), as well as hindering bidirectional translations between English and other languages (Copp et al., 2021).

Biological invasions are generally defined as directed, human-mediated processes whereby organisms are transported and subsequently released by humans either intentionally or unintentionally beyond their native biogeographical boundaries from which they can potentially spread (Simberloff, 2013; Pyšek et al., 2020). We also acknowledge that classification terms such as 'invasion' and 'native' can hold separate cultural meanings for stewardship approaches, including some perspectives by Indigenous Peoples (Wehi et al., 2023). To standardize the terminology in this paper and beyond, we first define the 'native' (i.e. natural) range of a species as the biogeographical area where its occurrence has been determined solely by natural evolutionary processes, without any direct or indirect human intervention, such as transporting species, altering their boundaries, and/or breaching natural barriers to their dispersal. This definition implies that a species' 'non-native' range is the area where the species is present due to human intervention, whether intentional or unintentional, and where it has not naturally evolved (McNeill, 2003). This definition remains applicable regardless of the duration of the species' presence in the area or whether it has undergone evolutionary adaptations in response to the novel environment. However, non-native ranges also include human-assisted expansions due to other phenomena like the removal of biogeographic or climatic barriers caused by anthropogenic activities (Essl et al., 2019).

The process of an initial invasion can be conceptualized as a series of stages — for example: (1) non-native species intentionally or unintentionally transported (including those classified as 'hitchhikers') to a new area through human activities, or naturally dispersing after a barrier is removed or made permeable through human action; (2) escape or introduction of individuals from captivity or cultivation into (evolutionary) novel locations; (3) establishment of a viable (i.e. self-sustaining) population; and (4) spread (when individuals of non-native species disperse spatially from the initial release area). While the latter two stages occur with or without direct human assistance, the quality, quantity, and frequency of introductions (i.e. generally termed 'propagule pressure') are relevant at all stages (e.g. Lockwood et al., 2005).

In light of the multifaceted and largely negative effects that non-native species introductions can have on both nature (Blackburn et al., 2011; Bellard et al., 2022; Rilov et al., 2023) and society (Vilà et al., 2010; Bacher et al., 2018; Diagne et al., 2021; Zhang et al., 2022), research on biological invasions lies at the crossroads of natural and social sciences (Vaz et al., 2017; Heger et al., 2021; Bortolus & Schwindt, 2022). While a species' native range is identified by a historical range (Fig. a) that reflects its evolutionary history, dispersal capacity, and biotic and abiotic constraints, historical records (Fig. b) have sometimes been used controversially to justify local reintroductions (Fig. c–d), as in the example of rewilding (Seddon et al., 2014). Past ecosystems are generally different from those in the present because ecosystems and their components are not static; therefore, even if historical records confirm the past presence of a species, these do not necessarily imply that species reintroductions will restore previous ecological conditions or positively affect contemporary ecological processes (Davis, 2006; Richardson & Pyšek, 2008; Guerisoli et al., 2023). Multi- and interdisciplinarity have allowed the implementation of innovative approaches to understand and manage biological invasions, but they have also introduced many related, and not always synonymous, terms and contrasting conceptualizations (Lockwood et al., 2005). Further complication derives from the growing scientific attention being asynchronous across habitats, phyla, and geographic regions (Puth & Post, 2005; McIsaac et al., 2011; Watkins et al., 2021; Carvalho et al., 2023), having led to the establishment of multiple ‘invasion science’ communities that develop their own standards and do not often interact (Ojaveer et al., 2015; Latombe et al., 2019). The resulting mix of terms and contexts (e.g. political, aesthetic, environmental) within and across disciplines has clouded universal comprehension, in turn impeding effective interventions (Padial et al., 2017; Shackleton et al., 2019; Heger et al., 2021).

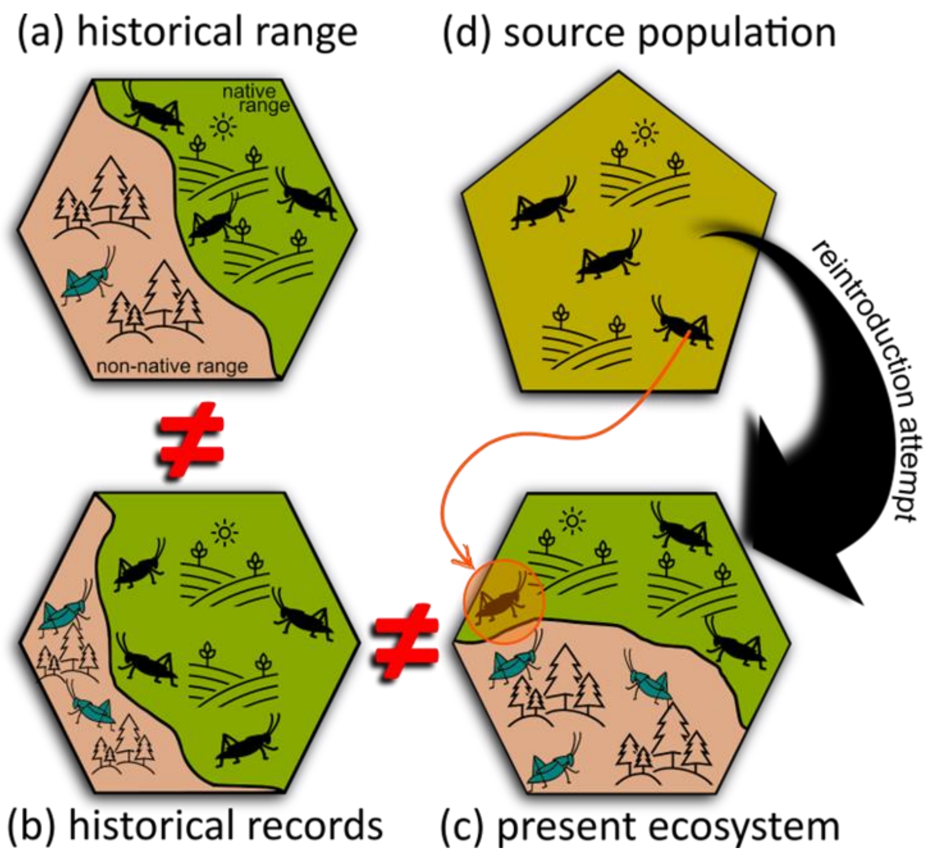

Figure 1: Relationships between the historical range (a), known historical records (b), and the species current distribution in an ecosystem (c) which are used to justify reintroduction attempts using potentially differing source populations (d).

II. Terminological expansion

The rate at which flora and fauna began to be redistributed widely as a consequence of human endeavour (e.g. the migration of Austronesians; during European colonialism and the so-called 'Columbian exchange') has since been fuelled by expanding transportation networks during the age of industrialization and rapid global change (Crosby, 1986; Amano et al., 2021; Elton, 2020;

Lenzner et al., 2022). The ecological effects of these introductions were so evident, pervasive, and manifold that they were noted by naturalists and others, including Indigenous Peoples, as early as the 19th Century (De Candolle, 1855; Darwin, 1859; Te Wehi, 1874; Berg, 1877), and more cogently in the first half of the 20th Century (Ritchie, 1920; Oliver, 1930; Madsen, 1937; King, 1942; Oosting, 1948; Leopold, 1949). However, following the publication of Charles S. Elton's seminal book *The Ecology of Invasions by Animals and Plants* in 1958, concerns have emerged about these phenomena (Cadotte, 2006), which Elton (1942) presciently described as an "ecological pandemonium". For the first time, Elton had described invasions as a process distinct from the colonizations that occur during ecological succession and that drove the breakdown of Wallace's biogeographic realms (Elton, 2020). Later, Baker & Stebbins (1965) took a more neutral stance, describing biological invasions as "probes" into the evolution and the inner workings of nature. Subsequently, invasion science, as in many other modern disciplines, grew out of a variety of older research fields, including agriculture, botany, ecology, entomology, forestry, mycology, human and animal pathology, and zoology, which often worked in isolation (Cadotte, 2006; Lockwood et al., 2013). This rapid growth proceeded without a generalizing framework to standardize and manage the proliferation of technical terminology employed in the field to describe similar phenomena. The international Scientific Committee on Problems of the Environment (SCOPE) programme of the 1980s focused on the integration of scientific knowledge in policy and decision-making related to prominent environmental challenges. It then finally initiated modern invasion science and triggered an explosion of publications (Simberloff, 2011) after setting an agenda for the study of biological invasions by posing three main questions: (1) What factors determine whether a species becomes invasive? (2) What attributes determine if an ecosystem is resilient or susceptible to invasion? and (3) How should invasions be managed, given knowledge addressing questions 1 and 2?

The continuous growth and advancements of invasion science are reflected in the increasing number of scientific publications on this topic, with > 8000 scientific papers published at its peak by 2019 (Fig. 1; see also Stevenson et al., 2023). This rapid increase partially reflects the extensive impact of biological invasions on various sectors, including the environment, socio-economy, and human well-being. The increasing interdisciplinarity of invasion science, and the diversity of community voices that were previously ignored in conservation science, underline the need to reconsider widely accepted definitions and concepts (Vaz et al., 2017). However, this trend also highlights the need to tighten the connections between invasion and conservation sciences, and between invasion science and policy, that could otherwise weaken over time (Copp et al., 2005; Stevenson et al., 2023).

To address these challenges already highlighted by Carlton (2002), interdisciplinary research is needed to bridge the gaps among fields (Fachinello et al., 2022), while simultaneously mitigating the proliferation of and reliance on disparate and convoluted terminology (Simberloff et al., 2013). The surging emphasis on frameworks (Wilson et al., 2020), theories, and hypotheses (Jeschke & Heger, 2018) has exposed certain concepts and ideas as potentially outdated and superfluous (Daly et al., 2023) or requiring amendment (Strayer et al., 2017; Soto et al., 2023a), while also identifying innovative paths such as moving beyond the 'linear' conceptualization of invasion dynamics (i.e. transport, introduction, establishment, spread; Blackburn et al., 2011). The first of four stage involves the movement of a species from its native range to a new location. This can be intentional, such as through trade or planting, or accidental, such as stowaways in shipping containers. In the second stage, the transported species is released into the new environment. It can be deliberate, such as when a species is introduced for pest control, or unintentional, such as escapees from aquaria, gardens, or ponds. Establishment refers to the successful reproduction and survival of a non-native species such that the new population becomes self-sustaining in its new environment. In the last stage the established non-native species expands its range within the new environment. Contemporary perspectives acknowledge the many context dependencies mediating invasions and challenging the simplistic view that invasions are isolated occurrences or linear processes, with invasions potentially better understood as part of an 'adaptive network'. This considers that spread and impact of non-native species are not simply determined by their intrinsic characteristics, but rather shaped by the broader ecological and socio-economic context (Hui & Richardson, 2019).

(1) Scale mismatches

Researchers focusing on specific aspects of invasion science across different disciplines have tended to favour nuanced terminology, which has resulted in polysemies evolving independently in each discipline. Another possible reason behind the many definitions that created ambiguity is the mismatch in spatial scale between measurement and inference of impact. Often, evaluations of a species' impacts are done at a local scale (e.g. within a specific lake or a forest patch), whereas broader large-scale impacts are inferred by extrapolating local-scale measurements of ecological effects and/or invader abundance across regions or even broader spatial scales, thereby ignoring the spatial variation in the type and severity of impacts that is expected to increase with spatial scale (Haubrock et al., 2022; Ahmed et al., 2023; Soto et al., 2023b). Furthermore, designating a species as 'non-native' is commonly reported at the national scale (the typical spatial entity for which regulations are established) depending on the perspective of each jurisdiction, but in reality nativeness is determined at the biogeographic scale, thereby de-emphasizing sub-national or regional differences and biogeographic boundaries. Furthermore, variation in national perspectives or definitions based on political boundaries (e.g. European Union Regulation 1143/2014) can generate inconsistent terminology. This is because distributions of non-native species frequently span many countries, while other species can be native to one part of a country and non-native to another (Baquero et al., 2023; Nelufule et al., 2023), exhibiting negative impacts only in the introduced parts of its range (Carey et al., 2012). This can lead to regional variation in approaches, terminology, and priorities within the same country (Vitule et al., 2019). One example is the pirarucu *Arapaima gigas* in Brazil, native to the Lower River Madeira basin in the Amazon. This species has been translocated to adjacent basins where it is not found naturally, resulting in detrimental effects on native species. While *A. gigas* is legally protected and threatened in its native range, the focus of local governments on farming this species generates a demand for more introductions into other basins (Doria et al., 2021).

Another profound example is the hundreds of non-native species crossing from the Red Sea to the Mediterranean Sea directly through the Suez Canal (Galil, 2006; Zenetos et al., 2012; Galil et al., 2021). In Israel, such species can be protected by law along the Red Sea coast, while they can be highly invasive in Mediterranean coastal ecosystems; e.g. lionfish *Pterois miles* (Sala et al., 2011; Stern et al., 2018; Ulman et al., 2020). These species might therefore require different legislative approaches, like targeted fishing in marine protected areas. The introduction of such species within specific regions or countries have posed challenges in measuring the extent of a species' native range (Pereyra, 2020).

The inconsistent use of terminology has also led to some native species being wrongly designated as 'non-native' (Valery et al., 2009). This issue is amplified in large countries such as Russia, Canada, China, Australia, South Africa, and Brazil, which have a diversity of biomes, basins and ecoregions, illustrating the complexity and nuance of species distribution within diverse environments (Yan et al., 2001; Spear & Chown, 2009; Maslyakov & Izhevsky, 2011; Dgebuadze, 2014; Ellender & Weyl, 2014; Nelufule et al. 2022). Furthermore, in countries spanning more than one biogeographical region, species can be both native in one part and non-native in another (e.g. largemouth bass *Micropterus salmoides* in Mexico; Wang et al., 2019). In countries with both continental and insular regions, the problem can be exacerbated, such as for some non-native species in Galápagos Islands native to continental Ecuador (e.g. Urquía et al., 2019), or others in Robinson Crusoe Island native to continental Chile (Correa et al., 2008).

The perceived status of a species can also shift from 'native' to 'non-native', requiring risk evaluation relative to other already assessed non-native species (e.g. the disputed status of crucian carp *Carassius carassius* in Great Britain; Clavero et al., 2016; Vilizzi et al., 2022a). Because the relative abundance of a non-native species within a community is often used to classify its degree of invasiveness (Catford et al., 2016; Haubrock et al., 2022), it can be difficult to separate species expanding their range from those that do not spread without considering the area of reference. Locally established populations of non-native species can exhibit invasive characteristics (i.e. through observed spread, a rapid increase in relative abundance, and/or impacts) in one location, but not in another due to differences in *inter alia* source populations, residence time, habitat invasibility, and environmental (including climatic) conditions of the newly occupied area (Schaffner, 2005).

From a legislative perspective, applying a uniform definition and management approach based solely on national boundaries overlooks the diverse ecological and social contexts, and potential impacts, that might exist within different regions of the same country (Matsuzaki et al., 2013; Weyl et al., 2016; Sommerwerk et al., 2017). Therefore, spatially explicit information on distribution and status within a biogeographic region and understanding socio-economic and cultural contexts and values, are important for effective management. However, policy and management strategies are generally framed within specific organizational scopes, such as at the country scale. In many cases, even categorizing a species as 'native' or 'non-native' itself at such scales shapes perception and subsequent actions, but there are exceptions. For example, the European Union Regulation on Invasive Alien Species 1143/2014 takes into account three spatial scales: European (i.e. encompassing all Member States), regional, and national. This multi-scale approach allows for a more nuanced consideration of species categorization and corresponding policies within the European Union.

(2) Lack of consensus

Despite more than four decades of modern invasion science and the recognized need for a consistent approach, there is still a lack of consensus over the meaning and usefulness of the terminologies currently in use (Colautti & MacIsaac, 2004; Valery et al., 2008; Shackleton et al., 2022). The lack of a clear terminology has been exploited in ongoing criticism from those who aim to undermine the value and fundamental goals of invasion science (see Richardson & Ricciardi, 2013), which has further impeded clear communication of the issues associated with biological invasions. In turn, ambiguity can (1) reduce people's understanding and willingness to support actions to avoid or manage biological invasions (e.g. Dunn et al., 2018; Cerri et al., 2020), (2) be used for ideological or political manipulation of controversial topics arising from non-native species, (3) shift liability and responsibility for management away from certain stakeholders or even nations that are otherwise bound to prevent and eliminate biological invasions based on prior commitments (e.g. parties to the *Convention on Biological Diversity*, cbd.int), and ultimately (4) hinder control and management in ways that increase risks of higher costs or even irreversible damage (Ahmed et al., 2022).

Our aims are to (1) review regularly used terms in invasion science and to break down the core definitions of the relevant terminology to identify any associated ideological interpretation; (2) explore recently proposed approaches by the Darwin Core terms ('degree of establishment' rs.tdwg.org/dwcdoe/values and 'means' dwc.tdwg.org/em; see Groom et al., 2019), the *Convention on Biological Diversity*, and by Blackburn et al. (2011) to identify their strengths and commonalities; (3) propose a simplified terminology to collapse synonymies to produce a harmonized set of terms for standardization; and (4) propose an objective classification protocol for non-native species considering four components: (*i*) dispersal mechanism, (*ii*) origin, (*iii*) status, and (*iv*) impact. Building on the extensive knowledge gained from previous research and tackling the entanglement of the ongoing discussion, our review attempts to mitigate these concerns by suggesting a consolidated, streamlined, and all-encompassing terminology. This framework aims to imbue the lexicon of invasion science with clarity. While striving for a consensus definition is beneficial, we concede that it might not always be attainable, particularly when dealing with pluralism and complex concepts like biodiversity, species, and life (Pascual et al., 2021). We therefore acknowledge that even among ourselves, there remains disagreement about how some terms should be defined, reflecting the diversity of opinions within our evolving field and demonstrating the importance of international and multidisciplinary discussions on how to clarify terminology.

III. Terminological tempest

The language of invasion science is a complex network of terms that are often used interchangeably, yet each of these terms carries specific implications for understanding the nature, origins, and impacts of the responsible organisms. The meaning of these terms can also vary among scholars in various disciplines, by culture and education, and among policymakers and the public (see Ricciardi & Cohen, 2007). In August 2023, we did a comprehensive search of the literature to identify relevant terms used to describe 'non-native' species (Table 1). We initially reviewed Colautti & MacIsaac (2004), Falk-Petersen et al. (2006), and Lockwood et al. (2013), which we subsequently expanded with suggestions by co-authors and checked the resulting terms in the *Web of Science* for relevance.

In total, we identified 59 terms used to describe or classify non-native species, which exceeds those identified by Colautti & MacIsaac (2004), Falk-Petersen et al. (2006), and Lockwood et al. (2013) more than a decade ago (they identified 25, 30, and 27 terms, respectively). Based on a comprehensive scoping review, employing platforms such as *Web of Science* and *Google Scholar*, as well as opportunistic searches to explore both scientific and grey literature, we then counted the number of papers that employed those 59 terms based on the specific search for each term (e.g. 'invasive' species; Table 1), while excluding unrelated fields such as medicine or psychology. We focused on literature published in English, but with the exponential growth in the number of potentially relevant papers in non-English languages (Chowdhury et al., 2023), we assume a similar boom in terminology could be also expected in many other languages. We recognize that integrating literature from other languages enriches many scientific disciplines (Angulo et al., 2021; Zenni et al., 2023); however, it could also introduce socio-political complexities that are not central to our primary objective — a concise terminology in invasion science. As non-English languages gain prominence in scientific discourse, the need to propose unified terminologies becomes even more pressing to ensure a global consensus on knowledge and best practice.

Table 1: Definitions of the English terms most often used in invasion science for classifying species. The terms highlighted in *italics* and **boldface** in the Definition column indicate cases where particular terms are themselves used as definitions. Brackets accompanying each term in the first column indicate the number of identified papers for that specific term. Related terms refer to synonyms and associated terms.

Term	Definition	Example references	Related terms
acclimatized (**8**)	despite being able to fulfil a portion or most of its life cycle in a ***foreign*** environment or climate, unable to reproduce or maintain a viable population without human intervention	Scalera & Zaghi (2004)	*adventive, casual, newcomer, non-resident, transient*
adventive (**162**)	in an early stage of ***invasion*** and not yet spread 'extensively' [undefined] beyond the point of introduction	Morris (1992); Binggeli (1994); Lawrence (2000); Klimaszewski et al. (2013)	*acclimatized, casual, newcomer, non-resident, transient*
alien (**8080**)	***introduced*** to an area in which does not occur naturally	Crawley et al. (1999), Pyšek et al. (2020)	*allochthonous, anthropochore, exotic, foreign, imported, immigrant, introduced, migrant, non-indigenous, non-native, transported, xenobiota*
allochthonous (**130**)	***introduced*** into a new area outside the native range (in which it is autochthonous in the latter)	Corsini-Foka & Economidis (2007)	*alien, anthropochore, exotic, foreign, imported, immigrant, introduced, migrant, neobiota, non-indigenous, non-native, transported, xenobiota*
anthropochore (**96**)	actively disperse seeds or propagules through direct or indirect human intervention	James & Hendrix (2004)	*alien, allochthonous, exotic, foreign, imported, immigrant, introduced, migrant, neobiota, non-indigenous, non-native, transported, xenobiota*
archaeophyte (**230**)	plants that became ***naturalized*** in a specific region or area before 1492 (pre-'Columbian exchange')	La Sorte & Pyšek (2009)	*neophyte*
bioinvader (**35**)	***non-native introduced*** to new environments and cause ecological and socio-economic damage	Pérez et al. (2008)	*biopollution, invasive/invader, noxious, nuisance, pest, unwanted, vermin, weed*
biopollution (**30**)	have harmful or disruptive effects on native ecosystems, often due to ***invasive*** nature or aggressive behaviours	Occhipinti-Ambrogi (2021)	*bioinvader, invasive/invader, noxious, nuisance, pest, unwanted, vermin, weed*
casual (**40**)	incapable of persisting in a novel environment, despite capacity for reproduction there; persistence depends on regular re-***introductions*** to rescue otherwise moribund populations	Wu et al. (2004)	*acclimatized, adventive, newcomer, non-resident, transient*
colonizer /	capable of ***establishing*** in a new area, often through a combination of	Davis & Thompson	*established, invasive/invader, naturalized, transformer*

Term	**Definition**	**Example references**	**Related terms**
colonist (**5954**)	high reproductive rates, efficient dispersal, and adaptive traits enabling it to tolerate or exploit the new environment; individuals in a founding population reproduce, increase in abundance, and form a self-perpetuating population	(2000); Davis (2009)	
cryptogenic (**162**)	when there is uncertainty about the native range, and native/***non-native*** status in an area	Carlton (1996)	*questionable*
domestic (invasive, exotic, alien) (**8**)	introduced to internal units from within the national border	Guo & Ricklefs (2010); Kamada et al. (2013)	*extralimital, translocated, intra-country established alien*
escaped **(9)**	escaped captivity (e.g. pet stores, aquaculture facilities, herbaria, zoos, garden plants), and ***established*** populations in the wild	Padilla & Williams (2004)	*feral, released*
established **(817)**	self-sustaining population(s) in a new area; phenomenon experienced by an ***alien*** after ***introduction*** aimed at ***establishing*** an independent population in natural habitats	Keller et al. (2011); Gormley et al. (2011)	*colonizer/colonist, invasive/invader, naturalized, transformer*
exotic **(6883)**	***introduced*** into a new area outside the native range	Green (1997); Myers et al. (2000)	*alien, allochthonous, anthropochore, foreign, imported, immigrant, introduced, migrant, neobiota, non-indigenous, non-native, transported, xenobiota*
extralimital **(56)**	native range falls within the political boundaries of a country, but presence in another part of the same country attributable to human transport across biogeographical barriers	Robinson et al. (2016)	*intra-country established alien, transferred, translocated, tramp, vagrant, waif*
feral **(53)**	organisms or their descendants domesticated, confined (animals) or cultivated (plants) and subsequently released or ***escaped*** into the natural environment	Liu & Li (2009)	*escaped, released*
foreign **(162)**	***non-native*** or ***non-indigenous*** to a particular region or country; ***translocated*** beyond its native range to another country across an international boundary	Richardson & Pyšek (2008)	*alien, allochthonous, anthropochore, exotic, imported, immigrant, introduced, migrant, neobiota, non-indigenous, non-native, transported, xenobiota*
immigrant **(64)**	moved from the native range to a new area where not previously occurring naturally	De Meester et al. (2007)	*alien, allochthonous, anthropochore, exotic, foreign, imported, introduced, migrant, neobiota, non-indigenous, non-native, transported, xenobiota*
imported	***translocated*** into a new area from the native range	Holzapfel &	*alien, allochthonous, anthropochore, exotic, foreign,*

Term	**Definition**	**Example references**	**Related terms**
(53)		Vinebrooke (2005); Williamson & Fitter (1996)	*immigrant, introduced, migrant, neobiota, non-indigenous, non-native, transported, xenobiota*
intra-country established alien **(1)**	successful ***introductions*** and ***establishment*** among regions or in a novel region within the same country	Vitule et al. (2019)	*extralimital, native-alien populations, transferred, translocated, tramp, vagrant, waif*
introduced **(5443)**	***translocated*** by humans to a new geographic location where did not occur naturally; intentional or unintentional (accidental) ***introduction*** and/or release by humans, either directly or indirectly, into natural or anthropogenically altered (e.g. urban) environments or locations, in geographical areas where (species, sub, race, or variety) is not found naturally	Simberloff et al. (2005)	*alien, allochthonous, anthropochore, exotic, foreign, imported, immigrant, migrant, neobiota, non-indigenous, non-native, transported, xenobiota*
invader **(9978) /** *invasive* **(26030)**	***non-natives introduced*** to a new environment with ability to spread and cause ecological and socio-economic damage; either native or ***alien*** that can spread and ***establish*** in natural or semi-natural habitats, either with or without human assistance; can encompass spread and/or impact	Simberloff (2010)	*colonizer/colonist, established, naturalized, transformer*
invasive alien **(2402)**	introduction and/or spread outside natural past or present distribution threatens biological diversity	CBD (2002); Pyšek et al. (2020)	*invasive non-native, invasive super dominant, neonative, new non-native*
invasive non-native **(242)**	***introduced*** by humans (intentionally or accidentally) into areas where does not occur naturally without recognisable negative impact	Vitule et al. (2021); CBD (2006)	*invasive alien, invasive super dominant, neonative, new non-native*
invasive super dominant **(1)**	not only successfully **established** in a new ecosystem, but also becomes dominant, having substantive influence on the ecosystem's structure or function	Pivello et al. (2018)	*invasive alien, invasive non-native, neonative, new non-native, transformer*
migrant **(444)**	moved from its native habitats to new geographic areas; can be natural (e.g. birds migrating between continents), or facilitated by humans	Ibanez et al. (2008)	*alien, allochthonous, anthropochore, exotic, foreign, imported, immigrant, introduced, neobiota, non-indigenous, non-native, transported, xenobiota*
naturalized **(379)**	***non-native*** successfully ***established*** self-sustaining populations in a new environment without human intervention; ***non-native*** after being ***introduced*** successfully ***established*** self-sustaining populations in the wild; must be present long enough to be perceived as an integral [undefined] part of the resident community of organisms	Wu et al. (2004)	*colonizer/colonist, established, invasive/invader, transformer*

Term	Definition	Example references	Related terms
neobiota **(40)**	***introduced*** into new habitats or regions, typically due to human activities; can have ecological impacts and include **invasives**	Schittko et al. (2020)	*alien, allochthonous, anthropochore, exotic, foreign, imported, immigrant, introduced, migrant, non-indigenous, non-native, transported, xenobiota*
neophyte (**766**)	***introduced*** to a new habitat or region after 1492; often not fully integrated into new ecosystems and can still be in the process of spreading and establishing	Kühn et al. (2017)	*archaeophyte*
new non-native (**28**)	fills similar role(s) to an extinct native that is not closely related (no more closely related than Order)	Blackman et al. (2017)	*invasive alien, invasive non-native, invasive super dominants, neonative*
neonative (**5**)	expanded geographically beyond native range and ***established*** populations driven by human-induced environmental change without human assistance	Essl et al. (2019, 2021) Wallingford et al. (2020)	*invasive alien, invasive non-native, new non-native*
newcomer (**6**)	recently ***established*** in a particular ecosystem or geographical area, often due to natural or human-mediated ***introductions***	Evans et al. (2020)	*acclimatized, adventive, casual, non-resident, transient*
non-indigenous (**2349**)	not found naturally in a particular geographic location or ecosystem	Ojaveer et al. (2015)	*alien, allochthonous, anthropochore, exotic, foreign, imported, immigrant, introduced, migrant, neobiota, non-native, transported, xenobiota*
non-native (**5341**)	***introduced*** to an area outside of natural range	Jeschke et al. (2014)	*alien, allochthonous, anthropochore, exotic, foreign, imported, immigrant, introduced, migrant, neobiota, non-indigenous, transported, xenobiota*
non-resident (**46**)	no recent evolutionary history in focal ecological network and not familiar with species in that network (cf. 'resident')	Eckstein et al. (2012); Saul & Jeschke (2015)	*acclimatized, adventive, casual, newcomer, transient*
noxious (**65**)	harmful or dangerous to human health, agriculture, or environment	Andreu et al. (2009)	*bioinvader, biopollution, invasive/invader, nuisance, pest, unwanted, vermin, weed*
nuisance (**256**)	annoying or inconveniencing humans; typically not harmful or dangerous; can be ***non-native*** or native	Barrett et al. (2019)	*bioinvader, biopollution, invasive/invader, noxious, pest, unwanted, vermin, weed*
pest (**2702**)	harmful or destructive to humans, crops, livestock, or property; can be ***non-native*** or native	Worner & Gevrey (2006)	*bioinvader, biopollution, invasive/invader, noxious, nuisance, unwanted, vermin, weed*
Pseudo-	***introduced*** species mistakenly identified as native	Carlton (2009)	

Term	Definition	Example references	Related terms
indigenous **(7)**			
questionable (**28**)	status as native or ***non-native*** (***alien***/***invasive***) uncertain or disputed	Zenetos et al. (2010)	*cryptogenic*
range-expanding (**65**)	extends geographical distribution beyond previously known or ***established*** range, often due to climate change, habitat modification, or dispersal abilities	Essl et al. (2019)	*colonizer/colonist, established, invasive/invader, naturalized, transformer*
released (**58**)	deliberately or accidentally ***introduced*** into an environment outside of native range by humans	Blumenthal (2006)	*escaped, feral*
restocked (**1**)	re-***introduced*** or replenished in a specific area through deliberate human intervention, often aimed at restoring or increasing population sizes, not specifically of same species	Roll et al. (2007)	*transplanted*
tramp (**48**)	ability to colonize and spread rapidly across new habitats, often facilitated by humans; (***non-native***) disturbance specialist, closely associated with humans	Passera (2021)	*extralimital, intra-country established alien, transferred, translocated, vagrant, waif*
transferred (**80**)	moved across a national border to a country within natural range	McGlynn (1999)	*extralimital, intra-country established alien, translocated, tramp, vagrant, waif*
transformer (**24**)	alter the character, condition, form, or nature of an ecosystem over a broad area	Richardson et al. (2000); Protopopova et al. (2015)	*colonizer/colonist, established, invasive/invader, invasive super dominants, naturalized*
transient (**496**)	occurs in a particular location only temporarily or sporadically	Snell Taylor et al. (2018)	*acclimatized, adventive, casual, newcomer, non-resident ,*
translocated (**98**)	moved from native range to a new location by humans; ***intra-country*** translocation is ***introduction*** from one region or political entity (country) within the same country where native to another region and where not found naturally; moved by humans for conservation (e.g. assisted migration/colonization); see also ***intra-country established alien***	Vitule et al. (2019); Doria et al. (2021); Essl et al. (2021)	*extralimital, intra-country established alien, transferred, tramp, vagrant, waif*
transplanted (**58**)	***introduced*** outside native range, usually for ecological restoration or commerce/recreation; can be either ***non-native*** or native to area of	Hargreaves et al. (2014)	*restocked*

Term	Definition	Example references	Related terms
	transplantation		
transported (**94**)	moved outside native range, can be either ***non-native*** or native to area of transport	Gross & Pharr (1982)	*alien, allochthonous, anthropochore, exotic, foreign, imported, immigrant, introduced, migrant, neobiota, non-indigenous, non-native, xenobiota*
unwanted (**97**)	undesirable for humans, crops, aquaculture, or property; can be ***non-native*** or native	Iuell (2002); Naylor et al. (2001); Caley & Kuhnert (2006); Nagy & Johnson II (2013)	*bioinvader, biopollution, noxious, nuisance, pest, vermin, weed*
vagrant (**61**)	occur outside typical or expected range or habitat, often individual or fine-scale occurrences	Luiz et al. (2013)	*extralimital, intra-country established alien, transferred, translocated, tramp, waif*
vermin (**147**)	undesirable due to detrimental impacts on agriculture, horticulture, or enemies to game preservation	Smout (2003)	*bioinvader, biopollution, noxious, nuisance, pest, unwanted, weed*
waif (**74**)	found outside normal geographic range, usually far from native habitat, often without clear evidence of human-mediated transport	Christy et al. (2009)	*extralimital, intra-country established alien, transferred, translocated, tramp, vagrant*
weed (**6146**)	plants considered undesirable or unwanted in a particular setting, typically due to competitive nature, rapid growth, and ability to spread quickly	Ogg & Dawson (1984)	*bioinvader, biopollution, noxious, nuisance, pest, unwanted, vermin*
xenobiota (**1**)	***introduced*** or ***non-native*** to a particular ecosystem or geographic region, often originating from a different ecosystem or geographic area	Tsadok et al. (2015)	*alien, allochthonous, anthropochore, exotic, foreign, imported, immigrant, introduced, migrant, neobiota, non-indigenous, non-native, transported*

Increasing scientific interest resulting in more published articles has introduced more terms to the lexicon (Fig. 1), which seems to be a source of confusion and potential driving force of ambiguity in identifying non-native species, prioritizing management, determining appropriate control measures, and allocating resources adequately and effectively (Ricciardi & Cohen, 2007; Lockwood et al., 2013; Iannone III et al., 2020). This issue is compounded by the use of acronyms and initialisms for terminology. An example is the initialism 'IAS' used by some for 'invasive alien species', whereas others have used it to mean 'invasive animal species' (Carlon & Dominoni, 2023). Similarly, South Africa's regulations on biological invasions refer to 'alien and invasive species', often shortened to 'AIS' and then confused with the narrower grouping of 'alien invasive species' ('AIS', a synonym of 'IAS'). Others have proferred the initialism 'A&IS' to resolve this confusion, although yet another initialism still represents specialist jargon (Zengeya & Wilson, 2020). At the same time, the initialism 'AIS' has been recently used to indicate 'aquatic invasive species' in the documentations and website of the Great Lakes Commission (Canada, USA; glc.org/work/ais), adding to the terminological confusion. Another example is the use of the term 'non-indigenous species' (and initialism 'NIS') (synonym: non-native species) in some peer-reviewed papers (Colautti et al., 2006; Colautti & Richardson, 2009; Ojaveer et al., 2015; Riera et al., 2018), whereas the same abbreviation has been used to indicate a 'nuisance invasive species' (Pereyra et al., 2012). Adding to the confusion, initialisms for the same term differ among nations and regions — adapted to their own language — such as the governmental initiatives in Argentina and Brazil called 'National Strategy on Invasive Exotic Species' ('NSIES' or 'ENEEI' in Portuguese or Spanish; Faria et al., 2022; Schwindt et al., 2022).

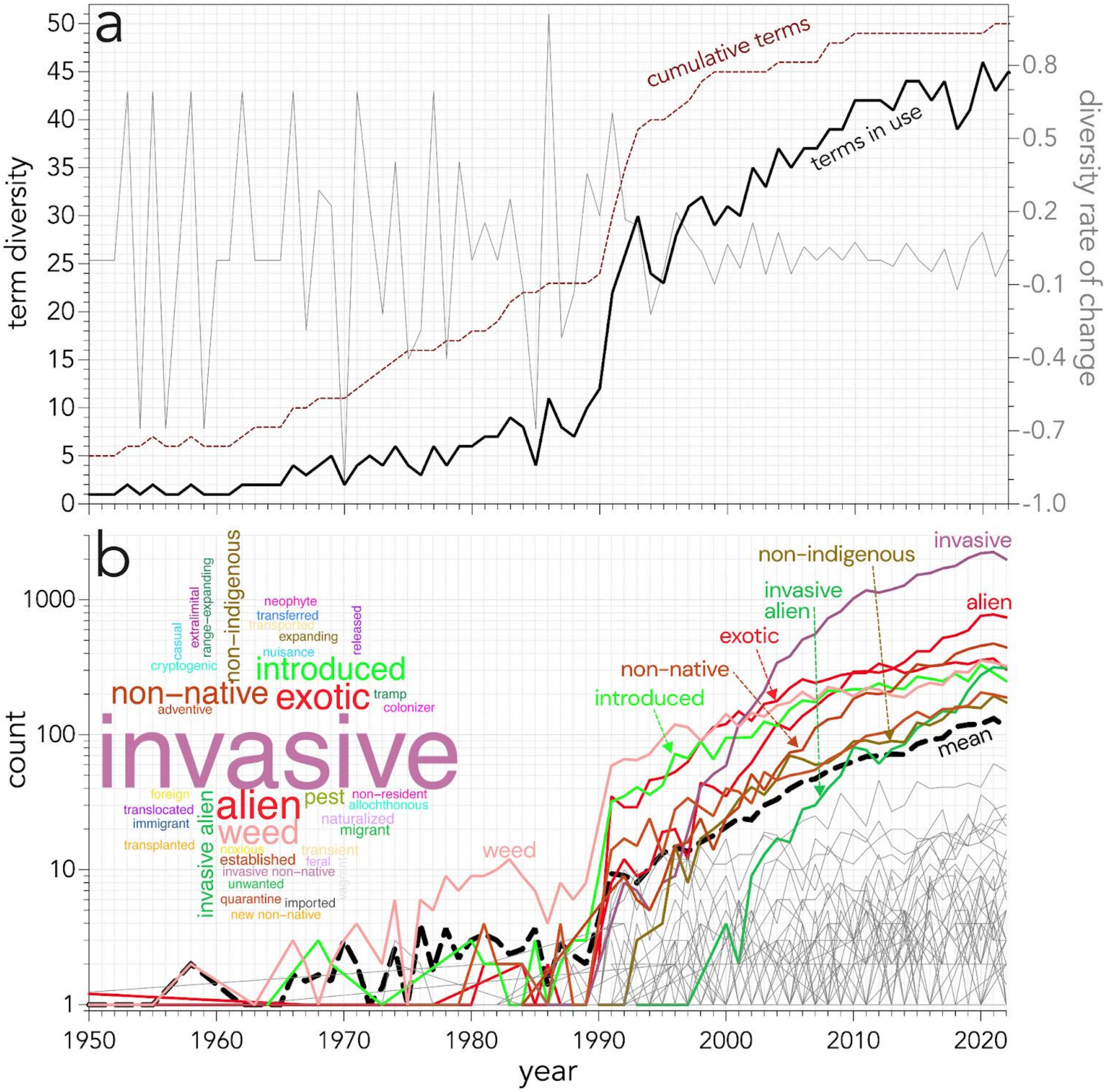

Figure 2. (a) Total term diversity (i.e. number of different terms used in each particular year) over time, cumulative term diversity, and the instantaneous rate of term change. (b) Count timeline (log_{10} scale) lines reflecting the trend for each individual term (some popular terms are highlighted with colours). Wordcloud (inset) shows the total frequency use of each term (size of text is proportional to the total number of uses — only 40 different terms shown). All terms here were accompanied by a terminal 'species' in the search string (e.g. 'invasive species'). Data and R code to reproduce trends and word cloud available from github.com/IsmaSA/Invasion-science-terminology.

Among the terms we found in the identified literature, the most frequent was 'invasive', appearing in 37.1% of the 70,188 publications (Fig. 2), followed by terms such as 'alien', 'non-native', 'exotic', and *inter alia* 'introduced'. However, the relative dominance of terms varied when using the adjective alone (i.e., without 'species'), albeit painting a comparable picture (Supplementary Figure 1). The use of these terms often varied according to the scientific discipline. For example, 'weed' is commonly used in botanical studies focusing on plant invasion. In contrast, 'invasive' is a more universal term applicable to all taxa, which likely explains its widespread uptake across many disciplines. The term 'invasive' itself has a convoluted origin. Initially used by Elton who was influenced by the two World Wars, a terminological shift occurred in the 1990s as 'invasive' began replacing terms like 'introduced' (sometimes used to refer to those at the arrival stage and/or those established) and 'non-indigenous'. At a national scale, this shift was deliberately implemented in US legislation, specifically when the *Non-Indigenous Aquatic Nuisance Prevention and Control Act 1990* was renewed in 1995 and renamed the *National Invasive Species Act*. The two main elements influencing this revision were that: (*i*) the term 'invasive' carried a more impactful and compelling implication compared to the milder 'non-indigenous' (Carlton, 2002), and (*ii*) the 1990 act lacked an easily pronounceable acronym, leading to alternative names such as the *Ballast Water Act* or *Zebra Mussel Act*. The definition of 'invasive' was further obscured with Executive Order 13112 by U.S. President Bill Clinton in 1999, which specifically included 'impact' and 'economic harm'. 'Invasive alien species' is currently used by the European Commission in its regulations (environment.ec.europa.eu/topics/nature-and-biodiversity/invasive-alien-species_en), which is also the term most widely used by the Convention on Biological Diversity (in English, but not in other languages), the United Nations Sustainable Development Goals, and International Union for Conservation of Nature (IUCN).

Several papers and book chapters subsequently explored and discussed the term 'invasive' (Sax et al., 2005; Lockwood et al., 2013). In general, terminological pitfalls have been avoided by providing definitions for selected terminology (e.g. Rilov & Crooks, 2009). However, 'invasive' is often used without a precise description of its implications, such as the extent of spread observed (for spread-based definitions) or impact caused (for harm-based definitions), which are themselves ambiguous. One type of impact is denoted 'species replacement', which has been ambiguously described as 'displacement', 'elimination', 'eradication', 'exclusion', 'extirpation', 'extinction', and 'supplanted'. 'Invasive' can also have several meanings; for example, it can refer to species that have successfully established and spread to new areas, regardless of their impacts (Richardson et al., 2000; Blackburn et al., 2011), or those causing ecological or socio-economic harm in their new environment regardless of the stage of the invasion process (Leung et al., 2002; Lockwood et al., 2013). 'Invasive' has also been misapplied to weedy species such as *Phragmites australis* in Europe and Asia, where it is native but can become dominant due to human disturbance (Lambert et al., 2010). 'Invasive' has even been applied to ecologically dominant native species undergoing a demographic explosion (Valery et al., 2009; Packer et al., 2017), possibly a legacy of early plant scientists using 'invading' synonymously with 'spreading'.

Amid this etymological complexity, the nuanced interpretations of several terms used by invasion scientists to describe species such as 'invasive', 'invader', 'introduced', 'naturalized', 'non-indigenous', and 'exotic' cannot be overlooked. These terms are often used interchangeably, even within a single study (to avoid word repetitions), raising several concerns about their potential misinterpretation and misapplication, including the politicization of non-native species (Ricciardi & Cohen, 2007; Russell & Blackburn, 2017). Each of these terms can have a unique, nuanced interpretation that relates to a specific aspect of population spread and the perceived negative impacts it can cause (Lockwood et al., 2013). As such, labelling a species 'invasive' implies that its populations pose some harm or threat according to some frequently adopted definitions, such as those used by the Convention on Biological Diversity (Leung et al., 2002; Lockwood et al., 2013), but other definitions do not invoke harm or impact in general (Falk-Petersen et al., 2006; Ricciardi & Cohen, 2007). Other terms such as 'exotic', 'alien', and 'non-indigenous' do not inherently imply harm to ecological or socio-economic systems (see also Falk-Petersen et al., 2006; Stoett, 2010; Fachinello et al., 2022).

(1) Previous attempts to tame the terminological tempest

Despite several attempts to address the complex terminology in invasion science (reviewed in Table 2), confusion nevertheless persists (Occhipinti-Ambrogi & Galil, 2004; Courchamp et al., 2017; Colautti & Richardson, 2009). This has led to proposed protocols to identify the most appropriate terms for classifying species based on their stage of invasion (Colautti & Richardson, 2009; Colautti et al., 2014). The Convention on Biological Diversity followed a simple and practical approach by defining 'invasive' as "... non-native plants, animals, pathogens, and other organisms that are introduced or that spread outside their natural habitats if they pose a threat to native biodiversity, otherwise cause environmental harm, impose negative economic consequences, or adversely affect human health". This definition emphasizes measurable, negative impact (itself time-dependent, and might occur without notice or measure) and the potential for spread, with these two phenomena not necessarily linked. However, the ability or potential to spread is, like introduction, often aided by humans. But all established non-native species, because they interact with the local environment, will have some type of ecological effect — positive, negative, or mixed — along a continuum from negligible to enormous (Ricciardi et al., 2013). Indeed, widely cited estimates of the proportion of invasions that have impacts are likely underestimated (Simberloff et al., 2013).

Determining what constitutes an 'invasive' species can be difficult because of the demographic dimensions of invasiveness (Colautti & MacIsaac, 2004) and the underlying mechanisms involved (Gurevitch et al., 2011; Rejmanek, 2011). Blackburn et al. (2011) proposed a highly cited and useful framework for biological invasions, where various terminologies for non-native species are associated throughout the different stages of an invasion. Therein, invasion state and impact are independent, because different populations can have measurable impacts at varying stages. While 'invasive' should be defined based on a population's stage of an invasion and spread patterns, the exerted impact should be considered a separate dimension pertaining to a specific invading population. However, various populations can exert differing magnitudes of impact at different stages of an invasion over time, which depend on the type of impact and the specific features of the invaded ecosystem (Gallardo et al., 2016). Inferences of impact can also depend on perceptions and socio-economic evaluations (Falk-Petersen et al., 2006).

Yet, defining a non-native species' invasiveness based exclusively on its ability to spread would imply that countless species qualify as 'invasive' as global change proceeds. Meanwhile, the focus on an identified impact could impede managers and stakeholders to act until a negative impact is measured, such as for non-native species not currently spreading, but that cause local harm (Balzani et al., 2022). This *modus operandi* would, however, reinforce the current predominance of reactive management strategies for biological invasions, rather than proactive actions that could avoid later harm (Cuthbert et al., 2022). Because all non-native species might have an impact at some point during the invasion process, such as by consuming resources or simply occupying space, the magnitude of impact can change unpredictably.

But measures of impact do not necessarily determine if a species is invasive, even though they are useful for assessing the risk of an invasion, and are therefore commonly applied in risk analyses. To identify the invasion risk or the invasiveness of non-native species based on their observed or predicted impacts, various methods such as the Australian Weed Risk Assessment scheme (Pheloung et al., 1999), the European and Mediterranean Plant Protection Organisation Platform on Pest Risk Analysis (Soliman et al., 2010), and related decision-support tools (Copp et al., 2016; Vilizzi et al., 2022b) have been developed. However, current risk-screening tools generally lack fully quantitative foundations, often incorporating qualitative information such as expert assessments due to limited tangible data or information on impacts (Roy et al., 2014, 2018). A knowledge gap arises from biassed impact research targeting specific taxa, regions, or values, further complicated by context-dependent and time-lagged effects. Unfortunately, the formal and reliable information required for accurate and objective assessments is frequently lacking and/or is (spatially) incomplete for many non-native species, resulting in discrepancies among inadequate spatial risk and impact assessments (González-Moreno et al., 2019).

Table 2: Published articles and books (arranged chronologically, without claiming completeness) that have highlighted the ongoing debate and confusion over terminology in invasion science, many of which aimed to standardize the invasion science lexicon.

Year	Reference
1995	Pyšek, P. (1995). On the terminology used in plant invasion studies. In *Plant invasions: General aspects and special problems*

	(eds P. Pyšek, K. Parch, M. Rejmanek and M. Wade), pp. 71–81. SPB Academic Publishing.
1997	Shigesada, N. & Kawasaki, K. (1997). Biological invasions: theory and practice. Oxford University Press.
1999	Lonsdale, W.M. (1999). Global patterns of plant invasions and the concept of invasibility. *Ecology* **80**, 1522–1536.
2000	Davis, M.A. & Thompson, K. (2000). Eight ways to be a colonizer; two ways to be an invader: a proposed nomenclature scheme for invasion ecology. *Bulletin of the Ecological Society of America* **81**, 226–230.
2000	Richardson, D.M., Pyšek, P., Rejmanek, M., Barbour, M.G., Panetta, F.D. & West, C.J. (2000). Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions* **6**, 93–107.
2002	Carlton, J.T. (2002). Bioinvasion ecology: assessing invasion impact and scale. In *Invasive aquatic species of Europe. Distribution, impacts and management* (eds E. Leppäkoski, S. Gollasch and S. Olenin), pp. 7–19. Dordrecht: Springer Netherlands.
2004	Colautti, R.I. & MacIsaac, H.J. (2004). A neutral terminology to define 'invasive' species. *Diversity and Distributions* **2**, 135–141.
2004	Brown, J.H. & Sax, D.F. (2004). An essay on some topics concerning invasive species. *Austral Ecology* **29**, 530–536.
2004	Pyšek, P., Richardson, D.M., Rejmánek, M., Webster, G.L., Williamson, M. & Kirschner, J. (2004). Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. *Taxon* **53**, 131–-143.
2005	Copp, G.H., Bianco, P.G., Bogutskaya, N.G., Erős, T., Falka, I., Ferreira, M.T., Fox, M.G., Freyhof, J., Gozlan, R.E., Grabowska, J., Kovac, V., Moreno-Amich, R., Naseka, A.M., Penaz, M., Povz, M., Przybylski, M., Robillard, M., Russell, I.C., Stakenas, S., Sumer, S., Vila-Gispert, A. & Wiesner, C. (2005). To be, or not to be, a non-native freshwater fish? *Journal of Applied Ichthyology* **21**, 242–262.
2005	Helmreich, S. (2005). How scientists think; about 'natives', for example. A problem of taxonomy among biologists of alien species in Hawaii. *Journal of the Royal Anthropological Institute* **11**, 107–128.
2006	Falk-Petersen, J., Bøhn, T. & Sandlund, O.T. (2006). On the numerous concepts in invasion biology. *Biological Invasions* **8**, 1409–1424.
2007	Warren, C.R. (2007). Perspectives on the 'alien' versus 'native' species debate: A critique of concepts, language and practice. *Progress in Human Geography* **31**, 427–446.
2007	Ricciardi, A. & Cohen, J. (2007). The invasiveness of an introduced species does not predict its impact. *Biological Invasions* **9**, 309–315.
2007	Larson, B.M. (2007). An alien approach to invasive species: objectivity and society in invasion biology. *Biological Invasions* **9**, 947–956.
2008	Valéry, L., Fritz, H., Lefeuvre, J.C. & Simberloff, D. (2008). In search of a real definition of the biological invasion phenomenon itself. *Biological Invasions* **10**, 1345–1351.
2009	Colautti, R.I. & Richardson, D.M. (2009). Subjectivity and flexibility in invasion terminology: too much of a good thing? *Biological Invasions* **11**, 1225–1229.
2009	Wilson, J.R.U., Dormontt, E.E., Prentis, P.J., Lowe, A.J. & Richardson DM (2009a). Biogeographic concepts define invasion biology. *Trends in Ecology & Evolution* **24**, 586.
2009	Wilson, J.R.U., Dormontt, E.E., Prentis, P.J., Lowe, A.J. & Richardson, D.M. (2009b). Something in the way you move: dispersal pathways affect invasion success. *Trends in Ecology & Evolution* **24**, 136–144.
2011	Richardson, D.M., Pyšek, P. & Carlton, J.T. (2011). A compendium of essential concepts and terminology in invasion ecology. In *Fifty years of invasion ecology: the legacy of Charles Elton* (ed D.M. Richardson), pp. 409–420. Wiley-Blackwell.
2011	Gurevitch, J., Fox, G.A., Wardle, G.M. & Inderjit D.T. (2011). Emergent insights from the synthesis of conceptual frameworks for biological invasions. *Ecology Letters* **14**, 407–418.
2013	Shackelford, N., Hobbs, R.J., Heller, N.E., Hallett, L.M. & Seastedt, T.R. (2013). Finding a middle-ground: the native/non-native debate. *Biological Conservation* **158**, 55–62.

2013	Lockwood, J. L., Hoopes, M.F. & Marchetti, M.P. (2013). Invasion Ecology. John Wiley & Sons.
2013	Heger, T., Saul, W.C. & Trepl, L. (2013). What biological invasions 'are' is a matter of perspective. *Journal for Nature Conservation* **21**, 93–96.
2013	Richardson, D.M. & Ricciardi, A. (2013). Misleading criticisms of invasion science: a field guide. *Diversity and Distributions* **19**, 1461–1467.
2013	Simberloff, D., Martin, J.L., Genovesi, P., Maris, V., Wardle, D.A., Aronson, J., Courchamp, F., Galis, B.S., Garcia-Berthou, E., Pascal, M., Pyšek, P., Sousa, R., Tabacchi, E. & Vilà, M. (2013). Impacts of biological invasions: what's what and the way forward. *Trends in Ecology and Evolution* **28**, 58–66.
2016	Robinson, T.B., Alexander, M.E., Simon, C.A., Griffiths, C.L., Peters, K., Sibanda, S., Miza, S., Groenewald, B., Majiedt, P. & Sink, K.J. (2016). Lost in translation? Standardising the terminology used in marine invasion biology and updating South African alien species lists. *African Journal of Marine Science* **38**, 129–140.
2018	Essl, F., Bacher, S., Genovesi, P., Hulme, P.E., Jeschke, J.M., Katsanevakis, S., Kowarik, I., Kühn, I., Pyšek, P., Rabitsch, W., Schindler, S., van Kleunen, M., Vilà, M., Wilson, J.R.U. & Richardson, D.M. (2018). Which taxa are alien? Criteria, applications, and uncertainties. *BioScience* **68**, 496–509.
2019	Essl, F., Dullinger, S., Genovesi, P., Hulme, P.E., Jeschke, J.M., Katsanevakis, S., Kühn, I., Lenzner, B., Pauchard, A., Pyšek, P., Rabitsch, W., Richardson, D.M., Seebens, H., van Kleunen, M., van der Putten, W.H., Vilà, M. & Bacher, S. (2019). A conceptual framework for range-expanding species that track human-induced environmental change. *BioScience* **69**, 908–919.
2019	Kapitza, K., Zimmermann, H., Martín-López, B. & von Wehrden, H. (2019). Research on the social perception of invasive species: A systematic literature review. *NeoBiota* **43**, 47–68.
2019	Latombe, G., Canavan, S., Hirsch, H., Hui, C., Kumschick, S., Nsikani, M. M., Potgieter, L.J., Robinson, T.B., Saul, W.-C., Turner, S.C., Wilson, J.R.U., Yannelli, F.A. & Richardson, D.M. (2019). A four-component classification of uncertainties in biological invasions: implications for management. *Ecosphere* **10**, e02669.
2020	Cassini, M.H. (2020). A review of the critics of invasion biology. *Biological Reviews* **95**, 1467–1478.
2020	Iannone III, B.V., Carnevale, S., Main, M.B., Hill, J.E., McConnell, J.B., Johnson, S.A., Enloe, S.F., Andreu, M., Bell, E.C., Cuda, J.P. & Baker, S.M. (2020). Invasive species terminology: Standardizing for stakeholder education. *The Journal of Extension* **58**, 27.
2021	Essl, F., Pyšek, P. & Richardson, D.M. (2021). Neonatives and translocated species: different terms are needed for different species categories in conservation policies. *NeoBiota* **68**, 101–104.
2022	Lepczyk, C.A. (2022). Time to retire "alien" from the invasion ecology lexicon. *Frontiers in Ecology and the Environment* **20**, 447–447.
2022	Shackleton, R.T., Vimercati, G., Probert, A.F., Bacher, S., Kull, C.A. & Novoa, A. (2022). Consensus and controversy in the discipline of invasion science. *Conservation Biology* **36**, e13931.
2022	Golebie, E.J., van Riper, C.J., Arlinghaus, R., Gaddy, M., Jang, S., Kochalski, S., Lu, Y., Olden, J.D., Stedman, R. & Suski, C. (2022). Words matter: a systematic review of communication in non-native aquatic species literature. *NeoBiota* **74**, 1–28.

(2) Language as a source of ambiguity

The circulation of many English terms and their translations can introduce ambiguity and hinder public engagement with diverse audiences. For instance, describing a species as 'exotic' can be perceived differently and carry positive connotations in several languages (like English, Portuguese, Italian, or Spanish), such as 'extravagant', 'fancy', and/or 'unique'. On the other hand, the dominance of English in scientific publishing implies that the meaning of terms with different connotations (often with no direct translation) in other languages will inevitably be unclear, while it can concomitantly impede effective transfer of information and create knowledge gaps (e.g. regarding the impacts of invasive species; Bortolus, 2012; Angulo et al., 2021; Nuñez et al., 2022). For instance, many of the current debates about disciplinary denialism, the misleading xenophobic formulation of analogies with international human migration, and the impact of using emotive language, are likely exacerbated by culture and translation (Copp et al., 2021; Bortolus & Schwindt, 2022). Indeed, many issues of terminological ambiguity and epistemic injustice arise from the pervasive 'diffusion of English' approach in scientific research and terminology being published, reviewed, and accepted almost exclusively in English. This was recently addressed with an application of the 'ecology of language' paradigm to the development of a multilingual decision-support tool for communicating the risks of invasive species to decision-makers and stakeholders in their native language (Copp et al., 2021). In this complex multicultural and multi-linguistic scenario, one must accept that (1) consensus concepts published in English might not be ideal in other languages, philosophical frameworks, and cultures, and (2) the aim is to achieve consensus of conceptual definition rather than on terms *per se*. Reviewing, comparing, and reaching agreements on definitions, as well as establishing precise regulations for translating technical terminology into various languages worldwide, constitutes an essential, but not easy, step.

'Exotic' and 'alien' denote species that have been introduced to a region outside their native ranges (Florencio et al., 2019). However, using 'alien' in public discourse is potentially confusing because it: (*i*) is sometimes synonymous with 'extraterrestrial', therefore potentially confusing (Lepczyk, 2022), (*ii*) has socio-political connotations and legal implications in human immigration policies, and (*iii*) can limit the application of Indigenous People's frameworks and management and impede biodiversity protection (Wehi et al., 2023). This occurs because of the dichotomous portrayal of 'aliens' and 'natives' that echoes detrimental historical narratives and marginalizes Indigenous stewardship, posing a barrier to protect biodiversity (Warren, 2007; Wehi et al., 2023). 'Non-indigenous' should not be considered a synonym of 'alien' species (Kolar & Lodge, 2001) because 'non-indigenous' also has a socio-political interpretation, particularly in light of the growing recognition and awareness of Indigenous rights (Wehi et al., 2023), political correctness, and the increasing popularity of the diversity, equity, and inclusion agenda within academia. Even terms like 'colonize' to describe processes of pre-colonial human movements are falling out of favour in disciplines such as anthropology and archaeology given their association with colonial injustices.

A possible alternative would be 'allochthonous' (*contra* 'autochthonous'), an established term in freshwater ecology. 'Allochthonous' is not (yet) politically charged; it is derived from the Greek 'allos' (*άλλος*, meaning 'other' or 'different') and 'chthon' (*χθών*, meaning 'Earth' or 'land'), and is commonly used in geology and ecology to describe something that originates or is formed in a location different from where it is currently found (displaced). However, this term is not in common usage and difficult to pronounce in or translate to non-Roman languages, and is therefore unlikely to become part of the public discourse, even though it is well-established among experts in some countries (e.g. France, Serbia, Spain, Italy).

Other terms focus on the capacity of a species to spread, such as 'escaped' (Table 2) and 'introduced', which strictly address the act of intentional or unintentional introduction of an organism by humans into the environment where it did not occur naturally (Simberloff et al., 2005). 'Naturalized', favoured by the 'naturalization and acclimatization' societies of the 19th and

20^{th} Centuries, not only mixes concepts related to the ability to spread and establish, but also how long a given species has been present in the new environment such that people perceive it as part of the native community — e.g. dingo *Canis dingo* in Australia (Smith et al., 2019), North American ash-leaved maple *Acer negundo* in Russia (Vinogradova, 2006), and the smooth cordgrass *Spartina alterniflora* in South America (Bortolus et al., 2015). 'Naturalized' describes a non-native species that has successfully established self-sustaining populations in the wild following introduction (Falk-Petersen et al., 2006), yet despite still being non-native, it sometimes attracts the same legal protection as native species (e.g. fallow deer *Dama dama* in the United Kingdom; Manchester & Bullock, 2000). However, other definitions have been applied to describe the naturalization phenomenon: (*i*) species that are non-native and reproduce in environments aided by human cultivation; (*ii*) a group of non-native species that propagate in natural or semi-natural environments; (*iii*) species that exist outside their native regions, with their reproductive success varying; or (*iv*) non-native species that have broadened their geographic distribution (see Richardson et al., 2000). Carlton (2009) disapproved of the terms 'naturalized' and 'resident', asserting that these do not constitute distinct categories within the realms of biogeography, ecology, environment, history, or evolutionary status, arguing instead that identifiable species should be categorized as either 'native', 'introduced', or 'cryptogenic'.

Terms applied less frequently but subjected to linguistic ambiguity include 'noxious' to refer to species that are harmful or dangerous to humans (Andreu et al., 2009), 'foreign' to denote species originating from a different geographical location (Iannone III et al., 2020), 'adventive' to refers to species that have been introduced to a new area but have not yet become invasive (Frank & McCoy, 1990; Klimaszewski et al., 2013), and the cultural terms 'pest' or 'weed' not necessarily related only to non-native species (Richardson et al., 2011), but often used for native insects, rodents, or widespread plant species with a negative impact on agricultural production, forestry, or urban ecosystems (Worner & Gevrey, 2006).

IV. Separating ideology from terminology

The emergence of novel terminology deviating from established definitions, as well as certain terms that broadly promote 'political correctness' (Klotz, 1999; Wagner, 2005; Pace & Severance, 2016) denote linguistic change. Such terms can have negative connotations and are therefore criticized (Colautti & MacIsaac, 2004; Lieurance et al., 2022). This has been argued for terms like 'alien' (Lockwood et al., 2013), and even 'invasive', which have been misused by populists and politicians (Schlaepfer et al., 2011; Sax et al., 2022) to advance ideologically based policies (Larson, 2005). The term 'invasive' itself is defined as "... (especially of diseases within the body) spreading very quickly and difficult to stop" (Oxford English Dictionary Online, 2023). According to Cambridge University Press (2023), "... an invasive organism is one that has arrived in a place from somewhere else and has a harmful effect on that place". Concomitantly, it is also connected to hostile (e.g. military) actions or directly from Medieval Latin *invasivus* meaning "tending to invade, aggressive" (Harper, 2008). 'Invasive' has been used in pathology (since the 1920s) and medicine (since the 1970s), and refers to both (1) propagation and (2) harmfulness (Oxford English Dictionary Online, 2023). 'Invasive', when used by invasion scientists to describe non-native species, can create confusion because it might be interpreted as pertaining only to spread, or incorrectly associated with negative impacts, or both.

While the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) uses the terms 'alien' and 'invasive' in its reports (aligning with the terminology used in the Convention on Biological Diversity), some scientific journals are already banning terms such as 'alien' due to its value-laden nature. It is therefore unfortunate that some international bodies still actively promote such terms, because they can obfuscate discourse, fuel divisiveness, and undermine the very principles of constructive dialogue and understanding. Rather than fostering healthy debates, such terminology serves only to entrench biases, deepen resentment, and polarize communities, nor does it align with principles fostering a balanced and informed discourse. While top-down initiatives echo recent calls to steer away from such concepts and terms in ecology (Ellwood et al., 2023), creating language rules and enforcing verbal hygiene can be disadvantageous by hindering open dialogue, stifling diverse perspectives, and impeding the advancement of knowledge (Cameron, 2012). In his 2022 address to the Convention on Biological Diversity–Global Biodiversity Facility negotiations in Montreal, the Secretary-General of the United Nations António Guterres used the term 'invasive non-native species'. The negative connotations of several terms used by invasion scientists possibly also take root from using 'invasive species' for the taxon as a whole, instead of 'invasive population', for example. No species is invasive *per se* (i.e. being native in their original range and not necessarily invasive everywhere where they are introduced; Colautti & MacIsaac, 2004) and impacts within populations can be triggered by environmental changes or trait evolution (Cuthbert et al., 2023).

(1) Avoiding problematic terminology

Different languages can employ different terms, and the translation between English and other languages can cause confusion (see Section *Language as a source of ambiguity*). This creates challenges when addressing non-native species, such as geographical and historical differences in the use of terminology (Richardson et al., 2011). To foster clarity and progress while enhancing communication and comprehension, we propose avoiding historically problematic , redundant, and/or confusing terminologies, especially but not only when non-native species are listed in different categories for management (Table 3). While clarifying the meaning of terms used in studies on biological invasions, we suggest avoiding 'Lessepsian migration' (Por, 1971) in view of the controversial history of Ferdinanc Marie de Lesseps. As one of the founders of the 'Compagnie Universelle du Canal maritime de Suez', Lesseps was responsible for wide-scale exploitation of unpaid forced labour (Brown, 1994; Farouk, 2019; Ortiz-Serrano & Forero-Laverde, 2020). 'Lessepsian' glorifies the person and his actions, thereby perpetuating a legacy of European imperialism and corruption. A replacement term could be 'Suezian non-native migration'. Our proposed terminology attempts to overcome problematic terms, but also redundancies and ambiguities, and these terms classifying species in categories should be limited or eliminated entirely in invasion science, especially when using them to describe the invasiveness of a non-native species. Specifically, we propose to avoid the following terms (especially when presented without context; e.g. Latombe et al., 2019) to classify a non-native species, or to consider their use carefully and contextualize appropriately: 'acclimatized', 'adventive', 'alien', 'anthropochore', 'bioinvader', 'biopollution', 'casual', 'colonizer', 'escaped', 'exotic', 'extralimital', 'foreign', 'immigrant', 'imported', 'intra-country established alien', 'invasive alien', 'migrant', 'naturalized', 'neobiota', 'new non-native', 'neonative', 'newcomer', 'non-indigenous', 'non-resident', 'noxious', 'nuisance', 'pest' or 'pest', 'questionable', 'released', 'restocked', 'tramp', 'transferred', 'transformer', 'transient', 'translocated', 'transplanted', 'transported', 'unwanted', 'vagrant', 'vermin', 'waif', 'weed', and 'xenobiota'.

Table 3: Terminology used by invasion scientists to describe non-native species that we suggest should be deprecated considering the likelihood they will perpetuate confusion or offend. Otherwise, authors should carefully consider their use and explain appropriately the specific context to avoid misunderstandings, confusions, and controversy.

Term(s)	**Reason**
alien, foreign, non-indigenous, exotic	often used interchangeably, and synonymous with ***non-native***, leading to potential confusion and ideological or political misuse
alien (including *invasive alien*), *immigrant, migrant, unwanted*	politicized with socio-political connotations often used in context of human migration; ***alien*** can also be confused with 'extraterrestrial being' in public discourse
acclimatized, adventive, anthropochore, established alien, intra-country, resident or transformer, bioinvader, biopollution, colonizer, tramp, vagrant, waif, xenobiota	also used in other contexts, creating ambiguity
casual, escaped, imported, neobiota, released, translocated, transferred, transported, transplanted, transient, vagrant, vermin, waif	do not indicate the invasive potential or establishment of the species
established, naturalized, questionable, transient	without context, remain too open to interpretation (subjective); note difference to ***established non-native*** proposed (see Table 4)
noxious, nuisance, pest, weed	(legal) term often used to describe harmful or destructive species, and not all ***non-native*** species are designated ***noxious***, therefore require context
neonative, new non-native, newcomer, non-resident, restocked	impractical, because human-caused climate disruption drives species distributional shifts, including species that are ecologically and phylogenetically distinct from resident native species; some of these species will become disruptive to ecosystems for the same reasons that cause ***invasive non-native*** species to do so; poorly linked and often conflicting with science, policy, and management.

(2) Conundrum of nativeness and non-nativeness

The dichotomy of 'non-native' and 'native' species can often be applied effectively at broader scales (e.g. continental) where clear biogeographical units are considered, while evolutionary boundaries are sub-continental for many taxa (especially in freshwaters), and are therefore more complex to delimitate due to taphonomic variation (Lockwood et al., 2013; Stigall, 2019; Lemoine & Svenning, 2022). Furthermore, classification becomes more complex at finer scales where the boundaries between native and non-native ranges are more difficult to delineate (Lockwood et al., 2013; Brodie et al., 2021). However, the fact that a species' native range might be challenging to observe from a human perspective does not imply that nativeness must possess a gradation terminology beyond an inherently binary state — either it is native or it is not. While it is generally advantageous to define the native range of a species as temporally and spatially static (Pereyra, 2020), the concept of 'nativeness' should be interpreted as an eco-evolutionary continuum. This implies that an unambiguous categorization of a species as native or non-native might not always be feasible due to varying ecological and evolutionary factors. This complexity arises, for instance, when species expand their native ranges within the same country or region due to human modification of the environment and/or climate change (Clements & Ditommaso, 2011; Saikkonen et al., 2012), possibly tracking their historical niches when the rates of environmental alteration exceed adaptation to those changes (Thomas, 2010), or when the biogeography of so-called 'cosmopolitan' species (distributed in most or all regions of the globe) is not well-resolved (Cerca et al., 2018; *cf*. Darling & Carlton, 2018). Nevertheless, addressing these classification issues could not be resolved with a broad range of naming conventions for these organisms as a way to offset the limited understanding of the human role in their distribution. For practical applications, we therefore support a dichotomous categorization ('native' or 'non-native') while still acknowledging the inherent ambiguities.

The newest term debated in the invasion lexicon is 'neonative' — referring to species that move on their own beyond their present natural range due to human-induced environmental changes (Wilson, 2020; Essl et al., 2019, 2020, 2021). 'Neonative' was proposed to distinguish species moved through human agency (i.e. 'non-native') and range-expanding native species responding to human-caused environmental (local) and climate (global) changes (Essl et al., 2019; Urban, 2020). However, it is often challenging to distinguish between the observation and status of species moving naturally from those shifted passively or actively by human endeavour (i.e. as a result of human-assisted pathways, environmental change; Essl et al., 2019). This differs from the proposed approach of Gilroy et al. (2017), who did not deal with the issue of intermediate populations (i.e. 'stepping stones'; Floerl et al., 2009), but defined all species transported outside their native range by direct transport as 'non-native', leaving species moving via unassisted dispersal as 'natives'.

If we consider species as 'non-native' based on their evolutionary lineage and native habitat, disregarding the mechanism of their dispersal, invasions resulting from establishment after a long-range dispersal, akin to anthropogenically facilitated extinctions and climate change, have been a persistent aspect throughout the history of life on Earth (Stigall, 2019). Nonetheless, analogous to the current rates of extinction and climate change, human activities influence the rate, scale, and the impact of biological invasions (Ricciardi, 2007). By viewing 'non-native' species in terms of evolutionary history, invasions can be understood as species settling populations outside their conventional biogeographic and evolutionary limits. Consequently, not every occurrence of range expansion can be classified as an invasion because all species experience natural range variation given enough time (Wilson, 1961). Yet, regardless of the reasons or processes involved, all invasions are indeed a form of range expansion (Ricciardi, 2007; Beest et al., 2013). 'Neonative' is therefore impractical and weakly linked to policy and management (Wilson, 2020, *cf*. Lenoir et al., 2020 for debate).

We recommend that 'neonative' should only be used to label native taxa undergoing climate-induced range extensions. But it should not be used to classify non-native species spreading via human-made pathways after an environmental barrier is removed, because this would overlook rapid, contemporary climate change driving some invasions and the erosion of biogeographic barriers via human influence. Assuming that the defining characteristic of 'non-native' is solely from direct, human-mediated dispersal, we would have to treat those species moving autonomously in response to shifting environmental conditions along human-made pathways like canals as natives, irrespective of human involvement in climate change. Endorsing this argument would require categorizing all species independently moving through canals as 'native'. While the movement of 'neonatives' might be necessary to avoid extinctions (e.g. 'assisted migration'; *cf*. Hällfors et al., 2014; Pereyra, 2020), these populations can cause ecological disruptions once established (Forgione et al., 2022), but might simultaneously require protection given threats in their native ranges (Essl et al., 2021; Forgione et al., 2022). The conundrum arises from the origin of environmental or climatic changes, which might also be considered anthropogenic, thereby blurring the distinction between 'neonative' and 'non-native'.

Terminological complications are exacerbated by the complexity of reintroductions of non-native populations of historically native species translocated for conservation (Essl et al., 2021). Stocking practices in recreational and commercial fisheries (Tarkan et al., 2017), or rewilding (Corlett, 2016) produce similar and recurring terminological problems. Such species fall under the definition of 'non-native', as in the case of the wild boar *Sus scrofa* in Ireland introduced into a new area by direct human action, but not 'non-native' for conservation and management purposes because they naturally inhabited Ireland in the past (before the 12^{th} Century). Inversely, the white-clawed crayfish *Austropotamobius pallipes* is considered native and threatened in Ireland, but was introduced from France in the Middle Ages (Gouin et al., 2001).

'Native invaders', 'invasive natives', 'native super-dominants' (Carey et al., 2012; Pivello et al., 2018), and 'new natives' (Lemoine & Svenning, 2022) describing native species that have expanded their ranges due to human-mediated dispersal or environmental changes are problematic because they blur the distinction between naturally evolving ecosystems and those impacted by humans (even those that happened hundreds or thousands of years ago; Bucher & Aramburú, 2014). Conflating natural range shifts with invasive behaviours by ignoring the species' respective evolutionary history could compromise conservation management. Native species can expand their ranges in response to shifting environmental conditions, and such movements do not necessarily imply negative impacts on ecosystems.

V. Proposal for a simplified terminology

All aforementioned initiatives and frameworks emphasized the need for more openness, neutrality, and consistency in invasion science, because no scientific discipline should continuously commiserate the lack of clear definitions without constructive progress. By revitalizing the approach of Colautti & MacIsaac (2004), we attempt to deprecate redundant and potentially offensive terms in invasion science and provide clear and standardized definitions of invasion terminology. While we acknowledge that our proposed updates will not necessarily replace the existing lexicon, our primary aim is to improve the consistency and definitive base for future terminology, while advocating the acceptance of pluralism as long as definitions are clear. This does not mean that a population of a 'non-native' species cannot be described as 'naturalized' or 'pest' (for example) in a given region or country to mean that is has achieved a self-sustaining population or it report its socio-economic impact (as in the case of the ring-necked pheasant *Phasianus colchicus* in North America; Taylor, 2023), but that the species should not be labelled 'naturalized' or 'pest', thereby blurring an otherwise clear terminology.

We therefore encourage the use of a restricted and controlled terminology (Table 4) to reduce confusion and avoid superfluous terms such as 'unwanted', and 'imported' species (Table 2), because they are synonymous with the more commonplace but politicized terminology (such as 'alien'). To simplify and streamline the terminology, especially when communicating with the public, stakeholders, policy makers, or other officials, we recommend adopting an acceptable, clear, and concise framework for journal editors, stakeholders, and scientists alike, which could be linked to existing biodiversity standards, particularly the Darwin Core terms (Groom et al., 2019). Invasion scientists often need to communicate the outcomes of their findings in a clear, detailed, and educational way to decision-makers and the public in languages other than English. In these cases, adopting the minimalist set of terms we propose will facilitate the translation from the original English and avoid the ambiguities that result from politically and/or culturally laden terms not available in those languages (see Copp et al., 2021).

We propose that 'non-native' should focus primarily on describing the evolutionary relationship of a species to the biogeographic area in which it originally did not evolve, concomitantly acknowledging the importance of human-mediated dispersal for modern invasions. The term 'invasiveness' should denote a population's ability to colonize, establish, and spread, possibly encompassing the criterion of 'superabundance' (i.e. a species that has exceeded its normal carrying capacity due to favourable conditions, resulting in potential ecological imbalances; Ricciardi & Cohen, 2007; Aizen et al., 2014).

This produces the following terminology when classifying populations, which should not be abbreviated as acronyms or initialisms because they confuse and provide no additional value: '**non-native**', referring to species that have been actively or passively translocated and released through human action beyond their known historical and natural range without the necessity of establishing in the new environment; '**established non-native**' to signify a non-native species that has successfully established in the area where it was introduced, evidenced by the presence of a self-sustaining population; and '**invasive non-native**', representing those populations of established non-native species that are currently spreading or have recently spread (see next section on the concept of spread) in their invaded range (Table 4). The 'invasive' condition varies temporally as well as spatially; i.e. a non-native population that has long maintained low abundance or remained largely confined to a specific region can suddenly undergo explosive growth (e.g. Witte et al., 2010) or expand well beyond its historical range (e.g. *Ficus* spp. following the arrival of coevolved pollinator Chalcidoidea fig wasps; Nadel et al., 1992). Initially non-invasive, or even considered benign, these populations can become invasive later due to triggering factors (Spear et al., 2021). Similarly, a population that has demonstrated invasiveness for an extended period can later stop spreading or diminish in abundance — for instance, following the introduction of an effective control agent or after encountering physical or ecological constraints. Such populations could become invasive once more if its constraints are removed (e.g. sea lamprey *Petromyzon marinus* in the Great Lakes after control was suspended during the COVID-19 pandemic) (Sullivan et al., 2021).

If a non-native species' invasiveness is solely defined by its ability to spread, 'invasive' (non-native) could be replaced with 'spreading (non-native)'. However, 'spreading (non-native)' is redundant because almost all 'established non-native' species eventually spread, albeit at variable rates, within the geographical and ecophysiological limits imposed by their new environment. If defined exclusively by the process of invasion (Ricciardi & Cohen, 2007), 'invasive' can be used to distinguish (and even rank) those species that have higher rates of establishment than others, or populations that have higher rates of spread than others. 'Invasive' could also be used to describe a non-native population that has suddenly begun to expand rapidly or become superabundant within a region after having remained at low densities prior to being triggered to increase following environmental (Spear et al., 2021) or anthropogenic changes (Bortolus, 2006). The absence of consensus among invasion scientists on objective, quantitative definitions for 'impact' and 'spread' has hindered progress in the conceptual understanding of populations being 'invasive'. The continuum of both 'spread' and 'impact' has lacked clearly definitive boundaries, mediated by many context dependencies. Defining 'invasive' solely on 'spread' would include many non-native species with potentially negligible effects on human society and biota, while defining it solely on 'impact' would yield similar outcomes because all non-native species eventually cause impacts, albeit possibly perceived as inconsequential to humans. Combining the two debated concepts would not resolve, but exacerbate, these challenges because some species spread and establish faster than others, while some exert larger or more observable impacts than others regardless of their dispersal ability. While the concepts of 'spread' and 'impact' are impossible to disentangle, the invasiveness of a species can be best defined as an ability to colonize, establish, and spread, which are integral components of the invasion process (Blackburn et al., 2011). Further, Ricciardi & Cohen (2007) found no relationship between characteristics of invasiveness (establishment success and rate of spread) and impact on biodiversity. They concluded that non-native species that spread and establish quickly are not necessarily the ones causing measureable ecological changes, although they could have larger cumulative impacts over broader spatial or temporal scales. Constructing a comprehensive table of definitions and terminology using both spread and impact is therefore infeasible. Instead, spread is more suitable for objective measurement in the context of biological invasions, with impact being a separate dimension that is much less studied.

While acknowledging the existence of sub-categories of invasions, such as 'failed' invasions (Zenni & Nuñez, 2013), or knowledge gaps where the establishment status or point of introduction are unknown, only a small proportion of the many introduced 'non-native' species eventually establishes and becomes invasive. This subset varies among ecosystems, regions, and other relevant contexts and is influenced by modes of introduction that affect propagule pressure and repeat inoculation events (Williamson & Fitter, 1996). Other than in some special cases (e.g. in isolated and altered microhabitats such as thermal springs or artificially heated outflows; Aksu et al., 2021), establishment results in the spread of the non-native species, and hence, potential invasiveness. This suggests that populations of 'established non-native' species that remain in this category are rare in reality because most populations of such species spread to some extent at some point after their arrival. Rare examples to the contrary include populations of warm-water species that were originally used as ornamental species and that established in thermally polluted waters (e.g. power plant discharge; Yanygina et al., 2010; Klotz et al., 2013; Castañeda et al., 2018), but are restricted to the artificially heated environments or went extinct eventually (Castañeda et al., 2018). The mosquitofish *Gambusia* spp. introduced to a canal in Liverpool (United Kingdom) due to the closure of a pet shop failed to spread beyond the introduction site (Vale Gordon H. Copp, *pers. commun*.). Another example is the golden clam *Corbicula fluminea* that invaded a section of the Saint Lawrence River immediately downstream of a nuclear power plant, established, but was extirpated after the plant shut down (Castañeda et al., 2018). Besides thermally polluted environments, an array of other examples of populations of 'established non-native' species are found in natural thermal springs (Yanygina et al., 2010; Bláha et al., 2022). Yet, cases satisfying the 'established non-native' criteria might disappear over time because self-sustaining populations do not establish under limited conditions (e.g. limited space), thereby being classified as a 'failed invasion'. Alternatively, an 'established non-native' species can adapt to less-favourable environments, and potentially become an 'invasive' population (Vandepitte et al., 2014; Weiperth et al., 2019), while potentially (even if only temporarily) returning to the 'established non-native' status once reaching a constraint or barrier. Most island introductions would qualify as 'invasive' species, having spread within, around, and on a given island.

Table 4: Proposed basic terminology for classifying populations of non-native species. These terms are hierarchical — a subset of all *non-native* species will become *established non-native* species, and a subset of those will become *invasive non-native species*. The terms highlighted in *italics* and **boldface** indicate cases where particular terms are themselves used as definitions. For proposed translations of the terminology suggested here, please see Supplementary Table 1.

Term	**Definition**	**Reason/Application**

non-native	present in or arriving to an area to which it is not native (has no evolutionary history there) either by (a) being introduced through direct human activities, or (b) 'natural' dispersal after a biogeographic barrier is removed, or across a created pathway after an artificial environmental gradient is removed following human intervention	Useful because it specifies a step in the invasion process — the introduction of a species outside its native range. It is used when an individual or population is first reported and its status is undetermined (e.g. found in only one collection, year, location), hence lacking evidence for establishment.
established non-native	A ***non-native*** species that reproduces (≥ *n* generations) in an area to which it is not native (has no evolutionary history there), but is currently not spreading or spread is unknown	Differentiates populations of non-native species that have arrived in a new environment and are confined to a location or area to those that reproduce and sustain populations over continuous life cycles (depending on the species, e.g. in several collections in separate years in the same location) without direct intervention by humans.
invasive non-native	An ***established non-native*** species that spreads (actively or passively), resulting in the establishment of successive populations beyond the introduction point(s)	Underscores the ability of a population of a non-native species to colonize, establish, and spread. While any population of a non-native species can be introduced into a new environment, not all will be able to survive and reproduce successfully in the new area. It is the species that establish self-sustaining populations and spread farther from the introduction point that become invasive.

Note: Impact can occur at any of the stages during the process of biological invasion and are not confined to the 'invasive' stage. Impacts can vary due to a change in the abundance and spread of the 'invasive' species. However, definitions of 'invasive' have often only considered impact, which can obfuscate the full scope of the biological invasion process. An established or invasive non-native species might not always be immediately or obviously harmful, because non-native species can cause more damage as environmental conditions change or as adaptations occur. At the same time, it is possible that a non-native species remains confined to one locality, where it has a severe impact on its recipient ecosystem, without being classifiable as 'invasive'.

(1) Conceptualizing invasive species and spread

The concept of 'spread' in invasion ecology is important because it refers to the movement and dispersal of a non-native species beyond its original point of introduction (Wilson et al., 2009a; Hui & Richardson, 2017), forming the basis for the classifications of 'non-native' populations as 'invasive'. As such, invasions must first be considered a population-level phenomenon, and then a context-dependent, species-level phenomenon. While it appears intuitive that a species' spread within biogeographical and administrative boundaries (and not its impact) constitutes the final stage of the invasion process biologically, and thus the classification 'invasive', quantifying the parameters and thresholds that define spread lacks resolution and likely differs among habitats, taxa, regions, and other contexts (Shigesada & Kawasaki, 1997; Suarez et al., 2001; With, 2002). Furthermore, an ill-defined conceptualization of 'spread', and possibly multiple introductions, make it challenging to measure spread rates (Hengeveld, 1992). Estimates of spread rate are however essential to validate and advance theoretical models predicting spatial patterns that arise from invasions (Hastings, 1996; Lewis et al., 2016).

While spread can be defined as the dispersion of a species beyond its introduction point or natural range, the identification of the latter is challenging for many species. This is especially the case in aquatic or terrestrial ecosystems in developing countries where non-native species are often detected when they are already abundant and widespread. When the location and date of introduction are unknown or anecdotal, an alternative is to default to the earliest recorded instance of the species as a proxy (e.g. Vargas et al., 2022). This information, coupled with ecological investigations that elucidate the species' dispersal capabilities, could potentially shed light on whether it has spread outward from its point of introduction. The introduction point requires context-specific interpretation due to its relative nature. In some cases there could be several points of introduction (Sax et al., 2005) arising from separating primary (initial human-mediated introduction of a non-native species) and secondary spread (subsequent dispersal within the new environment or to neighbouring environments). Determining the dispersal mechanism — specifically the importance of 'jump' dispersal *versus* 'diffusive' range extension (Borcherding et al., 2011; Reynolds, 2012; Liebhold et al., 2017) — is needed to disentangle issues associated with primary and secondary spread (Bartumeus et al., 2005; Viswanathan et al., 2011).

For terrestrial invasive non-native species, spread is commonly quantified as the distance from the introduction point (Renault, 2020). However, the relationship between spread and invasive species becomes more complex in the aquatic realm. For a bay or stream, the definition of spread is often subjective; not only are points of introduction poorly resolved, there is also no consensus on the criteria for designating a species 'invasive' based on spread within these environments. In freshwater environments, spread can occur within and among water bodies, both qualifying as criteria for invasiveness. For ponds and lakes, the same principle applies as for islands within an archipelago, because spread includes dispersal between insular ecosystems such as lakes and islands, and homogeneous diffusion within them (e.g. American bullfrog *Lithobates catesbeianus* in Uruguay; Laufer et al., 2023).

A comprehensive and accepted definition of spread that accounts for its nuances among different life forms, realms, habitats and biomes is needed to ensure clarity in the classification of invasive species. Without a clear definition of spread and knowledge on an 'invasive species' rate of spread per unit of time (Richardson et al., 2000, 2020), 'invasive' can be subjective and ambiguous. Spread is ultimately limited by geographical and ecophysiological boundaries, but also depends on species-specific dispersal. The rate of spread per unit time can differ depending on traits such as size, means of locomotion, or life stage. Neither is spread necessarily continuous, for it can fluctuate over time. To avoid ambiguity, we suggest that when a species or population is reported as 'invasive' (especially for the first time), the reporting authority should state the evidence for and scale of spread (Gago et al., 2016; Gkenas et al., 2023).

(2) Conceptualizing invader impacts and the importance for management

While the descriptor 'invasive' is based on a population's stage of invasion, different populations can be in different stages of the invasion process (Blackburn et al., 2011; Essl et al., 2011; Spear et al., 2021), leading to conflicting perceptions about their impacts (e.g. 'double-edge' invasive non-native species; Kourantidou et al., 2022). Prior to introduction (and dispersal), management should focus on prevention, but once established, management should shift to eradication, or at least to density reduction and containment if substantial spread has already occurred. Both population growth and spread indicate a species' abundance and geographical expansion, but they do not necessarily determine impacts that are instead dictated more by the characteristics of the invaded ecosystem and how societies perceive and evaluate impacts economically (Falk-Petersen et al., 2006; Gallardo et al., 2016).

While the 'invasive' label should primarily refer to the spread stage of a non-native population, the real or perceived impact of that invasive population represents a second dimension. Evaluating a species' impact can be subjective (Turbé et al., 2017) because (1) impact assessments are usually done at a local scale by targeting populations, and focus on specific areas where spread is confined by the boundaries of the ecosystem unless anthropogenically facilitated (Turner, 1996; Echeverría et al., 2006), and (2) total impacts are often inferred by extrapolating local-scale measurements of ecological effects and invader abundances to larger regions, neglecting potential spatial variation (Howard et al., 2018; Haubrock et al., 2022; Ahmed et al., 2023; Soto et al., 2023b), as well as non-linear impact-abundance relationships (Sofaer et al., 2018). Schemes such as the *Environmental Impact Classification for Alien Taxa* (EICAT, Hawkins et al., 2015; EICAT+, Vimercati et al., 2022) and the *Socio-Economic Impact Classification of Alien Taxa* (SEICAT, Bacher et al., 2018) have fortunately advanced the complex task of quantifying the impacts of invasions.

Management decisions often rely on perceived and subjective impacts, indicating that the goal of management has shifted from limiting spread to curtailing damage, particularly where limited resources necessitate efficient prioritization among many species and populations

(Kueffer & Daehler, 2009; García-Díaz et al., 2021). Impacts can be context-dependent, time-lagged, and co-mingled with other stressors, but as long as a species' invasiveness is contingent on its impact or quantified risk, management is handicapped. The spread-based term 'invasive' might therefore lose relevance in management, particularly when directed towards populations perceived as highly impactful. The issue of spread-based decisions in the management of 'invasive' (Epanchin-Niell & Hastings, 2010) is further complicated because the concept of spread itself is ambiguous among scales and environments.

An alternative is to assume that all established non-native species have negative impacts, and management interventions should be considered for those populations that are spreading, unless evidence demonstrates that their spread does not cause negative impacts. However, determining the potential impacts of all established non-native species during their spread can be complex and resource-intensive. Meanwhile, possible pre-invasion 'deny list' approaches (lists of species prohibited for import) to management following invasion might become impractical when applied over broad spatial scales (e.g. political entities like the European Union or United States), because assessment outcomes might vary among ecosystems, biogeographic regions, and value systems (Rilov et al., 2023). This issue is exacerbated by benefits perceived from invasive species due to human interest in some socio-economic sectors (e.g. fisheries or ornamental trade), as well as in climate-change hotspots where thermally sensitive native species are extirpated and thermophilic invaders with similar traits take their place, or where native species are the minority (Rodriguez-Barreras et al., 2020). Perceived and real benefits can obfuscate the negative effects at the expense of environmental degradation and community well-being (Mwangi & Swallow, 2008), presenting another challenge for management (Shackleton et al., 2019; Wehi et al., 2023), and creating difficulties in establishing universal criteria for management decisions that should be based on the species' invasion potential, and any ecological and(socio-)economic impacts (Sandvik et al., 2019).

Adopting a unified approach assuming that all established populations of non-native species will ultimately have a negative impact would lead to ineffective resource allocation and hinder the prioritization of 'high-risk invaders' — non-native species that spread rapidly, thrive in new environments, and exert large negative impacts. The primary aim should therefore be the prevention of both species-specific vectors and pathways. Emphasizing shifts in invasion pathways and vectors over time, along with their associated species, is important because problematic species likely entered through historical routes that might be less-relevant today. Managers, stakeholders, and scientists should subsequently base decisions on changes in population size, the population's potential to spread, and their *per capita* impacts, even in early invasion stages and, whenever possible, prioritize preventive measures. Quantifying *per capita* impacts is possible for example by estimating consumer functional responses (Dick et al., 2014; Faria et al., 2023). At later invasion stages, the *per capita* effects of a species are nevertheless modulated by the numerical response at the population level (Solomon, 1949; Dick et al., 2017). These *per capita* impacts can fluctuate across space and time (Gallardo et al., 2016); hence, management interventions should aim to reduce population size and growth, because abundance dictates the extent and magnitude of impacts (Dick et al., 2017; Ahmed et al., 2022).

VI. Proposed classification protocol

After having identified 'unclear' terms and recommended an acceptable, clear, and concise terminology moving forward, we also propose an objective approach to classify different populations of 'non-native' species for the scientific discourse. This is needed because the term 'invasive' itself lacks clear and objective boundaries given the complexities of measuring 'spread' across varying scales (i.e. local *versus* regional spread). While both impactful and spreading species are often wrongly referred to as 'invasive', and although useful to assist in focusing management resources and a wider discourse, assessments and classification are often bereft of quantitative boundaries and are subjective. Even if value-laden, the concern of those 'invasive' (spreading) species with impacts (*cf.* those with few impacts) is based on human values and thus, relevant for the distribution of limited management resources. We therefore recommend an alternative quantitative (binomial) assessment we deem unambiguous and ideal to classify populations of non-native species. The scheme is based on four main components that the current lexicon captures: 1. **DISPERSAL** mechanism, defining how a population arrived at a new locality; 2. **ORIGIN**, defining the origin (native region) of a species; 3. **STATUS**, describing if the population is expanding, stationary, or shrinking (either in terms of abundance or range) to describe 'invasiveness'; and 4. **IMPACT**, defining the real or perceived impact of the population as harmful or benign (Fig. 3).

On the far right in Figure 2, we provide the dependencies for each component, including how we should define 'here' and how we assess 'status' and 'impact'. Drawing inspiration from the IUCN Red List of Threatened Species (IUCN, 2023), we provide a few examples: Example 1 — a species that is intentionally introduced to a new country, its population expands both in abundance and range, resulting in economic and ecological harm. In this case, its classification would be **D**a$_{i}$**O**a**S**a$_{i,ii}$**I**a$_{i,ii}$; Example 2 — a species that is accidentally transported by humans from one part of its range to another. Although it remains static without an increase in range or abundance, it causes cultural harm locally: **D**a$_{ii}$**O**b**S**b**I**a$_{iii}$; Example 3 — a species that establishes itself in a new range following a human modification to its environment (e.g. building a canal connecting two previously isolated bodies of water), subsequently increasing its range and causing ecological problems: $\mathbf{D}\mathrm{b}_{ii}\mathbf{O}\mathrm{a}\mathbf{S}\mathrm{a}_{ii}\mathbf{I}\mathrm{a}_{ii}$.

To facilitate analyses of the drivers of different states and classifications, this descriptive classification scheme can be illustrated using a binomial matrix, wherein each component and subcomponent are depicted as columns, and species/populations as rows. This classification scheme avoids the use of terminology with a negative connotation and focuses on objective categorizations based on scientific and empirical grounds, while also considering impact, which can be value-laden, but relevant for prioritizing management. The scheme acknowledges that categorizations vary across time, space, and measurement intensity. Consequently, politically charged terms like 'invasive' or colonial terms such as 'non-indigenous', 'naturalized', 'colonized', or even terms like 'non-native' can be circumvented. While we recognize that this classification scheme might not replace common language, it would promote objectivity and consensus among invasion scientists, particularly in the peer-reviewed literature.

Some countries, especially low- and middle-income nations, often have insufficient data covering all four proposed components that are necessary for classifying non-native populations. This difficulty also applies to some taxa, such as fungi, protists, and phytoplankton for which many biogeography and taxonomy uncertainties persist. Nonetheless, we anticipate that our protocol will identify the types of information required. This could in turn enable such nations to prioritize resources towards the generation of this indispensable information for non-native species management.

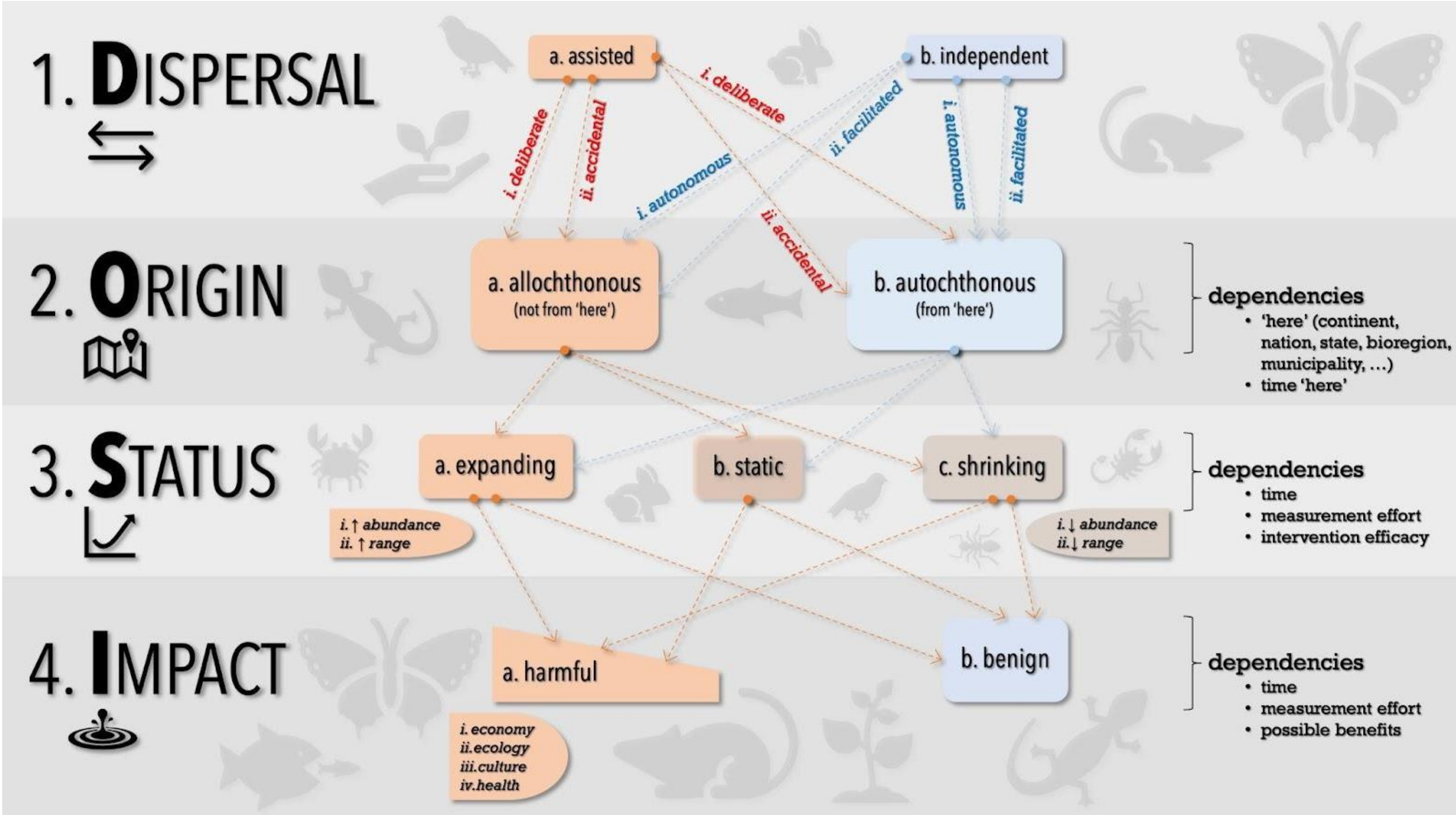

Figure 3. Flow diagram for the proposed classification scheme for species/populations moving into a novel environment. A species' **D**ISPERSAL mechanism can be assisted from its place of origin either *deliberately* (1a$_{i}$) or *accidentally* (1a$_{ii}$), or it can migrate *independently* of direct human intervention *autonomously* (1b$_{i}$) or by being *facilitated* (1b$_{ii}$) by exploiting a human-driven change to the environment (e.g. canals). The **O**RIGIN of a species that has its distribution shifted according to the mechanisms described in 1 can either be *allochthonous* (2a) (not from 'here', where the definition of 'here' depends on the spatial scale of interest), or *autochthonous* (2b) (from 'here', as in the case of local species moving within the region of focus). The definition of *allochthonous* or *autochthonous* can also depend on how much time has elapsed since the species arrived (e.g. events in geological time, ancient introductions, etc.). **S**TATUS refers to the state of the population(s) of the species, defined either/both in terms of *abundance* or/and *range* size

(*expanding*, *static*, or *shrinking*) — these assessments depend on the time the species has been present, how much measurement effort has been applied to assess population change, and whether interventions (if any) have been effective. The IMPACT category assesses whether the species causes harm to ≥ 1 sectors (ecology, economy, culture, [human] health — such an assessment can cover a gradient from little to extensive harm), or if it is benign (no effect) — this assessment also depends on the time since appearance, measurement effort to investigate impact, and any possible benefits along a temporal or stakeholder gradient that modify harm intensity. While we acknowledge that impacts can also be 'beneficial', negative impacts (e.g. by damaging local ecology) outweigh those perceived as positive (e.g. monetary gain) in magnitude and ecological consequences, and are therefore not considered in the context of classifying populations of species in this scheme.

VII. Conclusion

1. Invasion science is constantly growing and confronting existent terminological inconsistencies, often leading to misunderstanding and confusion that can come at the cost of conservation. Our review sheds light on the issue of lexical inconsistency pervading multiple scientific disciplines, here shown in the case of invasion science, underlining its potential to obstruct scientific progress, policy design, and effective communication.
2. We recommend reducing redundancy and propose a unified suite of terms in an attempt to increase the clarity and consistency in invasion science. Any deviation from the proposed terms outlined in Tables 4 (i.e. 'non-native' species', 'established non-native', species' and 'invasive non-native' species') and their translations in Supplementary Table 1 should be justified by requiring the author(s) to define terms appropriately and align with the definitions outlined in Table 4. But the successful implementation of this consensus requires collaboration among scientists, policy makers, and stakeholders to facilitate interdisciplinary dialogue and exchange of knowledge.
3. Reaching consensus and implementing measures to achieve consistency in the terminology used across various platforms (i.e. from science to policy, as well as public communication outlets) will not be easy or fast. Efforts by journals, editorial boards, or professional societies and organizations can be an avenue for identifying ways to recognize the challenge and ways to address it. The more simplistic and clearer terminology for broader audiences we propose is helpful to enhance communication and comprehension among scientists, decision-makers, and the public.

4. We hope that such a unified and standardized language can promote more effective management strategies, better policies, and public engagement in citizen-science initiatives to address the threats of non-native species. By bridging the gap between scientific understanding and practical action, we can improve conservation aiming to protect ecosystems and human health, while also minimizing economic losses.

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IX. Dedication

We dedicate this paper to Professor Gordon H. Copp, who passed away on 8 July 2023. Gordon was not only a hugely influential scientist, mentor and friend, but also a notable biologist who made major contributions to the field of aquatic ecology. His later work focused on understanding the mechanisms of biological invasions, assessing their ecological impacts, and developing strategies for their prevention and control. Gordon is best known for his research on the ecological impacts of invasive species and the management of freshwater and marine ecosystems published in more than 200 papers resulting from many national and international research projects and collaborations. On 25 May 2023, Gordon received a Doctor of Science degree for his major contributions to aquatic sciences, which he regarded "... a culmination of the scientific component of my life".

X. References

Ahmed, D.A., Hudgins, E.J., Cuthbert, R.N., Kourantidou, M., Diagne, C., Haubrock, P.J., Leung, B., Liu, C., Leroy, B., Petrovskii, S., Beidas, A. & Courchamp, F. (2022). Managing biological invasions: the cost of inaction. *Biological Invasions* **24**, 1927–1946.

Ahmed, D.A., Haubrock, P.J., Cuthbert, R.N., Bang, A., Soto. I,, Balzani. P,, Tarkan, A.S., Macêdo, R.L., Carneiro, L., Bodey, T.W., Oficialdegui, F.J., Courtois, P., Kourantidou, M., Angulo, E., Heringer, G., Renault, D., Turbelin, A.J., Hudgins, E.J., Liu, C., Gojery, S.A., Arbieu, U., Diagne, C., Leroy, B., Briski, E., Bradshaw, C.J.A. & Courchamp, F. (2023). Recent advances in availability and synthesis of the economic costs of biological invasions. *BioScience*. doi:10.1093/biosci/biad060

Aizen, M.A., Morales, C.L., Vázquez, D.P., Garibaldi, L.A., Sáez, A. & Harder, L.D. (2014). When mutualism goes bad: density-dependent impacts of introduced bees on plant reproduction. *New Phytologist* **204**, 322–328.

Aksu, S., Başkurt, S., Emiroğlu, Ö. & Tarkan, A. S. (2021). Establishment and range expansion of non-native fish species facilitated by hot springs: the case study from the Upper Sakarya Basin (NW, Turkey). *Oceanological and Hydrobiological Studies* ***50***, 247-258.

Amador-Cruz, F., Figueroa-Rangel, B.L., Olvera-Vargas, M. & Mendoza, M.E. (2021). A systematic review on the definition, criteria, indicators, methods and applications behind the Ecological Value term. *Ecological Indicators* **129**, 107856.

Amano, N., Bankoff, G., Findley, D.M., Barretto-Tesoro, G. & Roberts, P. (2021). Archaeological and historical insights into the ecological impacts of pre-colonial and colonial introductions into the Philippine Archipelago. *The Holocene* **31**, 313–330.

Andreu, J., Vilà, M. & Hulme, P.E. (2009). An assessment of stakeholder perceptions and management of noxious alien plants in Spain. *Environmental Management* **43**, 1244–1255.

Angulo, E., Diagne, C., Ballesteros-Mejia, L., Adamjy, T., Ahmed, D.A., Akulov, E., Banerjee, A.K., Capinha, C., Dia, C.A.K.M., Dobigny, G., Duboscq-Carra, V.G., Golivets, M., Haubrock, P.J., Heringer, G., Kirichenko, N., Kourantidou, M., Liu, C., Nuñez, M.A., Renault, D., Roiz, D. & Courchamp, F. (2021). Non-English languages enrich scientific knowledge: the example of economic costs of biological invasions. *Science of the Total Environment* **775**, 144441.

Bacher, S., Blackburn, T.M., Essl, F., Genovesi, P., Heikkilä, J., Jeschke, J.M., Jones, G., Keller, R., Kenis, M., Kueffer, C., Martinou, A.F., Nentwig, W., Pergl, J., Pyšek, P., Rabitsch, W., Richardson, D.M., Roy, H.E., Saul, W.-C., Scalera, R., Vilà, M., Wilson, J.R.U., & Kumschick, S. (2018). Socio-economic impact classification of alien taxa (SEICAT). *Methods in Ecology and Evolution* **9**, 159–168.

Baker, H.G. & Stebbins, G.L. (1965). The genetics of colonizing species. Academic Press, New York.

Balzani, P., Dekoninck, W., Feldhaar, H., Freitag, A., Frizzi, F., Frouz, J., Masoni, A., Robinson, E., Sorvari, J. & Santini, G. (2022). Challenges and a call to action for protecting European red wood ants. *Conservation Biology* **36**, e13959.

Baquero, R.A., Oficialdegui, F.J., Ayllón, D. & Nicola, G.G. (2023). The challenge of managing threatened invasive species at a continental scale. *Conservation Biology* doi:10.1111/cobi.14165.

Barrett, L.P., Stanton, L.A. & Benson-Amram, S. (2019). The cognition of 'nuisance' species. *Animal Behaviour* **147**, 167–177.

Bartumeus, F., Da Luz, M.G.E., Viswanathan, G.M. & Catalan, J. (2005). Animal search strategies: a quantitative random-walk analysis. *Ecology* **86**, 3078–3087.

Beest, M., Elschot, K., Olff, H. & Etienne, R. (2013). Invasion success in a marginal habitat: an experimental test of competitive ability and drought tolerance in *Chromolaena odorata*. *PLoS ONE* **8**, e68274.

Bellard, C., Marino, C. & Courchamp, F. (2022). Ranking threats to biodiversity and why it doesn't matter. *Nature Communications* **13**, 2616.

Berg, C. (1877). Enumeración de las plantas europeas que se hallan como silvestres en la provincia de Buenos Aires y en la Patagonia. *Anales de la Sociedad Científica Argentina* **3,** 183–204.

Binggeli, P. (1994). The misuse of terminology and anthropometric concepts in the description of introduced species. *Bulletin of the British Ecological Society* **25**, 10–13.

Blackburn, T.M., Pyšek, P., Bacher, S., Carlton, J.T., Duncan, R. P., Jarošík, V., Wilson, J.R.U. & Richardson, D.M. (2011). A proposed unified framework for biological invasions. *Trends in Ecology & Evolution* **26**, 333–339.

Blackman, R.C., Constable, D., Hahn, C., Sheard, A.M., Durkota, J., Hänfling, B. & Handley, L.L. (2017). Detection of a new non-native freshwater species by DNA metabarcoding of environmental samples—first record of *Gammarus fossarum* in the UK. *Aquatic Invasions* **12**, 177–189.

Bláha, M., Weiperth, A., Patoka, J., Szajbert, B., Balogh, E. R., Staszny, Á., Ferincz, Á., Lente, V., Maciaszek, R. & Kouba, A. (2022). The pet trade as a source of non-native decapods: the case of crayfish and shrimps in a thermal waterbody in Hungary. *Environmental Monitoring and Assessment* **194**, 795.

Blumenthal, D.M. (2006). Interactions between resource availability and enemy release in plant invasion. *Ecology Letters* **9**, 887–895.

Borcherding, J., Staas, S., Krüger, S., Ondračková, M., Šlapanský, L. & Jurajda, P. (2011). Non-native Gobiid species in the lower River Rhine (Germany): recent range extensions and densities. *Journal of Applied Ichthyology* **27**, 153–155.

Bortolus, A. (2006). The austral cordgrass *Spartina densiflora* Brong.: its taxonomy, biogeography and natural history. *Journal of Biogeography* **33,** 158–68.

Bortolus, A. (2012). Running like Alice and losing good ideas: on the quasi-compulsive use of english by on-native english speaking scientists. *Ambio* **41**, 769–772.

Bortolus, A. & Schwindt, E. (2022). Biological invasions and human dimensions: We still need to work hard on our social perspectives. *Ecología Austral* **32**, 767–783.

Bortolus, A., Carlton, J.T. & Schwindt, E. (2015). Reimagining South American coasts: unveiling the hidden invasion history of an iconic ecological engineer. *Diversity and Distributions* **21**, 1267–1283.

Boucher, D.H. (ed). (1985). The biology of mutualism: ecology and evolution. New York: Oxford University Press.

Brown, N.J. (1994). Who abolished corvée labour in Egypt and why? *Past & Present* **144**, 116–137.

Brown, J.H. & Sax, D.F. (2004). An essay on some topics concerning invasive species. *Austral Ecology* **29**, 530–536.

Bucher, E.H. & Aramburú, R.M. (2014). Land-use changes and monk parakeet expansion in the Pampas grasslands of Argentina. *Journal of Biogeography* **41**, 1160–1170.

Bullock, O.M., Colón Amill, D., Shulman, H.C. & Dixon, G.N. (2019). Jargon as a barrier to effective science communication: Evidence from metacognition. *Public Understanding of Science* **28**, 845–853.

Cadotte, M.W. (2006). Darwin to Elton: early ecology and the problem of invasive species. In *Conceptual ecology and invasion biology: reciprocal approaches to nature* (eds M.W. Cadotte, S.M. McMahon and T. Fukami), pp. 15–33. Dordrecht: Springer Netherlands.

Caley, P. & Kuhnert, P.M. (2006). Application and evaluation of classification trees for screening unwanted plants. *Austral Ecology* **31**, 647–655.

Cambridge English Dictionary Online. (2023). Invasive (adjective). In Cambridge English Dictionary Online. https://dictionary.cambridge.org/dictionary/english/invasive

Cameron, D. (2012). Verbal hygiene. 2nd edition, London: Routledge, pp. 268.

Carey, M.P., Sanderson, B.L., Barnas, K.A. & Olden, J.D. (2012). Native invaders–challenges for science, management, policy, and society. *Frontiers in Ecology and the Environment* **10**, 373–381.

Carlon, E. & Dominoni, D.M. (2023). Reviewing the role of urbanisation in facilitating the introduction and establishment of invasive animal species. EcoEvoRxiv. doi:10.32942/X2D60D.

Carlton, J.T. (1996). Biological invasions and cryptogenic species. *Ecology* **77**, 1653–1655.

Carlton, J.T. (2002). Bioinvasion ecology: assessing invasion impact and scale. In *Invasive aquatic species of Europe. Distribution, impacts and management* (eds E. Leppäkoski, S. Gollasch and S. Olenin), pp. 7–19. Dordrecht: Springer Netherlands.

Carlton, J.T. (2009). Deep invasion ecology and the assembly of communities in historical time. In *Biological invasions in marine ecosystems: ecological, management, and geographic perspectives* (eds G. Rilov and J.A. Crooks), pp.13–56. Springer Berlin, Heidelberg.

Cassini, M.H. (2020). A review of the critics of invasion biology. *Biological Reviews* **95**, 1467–1478.

Castañeda, R.A., Cvetanovska, E., Hamelin, K. M., Simard, M.A. & Ricciardi, A. (2018). Distribution, abundance and condition of an invasive bivalve (*Corbicula fluminea*) along an artificial thermal gradient in the St. Lawrence River. *Aquatic Invasions* **13**, 379–392.

Castro, A., Ribeiro, J., Reino, L. & Capinha, C. (2023). Who is reporting non-native species and how? A cross-expert assessment of practices and drivers of non-native biodiversity reporting in species regional listing. *Ecology and Evolution* **13**, e10148.

Catford, J.A., Baumgartner, J.B., Vesk, P.A., White, M., Buckley, Y.M. & McCarthy, M.A. (2016). Disentangling the four demographic dimensions of species invasiveness. *Journal of Ecology* **104**, 1745–1758.

Cerca, J., Purschke, G. & Struck, T.H. (2018). Marine connectivity dynamics: clarifying cosmopolitan distributions of marine interstitial invertebrates and the meiofauna paradox. *Marine Biology* **165**, 123.

Cerri, J., Mori, E., Zozzoli, R., Gigliotti, A., Chirco, A. & Bertolino, S. (2020). Managing invasive Siberian chipmunks Eutamias sibiricus in Italy: a matter of attitudes and risk of dispersal. *Biological Invasions* **22**, 603–616.

Christy, J.A., Kimpo, A., Marttala, V., Gaddis, P.K. & Christy, N.L. (2009). Urbanizing flora of Portland, Oregon, 1806-2008. *Native Plant Society of Oregon Occasional Paper* **3**, 1–319.

Chowdhury, S., Dey, P., Joel-Edgar, S., Bhattacharya, S., Rodriguez-Espindola, O., Abadie, A. & Truong, L. (2023). Unlocking the value of artificial intelligence in human resource management through AI capability framework. *Human Resource Management Review* **33**, 100899.

Clavero, M., Nores, C., Kubersky-Piredda, S. & Centeno-Cuadros, A. (2016). Interdisciplinarity to reconstruct historical introductions: solving the status of cryptogenic crayfish. *Biological Reviews* **91**, 1036–1049.

Clements, D.R. & Ditommaso, A. (2011). Climate change and weed adaptation: can evolution of invasive plants lead to greater range expansion than forecasted? *Weed Research* **51**, 227–240.

Colautti, R.I. & MacIsaac, H.J. (2004). A neutral terminology to define 'invasive' species. *Diversity and Distributions* **2**, 135–141.

Colautti, R.I. & Richardson, D.M. (2009). Subjectivity and flexibility in invasion terminology: too much of a good thing? *Biological Invasions* **11**, 1225–1229.

Colautti, R.I., Grigorovich, I.A. & MacIsaac, H.J. (2006). Propagule pressure: a null model for biological invasions. *Biological invasions* **8**, 1023–1037.

Colautti, R.I., Parker, J.D., Cadotte, M.W., Pysek, P., Brown, C.S., Sax, D.F. & Richardson, D.M. (2014). Quantifying the invasiveness of species. *NeoBiota* **21**, 7–27.

Copp, G.H., Bianco, P.G., Bogutskaya, N.G., Erős, T., Falka, I., Ferreira, M.T., Fox, M.G., Freyhof, J., Gozlan, R.E., Grabowska, J., Kovac, V., Moreno-Amich, R., Naseka, A.M., Penaz, M., Povz, M., Przybylski, M., Robillard, M., Russell, I.C., Stakenas, S., Sumer, S., Vila-Gispert, A. & Wiesner, C. (2005). To be, or not to be, a non-native freshwater fish? *Journal of Applied Ichthyology* **21**, 242–262.

Copp, G.H., Vilizzi, L., Tilbury, H., Stebbing, P., Tarkan, A.S., Miossec, L. & Goulletquer, P. (2016). Development of a generic decision-support tool for identifying potentially invasive aquatic taxa: AS-ISK. *Management of Biological Invasions* **7**, 343–350.

Copp, G.H., Vilizzi, L., Wei, H., Li, S., Piria, M., Al-Faisal, A.J., Almeida, D., Atique, U., Al-Wazzan, Z., Bakiu, R., Bašić, T., Bui, T.D., Canning-Clode, J., Castro, N., Chaichana, R., Çoker, T., Dashinov, D., Ekmekçi, F.G., Erős, T., Ferincz, Á., Ferreira, T., Giannetto, D., Gilles, A.S. Jr, Głowacki, Ł., Goulletquer, P., Interesova, E., Iqbal, S., Jakubčinová, K., Kanongdate, K., Kim, J.-E., Kopecký, O., Kostov, V., Koutsikos, N., Kozic, S., Kristan, P., Kurita, Y., Lee, H.-G., Leuven, R.S.E.W., Lipinskaya, T., Lukas, J., Marchini, A., González Martínez, A.I., Masson, L., Memedemin, D., Moghaddas, S.D., Monteiro, J., Mumladze, L., Naddafi, R., Năvodaru, I., Olsson, K.H., Onikura, N., Paganelli, P., Pavia, R.T. Jr, Perdikaris, C., Pickholz, R., Pietraszewski, D., Povž, M., Preda, C., Ristovska, M., Rosíková, K., Santos, J.M., Semenchenko, V., Senanan, W., Simonović, P., Smeti, E., Števove, B., Švolíková, K., Ta, K.A.T., Tarkan, A.S., Top, N., Tricarico, E., Uzunova, E., Vardakas, L., Verreyken, H., Zięba, G., Mendoza, R. (2021). Speaking their language – development of a multilingual decision-support tool for communicating invasive species risks to decision makers and stakeholders. *Environmental Modelling & Software* **135**, 104900.

Corlett, R.T. (2016). Restoration, reintroduction, and rewilding in a changing world. *Trends in Ecology & Evolution* **31**, 453–462.

Correa, C., Lobos, G., Pastenes, L. & Méndez, M.A. (2008). Invasive *Pleurodema thaul* from Robinson Crusoe Island: molecular identification of its geographic origin and comments on the phylogeographic structure of this species in mainland Chile. *The Herpetological Journal* **18**, 77–82.

Corsini-Foka, M. & Economidis, P.S. (2007). Allochthonous and vagrant ichthyofauna in Hellenic marine and estuarine waters. *Mediterranean Marine Science* **8**, 67–90.

Courchamp, F., Fournier, A., Bellard, C., Bertelsmeier, C., Bonnaud, E., Jeschke, J.M. & Russell, J.C. (2017). Invasion biology: specific problems and possible solutions. *Trends in Ecology and Evolution* **32**, 13–22.

Crawley, M.J., Brown, S.L., Heard, M.S. & Edwards, R. (1999). Invasion-resistance in experimental grassland communities: species richness or species identity? *Ecology Letters* **2**,140–148.

Crosby, A.W. (1986). Ecological imperialism: the biological expansion of Europe, 900–1900. London: Cambridge University Press.

Cuthbert, R.N., Diagne, C., Hudgins, E.J., Turbelin, A., Ahmed, D.A., Albert, C., Bodey, T.W., Briski, E., Essl, F., Haubrock, P.J., Gozlan, R.E., Kirichenko, N., Kourantidou, M., Kramer, A.M., & Courchamp, F. (2022). Biological invasion costs reveal insufficient proactive management worldwide. *Science of the Total Environment* **819**, 153404.

Cuthbert, R., Bodey, T.W., Briski, E., Capellini, I., Dick, J.T., Kourantidou, M., Ricciardi, A. & Pincheira-Donoso, D. (2023). Harnessing Trait Evolution to Predict Economic Costs of Biological Invasions. *ASSRN* https://dx.doi.org/10.2139/ssrn.4430070.

Daly, E.Z., Chabrerie, O., Massol, F., Facon, B., Hess, M.C., Tasiemski, A., Grandjean, F., Chauvat, M., Viard, F., Forey, E., Folcher, L., Buisson, E., Boivin, T., Baltora-Rosset, S., Ulmer, R., Gibert, P., Thiébaut, G., Pantel, J.H., Heger, T., Richardson, D.M. & Renault, D. (2023). A synthesis of biological invasion hypotheses associated with the introduction–naturalisation–invasion continuum. *Oikos* **2023**, e09645.

Darling, J.A. & Carlton, J.T. (2018). A framework for understanding marine cosmopolitanism in the Anthropocene. *Frontiers in Marine Science* **5**, 293.

Darwin, C. (1859). On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life. John Murray, London, pp. 502.

Davis, M.A. (2006). Invasion biology 1958-2005: the pursuit of science and conservation. In *Conceptual ecology and invasion biology: reciprocal approaches to nature* (eds M.W. Cadotte, S.M. McMahon and T. Fukami), pp. 35–64. Dordrecht: Springer Netherlands.

Davis, M.A. (2009). Invasion biology. Oxford University Press.

Davis, M.A. & Thompson, K. (2000). Eight ways to be a colonizer; two ways to be an invader: a proposed nomenclature scheme for invasion ecology. *Bulletin of the Ecological Society of America* **81**, 226–230.

De Candolle, A.P. (1855). Géographie Botanique Raisonné, vol. 2. V. Masson, Paris.

De Meester, L., Louette, G., Duvivier, C., Van Damme, C. & Michels, E. (2007). Genetic composition of resident populations influences establishment success of immigrant species. *Oecologia* **153**, 431–440.

Dgebuadze, Y.Y. (2014). Invasions of alien species in Holarctic: some results and perspective of investigations. *Russian Journal of Biological Invasions* **1**, 2–8.

Diagne, C., Leroy, B., Vaissière, A.-C., Gozlan, R.E., Roiz, D., Jaríc, I., Salles, J.-M., Bradshaw, C.J.A. & Courchamp, F. (2021). High and rising economic costs of biological invasions worldwide. Nature **592**, 571–576.

Dick, J.T., Alexander, M.E., Jeschke, J.M., Ricciardi, A., MacIsaac, H.J., Robinson, T.B., Kumschick, S., Weyl, O.L.F., Dunn, A.M., Hatcher, M.J., Paterson, R.A., Farnsworth, K.D. & Richardson, D.M. (2014). Advancing impact prediction and hypothesis testing in invasion ecology using a comparative functional response approach. *Biological Invasions* **16**, 735–753.

Dick, J.T., Laverty, C., Lennon, J.J., Barrios-O'Neill, D., Mensink, P.J., Britton, R.J., Médoc, V., Boets, P., Alexander, M.E., Taylor, N.G., Dunn, A.M., Hatcher, M.J., Rosewarne, P.J., Crookes, S., MacIsaac, H.J., Xu, M., Ricciardi, A., Wasserman, R.J., Ellender, B.R., Weyl, O.L.F., Lucy, F.E., Banks, P.B., Dodd, J.A., MacNeil, C., Penk, M.R., Aldridge, D.C. & Caffrey, J.M. (2017). Invader Relative Impact Potential: a new metric to understand and predict the ecological impacts of existing, emerging and future invasive alien species. *Journal of Applied Ecology* **54**, 1259–1267.

Doria, C.R.d.C., Agudelo, E., Akama, A., Barros, B., Bonfim, M., Carneiro, L., Briglia-Ferreira, S.R., Nobre Carvalho, L., Bonilla-Castillo, C.A., Charvet, P., dos Santos Catâneo, D.T.B., da Silva, H.P., Garcia-Dávila, C.R., dos Anjos, H.D.B., Duponchelle, F., Encalada, A., Fernandes, I., Florentino, A.C., Guarido, P.C.P., de Oliveira Guedes, T.L., Jimenez-Segura, L., Lasso-Alcalá, O.M., Macean, M.R., Marques, E.E., Mendes-Júnior, R.N.G., Miranda-Chumacero, G., Nunes, J.L.S., Occhi, T.V.T., Pereira, L.S., Castro-Pulido, W., Soares, L., Sousa, R.G.C., Torrente-Vilara, G., Van Damme, P.A., Zuanon, J. & Vitule, J.R.S. (2021). The silent threat of non-native fish in the amazon: ANNF database and review. *Frontiers in Ecology and Evolution* **9**, 646702.

Dunn, M., Marzano, M., Forster, J. & Gill, R.M. (2018). Public attitudes towards “pest” management: Perceptions on squirrel management strategies in the UK. *Biological Conservation* **222**, 52–63.

Echeverría, C., Coomes, D., Salas, J., Rey-Benayas, J. M., Lara, A. & Newton, A. (2006). Rapid deforestation and fragmentation of Chilean temperate forests. *Biological Conservation* **130**, 481–494.

Eckstein, R.L., Ruch, D., Otte, A. & Donath, T.W. (2012). Invasibility of a nutrient-poor pasture through resident and non-resident herbs is controlled by litter, gap size and propagule pressure. *PLoS One* **7**, e41887.

Ellender, B.R. & Weyl, O.L. (2014). A review of current knowledge, risk and ecological impacts associated with non-native freshwater fish introductions in South Africa. *Aquatic Invasions* **9**, 117–132.

Ellwood, E.R., Pauly, G.B., Ahn, J., Golembiewski, K., Higgins, L.M., Ordeñana, M.A. & von Konrat, M. (2023). Citizen science needs a name change. *Trends in Ecology & Evolution* **38**, 485–489.

Elton, C. (1942). Voles, mice and lemmings. Problems in population dynamics. Oxford: Clarendon Press.

Elton, C.S. (2020) The ecology of invasions by animals and plants. Switzerland: Springer, 2nd edition, 2020. 181 p.

Epanchin-Niell, R.S. & Hastings, A. (2010). Controlling established invaders: integrating economics and spread dynamics to determine optimal management. *Ecology Letters* **13**, 528–541.

Essl, F., Dullinger, S., Rabitsch, W., Hulme, P.E., Hülber, K., Jarošík, V., Kleinbauer, I., Krausmann, F., Kühn, I., Nentwig, W., Vilà, M., Genovesi, P., Gherardi, F., Desprez-Loustau, M.-L., Roques, A. & Pyšek, P. (2011). Socioeconomic legacy yields an invasion debt. *Proceedings of the National Academy of Sciences* **108**, 203–207.

Essl, F., Bacher, S., Genovesi, P., Hulme, P.E., Jeschke, J.M., Katsanevakis, S., Kowarik, I., Kühn, I., Pyšek, P., Rabitsch, W., Schindler, S., van Kleunen, M., Vilà, M., Wilson, J.R.U. & Richardson, D.M. (2018). Which taxa are alien? Criteria, applications, and uncertainties. *BioScience* **68**, 496–509.

Essl, F., Dullinger, S., Genovesi, P., Hulme, P.E., Jeschke, J.M., Katsanevakis, S., Kühn, I., Lenzner, B., Pauchard, A., Pyšek, P., Rabitsch, W., Richardson, D.M., Seebens, H., van Kleunen, M., van der Putten, W.H., Vilà, M. & Bacher, S. (2019). A conceptual framework for range-expanding species that track human-induced environmental change. *BioScience* **69**, 908–919.

Essl, F., Dullinger, S., Genovesi, P., Hulme, P.E., Jeschke, J.M., Katsanevakis, S., Kühn, I., Lenzner, B., Pauchard, A., Pyšek, P., Rabitsch, W., Richardson, D.M., Seebens, H., van Kleunen, M., van der Putten, W.H., Vilà, M. & Bacher, S. (2020). Distinct biogeographic phenomena require a specific terminology: A reply to Wilson and Sagoff. *BioScience* **70**, 112–114.

Essl, F., Pyšek, P. & Richardson, D.M. (2021). Neonatives and translocated species: different terms are needed for different species categories in conservation policies. *NeoBiota* **68**, 101–104.

Evans, J., Arndt, E. & Schembri, P.J. (2020). Atlantic fishes in the Mediterranean: Using biological traits to assess the origin of newcomer fishes. *Marine Ecology Progress Series* **643**, 133–143.

Fachinello, M.C., Romero, J.H.C. & de Castro, W.A.C. (2022). Defining invasive species and demonstrating impacts of biological invasions: a scientometric analysis of studies on invasive alien plants in Brazil over the past 20 years. *NeoBiota* **76**, 13–24.

Falk-Petersen, J., Bøhn, T. & Sandlund, O.T. (2006). On the numerous concepts in invasion biology. *Biological Invasions* **8**, 1409–1424.

Faria, L., de Carvalho, B.M., Carneiro, L., Miiller, N.O.R., Pedroso, C.R., Occhi, T.V.T., Tondella, L.H. & Vitule, J.R.S. (2022). Invasive species policy in Brazil: a review and critical analysis. *Environmental Conservation* **50**, 67–72.

Faria, L., Cuthbert, R.N., Dickey, J.W., Jeschke, J.M., Ricciardi, A., Dick, J.T. & Vitule, J.R. (2023). The rise of the Functional Response in invasion science: a systematic review. *NeoBiota* **85**, 43–79.

Farouk, M. (2019). La corvée lors du creusement de l'isthme: Guerre des discours et représentation romanesque. *Sociétés & Représentations* **48**, 143–155.

Floerl, O., Inglis, G.J., Dey, K. & Smith, A. (2009). The importance of transport hubs in stepping-stone invasions. *Journal of Applied Ecology* **46**, 37–45.

Florencio, M., Lobo, J.M. & Bini, L.M. (2019). Biases in global effects of exotic species on local invertebrates: a systematic review. *Biological Invasions* **21**, 3043–3061.

Forgione, L., Bacher, S. & Vimercati, G. (2022). Are species more harmful in their native, neonative or alien range? Insights from a global analysis of bark beetles. *Diversity and Distributions* **28**, 1832–1849.

Frank, J.H. & McCoy, E.D. (1990). Endemics and epidemics of shibbolets and other things causing chaos. *Florida Entomologist* **73**, 1–8.

Gago, J., Anastácio, P., Gkenas, C., Banha, F. & Ribeiro, F. (2016). Spatial distribution patterns of the non-native European catfish, *Silurus glanis*, from multiple online sources–a case study for the River Tagus (Iberian Peninsula). *Fisheries Management and Ecology* **23**, 503–509.

Galil, B.S. (2006). The marine caravan–the Suez Canal and the Erythrean invasion. In *Bridging divides: maritime canals as invasion corridors* (eds. S. Gollasch, B.S. Galil and A.N. Cohen), pp. 207–300. Dordrecht: Springer, Netherlands.

Galil, B.S., Mienis, H.K., Hoffman, R. & Goren, M. (2021). Non-indigenous species along the Israeli Mediterranean coast: tally, policy, outlook. *Hydrobiologia* **848**, 2011–2029.

Gallardo, B., Clavero, M., Sánchez, M.I. & Vilà, M. (2016). Global ecological impacts of invasive species in aquatic ecosystems. *Global Change Biology* **22**, 151–163.

García-Díaz, P., Cassey, P., Norbury, G., Lambin, X., Montti, L., Pizarro, J. C., Powell, P.A., Burslem, D.F.R.P., Cava, M., Damasceno, G., Fasola, L., Fidelis, A., Huerta, M.F., Langdon, B., Linardaki, E., Moyano, J., Núñez, M.A., Pauchard, A., Phimister, E., Raffo, E., Roesler, I., Rodríguez-Jorquera, I. & Tomasevic, J.A. (2021). Management policies for invasive alien species: addressing the impacts rather than the species. *BioScience* **71**, 174–185.

Gilroy, J.J., Avery, J.D. & Lockwood, J.L. (2017). Seeking international agreement on what it means to be "native". *Conservation Letters* **10**, 238–247.

Gkenas, C., Martelo, J., Ribeiro, D., Gago, J., Dias, D., Santos, G. & Ribeiro, F. (2023). Westwards expansion of the European catfish *Silurus glanis* in the Douro River (Portugal). *Limnetica* 43, 1–8.

Golebie, E.J., van Riper, C.J., Arlinghaus, R., Gaddy, M., Jang, S., Kochalski, S., Lu, Y., Olden, J.D., Stedman, R. & Suski, C. (2022). Words matter: a systematic review of communication in non-native aquatic species literature. *NeoBiota* **74**, 1–28.

González-Moreno, P., Lazzaro, L., Vilà, M., Preda, C., Adriaens, T., Bacher, S., Brundu, G., Copp, G.H., Essl, F., García-Berthou, E., Katsanevakis, S., Moen, T.L., Lucy, F.E., Nentwig, W., Roy, H.E., Srėbalienė, G., Talgø, V., Vanderhoeven, S., Andjelković, A., Arbačiauskas, K., Auger-Rozenberg, M.-A., Bae, M.-J., Bariche, M., Boets, P., Boieiro, M., Borges, P.A., Canning-Clode, J., Cardigos, F., Chartosia, N., Cottier-Cook, E.J., Crocetta, F., D'hondt, B., Foggi, B., Follak, S., Gallardo, B., Gammelmo, Ø., Giakoumi, S., Giuliani, C., Fried, G., Šerić Jelaska, L., Jeschke, J.M., Jover, M., Juárez-Escario, A., Kalogirou, S., Kočić, A., Kytinou, E., Laverty, C., Lozano, V., Maceda-Veiga, A., Marchante, E., Marchante, H, Martinou, A.F., Meyer, S., Michin, D., Montero-Castaño, A., Morais, M.C., Morales-Rodriguez, C., Muhthassim, N., Nagy, Z.Á., Ogris, N., Onen, H., Perg, J., Puntila, R., Rabitsch, W., Ramburn, T.T., Rego, C., Reichenbach, F., Romeralo, C., Saul, W.-C., Schrader, G., Sheehan, R., Simonović, P., Skolka, M., Soares, A.O., Sundheim, L., Tarkan, A.S., Tomov, R., Tricarico, E., Tsiamis, K., Uludağ, A., van Valkenburg, J., Verreycken, H., Vettraino, A.M., Vilar, L., Wiig, Ø., Witzell, J., Zanetta, A. & Kenis, M. (2019). Consistency of impact assessment protocols for non-native species. *NeoBiota* **44**, 1–25.

Gormley, A.M., Forsyth, D.M., Griffioen, P., Lindeman, M., Ramsey, D.S., Scroggie, M.P. & Woodford, L. (2011). Using presence-only and presence–absence data to estimate the current and potential distributions of established invasive species. *Journal of Applied Ecology* **48**, 25–34.

Gouin, N., Grandjean, F., Bouchon, D., Reynolds, J.D. & Souty-Grosset, C. (2001). Population genetic structure of the endangered freshwater crayfish *Austropotamobius pallipes*, assessed using RAPD markers. *Heredity* **87**, 80–87.

Green, R.E. (1997). The influence of numbers released on the outcome of attempts to introduce exotic bird species to New Zealand. *Journal of Animal Ecology* **66**, 25–35.

Groom, Q., Desmet, P., Reyserhove, L., Adriaens, T., Oldoni, D., Vanderhoeven, S., Baskauf, S.J., Chapman, A., McGeoch, M., Walls, R., Wieczorek, J., Wilson, J.R.U., Zermoglio, P.F.F. & Simpson, A. (2019). Improving Darwin Core for research and management of alien species. *Biodiversity Information Science and Standards* **3**, e38084.

Gross, K.C. & Pharr, D.M. (1982). A potential pathway for galactose metabolism in *Cucumis sativus* L., a stachyose transporting species. *Plant Physiology* **69**, 117–121.

Guerisoli, M.M., Schiaffini, M.I., Teta, P., Valenzuela, A.E.J., Mirol, P., Defossé, G.E., Godoy, M.M., Krieger, P., Whittington, T., Agostini, M.G., Anderson, C.B., Anello, M., Aprile, G., Aquino, J.E., Argoitia, A., Arzamendia, Y., Baigorria, J.E.M., Baldo, D., Baldo, J.L., Balza, U., Barbe, I., Barrasso, D.A., Barri, F.R., Barrios-Garcia, M.N., Bartolucci, C., Bastida, R.O., Bauer, G., Berrozpe, P., Bertonatti, C., Bó, R.F., Bracamonte, J.C., Campo, D.H., Cannizzo, M., Carmanchahi, P., Caruso, F., Cassinelli, F., Chalukian, S.C., Chatellenaz, M.L., Chemisquy, M.A., Cosse, M., Cuyckens, G.A.E., D'Agostino, R.L., D'Agostino, V.C., Deferrari, G., Degrati, M., del Valle Ferreyra, H., Derlindati, E.J., Di Cataldo, S., Di Rocco, F., Dominino, J., Durante, C.A., Eder, E.B., Esquenazi, S.M., Ezquiaga, M.C., Faivovich, J., Fernández, F.J., Ferreyra, N., Lacoste, F.F., Flores, D., Formoso, A., Franchini, M., Francisco, E.E., Gómez Fernández, M.J., González, B., González, E.M., González, S., Guerrero, J.C., Guiscafré, A., Juan, E.E., Kin, M.S., Kowalewski, M., Laitán, M.G., Lanzone, C., Laufer, G., Leizagoyen, C., Leonardi, M.S., Loizaga, R., Mapelli, F.J., Martin, G.M., Massaccesi, G., Merani, M.S., Mignino, J., Miño, C.I., Miotti, M.D., Morici, A., Moschione, F.N., Mosti, P.A., Muzzachiodi, N., Nori, J., Novillo, A., Oklander, L.I., Orozco, M.M., Ovejero, R., Palmerio, A.G., Paso Viola, M.N., Pastore, H., Paszko, L.M., Pérez Carusi, L.C., Perovic, P.G., Perretta, A., Pozzi, C.M., Ramírez-Chaves, H.E., Relva, M.A., Reppucci, J.I., Robino, F., Rodríguez-Cabal, M.A., Rodríguez-Planes, L.I., Roesler, I., Rossi, L.F., Segura, V., Sillero, C., Sittoni, F., Tálamo, A., Torres Monges, J.C., Travaini, A., Túnez, J.I., Udrizar Sauthier, D., Uhart, M., Urquizo, J.H., Vargas, O.E., Wiemeyer, G.M., Winter, M., Wolfenson, L.I., Ojeda, R. & Ojeda, A.A. (2023). Reflexiones acerca del «reasilvestramiento» en la Argentina. *Mastozoología Neotropical* **30**, e0946.

Guo, Q. & Ricklefs, R.E. (2010). Domestic exotics and the perception of invasibility. *Diversity and Distributions* **16,** 1034–1039.

Gurevitch, J., Fox, G.A., Wardle, G.M. & Inderjit D.T. (2011). Emergent insights from the synthesis of conceptual frameworks for biological invasions. *Ecology Letters* **14**, 407–418.

Hällfors, M.H., Vaara, E.M., Hyvärinen, M., Oksanen, M., Schulman, L.E., Siipi, H. & Lehvävirta, S. (2014). Coming to terms with the concept of moving species threatened by climate change - a systematic review of the terminology and definitions. *PloS One* **9**, e102979.

Hargreaves, A.L., Samis, K.E. & Eckert, C.G. (2014). Are species' range limits simply niche limits writ large? A review of transplant experiments beyond the range. *The American Naturalist* **183**, 157–173.

Harper, D. (2008). Weekley an etymological dictionary of modern English.

Hastings, A. (1996). Models of spatial spread: a synthesis. *Biological Conservation* **78**, 143–148.

Haubrock, P.J., Ahmed, D.A., Cuthbert, R.N., Stubbington, R., Domisch, S., Marquez, J.R.G., Beidas, A., Amatulli, G., Kiesel, J., Shen, L.Q., Soto, I., Angeler, D.G., Bonada, N., Cañedo-Argüelles, M., Csabai, Z., Datry, T., de Eyto, E., Dohet, A., Drohan, E., England, J., Feio, M.J., Forio, M.A.E., Goethals, P., Graf, W., Heino, J., Hudgins, E.J., Jähnig, S.C., Johnson, R.K., Larrañaga, A., Leitner, P., L'Hoste, L., Lizee, M.-H., Maire, A., Rasmussen, J.J., Schäfer, R.B, Schmidt-Kloiber, A., Vannevel, R., Várbíró, G., Wiberg-Larsen, P. & Haase, P. (2022). Invasion impacts and dynamics of a European-wide introduced species. *Global Change Biology* **28**, 4620–4632.

Hawkins, C.L., Bacher, S., Essl, F., Hulme, P.E., Jeschke, J.M., Kühn, I., Kumschick, S., Nentwig, W., Pergl, J., Pyšek, P., Rabitsch, W., Richardson, D.M., Vilà, M., Wilson, J.R.U., Genovesi, P. & Blackburn, T.M. (2015). Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). *Diversity and Distributions* **21**, 1360–1363.

Heger, T., Saul, W.C. & Trepl, L. (2013). What biological invasions 'are' is a matter of perspective. *Journal for Nature Conservation* **21**, 93–96.

Heger, T., Jeschke, J.M., Kollmann, J. (2021). Some reflections on current invasion science and perspectives for an exciting future. *NeoBiota* **68**, 79–100.

Helmreich, S. (2005). How scientists think; about 'natives', for example. A problem of taxonomy among biologists of alien species in Hawaii. *Journal of the Royal Anthropological Institute* **11**, 107–128.

Hengeveld, R. (1992). Potential and limitations of predicting invasion rates. *Florida Entomologist* **75**, 60–72.

Herrando-Pérez, S., Delean, S., Brook, B.W., Bradshaw, C.J.A. (2012). Density dependence: an ecological Tower of Babel. *Oecologia* **170**, 585–603.

Hirst, R. (2003). Scientific jargon, good and bad. *Journal of Technical Writing and Communication* **33**, 201–229.

Hodges, K.E. (2008). Defining the problem: terminology and progress in ecology. *Frontiers in Ecology and the Environment* **6**, 35–42.

Holzapfel, A.M. & Vinebrooke, R.D. (2005). Environmental warming increases invasion potential of alpine lake communities by imported species. *Global Change Biology* **11**, 2009–2015.

Howard, B.R., Barrios-O'Neill, D., Alexander, M.E., Dick, J.T., Therriault, T.W., Robinson, T.B. & Côté, I.M. (2018). Functional responses of a cosmopolitan invader demonstrate intraspecific variability in consumer-resource dynamics. *PeerJ* **6**, e5634.

Hui, C. & Richardson, D.M. (2017). Invasion Dynamics. Oxford University Press, Oxford.

Hui, C., & Richardson, D.M. (2019). How to invade an ecological network. *Trends in Ecology & Evolution* **34**, 121–131.

Iannone III, B.V., Carnevale, S., Main, M.B., Hill, J.E., McConnell, J.B., Johnson, S.A., Enloe, S.F., Andreu, M., Bell, E.C., Cuda, J.P. & Baker, S.M. (2020). Invasive species terminology: Standardizing for stakeholder education. *The Journal of Extension* **58**, 27.

Ibanez, I., Clark, J.S. & Dietze, M.C. (2008). Evaluating the sources of potential migrant species: implications under climate change. *Ecological Applications* **18**, 1664–1678.

IUCN. (2023). The IUCN Red List of Threatened Species. Version 2023-1. iucnredlist.org. Accessed on 19 July 2023.

Iuell, B. (2002). Prevention of unwanted species immigrating to islands on strait crossings. In: Proceedings of the International Conference on Ecology and Transportation. September 24–28, 2001.

James, S.W. & Hendrix, P.F. (2004). Invasion of exotic earthworms into North America and other regions. *Earthworm Ecology* **441**, 75–88.

Jeschke, J. & Heger, T. (eds) (2018). Invasion Biology: Hypotheses and Evidence. CABI, 188 pp.

Jeschke, J.M., Bacher, S., Blackburn, T.M., Dick, J.T., Essl, F., Evans, T., Gaertner, M., Hulme, P.E., Kühn, I, Mrugala, A., Pergl, J., Pyšek, P., Rabitsch, W., Ricciardi, A., Richardson, D.M., Sendek, A., Vilà, M., Winter, M. & Kumschick, S. (2014). Defining the impact of non-native species. *Conservation Biology* **28**, 1188–1194.

Kamada, S., Murakami, T., Masuda, R. (2013). Multiple origins of the Japanese marten *Martes melampus* introduced into Hokkaido Island, Japan, revealed by microsatellite analysis. *Mammal Study* **38,** 261–267.

Kapitza, K., Zimmermann, H., Martín-López, B. & von Wehrden, H. (2019). Research on the social perception of invasive species: A systematic literature review. *NeoBiota* **43**, 47–68.

Keller, R.P., Geist, J., Jeschke, J.M. & Kühn, I. (2011). Invasive species in Europe: ecology, status, and policy. *Environmental Sciences Europe* **23**, 1–17.

King, R.T. (1942). Is it wise policy to introduce exotic game birds? *Audubon Magazine* **44,** 136–145.

Kirk, D.A., Park, A.C., Smith, A.C., Howes, B.J., Prouse, B.K., Kyssa, N.G., Fairhurst, E.N. & Prior, K.A. (2018). Our use, misuse, and abandonment of a concept: Whither habitat? *Ecology and Evolution* **8**, 4197–4208.

Klimaszewski, J., Bourdon, C. & Pelletier, G. (2013). Synopsis of adventive species of Coleoptera (Insecta) recorded from Canada. Part 2: Staphylinidae.

Klotz, P. (1999). Politeness and political correctness: Ideological implications. Pragmatics. *Quarterly Publication of the International Pragmatics Association* **9**, 155–161.

Klotz, W., Miesen, F.W., Hüllen, S. & Herder, F. (2013). Two Asian fresh water shrimp species found in a thermally polluted stream system in North Rhine-Westphalia, Germany. *Aquatic Invasions* **8**, 333–339.

Kolar, C.S. & Lodge, D.M. (2001). Progress in invasion biology: Predicting invaders. *Trends in Ecology & Evolution* **16**, 199–204.

Kourantidou, M., Haubrock, P.J., Cuthbert, R.N., Bodey, T.W., Lenzner, B., Gozlan, R.E., Nuñez, M.A., Salles, J.-M., Diagne, C. & Courchamp, F. (2022). Invasive alien species as simultaneous benefits and burdens: trends, stakeholder perceptions and management. *Biological Invasions* **24**, 1905–1926.

Kueffer, C. & Daehler, C.C. (2009). A habitat-classification framework and typology for understanding, valuing, and managing invasive species impacts. In *Management of invasive weeds* (eds C. Kueffer, C.C. Daehler and S. Inderjit). pp. 77–101, Springer Dordrecht.

Kühn, I., Wolf, J. & Schneider, A. (2017). Is there an urban effect in alien plant invasions? *Biological Invasions* **19**, 3505–3513.

La Sorte, F.A. & Pyšek, P. (2009). Extra-regional residence time as a correlate of plant invasiveness: European archaeophytes in North America. *Ecology* **90**, 2589–2597.

Lambert, A.M., Dudley, T.L. & Saltonstall, K. (2010). Ecology and impacts of the large-statured invasive grasses *Arundo donax* and *Phragmites australis* in North America. *Invasive Plant Science and Management* **3**, 489–494.

Larson, B.M. (2005). The war of the roses: demilitarizing invasion biology. *Frontiers in Ecology and the Environment* **3**, 495–500.

Larson, B.M. (2007). An alien approach to invasive species: objectivity and society in invasion biology. *Biological Invasions* **9**, 947–956.

Latombe, G., Canavan, S., Hirsch, H., Hui, C., Kumschick, S., Nsikani, M. M., Potgieter, L.J., Robinson, T.B., Saul, W.-C., Turner, S.C., Wilson, J.R.U., Yannelli, F.A. & Richardson, D.M. (2019). A four-component classification of uncertainties in biological invasions: implications for management. *Ecosphere* **10**, e02669.

Laufer, G., Gobel, N., Kacevas, N. & Lado, I. (2023). American bullfrog (*Lithobates catesbeianus*) distribution, impact on native amphibians and management priorities in San Carlos, Uruguay. *Knowledge & Management of Aquatic Ecosystems* **424**, 20.

Lawrence, E. (2000) Henderson's Dictionary of Biological Terms. Prentice Hall, Harlow, 719 pp.

Lemoine, R.T. & Svenning, J.C. (2022). Nativeness is not binary—a graduated terminology for native and non-native species in the Anthropocene. *Restoration Ecology* **30**, e13636.

Lenoir, J., Bertrand, R., Comte, L., Bourgeaud, L., Hattab, T., Murienne, J. & Grenouillet, G. (2020). Species better track climate warming in the oceans than on land. *Nature Ecology & Evolution* **4**, 1044–1059.

Lenzner, B., Latombe, G., Schertler, A., Seebens, H., Yang, Q., Winter, M., Weigelt, P., van Kleunen, M., Pyšek, P., Pergl, J., Kreft, H., Dawson, W., Dullinger, S. & Essl, F. (2022). Naturalized alien floras still carry the legacy of European colonialism. *Nature Ecology and Evolution* **6**, 1723–1732.

Leopold, A. (1949). A Sand County almanac and sketches here and there. New York: Oxford University Press.

Lepczyk, C.A. (2022). Time to retire "alien" from the invasion ecology lexicon. *Frontiers in Ecology and the Environment* **20**, 447–447.

Leung, B., Lodge, D.M., Finnoff, D., Shogren, J.F., Lewis, M.A. & Lamberti, G. (2002). An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. *Proceedings of the Royal Society B* **269**, 2407–2413.

Lewis, M.A., Petrovskii, S.V. & Potts, J.R. (2016). The Mathematics Behind Biological Invasions, Interdisciplinary Applied Mathematics. Springer International Publishing, Cham.

Liebhold, A.M., Brockerhoff, e.g. Kalisz, S., Nuñez, M.A., Wardle, D.A. & Wingfield, M.J. (2017). Biological invasions in forest ecosystems. *Biological Invasions* **19**, 3437–3458.

Lieurance, D., Kuebbing, S., McCary, M.A. & Nuñez, M.A. (2022). Words matter: how to increase gender and LGBTQIA+ inclusivity at Biological Invasions. *Biological Invasions* **24**, 341–344.

Liu, X. & Li, Y. (2009). Aquaculture enclosures relate to the establishment of feral populations of introduced species. *PloS One* **4**, e6199.

Lockwood, J.L., Cassey, P. & Blackburn, T. (2005). The role of propagule pressure in explaining species invasions. *Trends in Ecology & Evolution* **20**, 223–228.

Lockwood, J. L., Hoopes, M.F. & Marchetti, M.P. (2013). Invasion Ecology. John Wiley & Sons.

Lonsdale, W.M. (1999). Global patterns of plant invasions and the concept of invasibility. *Ecology* **80**, 1522–1536.

Luiz, O.J., Floeter, S.R., Rocha, L.A. & Ferreira, C.E. (2013). Perspectives for the lionfish invasion in the South Atlantic: Are Brazilian reefs protected by the currents? *Marine Ecology Progress Series* **485**, 1-7.

Macêdo, R.L., Elmoor-Loureiro, L.M., Sousa, F.D.R., Rietzler, A.C., Perbiche-Neves, G. & Rocha, O. (2023). From pioneers to modern-day taxonomists: the good, the bad, and the idiosyncrasies in choosing species epithets of rotifers and microcrustaceans. *Hydrobiologia*, 1–12.

Madsen, D.H. (1937). Protection of native fishes in the national parks. *Transactions of the American Fisheries Society* **66,** 395–397.

Manchester, S.J. & Bullock, J.M. (2000). The impacts of non-native species on UK biodiversity and the effectiveness of control. *Journal of Applied Ecology* **37**, 845–864.

Martínez, A. & Mammola, S. (2021). Specialized terminology reduces the number of citations of scientific papers. *Proceedings of the Royal Society B* **288**, 20202581.

Maslyakov, V.Y. & Izhevsky S.S. (2011). Alien Phytophagous Insects Invasions in the European Part of Russia. Moscow, IGRAS, 272 pp. [in Russian].

Matsuzaki, S.S., Sasaki, T. & Akasaka, M. (2013). Consequences of the introduction of exotic and translocated species and future extirpations on the functional diversity of freshwater fish assemblages. *Global Ecology and Biogeography* **22,** 1071–1082.

McGlynn, T. P. (1999). The worldwide transfer of ants: geographical distribution and ecological invasions. *Journal of Biogeography* **26**, 535–548.

McNeill, J.R. (2003). Europe's place in the global history of biological exchange. *Landscape Research* **28**, 33–39.

Metzger, N. & Zare, R.N. (1999). Interdisciplinary research: from belief to reality. *Science* **283**, 642–643.

Montgomery, S.L. (1989). The cult of jargon: Reflections on language in science. *Science as Culture* **1**, 42–77.

Morris, C. (1992) Academic Press Dictionary of Science and Technology. Academic Press, San Diego, 2432 pp.

Mwangi, E. & Swallow, B. (2008). *Prosopis juliflora* invasion and rural livelihoods in the Lake Baringo area of Kenya. *Conservation and Society* **6**, 130–140.

Myers, J.H., Simberloff, D., Kuris, A.M. & Carey, J.R. (2000). Eradication revisited: dealing with exotic species. *Trends in Ecology and Evolution* **15**, 316–320.

Nadel, H., Frank, J.H. & Knight, R.J. (1992). Escapees and Accomplices: The naturalization of exotic *Ficus* and their associated faunas in Florida. *Florida Entomologist* **75**, 29–38.

Nagy, K. & Johnson II, P.D. (eds) (2013). Trash animals: How we live with nature's filthy, feral, invasive, and unwanted species. University of Minnesota Press.

Naylor, R.L., Williams, S.L. & Strong, D.R. (2001). Aquaculture — a gateway for exotic species. *Science* **294**, 1655–1656.

Nelufule, T., Robertson, M.P., Wilson, J.R.U. & Faulkner, K.T. (2022). Native-alien populations—an apparent oxymoron that requires specific conservation attention. *NeoBiota* **74**, 57–74.

Nelufule, T., Robertson, M.P., Wilson, J.R.U. & Faulkner, K.T. (2023). An inventory of native-alien populations in South Africa. *Scientific Data* **10**, 213.

Nuñez, M.A., Chiuffo, M.C., Seebens, H., Kuebbing, S., McCary, M.A., Lieurance, D., Zhang,. B., Simberloff, D. & Meyerson, L.A. (2022). Two decades of data reveal that Biological Invasions needs to increase participation beyond North America, Europe, and Australasia. *Biological Invasions* **24**, 333–340.

Occhipinti-Ambrogi, A. (2021). Biopollution by invasive marine non-indigenous species: a review of potential adverse ecological effects in a changing climate. *International Journal of Environmental Research and Public Health* **18**, 4268.

Occhipinti-Ambrogi, A. & Galil, B.S. (2004). A uniform terminology on bioinvasions: A chimera or an operative tool? *Marine Pollution Bulletin* **49**, 688–694.

Ogg, A.G. & Dawson, J.H. (1984). Time of emergence of eight weed species. *Weed Science* **32**, 327–335.

Ojaveer, H., Galil, B.S., Campbell, M.L., Carlton, J.T., Canning-Clode, J., Cook, E.J., Davidson, A.D., Hewitt, C.L., Jelmert, A., Marchini, A., McKenzie, C.H., Minchin, D., Occhipinti-Ambrogi, A., Olenin, S. & Ruiz, G. (2015). Classification of non-indigenous species based on their impacts: considerations for application in marine management. *PLoS Biology* **13**, e1002130.

Oliver, W.R.B. (1930). New Zealand Birds. Wellington: A.H. and A.D. Reed.

Oosting, H.J. (1948). The study of plant communities: an introduction to plant ecology. San Francisco, CA, W.H. Freeman.

Ortiz-Serrano, M. & Forero-Laverde, G. (2020). Fake news and talking up the market: the case of the Compagnie universelle du canal interocéanique de Panama in 1888. *Entreprises et Histoire* **101**, 27–43.

Orwell, G. (1968). Politics and English Language. In *The collected essays, journalism and letters of George Orwell* (eds S. Orwell and I. Angos), pp. 127–140. New York, NY.

Oxford English Dictionary Online. (2023). Invasive (adjective). In *Oxford English Dictionary Online*. https://www.oed.com/dictionary/invasive_adj?tab=factsheet#181340

Pace, P. & Severance, K. (2016). Migration terminology matters. *Forced Migration Review* **51**, 69–70.

Packer, J.G., Meyerson, L.A., Skálová, H., Pyšek, P. & Kueffer, C. (2017). Biological flora of the British Isles: *Phragmites australis*. *Journal of Ecology* **105**, 1123–1162.

Padial, A.A., Agostinho, Â.A., Azevedo-Santos, V.M., Frehse, F.A., Lima-Junior, D.P., Magalhães, A.L., Mormul, R.P., Pelicice, F.M., Bezerra, L.A.V., Orsi, M.L., Petrere-Junior, M. & Vitule, J.R. (2017). The "Tilapia Law" encouraging non-native fish threatens Amazonian River basins. *Biodiversity and Conservation* **26**, 243–246.

Padilla, D.K. & Williams, S.L. (2004). Beyond ballast water: aquarium and ornamental trades as sources of invasive species in aquatic ecosystems. *Frontiers in Ecology and the Environment* **2**, 131–138.

Pascual, U., Adams, W.M., Díaz, S., Lele, S., Mace, G.M. & Turnhout, E. (2021). Biodiversity and the challenge of pluralism. *Nature Sustainability* **4**, 567–572.

Passera, L. (2021). Characteristics of tramp species. In *Exotic Ants: biology, impact, and control of introduced species* (ed D.F. Williams), pp 23–43. CRC Press.

Pereyra, P.J. (2020). Rethinking the native range concept. *Conservation Biology* **34**, 373–377.

Pereyra, P.J., Rossini, G.B. & Darrigran, G. (2012). Toxicity of neem's oil, a potential biocide against the invasive mussel *Limnoperna fortunei* (Dunker 1857). *Anais da Academia Brasileira de Ciências* **84**, 1065–1071.

Pérez, J.E., Alfonsi, C., Nirchio, M. & Salazar, S.K. (2008). Bioinvaders: the acquisition of new genetic variation. *Interciencia* **33**, 935–940.

Pheloung, P.C., Williams, P.A. & Halloy, S.R. (1999). A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management* **57**, 239–251.

Pivello, V.R., Vieira, M.V., Grombone-Guaratini, M.T. & Matos, D.M.S. (2018). Thinking about super-dominant populations of native species – Examples from Brazil. *Perspectives in Ecology and Conservation* **16**, 74–82.

Plavén-Sigray, P., Matheson, G.J., Schiffler, B.C. & Thompson, W.H. (2017). The readability of scientific texts is decreasing over time. *eLife* **6**, e27725.

Por, F.D. (1971). One hundred years of Suez Canal—a century of Lessepsian migration: retrospect and viewpoints. *Systematic Zoology* **20**, 138–159.

Protopopova, V.V., Shevera, M.V., Orlov, O.O. & Panchenko, S.M. (2015). The transformer species of the Ukrainian Polissya. *Biodiversity Research and Conservation* **39**, 7–18.

Pyšek, P. (1995). On the terminology used in plant invasion studies. In *Plant invasions: General aspects and special problems* (eds P. Pyšek, K. Parch, M. Rejmanek and M. Wade), pp. 71–81. SPB Academic Publishing.

Pyšek, P., Richardson, D.M., Rejmánek, M., Webster, G.L., Williamson, M. & Kirschner, J. (2004). Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. *Taxon* **53**, 131–-143.

Pyšek, P., Hulme, P.E., Simberloff, D., Bacher, S., Blackburn, T.M., Carlton, J.T., Dawson, W., Essl, F., Foxcroft, L.C., Genovesi, P., Jeschke, J.M., Kühn, I., Liebhold, A.M., Mandrak, N.E., Meyerson, L.A., Pauchard, A., Pergl, J., Roy, H.E., Seebens, H., van Kleunen, M., Vilà, M., Wingfield, M.J. & Richardson, D.M. (2020). Scientists' warning on invasive alien species. *Biological Reviews* **95**, 1511–1534.

Regan, H.M., Colyvan, M. & Burgman, M.A. (2002). A taxonomy and treatment of uncertainty for ecology and conservation biology. *Ecological Applications* **12**, 618–628.

Rejmanek, M. (2011) Invasiveness. In *Encyclopedia of Biological Invasions* (eds. D. Simberloff and M. Rejmanek), pp. 379–385. University of California Press, Berkeley, CA, USA.

Renault, D. (2020). A review of the phenotypic traits associated with insect dispersal polymorphism, and experimental designs for sorting out resident and disperser phenotypes. *Insects* **11**, 214.

Reynolds, A.M. (2012). Olfactory search behavior in the wandering albatross is predicted to give rise to Lévy flight movement patterns. *Animal Behaviour* **83**, 1225–1229.

Ricciardi, A. (2007). Are modern biological invasions an unprecedented form of global change? *Conservation Biology* **21,** 329–336.

Ricciardi, A. & Cohen, J. (2007). The invasiveness of an introduced species does not predict its impact. *Biological Invasions* **9**, 309–315.

Ricciardi, A., Hoopes, M.F., Marchetti, M.P. & Lockwood, J.L. (2013). Progress toward understanding the ecological impacts of nonnative species. *Ecological Monographs* **83**, 263–282.

Richardson, D.M. & Pyšek, P. (2008). Fifty years of invasion ecology–the legacy of Charles Elton. *Diversity and Distributions* **14**, 161–168.

Richardson, D.M. & Ricciardi, A. (2013). Misleading criticisms of invasion science: a field guide. *Diversity and Distributions* **19**, 1461–1467.

Richardson, D.M., Pyšek, P., Rejmanek, M., Barbour, M.G., Panetta, F.D. & West, C.J. (2000). Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions* **6**, 93–107.

Richardson, D.M., Pyšek, P. & Carlton, J.T. (2011). A compendium of essential concepts and terminology in invasion ecology. In *Fifty years of invasion ecology: the legacy of Charles Elton* (ed D.M. Richardson), pp. 409–420. Wiley-Blackwell.

Richardson, D.M., Foxcroft, L.C., Latombe, G., Le Maitre, D.C., Rouget, M. & Wilson, J.R.U. (2020). The biogeography of South African terrestrial plant invasions. In *Biological Invasions in South Africa* (eds B.W. van Wilgen, J. Measey, D.M. Richardson, J.R.U. Wilson and T.A. Zengeya), pp. 67–96. Springer Nature.

Riera, L., Ramalhosa, P., Canning-Clode, J. & Gestoso, I. (2018). Variability in the settlement of non-indigenous species in benthic communities from an oceanic island. *Helgoland Marine Research* **72**, 1–15.

Rilov, G. & Crooks, J.A. (2009). Biological Invasions in Marine Ecosystems: Ecological, Management, and Geographic Perspectives. Ecological Studies Series (ed. U. Sommer), pp. 626. Springer, Heidelberg, Germany

Rilov, G., Canning-Clode, J. & Guy-Haim, T. (2023). Ecological impacts of invasive ecosystem engineers: a global perspective across terrestrial and aquatic systems. Functional Ecology **00**, 1–15.

Ritchie, J. (1920). The influence of man on animal life in Scotland. Cambridge: Cambridge University Press.

Robinson, T.B., Alexander, M.E., Simon, C.A., Griffiths, C.L., Peters, K., Sibanda, S., Miza, S., Groenewald, B., Majiedt, P. & Sink, K.J. (2016). Lost in translation? Standardising the terminology used in marine invasion biology and updating South African alien species lists. *African Journal of Marine Science* **38**, 129–140.

Rodríguez-Barreras, R., Zapata-Arroyo, C., Falcón L, W. & Olmeda, M.D.L. (2020). An island invaded by exotics: a review of freshwater fish in Puerto Rico. *Neotropical Biodiversity* **6**, 42–59.

Roll, U., Dayan, T., Simberloff, D. & Goren, M. (2007). Characteristics of the introduced fish fauna of Israel. *Biological Invasions* **9**, 813–824.

Roth, N., Jaramillo, F., Wang-Erlandsson, L., Zamora, D., Palomino-Ángel, S. & Cousins, S.A. (2021). A call for consistency with the terms 'wetter' and 'drier' in climate change studies. *Environmental Evidence* **10**, 8.

Roy, H.E., Peyton, J., Aldridge, D.C., Bantock, T., Blackburn, T.M., Britton, R., Clark, P., Cook, E., Dehnen-Schmutz, K., Dines, T., Dobson, M., Edwards, F., Harrower, C., Harvey, M.C., Minchin, D., Noble, D. G., Parrott, D., Pocock, M.J.O., Preston, C.D., Roy, S., Salisbury, A., Schönrogge, K., Sewell, J., Shaw, R.H., Stebbing, P., Stewart, A.J.A. & Walker, K.J. (2014). Horizon scanning for invasive alien species with the potential to threaten biodiversity in Great Britain. *Global Change Biology* **20**, 3859–3871.

Roy, H.E., Rabitsch, W., Scalera, R., Stewart, A., Gallardo, B., Genovesi, P., Essl, F., Adriaens, T., Bacher, S., Booy, O., Branquart, E., Brunel, S., Copp, G.H., Dean, H., D'hondt, B., Josefsson, M., Kenis, M., Kettunen, M., Linnamagi, M., Lucy, F., Martinou, A., Moore, N., Nentwig, W., Nieto, A., Pergl, J., Peyton, J., Roques, A., Schindler, S., Schönrogge, K., Solarz, W., Stebbing, P.D., Trichkova, T., Vanderhoeven, S., van Valkenburg, J. & Zenetos, A. (2018). Developing a framework of minimum standards for the risk assessment of alien species. *Journal of Applied Ecology* **55**, 526–538.

Russell, J.C. & Blackburn, T.M. (2017). The rise of invasive species denialism. *Trends in Ecology and Evolution* **32**, 3–6.

Saikkonen, K., Taulavuori, K., Hyvönen, T., Gundel, P.E., Hamilton, C.E., Vänninen, I., Nissinen, A. & Helander, M. (2012). Climate change-driven species' range shifts filtered by photoperiodism. *Nature Climate Change* **2**, 239–242.

Sala, E., Kizilkaya, Z., Yildirim, D. & Ballesteros, E. (2011). Alien marine fishes deplete algal biomass in the eastern Mediterranean. *PLoS One* **6**, e17356.

Sandvik, H., Hilmo, O., Finstad, A.G., Hegre, H., Moen, T.L., Rafoss, T., Skarpaas, O., Elven, R., Sandmark, H.

& Gederaas, L. (2019). Generic ecological impact assessment of alien species (GEIAA): the third generation of assessments in Norway. *Biological Invasions* **21**, 2803–2810.

Saul, W.C. & Jeschke, J.M. (2015). Eco-evolutionary experience in novel species interactions. *Ecology Letters* **18**, 236–245.

Sax, D.F., Stachowicz, J.J. & Gaines, S.D. (eds) (2005). Species invasions: insights into ecology, evolution, and biogeography. Sinauer Associates.

Sax, D.F., Schlaepfer, M.A. & Olden, J.D. (2022). Valuing the contributions of non-native species to people and nature. *Trends in Ecology and Evolution* **37**, 1058–1066.

Scalera, R. & Zaghi, D. (2004). Alien species and nature conservation in the EU: the role of the LIFE program. Brussels: European Commission.

Schaffner, U. (2005). What makes a species invasive? Environmental Documentation Nr. 191, 91 pp.

Schittko, C., Bernard-Verdier, M., Heger, T., Buchholz, S., Kowarik, I., von der Lippe, M., Seitz, B., Joshi, J. & Jeschke, J.M. (2020). A multidimensional framework for measuring biotic novelty: How novel is a community? *Global Change Biology* **26**, 4401–4417.

Schlaepfer, M.A., Sax, D.F. & Olden, J.D. (2011). The potential conservation value of non-native species. *Conservation Biology* **25**, 428–437.

Schwindt, E., Battini, N., Bortolus, A. & Scarabino, F. (2022). 20 years of marine bioinvasions research: Achievements and challenges for the Southwestern Atlantic. *Ecología Austral* **32,** 734–748.

Seddon, P.J., Griffiths, C.J., Soorae, P.S. & Armstrong, D.P. (2014). Reversing defaunation: restoring species in a changing world. *Science* **345**, 406–412.

Shackelford, N., Hobbs, R.J., Heller, N.E., Hallett, L.M. & Seastedt, T.R. (2013). Finding a middle-ground: the native/non-native debate. *Biological Conservation* **158**, 55–62.

Shackleton, R.T., Richardson, D.M., Shackleton, C.M., Bennett, B., Crowley, S.L., Dehnen-Schmutz, K., Estévez, R.A., Fischer, A., Kueffer, C., Kull, C.A., Marchante, E., Novoa, A., Potgieter, L.J., Vaas, J., Vaz, A.S. & Larson, B.M. (2019). Explaining people's perceptions of invasive alien species: a conceptual framework. *Journal of Environmental Management* **229**, 10–26.

Shackleton, R.T., Vimercati, G., Probert, A.F., Bacher, S., Kull, C.A. & Novoa, A. (2022). Consensus and controversy in the discipline of invasion science. *Conservation Biology* **36**, e13931.

Shigesada, N. & Kawasaki, K. (1997). Biological invasions: theory and practice. Oxford University Press.

Simberloff, D. (2010). Invasive species. In *Conservation biology for all* (eds N.S. Sodhi and P.R. Ehrlich), pp 131–152. Oxford University Press Inc, New York.

Simberloff, D. (2011). SCOPE project. In *Encyclopedia of Biological Invasions* (eds D. Simberloff and M. Rejmánek), pp 617–619. Berkeley: University of California Press.

Simberloff, D. (2013). Invasive species: what everyone needs to know. Oxford University Press.

Simberloff, D., Parker, I.M. & Windle, P.N. (2005). Introduced species policy, management, and future research needs. *Frontiers in Ecology and the Environment* **3**, 12–20.

Simberloff, D., Martin, J.L., Genovesi, P., Maris, V., Wardle, D.A., Aronson, J., Courchamp, F., Galis, B.S., Garcia-Berthou, E., Pascal, M., Pyšek, P., Sousa, R., Tabacchi, E. & Vilà, M. (2013). Impacts of biological invasions: what's what and the way forward. *Trends in Ecology and Evolution* **28**, 58–66.

Smith, B.P., Cairns, K.M., Adams, J.W., Newsome, T.M., Fillios, M., Déaux, E.C., Parr, W.C.H., Letnic, M., van Eeden, L.M., Appleby, R.G., Bradshaw, C.J.A., Savolainen, P., Ritchie, e.g. Nimmo, D.G., Archer-Lean, C., Greenville, A.C., Dickman, C.R., Watson, L., Moseby, K.E., Doherty, T.S., Wallach, A.D., Morrant, D.S., Crowther, M.S. (2019). Taxonomic status of the Australian dingo: the case for *Canis dingo* Meyer, 1793. *Zootaxa* **4564**, 173–197.

Smout, T.C. (2003). The alien species in 20th-century Britain: Constructing a new vermin. *Landscape Research* **28**, 11–20.

Snell Taylor, S.J., Evans, B.S., White, E.P. & Hurlbert, A.H. (2018). The prevalence and impact of transient species in ecological communities. *Ecology* **99**, 1825–1835.

Sofaer, H.R., Jarnevich, C.S. & Pearse, I.S. (2018). The relationship between invader abundance and impact.

Ecosphere **9**, e02415.

Soliman, T., Mourits, M.C.M., Lansink, A.O. & Van der Werf, W. (2010). Economic impact assessment in pest risk analysis. *Crop Protection* **29**, 517–524.

Solomon, M.E. (1949). The natural control of animal populations. *Journal of Animal Ecology* **18**, 1–35.

Sommerwerk, N., Wolter, C., Freyhof, J. & Tockner, K. (2017). Components and drivers of change in European freshwater fish fauna. *Journal of Biogeography* **44**, 1781–1790.

Soto, I., Ahmed, D.A., Balzani, P., Cuthbert, R.N. & Haubrock, P.J. (2023a). Sigmoidal curves reflect impacts and dynamics of aquatic invasive species. *Science of The Total Environment* **872**, 161818.

Soto, I., Cuthbert, R.N., Ricciardi, A., Ahmed, D.A., Altermatt, F., Schäfer, R.B., Archambaud-Suard, G., Bonada, N., Cañedo-Argüelles, M., Csabai, Z., Datry, T., Dick, J.T.A., Floury, M., Forio, M.A.E., Forcellini, M., Fruget, J.-F., Goethals, P., Haase, P., Hudgins, E.J., Jones, J.I., Kouba, A., Leitner, P., Lizée, M.-H., Maire, A., Murphy, J.F., Ozolins, D., Rasmussen, J.J., Schmidt-Kloiber, A., Skuja, A., Stubbington, R., Van der Lee, G.H., Vannevel, R., Várbíró, G., Verdonschot, R.C.M., Wiberg-Larsen, P., Haubrock, P.J. & Briski, E. (2023b). The faunal Ponto-Caspianization of central and western European waterways. *Biological Invasions* **25**, 2613–2629.

Spear, D. & Chown, S.L. (2009). The extent and impacts of ungulate translocations: South Africa in a global context. *Biological Conservation* **142**, 353–363.

Spear, M.J., Walsh, J.R., Ricciardi, A. & Vander Zanden, M.J. (2021). The invasion ecology of sleeper populations: prevalence, persistence, and abrupt shifts. *BioScience* **71**, 357–369.

Stern, N., Rothman, S.B., Hüseyinoglu, M.F. & Öztürk, B. (2018). Iron Lion Zion: the successful, albeit lingered, invasion of the lionfish in the Israeli Mediterranean Sea. Lionfish Invasion and Its Management in the Mediterranean Sea; Turkish Marine Research Foundation (TUDAV) Publication Istanbul: Istanbul, Turkey, 49, pp.51-56.

Stevenson, E.A., Robertson, P., Hickinbotham, E., Mair, L., Willby, N.J., Mill, A., Booy, O., Witts, K. & Pattison, Z. (2023). Synthesising 35 years of invasive non-native species research. *Biological Invasions* **25**, 2423–2438.

Stigall, A.L. (2019). The invasion hierarchy: ecological and evolutionary consequences of invasions in the fossil record. *Annual Review of Ecology and Evolutionary Systematics* **50**, 355–380.

Stoett, P. (2010). Framing bioinvasion: biodiversity, climate change, security, trade, and global governance. *Global Governance* **16**, 103–120.

Strayer, D.L., D'Antonio, C.M., Essl, F., Fowler, M.S., Geist, J., Hilt, S., Jarić, I., Jöhnk, K., Jones, C.G., Lambin, X., Latzka, A.W., Pergl, J., Pyšek, P., Robertson, P., von Schmalensee, M., Stefansson, R.A., Wright, J. & Jeschke, J.M. (2017). Boom-bust dynamics in biological invasions: towards an improved application of the concept. *Ecology Letters* **20**, 1337–1350.

Stroud, J.T., Bush, M.R., Ladd, M.C., Nowicki, R.J., Shantz, A.A. & Sweatman, J. (2015). Is a community still a community? Reviewing definitions of key terms in community ecology. *Ecology and Evolution* **5**, 4757–4765.

Suarez, A.V., Holway, D.A. & Case, T.J. (2001). Patterns of spread in biological invasions dominated by long-distance jump dispersal: insights from Argentine ants. *Proceedings of the National Academy of Sciences* **98**, 1095–1100.

Sullivan, W.P., Burkett, D.P., Boogaard, M.A., Criger, L.A., Freiburger, C.E., Hubert, T. D., Leistner, K.G., Morrison, B.J., Nowicki, S.M., Robertson, S.N.P., Rowlinson, A.K., Scotland, B.J. & Sullivan, T.B. (2021). Advances in the use of lampricides to control sea lampreys in the Laurentian Great Lakes, 2000–2019. *Journal of Great Lakes Research* **47**, S216–S237.

Tarkan, A.S., Vilizzi, L., Top, N., Ekmekçi, F.G., Stebbing, P.D. & Copp, G.H. (2017). Identification of potentially invasive freshwater fishes, including translocated species, in Turkey using the Aquatic Species Invasiveness Screening Kit (AS-ISK). *International Review of Hydrobiology* **102**, 47–56.

Taylor, D.M. (2023). The status of naturalized bird species in Idaho. *Northwestern Naturalist* **104**, 99–116.

Te Wehi. (1874). Ki a te Kai Tuhi o te Waka Maori. Te Waka Maori o Niu Tirani. **10**, 239–240. [in māori].

Thomas, C.D. (2010). Climate, climate change and range boundaries. *Diversity and Distributions* **16**, 488–495.

Tsadok, R., Rubin-Blum, M., Shemesh, E. & Tchernov, D. (2015). On the occurrence and identification of

Abudefduf saxatilis (Linnaeus, 1758) in the easternmost Mediterranean Sea. *Aquatic invasions* **10**, 101–105.

Turbé, A., Strubbe, D., Mori, E., Carrete, M., Chiron, F., Clergeau, P., González-Moreno, P., Le Louarn, M., Luna, A., Menchetti, M., Nentwig, W., Pârâu, L.G., Postigo, J.-L., Rabitsch, W., Senar, J.C., Tollington, S., Vanderhoeven, S., Weiserbs, A. & Shwartz, A. (2017). Assessing the assessments: evaluation of four impact assessment protocols for invasive alien species. *Diversity and Distributions* **23**, 297–307.

Turner, I.M. (1996). Species loss in fragments of tropical rain forest: a review of the evidence. *Journal of Applied Ecology **33***, 200–209.

Urban, M.C. (2020). Climate-tracking species are not invasive. *Nature Climate Change* **10**, 382–384 .

Ulman, A., Tunçer, S., Kizilkaya, I.T., Zilifli, A., Alford, P. & Giovos, I. (2020). The lionfish expansion in the Aegean Sea in Turkey: A looming potential ecological disaster. *Regional Studies in Marine Science* **36**, 101271.

Urquía, D., Gutierrez, B., Pozo, G., Pozo, M.J., Espín, A. & Torres, M.D.L. (2019). *Psidium guajava* in the Galapagos Islands: population genetics and history of an invasive species. *PloS One* **14**, e0203737.

Valéry, L., Fritz, H., Lefeuvre, J.C. & Simberloff, D. (2008). In search of a real definition of the biological invasion phenomenon itself. *Biological Invasions* **10**, 1345–1351.

Valéry, L., Fritz, H., Lefeuvre, J.C. & Simberloff, D. (2009). Invasive species can also be native. *Trends in Ecology and Evolution* **24**, 585.

Vandepitte, K., De Meyer, T., Helsen, K., Van Acker, K., Roldán-Ruiz, I., Mergeay, J. & Honnay, O. (2014). Rapid genetic adaptation precedes the spread of an exotic plant species. *Molecular Ecology* **23**, 2157–2164.

Vargas, A., Herrera, I., Nualart, N., Guézou, A., Gómez-Bellver, C., Freire, E., Jaramillo Diaz, P. & López-Pujol, J. (2022). The genus Kalanchoe (Crassulaceae) in Ecuador: from gardens to the wild. *Plants* **11**, 1746.

Vaz, A.S., Kueffer, C., Kull, C.A., Richardson, D.M., Schindler, S., Muñoz-Pajares, A.J., Vicente, J.R., Martins, J., Hui, C., Kühn, I. & Honrado, J.P. (2017). The progress of interdisciplinarity in invasion science. *Ambio* **46**, 428–442.

Vilà, M., Basnou, C., Pyšek, P., Josefsson, M., Genovesi, P., Gollasch, S., Nentwig, W., Olenin, S., Roques, A., Roy, D., Hulme, P.E. & DAISIE partners. (2010). How well do we understand the impacts of alien species on ecosystem services? A pan-European cross-taxa assessment. *Frontiers in Ecology and the Environment* **8**, 135–144.

Vilizzi, L., Hill, J.E., Piria, M. & Copp, G.H. (2022a). A protocol for screening potentially invasive non-native species using Weed Risk Assessment-type decision-support tools. *Science of the Total Environment* **832**, 154966.

Vilizzi, L., Piria, M., Kopecký, O., Pietraszewski, D., Radočaj, T., Špelić, I., Šprem, N., Ta, K.A.T., Tarkan, A.S., Weiperth, A., Yoğurtçuoğlu, B., Candan, O., Herczeg, G., Killi, N., Lemić, D., Szajbert, B., Almeida, D., Al-Wazzan, Z., Atique, U., Bakiu, R., Chaichana, R., Dashinov, D., Ferincz, Á., Flieller, G., Gilles, A.S. Jr., Goulletquer, P., Interesova, E., Iqbal, S., Koyama, A., Kristan, P., Li, S., Lukas, J., Moghaddas, S.D., Monteiro, J.G., Mumladze, L., Olsson, K.H., Paganelli, D., Perdikaris, C., Pickholtz, R., Preda, C., Ristovska, M., Slovák Švolíková, K., Števove, B., Uzunova, E., Vardakas, L., Verreycken, H., Wei, H. & Zięba, G. (2022b). Development and application of a multilingual electronic decision-support tool for risk screening non-native terrestrial animals under current and future climate conditions. *Neobiota* **76**, 211–236.

Vimercati, G., Probert, A.F., Volery, L., Bernardo-Madrid, R., Bertolino, S., Céspedes, V., Essl, F., Evans, T., Gallardo, B., Gallien, L., González-Moreno, P., Grange, M.C., Hui, C., Jeschke, J.M., Katsanevakis, S., Kühn, I., Kumschick, S., Pergl, J., Pyšek, P., Rieseberg, L., Robinson, T.B., Saul, W.-C., Sorte, C.J.B., Vilà, M., Wilson, J.R.U. & Bacher, S. (2022). The EICAT+ framework enables classification of positive impacts of alien taxa on native biodiversity. *PLoS Biology* **20**, e3001729.

Vinogradova, Y.K. (2006). Formation of the secondary range and variability of the invasive populations of the ash-leaved maple (*Acer negundo* L.). *Bulletin of the Main Botanical Garden* **190**, 25–47. [in Russian].

Viswanathan, G.M., Da Luz, M.G.E., Raposo, E.P. & Stanley, H.E. (2011). The Physics of Foraging: An Introduction to Random Searches and Biological Encounters, 1st ed. Cambridge University Press.

Vitule, J.R.S., Occhi, T.V.T., Kang, B., Matsuzaki, S.-I., Bezerra, L.A., Daga, V.S., Faria, L., de A. Frehse, F., Walter, F. & Padial, A.A. (2019). Intra-country introductions unraveling global hotspots of alien fish species.

Biodiversity and Conservation **28**, 3037–3043.

Vitule, J.R., Occhi, T.V., Carneiro, L., Daga, V.S., Frehse, F.A., Bezerra, L.A., Forneck, S., de Pereira, H.S., Freitas, M.O., Hegel, C.G.Z., Abilhoa, V., Grombone-Guaratini, M.T., Queiroz-Sousa, J., Pivello, V.R., Silva-Matos, D.M., Oliveira, I., Toledo, L.F., Vallejos, M.A.V., Zenni, R.D., Ford, A.G.P. & Braga, R.R. (2021). Non-native species introductions, invasions, and biotic homogenization in the Atlantic Forest. In *The Atlantic Forest: History, Biodiversity, Threats and Opportunities of the Mega-diverse Forest* (eds M.C.M. Marques, C.E.V. Grelle), pp. 269–295. Springer Cham.

Wagner, R.G. (2005). Forest regeneration trends: Dinosaurs, political correctness, and the future. The Thin Green Line: A Symposium on the State-of-the-Art in Reforestation, pp. 36–42.

Wallingford, P.D, Morelli, T.L., Allen, J.M., Beaury, E.M., Blumenthal, D.M., Bradley, B.A., Dukes, J.S., Early, R., Fusco, E.J., Goldberg, D.E., Ibáñez, I., Laginhas, B.B., Vilà, M. & Sorte, C.J.B. (2020). Adjusting the lens of invasion biology to anticipate impacts of climate-driven range shifts. *Nature Climate Change* **10**, 398–405

Wang, D., Yao, H., Li, Y.H., Xu, Y.J., Ma, X.F. & Wang, H.P. (2019). Global diversity and genetic landscape of natural populations and hatchery stocks of largemouth bass *Micropterus salmoides* across American and Asian regions. *Scientific Reports* **9**, 16697.

Warren, C.R. (2007). Perspectives on the 'alien' versus 'native' species debate: A critique of concepts, language and practice. *Progress in Human Geography* **31**, 427–446.

Wehi, P.M., Kamelamela, K.L., Whyte, K., Watene, K. & Reo, N. (2023). Contribution of Indigenous Peoples' understandings and relational frameworks to invasive alien species management. *People and Nature **00***, 1–12.

Weiperth, A., Gábris, V., Danyik, T., Farkas, A., Kuříková, P., Kouba, A. & Patoka, J. (2019). Occurrence of non-native red cherry shrimp in European temperate waterbodies: a case study from Hungary. *Knowledge & Management of Aquatic Ecosystems* **420**, 9.

Weyl, O.L.F., Daga, V.S., Ellender, B.R. & Vitule, J.R.S. (2016). A review of *Clarias gariepinus* invasions in Brazil and South Africa. *Journal of Fish Biology* **89**, 386–402.

Williamson, M. & Fitter, A. (1996). The varying success of invaders. *Ecology* **77**, 1661–1666.

Wilson, E.O. (1961). The nature of the taxon cycle in the Melanesian ant fauna. *The American Naturalist* **95**, 169–193.

Wilson, J.R.U. (2020). Definitions can confuse: Why the 'neonative' neologism is bad for conservation. *BioScience* **70**, 110–111.

Wilson, J.R.U., Dormontt, E.E., Prentis, P.J., Lowe, A.J. & Richardson DM (2009a). Biogeographic concepts define invasion biology. *Trends in Ecology & Evolution* **24**, 586.

Wilson, J.R.U., Dormontt, E.E., Prentis, P.J., Lowe, A.J. & Richardson, D.M. (2009b). Something in the way you move: dispersal pathways affect invasion success. *Trends in Ecology & Evolution* **24**, 136–144.

Wilson, J.R.U., Bacher, S., Daehler, C.C., Groom, Q.J., Kumschick, S., Lockwood, J.L., Robinson, T.B., Zengeya, T.A. & Richardson, D.M. (2020). Frameworks used in invasion science: progress and prospects. *Neobiota* **62**, 1–30.

With, K.A. (2002). The landscape ecology of invasive spread. *Conservation Biology* **16**, 1192–1203.

Witte, S., Buschbaum, C., van Beusekom, J. E. & Reise, K. (2010). Does climatic warming explain why an introduced barnacle finally takes over after a lag of more than 50 years? *Biological Invasions* **12**, 3579–3589.

Worner, S.P. & Gevrey, M. (2006). Modelling global insect pest species assemblages to determine risk of invasion. *Journal of Applied Ecology* **43**, 858–867.

Wu, S.H., Hsieh, C.F., Chaw, S.M. & Rejmánek, M. (2004). Plant invasions in Taiwan: insights from the flora of casual and naturalized alien species. *Diversity and Distributions* **10**, 349–362.

Yan, X., Zhenyu, L., Gregg, W.P. & Li D. (2001). Invasive species in China — an overview. *Biodiversity and Conservation* **10,** 1317–1341.

Yanygina, L.V., Kirillov, V.V. & Zarubina, E.Y. (2010). Invasive species in the biocenosis of the cooling reservoir of Belovskaya power plant (Southwest Siberia). *Russian Journal of Biological Invasions* **1**, 50–54.

Zenetos, A., Gofas, S., Verlaque, M., Çinar, M.E., García Raso, J.E., Bianchi, C.N., Morri, C., Azzurro, E., Binecenoglu, M., Froglia, C., Siokou, I., Violanti, D., Sfriso, A., San Martin, G., Giangrande, A., Katagan, T., Ballesteros, E., Ramos-Espla, A., Mastrototaro, F., Ocana, O., Zingone, A., Gambni, M.C. & Streftaris, N. (2010). Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. *Mediterranean Marine Science* **11**, 381–493.

Zenetos, A., Gofas, S., Morri, C., Rosso, A., Violanti, D., García Raso, J.E., Çinar, M.E., Almogi-Labin, A., Ates, A.S., Azzurro, E., Ballesteros, E., Bianchi, C.N., Bilecenoglu, M., Gambi, M.C., Giangrande, A., Gravili, C., Hyams-Kaphzan, O., Karachle, P.K., Katsanevakis, S., Lipej, L., Mastrototaro, F., Mineur, F., Pancucci-Papadopoulou, M.A., Ramos Esplá, A., Salas, C., San Martín, G., Sfriso, A., Streftaris, N. & Verlaque, M. (2012). Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways. *Mediterranean Marine Science* **13**, 328–352.

Zengeya, T.A. & Wilson, J.R.U. (2020). The status of biological invasions and their management in South Africa in 2019. South African National Biodiversity Institute, Kirstenbosch and DSI-NRF Centre of Excellence for Invasion Biology, Stellenbosch, 71 pp.

Zenni R.D. & Nuñez M.A. (2013). The elephant in the room: The role of failed invasions in understanding invasion biology. *Oikos* **122**, 801–815.

Zenni, R.D., Barlow, J., Pettorelli, N., Stephens, P., Rader, R., Siqueira, T., Gordon R., Pinfield, T. & Nuñez, M.A. (2023). Multi-lingual literature searches are needed to unveil global knowledge. *Journal of Applied Ecology* **60**, 380–383.

Zhang, L., Rohr, J., Cui, R., Xin, Y., Han, L., Yang, X., Gu, S., Du, Y., Liang, J., Wang, X., Wu, Z., Hao, Q. & Liu, X. (2022). Biological invasions facilitate zoonotic disease emergences. *Nature Communications* **13,** 1762.