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Species Home-Making in Ecosystems: Toward Place-Based Ecological Metrics of Belonging

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Globalization has undeniably impacted the Earth's ecosystems, but it has also influenced how we think about natural systems. Three fourths of the world's forests are now altered by human activity, which challenges our concepts of native ecosystems. The dichotomies of pristine vs. disturbed as well as our view of native and non-native species, have blurred; allowing us to acknowledge new paradigms about how humans and nature interact. We now understand that the use of militaristic language to define the perceived role of a plant species is holding us back from the fact that novel systems (new combinations of all species) can often provide valuable ecosystem services (i.e., water, carbon, nutrients, cultural, and recreation) for creatures (including humans). In reality, ecosystems exist in a gradient from native to intensely managed – and "non-nativeness" is not always a sign of a species having negative effects. In fact, there are many contemporary examples of non-native species providing critical habitat for endangered species or preventing erosion in human-disturbed watersheds. For example, of the 8,000–10,000 non-native species introduced to Hawai'i, less than 10% of these are self-sustaining and 90 of those pose a danger to native biota and are considered invasive. In this paper, we explore the native/non-native binary, the impacts of globalization and the political language of invasion through the lens of conservation biology and sociology with a tropical island perspective. This lens gives us the opportunity to offer a place-based approach toward the use of empirical observation of novel species interactions that may help in evaluating management strategies that support biodiversity and ecosystem services. Finally, we offer a first attempt at conceptualizing a site-specific approach to develop "metrics of belonging" within an ecosystem.

Keywords: non-native, native/alien binary, globalization, invasion, Hawai'i

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INTRODUCTION

Decades of restricting humans from natural areas has sometimes led to failed attempts, socially and economically, to protect and restore our planet's biodiversity. The conservation and protection of nature without humans was our collective response to honoring the forces of nature – and within that effort was a paradigm that native species are inherently good, and non-native species must be removed to protect the integrity of a system. If at all possible and feasible, promotion, and

preservation of naturally evolved ecosystems is the gold standard that we should strive to achieve. However, in many parts of the world we cannot uncouple the fact that humans and natural systems are linked– and that pristine landscapes are often in fact a mirage. Certainly this "coupling" is often unsustainable and we as humans need to revise our assumptions and expectations of what and how we can extract from nature so that nature has sufficient space and time to face disturbance. But if we acknowledge that not all non-native species are harmful or especially impactful in ecosystems – can we also reevaluate our attitudes toward native and non-native species and place more importance and emphasis on harmful invasions rather than the mere distinction between native and non-native? In other words, the native/non-native binary assumes that native is "good" and non-native is "bad" and has the effect of uncritically assigning the moral status of species based on a one dimensional logic of origins. This binary treatment can be seen as justifying the deployment of full-scale eradication programs of all non-native species.

The authors of this essay are based in Hawai'i and hail from disciplines in philosophy, conservation biology, and natural resource management. In this island environment, there is a sharp focus on the native/non-native binary because >55% of the Hawaiian flora is non-native (Brock and Daehler, 2020). Unlike some continental landscapes where the focus is on one or a few particularly harmful non-native species, in Hawai'i every ecosystem has multiple invaders that often interact with each other (D'Antonio et al., 2017). Perhaps because we live in a socioecological island system that is at one end of a continuum, our viewpoints may differ from those in continental landscapes. Here, we provide examples from a tropical island ecosystem where rates of change occur much faster than continental systems and offer new perspectives that might unsettle long-standing assumptions toward native and non-native species.

In this paper, we also discuss the history of militaristic language use in invasive species biology and how that language influenced our attitudes toward conservation. We consider the dichotomies that have biased our understanding of nature and the influence of globalization on the functioning of ecosystems. We propose that the incorporation of place-based empirical observation of novel species interactions is one consideration that can help in evaluating management strategies that support biodiversity and ecosystem services. The place-based framework asks if conservation-based decisions should move away from a universal norm that judges species based on origins or immigration status and suggests that non-native species be evaluated on the degree of damage they impose on ecosystems or how well they "play" with others.

THE POLITICAL LANGUAGE OF INVASION

"Names are the way we humans build relationships, not only with each other but with the living world" – Kimmerer (2013).

In today's world of diversity, equity, and inclusion, some of the language of ecology and conservation, particularly around the processes of biological invasion, can feel dated. Terms in the invasion biology literature commonly describe organisms as alien, exotic, invasive, and enemies; management strategies are described using verbs such as control, combat, and attack. These terms elicit images of a world with distinct boundaries where species and systems are siloed, restricted, evaluated, and/or rejected (**Figure 1**).

Modern scientific objectivity is threatened by the valuations of a social context, yet science is deeply saturated in the social logics of language in order to render intelligible its empirical truths. Hence, it is no surprise that the clarity of how to articulate unwanted and alien nature that motivated early writings in invasion biology is deeply influenced by the logics of the social world. This move to understand how language operates in representing nature reveals that language rarely captures nature accurately. How we classify nature often represents more of our human values of nature rather than nature itself. Yet, nature betrays our secure values and "surprises" us, providing motivation to reassess our understandings. The language of conservation shifts as our understanding of nature shifts. One important term to reckon with is native nature. For many Indigenous peoples, terms such as native in modern scientific discourse disclose a familiarity, a connection to nature (Salmón, 2000). More specifically, the Anishinaabe people view nature through a person-centered ontology hence understanding non-native species as subjects that have migrated to new lands. Rather than a western perspective that treats non-native species as inherently invasive, this indigenous ecological perspective views non-native species as potential members of an ecological community once proper observation and understanding of the contributions non-native species brings to the ecological community (Reo and Ogden, 2018). However, in modern scientific discourse the term native is specific. It refers to origins of species, a biological natalism. Charles Warren (2021) points out that implicit in the discourse surrounding biological nativism is the assumption of a form of nativist purism that emerges in social and cultural contexts, which inevitably imports

FIGURE 1 | A mural by street-artist Banksy, that was located in Clacton-on-Sea in the Essex district in eastern England, that was removed by the local council due to complaints of being offensive (https://www.bbc.com/news/uk-england-essex-29446232). We highlight here to demonstrate that the concepts of belonging cross-cut species' boundaries.

sentiments of racism and ecological fascism. Hence, how we think about a species origin will influence how we value immigrant species. One potential problem with this logic is that there can be a huge difference in a species that is non-native/non-invasive compared with one that is unwanted/invasive based on the degree of negative impacts the species have on a given ecosystem. Another potential problem is that native is placed in static terms (tied fixedly to origins) rather than within a dynamic and migratory understanding of an ecosystem with changing stressors and environmental conditions, that is bound to encounter migrant species.

THINKING BEYOND THE NATIVE/NON-NATIVE BINARY TOWARD A CONTINUUM

> *"Being naturalized to place means to live as if this is the land that feeds you, as if these are the streams from which you drink, that build your body and fill your spirit"* – Kimmerer (2013).

How we talk about nature informs how we think about nature; thus, part of the problem of conceptualizing non-native species is the paucity of language that is non-militaristic at our disposal to think about unwanted nature. Charles Elton, in his career-defining work, The Ecology of Invasions by Animals and Plants Elton (1958), utilized militaristic language to describe the threat of invasive species, characterizing the rapid migration as "ecological explosions." Wilson (1997) along with other leading American conservationists argued for a "national program to combat invasions." The use of militaristic language in ecology and conservation biology literature was recently quantified, and word counts of militaristic language were greater in articles on invasive species than other topics and were also greater in basic science journals than in applied science journals (Janovsky and Larson, 2019). Although these word choices may have been said unwittingly (i.e., alerting toward newly found problems), to some they overly express a nativist language of militarism, inciting greater protections of nation-state borders through the preservation of ecosystems to resist biological invaders (see **Figure 1**). It appears that the native/non-native binary has the unfortunate consequence of eliding the descriptive term of "non-native" with the more prescriptive or normative terms such as "alien," which elicits xenophobic value judgments (Warren, 2021). Furthermore, the ethic of killing implied in the use of militaristic language contradicts the ethic of care in conservation management (Warren, 2021). Several authors have suggested recommendations to remedy word choices to better reflect the harm a species does or its ability to spread (Byrne and Hart, 2009; Janovsky and Larson, 2019).

Scholars have challenged the ethical implications of the native/non-native binary charging that the binary is impractical to apply to conservation management policies (Warren, 2007). Further, the native/non-native binary can be viewed as ethically supporting colonial logics of exclusion and dispossession – ideas that had been used to undermine undocumented migrants and Indigenous peoples (Sinclair and Pringle, 2017). Moreover, the native/non-native binary does not fit well within the context of many contemporary restoration examples in which non-native species often provide critical habitat for endangered species or prevent erosion in human-disturbed watersheds (Ewel and Putz, 2004; Schlaepfer et al., 2011). Given the ethical and practical problems of the native/non-native binary in conservation ecology, it has been suggested that the binary has functioned as an unrealistic myth and ought to be reconsidered in terms of guiding conservation management policies (Warren, 2021).

Most of the public is not necessarily concerned with ecological authenticity (Warren, 2007), but rather have developed new relationships within a continuum of species. These relationships with plants and animals (native or non-native) typically revolve around a species utility (food or function), a cultural link, or beauty and awe (Selge et al., 2011; Kueffer and Kull, 2017; Vilà and Hulme, 2017). The length of time that non-native species are in an ecosystem also influences social and ecological impacts. For example, non-native bird or frog calls may become beloved, or plants or animals that become symbols representing a place to which they are not considered native (such as the coconut tree is to Hawai'i). Plants brought by early Hawaiians on voyaging canoes, known as canoe plants, are non-native plants, but have multi-faceted cultural significance in Hawai'i, are widely valued for their practical utility, have names in the Indigenous language, and representations of these plants convey a sense of place and are often the subject of contemporary art and fashion. Hawai'i has become linked to these plants through its human history. This linkage is not necessarily good or bad–it should be evaluated in a place-based manner.

We argue that non-judgmental observations of novel species interactions should elucidate when a system is supportive of biodiversity or ecosystem services. Non-native species could be evaluated on the degree of damage they impose or how well they "play" with others rather than where they are from or how they got there. In a global analysis of 1,551 individual cases that addressed the impact of a non-native plant species, it was concluded that impact is strongly dependent on context, and that there was no singular measure (Pyšek et al., 2012). The fact that non-native species' effects are place-based, dependent on species' characteristics, species interactions, environmental conditions, and the resident community, suggests that decisions about non-native species by the conservation community ought to move away from ahistorical and delocalized methodologies and shift toward evaluative standards that could be inclusive of placed-based values and needs.

THE IMPACTS OF GLOBALIZATION ON NATIVE SYSTEMS

The ecological impacts of globalization on natural systems are far reaching and well documented (Vitousek et al., 1996; Young et al., 2006; Meyerson and Mooney, 2007; Hulme, 2009; Morse et al., 2014; Ricciardi et al., 2017; Závorka et al., 2018; Tromboni et al., 2021). The movement of species both intentionally and accidentally has spawned decades of research on the ecological and economic impacts of non-native species (Pimentel et al., 2001; Pyšek et al., 2012; Vilà and Hulme, 2017). Furthermore, the interaction of species movement with

anthropogenic disturbances and stressors such as climate change and land conversion have exponentially elevated this issue to the point that no ecosystem is exempt from vulnerability to invasion (Didham et al., 2005; Brook et al., 2008; Crowl et al., 2008; Lugo, 2020). It is now clear that many ecosystems are largely governed by novel systems and interactions (Van Kleunen et al., 2015), and that ecological integrity is a continuum from high functioning ecosystems to low functioning systems, relative to disturbance and invasion. In this continuum, high functioning novel ecosystems can exist, but the vast majority of our Earth's ecosystems (ranging from native to novel) lie somewhere in the middle of the continuum (Vitousek et al., 1997; Sanderson et al., 2002; Watson et al., 2016). In lieu of this reality, there is a renewed interest in better understanding novel ecosystems and their potential positive or negative contributions to ecosystem integrity, ecosystem services, and resilience (Ricciardi et al., 2013; Kuebbing and Nuñez, 2015; Sapsford et al., 2020).

Examples from Hawai'i demonstrate how native species can benefit from non-native species interactions. An endangered sphinx moth (*Manduca blackburni*), dependent on an endangered tree in the Solanaceae family as a host for the caterpillar stage, now relies on a non-native Solanaceae tree species (*Nicotiana glauca*) for this service (Mitchell et al., 2005). Similarly, populations of the endangered hawk known as the 'io (*Buteo solitarius*) have shifted their foraging strategies to include non-native food sources (rodents, non-native birds, etc.) (Griffin et al., 1998). Further, in some habitats, pollination and dispersal of many native species are now largely from non-native animals (Foster and Robinson, 2007; Aslan et al., 2014). Arguably, it is unclear if these analog species serve the role equally as well as their native counterparts, but a partial service is clearly better than none (Rodriguez, 2006; Schlaepfer et al., 2011). It is also unclear how cascading impacts (i.e., the consequences of non-native species on non-target and tangentially related species) will influence ecosystem functioning. Rodriguez (2006) argues that facilitative interactions between invasive and native species or non-native and native species can have both positive and negative cascading effects across trophic levels, leading to restructured communities and ultimately evolutionary changes. Inserting non-native species deliberatively and or haphazardly into a system can be considered dangerous – and a sign of giving up. For clarity, we are not discounting the most precious benefits we receive from a healthy native ecosystem. Preservation and conservation of the Earth's biodiversity and associated ecosystems must be of the utmost priority. Preservation of these natural areas is as important now than ever. In fact, there are many successful examples of passive restoration where removal of threats to that system leads to a functioning native system. But, striving to return a highly disturbed environment to an all-native historic ecosystem in many areas is often an unproductive and unsustainable use of time and resources (see Cordell et al., 2016 for a case study).

It is also becoming increasingly clear that removal of many novel interactions will not benefit ecosystem integrity and could lead to ecosystem harm or extinction (Zavaleta et al., 2001; Prior et al., 2018). Examples of this include reduced populations of rare endemic snails in the Azores following the removal of non-native vegetation (Van Riel et al., 2000). Corbin and D'Antonio (2012) elucidate belowground legacy effects of non-native species where nutrient dynamics and mycorrhizal associations have been altered over time and do not readily recover following removal of these species. Restoration outcomes often result in successful regeneration of new assemblages of non-native plant species. These examples illustrate that novelty in ecological systems is a current reality, particularly in urban environments (Aronson et al., 2015). Finally, we fully understand that many non-native species have the potential to become invasive due to changing dynamics and lag times. Weed risk assessments and barrier zones are effective but not foolproof tools to reduce the likelihood of future invasion (Coutts et al., 2018).

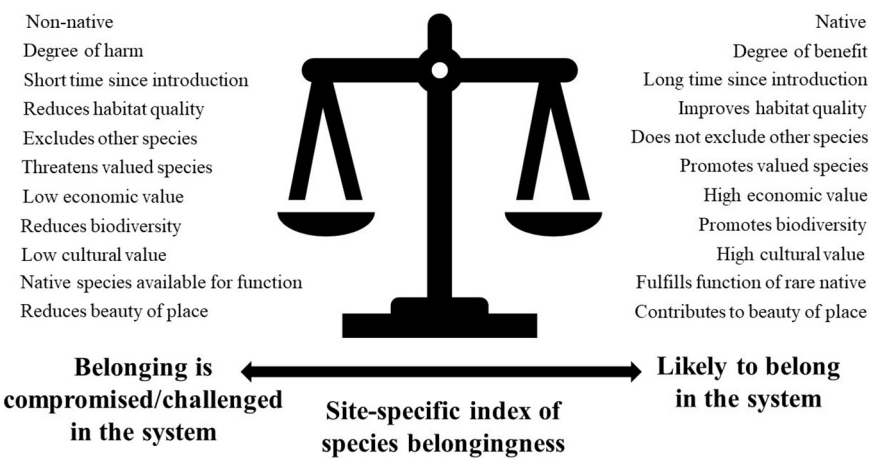

FIGURE 2 | A new conceptual model for determining the viability of a non-native species in a given area. The criteria presented here are not absolutes but can be modified depending on circumstances. The end result would be a score analogous to a weed risk assessment.

A REVISED CONCEPTUAL FRAMEWORK

From our reference point, we propose a first attempt at a revised conceptual framework to evaluate all species, rooted in weed risk assessments, but expanded for local conditions and values. Weed risk assessments were developed as a tool to evaluate the likelihood of non-native species becoming problematic (Pheloung et al., 1999). They employ quantitative scoring on biological characteristics of a species that are summed, with thresholds set to gauge the overall risk of a species becoming invasive (Williams and Newfield, 2002). The predictive value of these tools has been tested (Daehler et al., 2004; Gordon et al., 2008; Gassó et al., 2010) and their limitations have been well articulated (Hulme, 2012).

Our proposition is that the concept of weed risk assessments could be reimagined as metrics of belonging (**Figure 2**). Rather than simply scoring on biological characteristics (e.g., dispersal mode), sociocultural components could be added such as economic and cultural values. Importantly, the qualities scored (i.e., questions asked in the assessment) should be site-specific, so that these species assessments are locally based. A non-native species may be deemed harmful to the environment in one part of its range yet fulfill core cultural roles in another area. Like a weed-risk assessment, the characteristics of a species would be summed, but sociocultural characteristics could be weighted differently, depending on local values.

Figure 2 suggests some of the qualities by which a species could be judged, but these are suggestions, not absolutes. The metrics of belonging concept is still a work in progress that with further development could become a decision support tool. Consensus would need to be developed on the framework, with the understanding that the evaluative component is flexible, pragmatic, and value laden. Thus, by its very nature, the metric of belonging is place-based, context-dependent, and subjective. Decisions could be made with input from community members working in the landscape, in a way that is participatory. However, there are risks to accepting a species as belonging into an ecosystem, and thus any management decision needs to acknowledge actions to potentially mitigate those risks. A recent example that could test out this framework is the controversy surrounding the release of a biocontrol of strawberry guava (*Psidium cattleianum*) in Hawai'i (Warner and Kinslow, 2013). The plant does enormous harm to the environment that is undisputable (Patel, 2012), but it provides some modest income to local residents (e.g., jams, back scratchers, and furniture), has been used as hula implements in replacement of using native trees, such as 'ōhi'a and has a name in the Hawaiian language. While this highly invasive species would not be chosen as belonging in the Hawaiian wet forests, a metric could explicitly acknowledge that this plant provides gifts to cottage industries, consumers, and cultural practitioners, thereby making room for evaluations of species based on reciprocity in ecosystems. Perhaps spelling it out in this way would allow for clear messaging that harms outweigh benefits, and in this way might reduce community strife.

In reality, humans rely on ecosystems now more than ever. We conclude that forced distinctions of language and binaries impede our ability to move forward and focus on the promotion of resilient forest landscapes. Rather than argue about semantics and whether species are good or bad, we need to focus on understanding socioecological factors that influence both degradation and successional trajectories of future ecosystems and how and when interventions can help. We promote the idea that nature and strategies to restore natural systems lies in a continuum that requires place-based empirical observations of how novel species interact with native species. However, this framework does not discount the need to protect native biodiversity, nor abandon effective management actions to support and promote native systems.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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