

PERSPECTIVE

On the History, Politics and Science of Invasion Ecology

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Abstract

The socio-political influence on conservation science has always been contested. One such arena, which has aroused much interest, is of biological invasions. Owing to the inherent paradoxes and dilemmas in defining geographies and impacts, invasion ecology was criticized for being value-driven. The present study explores value-judgements in the evolution of invasion ecology, by reviewing the historical and modern opinions that identified species with their geographic origin or perceived impacts. We found 'weediness' to be the primitive term that identified species as inherently 'bad' and was rooted in the biblical thoughts of the Dark Age. Western enlightenment and oriental connectivity questioned such claim of species being inherently 'bad'. Particularly, naturalist and geological expeditions after the 15th century observed that the species that were transferred out of their range, induce negative impacts on the native ecosystem. We found this phenomenon politicized during the late 19th and 20th century, where species were identified with political boundaries, leading to malpractices of 'exotic introduction' and extreme 'bio-nativism'. 'Biological invasion' was a scientific term of the 1950s, but the post-World War society perceived this 'invasion' with its martial influence. In the subsequent years, a quantitative and technological revolution in long-term ecological monitoring challenged the normative way of perceiving an ecosystem equilibrium or identifying changes brought to it by an invasive species. With the current science-values interface in the subject, we conclude that value-judgements about managing invasive species can help achieve conservation goals; however, its influence on the conceptualization of ecology can distort the scientific premise and should be avoided.

Keywords. Bio-nativism; exotic introduction; postmodern ecology; value-neutrality.

Introduction

Biological invasion is declared as the second most pervasive threat to biodiversity after habitat destruction (Sala *et al* 2000). It is perceived as a threat to global biodiversity, agriculture and human health, and has hence attracted attention from diverse sectors (Pimentel *et al* 2001; McGeoch *et al* 2010). Defining an invasive species thus becomes pertinent for categorizing a species or taking any action against it. Popularly, an invasive species is defined as a widespread non-native species that has a negative impact on a native ecosystem. Owing to subjective terms like ‘non-native’ and ‘negative’ in the definition, invasion ecology has been criticized for its ambiguous nature (Peters 1991). Although these terms refer to biogeography and effect on non-human systems, their rationalization is influenced by human perceptions (Richardson *et al* 2000). When a term that explains a phenomenon is influenced by human perceptions, it can overtake the rational understanding; and in extreme cases, can influence the conceptualization of a value-laden science like Ecology (Pyšek 1995; Richardson *et al* 2000). For example, interpretation of invasion-related terms has perpetually produced metaphors like ‘alien’, ‘noxious’, and ‘exotic’ that carry an innate sense of wrongness and are extensively used in ecology (Chew and Laubichler 2003). Though studies have argued that such innate wrongness helps to manage the ill-effects caused by an invasive species; it can influence science and societal opinions about the environment. Cognitive linguists have inferred that a metaphor is not just a matter of words but also triggers the intended thought process, with the immediate comparative perception of facts (Lakoff and Johnson 1999).

As a result, scholars tried to make a value-neutral definition (e.g., Colautti and MacIsaac 2004) of an invasive species by trying to eliminate the human perception. However, owing to its popularity, value-driven metaphors and adjectives are retained in invasion ecology (MacIsaac *et al* 2011). Different opinions of scholars regarding the identity of invasive species have divided the academicians into two visible groups, one proclaiming the value-neutrality of invasion science (Richardson *et al* 2000; Holle and Simberloff 2005; Richardson and Ricciardi 2013) and another questioning the necessity of value-neutrality (Brown and Sax 2004; Davis *et al* 2011; Schlaepfer *et al* 2011). These extreme opinions highlight the importance of a question that the subject must raise: how strong is the science-value interface in invasion ecology and why? There have been numerous attempts to rationalize the terminologies associated with invasion ecology and biology (Blackburn *et al* 2011; Jeschke *et al* 2014). In fact, a few scholars argue that limiting or standardizing the terminologies can impede the development of the field of invasion ecology in different sections of society (Carlton 2002; Hodges 2008). The nature and reason of this argument polarity maybe explained by the science-value interface that has influenced the present-day conservation philosophy (Proctor 2001).

Since the notable mention of invasive species by the 19th century scientists, including Alphonse De Candolle, Charles Lyell and Charles Darwin ([Darwin 1859](#)), though not using the same term, there have been efforts to rationalize the definition of geographies and effects on non-human systems. Conceptualization of these geographies and non-human systems, in fact, traces back to the belief system before modern science, with its roots in the enlightenment era, mercantilism, Renaissance, middle ages and the historical agrarian societies. It is the idea of 'otherness' that has persisted in each of these identities. The rationale behind such identities is uncertain because issues like these are examined from a constructivist perspective and are, therefore, vulnerable to personal bias ([Warren 2007](#)). Recently, due to the influence of these metaphors on conceptualisation in ecology ([Davis 2009](#)), invasion ecology has been seen in the larger social milieu of values and politics and the 'wrongness' or the 'rightness' of biological invasion has been vehemently debated.

It is beyond the scope of the present study to review all these studies. The present study explores the influence of societal value in the development of the concept of invasion ecology. Resisting the temptation to accept invasion ecology as a value-neutral science, this article reviews multiple narratives about the epistemology of biological invasions and highlights the necessity of inter-disciplinary philosophies in the subject.

Weed and Weediness

The earliest known concept of invasive species was in regarding plants that affected food resources of primitive human societies as weeds. Weeds and weediness are two ideas that have been constructed since the start of agriculture ([Clayton 2003](#)). With the advent of agriculture, the people-nature relationship changed. Any species that damaged cultivable 'good species' were identified as 'bad species' ([White 1975](#)). It was not until the biblical ages that weediness was used as a metaphor for representing anything evil and 'unnatural'. Genesis (3:18) states Adam to be cursed with weeds ([Speiser 1964](#)), suggesting weediness to be equivalent to something evil (e.g. *"The one who sowed the good seed is the son of man. The weeds are the sons of the evil one, and the enemy who sows them is the devil."* Matthew 13:33). Because of biblical supremacy, contemporary scholars raised concern for the lost innocence by condemning the 'unnatural' weeds as its cause. This influence always persisted with the term and was even referred by Shakespeare, a scholar of Renaissance Europe (*"tis (world) an unweeded Garden..."* Hamlet 1.2.6).

The theological overtone of unnaturalness in weeds was questioned by different philosophers (e.g. Heraclitus, Zeno of Citium, and Plutarch). Such ideas challenged the dichotomy of 'natural' and 'unnatural' since historic times. These voices were heard with the fall in biblical supremacy. But the visible arguments were due to the growing global connectivity of European scholars during the Renaissance, particularly with the eco-centric oriental societies, who influenced the redefinition of human-nature relation ([Kelly 2012](#)). The scholars during the

Enlightenment era found otherness of weeds to be an outcome of human artifice ([King 1957](#)). For example, in the 18th century, botanists argued that weeds were not the cause, but rather, an effect of soil impoverishment ([McDonald 1941](#)). Many post-Renaissance scholars, including Wolfgang Goethe and Russell Lowell, romanticized weeds as ‘wilderness that rebelled against human regulation’ ([Clayton 2003](#)). However, the majority of society was still driven by biblical supremacy that treated few species as innately evil and supported the dominance of what they considered as good species.

Exotic Introduction

Scholars influenced by the idea of European supremacy over others took the advantage of biblical references. For example, Sir Matthew Hale (1667), an English barrister, stated that man is superior to nature and hence must have control to change it (influenced by “*Thou hast given him dominion over the works of thy hands; thou hast put all things under his feet*” Psalm 8:6) ([Clayton 2003](#)). Similarly, Raynal (1713–1796), a French writer, believed that modifying wild nature to a garden was what distinguished civilized Europeans from uncivilised Indians ([Gilderson 1996](#)). Nevertheless, with the growth of the positivist movement in Europe, science was advocated for any political decision and was reflected by the arguments of scholars advocating species introductions. For example, Walter Buller, a 19th century naturalist from New Zealand, invoked Darwinism for the displacement of native flora and fauna (including people) by superior European species ([Clayton 2003](#)). This attitude of ‘European gardens better than wilderness’ was further backed by the vast improvement in navigation technique and diversity of available modification tools, which helped in transferring the species across the globe and modifying the native biota for economic and political purposes. Amidst the positivist movement, using science for justifying species transfer during the imperial era was thus biblical rooted and was enhanced by capitalist mercantilism and the navigation technology ([Beghin and Potier 1997](#); [Hulme 2009](#)).

The transfer of crop plants out of their native areas was an important step in world history, as it facilitated the expansion of societies and empires ([Peretti 1998](#)). Most of the non-European societies, particularly Oriental and native Americans were constrained to using and breeding the available species in their area ([DiZerega 1996](#); [Kalland and Persoon 1998](#)). However, colonial rule tried to modify the new countries by introducing exotic species, to make the ambience depict their homeland (e.g. introduction of oak, pheasants and rabbits in New Zealand ([Wells 2006](#))) and for economic resources (e.g. introductions of *Prosopis juliflora* in South Africa ([Bennett and Kruger 2013](#))). Perception of native people to such introductions was varied. People fascinated with the imperial lifestyle tried to accept the changes. Those who revolted against the rule led to the movement of conserving the native values and biota.

Hence, 'exotic' was used both as a metaphor for appreciating a unique difference, as well as for criticizing an alien entity.

Nativism

Few of the introduced species escaped in the wild, spreading at an alarming and outcompeting the native cultivable and natural species. As a response to this damage, farmers and forest managers started removing such species. For example, Noxious Weeds Act (1900) was established in New Zealand to eradicate harmful introduced species (Chapin et al 2010); and *Lantana camara* (introduced species) management was initiated (1912) in parts of India (Bhagwat et al 2012). An extreme version of this idea was to remove any entity that didn't belong to the political extent of a particular society; an idea that led to biotic nativism. 'Native', before the 19th century, meant anything that was not a direct output of human artifice (Chew and Hamilton 2011). It was later related to the purism of landscape, and such purism was perceived to be free from any foreign invasions. As species were segregated based on the political boundaries and the human race in it, biological nativism was the historical outcome of apartheid cultures. For example, in pre-World War II Germany, strict biological nativism was supported by Nazism. Ideologically and ecologically, the Nazis attempted to purify their nation and nature, by eliminating people and biota that were supposedly non-native (Peretti 1998). For example, Reinhold Tuxen, head of the Reich Central Office for Vegetation Mapping, announced a fight against the 'Mongolian invader' *Impatiens parviflora*. Such decisions converted the wilderness into 'natural gardens', as all the ecological selections were controlled and manipulated by human interventions (Pollan 1994).

Scholars suggest that the emergence of biological nativism could also be a product of newly emerged, democratic, less-developed countries, who suffered due to (political) invasions during the World War II (Peretti 1998; Nunez and Pauchard 2010). The approach adopted by such countries usually relies on eradicating non-native species based on political boundaries. Not surprisingly, the Leopold Report (1963), a scientific document to manage national parks in the United States of America, stated that management should aim to protect and recreate native nature that was present before invasion and degradation by the first white man and biota brought by them (Hecht and Cockburn 2010). Such perspectives were based on a myth of an idealized primitive society living in harmony with the environment (Katz 2014).

Although environmental purism is not inherently racist, there are compelling arguments that nativist purism is undesirable in all spheres-political, cultural and ecological (Peretti 1998). Species ranges and extents are driven by how far they can disperse and how far back in time they did so; political boundaries are proximate, ever-changing and artificial and do not match up with the time scales at which species ranges expand. Hence, political boundaries should not be considered for assigning species with their identities. All the same, contemporary attempts to preserve differing cultures and small-town community life by limiting foreign influence

need not be racist or xenophobic, but rather, an attempt to preserve the spectacular diversity on earth (Hettinger 2001). However, if human modification of ecosystems is left unchecked for natural selection to happen, it will lead to the completely human-controlled ecosystems (Katz 2014).

Biological Invasion

The experience of few species being harmful to the ecosystem, their geographic identities, need to control their impacts and emerging quantitative ecology of the 20th century led to the rationalization of the concept of biological invasions. The species out of their geographies were recorded by naturalists of the 18th and 19th century including Pehr Kalm, Alexander Humboldt and many others (Davis 2009; Chew 2011). Charles Darwin considered this phenomenon when he observed that non-native species could threaten native species on islands (Darwin 1859; Richardson and Pyšek 2008). As described by the previous study (Davis 2009), the influence of geographies on species was also motivated by Wallace's six distinct bioregions of earth that inspired the contemporary biogeographers to explore the biology of species outside their bioregion. To geographers and voyagers of the 19th century, this was all about human introductions that affected the species of distinct geographies. One of the first few published records of invasive species, was for species (native or non-native) that burgeoned, resulting in the rarity of other species (Brandis 1891). Subsequently, ecological knowledge accumulated as a product of geological and naturalists' expeditions. Early ecologists observed the ecological difference brought by the species that got out of its native area (Spalding 1909; Thomson 1922; Egler 1942). The impacts that these species can have on the introduced area started getting the attention, particularly with non-native plants (Campbell 1926).

It was not until the 1950s that the subject gained ground in the scientific community. Marston Bates 1956, in his chapter, 'Man as an agent in the spread of organisms', reported that the species which spread with human movement can become 'Neobiota' in different regions. Another contribution was by Charles Elton (popularly known as the father of invasion biology) in 'The Ecology of Invasions by Animals and Plants' (1958). Elton flagged the concern on biological invasions using radio broadcast and used general language to convey the seriousness of the topic. Unlike many other scientific publications by Elton, the starting paragraph of his book 'The Ecology of Invasions by Animals and Plants' dramatically claimed "*It is not just nuclear bombs and war that threatens us. There are other sorts of explosions, and this book is about ecological explosions*" (Elton 1958). Based on the ecological observations for more than a decade, Elton warned that the loss of biodiversity due to invasive species would be so severe that "*Instead of six continental realms of life, there will only be one world...*" (Elton 1958). Scholars criticized Elton's idea as a product of his martial mindset and language

developed by the World War society (Chew 2006). However, Elton's work since the 1930s indicates that his monograph was the output of long-term ecological observations that lead to the concept of biological invasion in 1958 (Kitching 2011). Although Elton's idea was not influenced by the post-war martial mindset, the society that was habituated with everyday war news could have perceived these martial metaphors literally. And hence, out of two contemporary metaphors of 'neobiota' and 'biological invasion,' it was only the latter that eventually became the highest cited term (Richardson and Pyšek 2008; MacIsaac et al 2011).

Modern Invasion Ecology

Modern invasion ecology that constituted itself somewhere in the 1980s, owes its presence to the advancement in quantitative ecology (Davis 2006). The global awareness for biological invasions was reflected in the SCOPE program (Macdonald and Jarman 1984) that resulted in an exponential increase in quantitative data about the spread and effects of biological invasions (Richardson and Pyšek 2008). Association of the impacts with ecosystem services and biological extinctions enabled the subject to gain strength for raising funds and carrying long-term research. The post-1980 rise in scientific publication and citations on biological invasions symbolizes a modern rationalization of the subject (Pyšek 1995). As evident from the adjective 'modern', the new version of invasion ecology was based on induction (ecological surveys, lab experiments, etc.) and deduction through statistical hypothesis testing. But the ultimate objective of biodiversity management was to maintain the 'balance of nature' by managing invasions. Definition of the geographies and 'negativity' associated with the identified species is only partially addressed by such modern approaches. Thus, the workable modern definition for an invasive species was widespread non-native species whose introduction is mainly attributed to humans and which negatively impact the ecological integrity (Colautti and MacIsaac 2004). The meaning of 'non-native', 'human-induced' and 'negative impact' are left to interpretation by the scholars and the stage of invasion in the ecosystem.

In the modern definition of biological invasion, anthropogenic activity (Hulme 2009) is popularly considered responsible for introducing a species out of its evolutionary range, where it might turn invasive due to a release from controlling agents (competitors, predators and disease). Such assumptions suffer from ecological limitations as one cannot be definitive about the evolutionary history, or about the conservatism of this evolutionary niche of a species. Species' distributions are dynamic; each species originated somewhere, had subsequent changes in its life histories that has resulted in its current distribution and will determine further speciation within the geographic barriers (Walther et al 2002). With increased human transport available, humans are spreading many species out of the geographic barrier, will all these species become invasive? There have been evidences suggesting that distinct geographic origin of a species cannot be the only reason for its invasiveness elsewhere (Davis et al 2011; Hassan and Ricciardi 2014). Hence, the duration for which a species be present in a particular

location to be classified as native is more of a philosophical issue (Westman 1990) and then an ecological one. The second criterion of 'negative' impacts was developed keeping in mind that not all human-induced non-native species turnout to be harmful. According to this criterion, invasive species are not integrated into the ecological community but are the ones that degrade it. Paradoxically, recent studies show that natural communities are dynamic and hence, constantly prone to change (Lavergne et al 2010). Moreover, scholars have been challenged with providing a principled distinction between harming a natural system and changing it (Gunn and Throop 2002). When the harm is to a non-human system, the justification for negative impact is complex, and scholars have recently proposed to incorporate human-values in the framework of defining negativity of impacts (Jeschke et al 2014). Biological invasion is a special case where all the criteria are the same, except that it enforces immediate changes on the ecosystem, which in an ideal evolutionary time would give equal opportunity to the native species to respond. These imminent changes are manifested into the localized extinction of native species, loss in functional diversity and gradual homogenization of the global biota (McGeoch et al 2010).

Further, as climate change unfolds, species will change their current distributions to survive (Peterson et al 2002; Mungi et al 2018). Will such species then be considered as invasive? It is inevitable that differential changes in any community will lead to the introduction of hitherto unknown species and can even result in them becoming abundant. If we want the natural processes to occur without human intervention, then the ecosystems will be invaded. And if we intervene, the processes will be no longer 'human-free'; this alarms the onset of Anthropocene (Crutzen 2006; Steffen et al 2007). The recent culture in conservation science that denotes a native ecosystem as a stable equilibrium and invasive species as something that disrupts that equilibrium is thus, no longer tenable. With the fall of the Clementsian concept of climax in modern ecology, thoughts began to appear that challenged balance-of-nature paradigms regarding ecosystems. Scholars highlighted that 'species move freely on all geographical scales' (Hengeveld 1989). Such thoughts that challenged the ecological constructions of species, communities, and nativity, were very outcome of postmodern science (White 1998; Warren 2007).

Contemporary Invasion Ecology

Invasion ecology, as a subject, has evolved from the normative binary of 'good' and 'bad' species to a modern thought of the abrupt state of ecological equilibrium. The upsurging era of postmodernity (Lyotard 1984) is questioning the 'balance of nature' and perceiving it as multiple states based on chaotic processes (White 1998). Postmodernity, as a state of society, might be yet debated but, increased references of chaotic processes in ecology (Evans et al 2013) and the new paradigms of multiple stable states (Fukami and Nakajima 2011) allude to a common reference of postmodern thoughts. Ecosystems states can be defined in multiple ways

and that complicates the utility of this concept. What state – structural or functional – must one prioritize is still a deeply subjective choice. An ecosystem is now perceived as a dynamic response to the changes in the environment, and a complex interaction explanation of which is beyond the scope of present study but can be found elsewhere (Scheffer and Carpenter 2003; Hobbs and Norton 2004). This criterion does not weigh the geographic origin of a species or negativity of its impacts as important. The first important factor is the potential regime shift in a non-ecological time and second, the anthropogenic base of such shifts. The alternate stable state is a product of human manipulation of the ecosystem, in an era of biodiversity crises due to anthropogenic influence, and thus it induces concern. Secondly, biological invasions claim to accelerate biological extinctions and economic loss (e.g. loss of US\$ 314 billion per year for six nations (Pimentel et al 2011)), and hence could be perceived as a risk (Burgman 2005). Hence, accounting human as a causal agent within a system, and not an external entity, serves the purpose of conservation. However, the potential alternate stable state poses an interesting conundrum for managerial action as removing an invader from the new regime of the ecosystem can disturb the newly established ecological networks and processes. This loss of interaction could further move the system into other chaotic states (Hughes et al 2013). Reverting back the ecosystem to its pre-invasion state, which in itself is subjective, needs control on all micro-parameters of the ecosystem. Moreover, waiting for an ecosystem to cross the existing regime and then reverting it back consumes resources with uncertain ecological gain. The way science can help is by providing early warning signals of ecological regime shift by biological invasions, so that strategies to resist it or adapt to it, could be timely availed. This needs continuous monitoring at an optimal scale and observing any indicators of such abrupt shifts, which is yet a challenging science.

The contemporary conservation strategies propose restoration of lost ecological regimes rather than the only removal of invasive species. Owing to small sizes of protected areas and human influence on its ecology, the probability of ecosystem reverting back to its original regimes on its own is minuscule. Although humans would regulate transformation to such a system, thereby making it anthropogenic selection; it would minimize the relative damage caused to the biodiversity. The current postmodernist views, alluding to their placement of human as a part of nature will support interventions in such cases (Robertson and Hull 2001) but should be freed from the xenophobic base. There is an urgent need to modify certain thoughts to compliment scientific decision in dealing with such conservation strategies. Many conservation biologists emphasize the importance and pervasiveness of species migration while maintaining a nativist ideology (Peretti 1998). This clash, many a time, has resulted in deactivating the management of some harmful invasions, while sometimes having resulted in the removal of native species (Sagoff 2000) and has also ended up terming threatened species as exotic and alien (e.g. Thapar 2013). Secondly, conservationists often target species that have visibly altered the landscape to an extent that adaptation to the change is costlier than removing the species. Such dissonance could be overcome by multi-disciplinary studies that have already been demanded (Larson et al 2011).

It is a time where, scholars from ecology, sociology and quantitative science come together to address the conceptualization and actions regarding biological invasions. Multi-disciplinary initiatives are showing success in using value-judgements without influencing the scientific premise. For example, considering opinions of the animal rights group resulted in successful control of feral pigs in Texas USA ([Perry and Perry 2008](#)), public participation for controlling invasive plants spread in Australia ([Williams and West 2000](#)). Invasion, in its entire context, is part of ecological science and not a different science in itself as indicated by few. Additionally, acknowledging socio-political and cultural values while addressing this conservation-oriented issue is crucial. Science in its positivist form is inept to solve such problems alone as “meanings cannot be measured, only understood” ([Bhaskar 2005](#)). Meaning could be multi-narratives and should not be feared; as our study demonstrates, including the contradictions in existing views, environmental conservation has always been a heterogeneous mixture of ecology, politics, sociology and culture.

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