

Embracing change: Invasive species and novel ecosystems

Combining ecological and socio-cultural analysis, we propose embracing the future-oriented concept of novel ecosystems. This perspective offers an alternative to the backwards-looking conservation attitude that uses metaphors of biological invasion, for example. With the case study of species whose range is shifting to include cities, we show that in a world of environmental novelty, effective conservation thinking must supplement narratives of invasive species with those about climate refugee species and novel ecosystems.

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Changing world – novel ecosystems

The planet is undergoing rapid anthropogenic change, including climate shifts, land-use alterations, and urbanization. These processes reshape bio-geographical barriers and profoundly impact ecosystems. As irreversible ecosystem changes become more prevalent and resources for conservation remain limited, the concept of novel ecosystems has emerged as a response to the need for conservation strategies beyond traditional approaches (Hobbs et al. 2013, p. 18; see also Montana et al. 2024, in this issue). Novel ecosystems arise when unique combinations of species emerge under significantly altered environmental conditions. Rather than viewing these ecosystems as “trash” or “degraded”, the concept of novel ecosystems provides a framework for stakeholders to design conservation goals that embrace ecological changes while incorporating socio-cultural aspects as integral components (Santana 2022).

Invasive species¹ play a pervasive role in ecosystem transformation, functioning as both drivers and passengers of these changes (Mooney and Hobbs 2000, p. 425). They also hold significant potential within novel ecosystems, acting as both nuisanc-

es and agents of ecosystem building. This generates dual attitudes towards invasive species. On one hand, many conservationists, concerned about the threats posed by biological invasions to biodiversity, often describe invasive species using urgent and antagonistic language. On the other hand, some researchers question the concept of invasive species itself, challenging its historical militaristic associations, the arbitrariness of its definitions, and the complex value systems it conveys under the veneer of science (Tassin and Kull 2015).

In this article, we argue that embracing the idea of novel ecosystems provides a valuable counter-narrative to traditional narratives of biological invasion. Rethinking the role of invasive species becomes crucial in adapting to inevitable ecological novelty. To illustrate our ideas, we examine how novel ecosystems in urban settings can offer refuge to invasive species experiencing declines in their native habitats. This interdisciplinary effort underscores the complex role of invasive species in novel ecosystems, and suggests the potential for reconciling the contested field of invasion biology.

Roles of invasive species in novel ecosystems

Restoration ecologists have defined novel ecosystems as systems of “abiotic, biotic and social components (and their interactions) that, by virtue of human influence, differ from those that prevailed historically, having a tendency to self-organize and manifest novel qualities without intensive human management” (Hobbs et al. 2013, p. 58). This category departs from conventional ecological categories by questioning “easy binaries that permeate conservation discourse” and by “recognizing the cen-

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¹ “Invasive species” lacks a universal definition and is sometimes used interchangeably with terms like “exotic” or “non-native species”; for clarity we only use “invasive species” here to refer to non-native species that can cause (perceived or real) economic and ecological harm in their new environment.

trality of human agency” (Yung et al. 2013, p. 248). Conceptually, novel ecosystems open new patterns of understanding the place of invasive species in our changing world. The approach allows us to reexamine species that are labeled invasive in the light of updated conservation objectives without dismissing threats posed by biological invasions.

In practice, invasive species play a crucial role in novel ecosystems after disturbances like habitat loss and climate change, modifying conditions and creating new habitats (Simberloff 2015, Potgieter et al. 2017). Species identified as invasive are especially likely to do so, because the same traits that make them effective invaders allow them to quickly (re)colonize disturbed ecosystems (Kalusová et al. 2017). For instance, invasive plants can form dense canopies, provide shade, alter soil moisture and nutrient cycles, and reduce soil erosion, thus offering valuable services to a variety of native and non-native species (Vilà et al. 2011, Belnap et al. 2012).

Invasive species can also have negative impacts on novel ecosystems, such as outcompeting native species or altering ecosystem processes like nutrient cycles and fire regimes (Gaertner et al. 2017, Teixeira et al. 2020). This has led to calls for invasive species management within the context of novel ecosystems (Gaertner et al. 2016). However, it is crucial to avoid inferring that a species poses an ecological threat to an ecosystem based solely on its origin or invasive status (Davis et al. 2011).

Given the extent of rapid environmental changes, novel ecosystems can be important sites for conservation, both as habitats for non-human organisms and as sources of ecosystem services (Santana 2022). We can take advantage of the conservation potential of novel ecosystems by focusing on species’ capacity to foster or disrupt beneficial processes and de-emphasizing geographical origins. Considering all invasive species as fundamentally harmful restricts our ability to nurture beneficial ecological processes in novel ecosystems. Adopting a nuanced approach allows us to shape a better future wisely. This conceptual shift that novel ecosystems offer goes hand in hand with what some critics of the negative framing of invasive species have called for – namely, re-evaluating invasive species in terms of productive conservation values, in the context of unavoidable human influences, and with a forward vision in face of irreversible global changes. The following section maps some of the main arguments in the debate around invasive species across disciplines, and how the concept of novel ecosystems can reassess the notion as an expression of ecological novelty.

Invasive species on contested terrain

Invasive species have become a global phenomenon with significant ecological impacts (Pyšek et al. 2020). The ensuing debates have created a contested terrain, questioning the conceptualization, application, and history of invasive species as an idea and an ecological category, as well as its role and appropriateness in a rapidly changing world.

While not all non-native species are seen as invasive, non-nativeness is a prerequisite of what can be considered an invasive species. However, terms like “non-native”, “alien”, and “exotic” are often conflated or used indiscriminately with “invasive”, despite their different meanings (Richardson et al. 2000). Various understandings of key concepts and risk assessments among stakeholders further cloud this debate (Humair et al. 2014). Some ecologists argue the preoccupation with species’ nativeness is counter-productive to conservation goals on a fast-changing planet (Davis et al. 2011, Lemoine and Svenning 2022). Some problematize the very idea of native origin, given that it is an oversimplification that is inadequate for a globalized world filled with new ecosystems like cities (Thompson 2015).

Similarly, humanities scholars argue that such nativism is best understood as a preference to a certain desired ecosystem rather than a reference to a correct historical ecological state. This imaginary of a desired nature, that sees an existing order of nature as value itself, influences the use of arbitrary thresholds like historical dates to separate natives from aliens in the realm of invasion science, and reinforces its past-oriented approach (Tassin and Kull 2015, Head 2012).

The very binary of native/alien has been examined within the broader framework of the nature/culture dichotomy, which a considerable body of scholarship has interrogated. One common argument is that the native/alien binary indicates an in-depth and eurocentric refusal to accept human intervention (such as introduction of species and ruderal ecosystems in cities) as part of “natural” ecological processes. It also conveys an anthropocentric and short-term view of nature: that it can be and ought to be controlled to achieve a certain vision of species assemblages (Eser 2016, Marris 2013, Head 2012).

Increasing attention has also been drawn to the historical tie of the idea of invasive species to militarism and nationalism. Critics argue that loaded terms like “invasive” perpetuate xenophobia and stir up emotions. For example, scholars have attributed the militaristic rhetoric of invasion science in part to the military background of Charles Elton, widely considered the founder of the discipline (Davis et al. 2001, Groves 2009, Fall 2021). Understood as a situated social practice, invasion science and its rhetoric should be subject to social scrutiny, and scholars have urged caution in the use of emotional and militaristic language in scientific communication about invasive species, as populist sentiments have grounded the history of this discipline.

These critiques do not seek to dismiss invasion science. On the contrary, they highlight how important the study of invasive species is, which is why we need forward-looking frameworks that draw on both natural science and socio-cultural research. The concept of novel ecosystems offers a promising imaginary for invasion science to recalibrate its pursuit of a desired nature. By recognizing that “invasion by transformative species” is one of the causes from which novel ecosystems arise (Hobbs et al. 2013, p. 64), it places invasive species as a functional and structural part of ecosystem transformation, instead of a presumptively malicious intruder. Its emphasis on unavoidable and on-going



changes resists crude binaries like native/alien. By acknowledging both human and non-human agency in ecological transformations, it opens conceptual space to study and manage invasive species from the perspective of future planetary coexistence and serves as a heuristic tool for interdisciplinary exchange. And as some environmental humanities scholars describe it, it unravels ecological stories and a “web of relations” (Orion 2015, p. 57). In this way, “failed” invasive species eradication, for instance, is not seen as a battle lost, but an opportunity to design better conservation goals that are realistic and adaptive to changes. In this context, however, policymakers and land managers require socio-cultural sensibility to communicate and implement corresponding conservation plans. In the following, we illustrate how the concept of novel ecosystems provides more effective conservation thinking when it comes to invasive species, particularly in urban settings.

Dwelling into novelty: Invasive species and novel ecosystems in cities

Consider, for example, the intersection of urban ecology and invasion biology. The backward-looking normativity of concepts like native and invasive make them a poor fit for urban ecosystems in particular. We have known for centuries that the climate of cities differs from both their historical climate and the climate of their surroundings (Howard 1818). Biogeochemical cycles in cities operate as novel “social-ecological-technological systems” (McPhearson et al. 2022), where socio-technological features mediate how water, carbon, and other features of biogeochemistry are transported and transformed. Inevitably, novelty in these abiotic factors shapes novel biotic communities. Cities are populated by new assemblages of organisms and may even constitute new ecological macrosystems (Kowarik 2011). Given such ecological changes, standards based on historical baselines make little sense in dynamic urban ecosystems. In these contexts, the native/non-native distinction might lose relevance.

It is thus impractical to talk about invasive species in the context of novel ecosystems like modern cities. Equally problematic, treating species as “invasive” impairs the very conservation goals invasive species management is meant to address. Environmental thinkers have argued that a key driver of the extinction crisis is the loss of refugia, places where species and communities can regenerate from disturbances and shelter from threats (Haraway 2015). As terrestrial and aquatic ecosystems are converted for human use, non-human organisms lose access to shelters, resources, and processes they have historically used to recover after population declines.

For many organisms, however, cities have become replacement refugia, given their density of resources, abundant shelter, and diversity of microclimates. The story of cities as habitat for non-human organisms is not straightforward (Faeth et al. 2011), but cities can be, and often are, sites of high species richness (Goddard et al. 2010). In fact, for many taxa, species richness pos-

itively correlates with human population density (Barbosa et al. 2013). As many natural refugia have been lost, species – such as those that shift their ranges because of climate change – often find sanctuary in the novel ecosystems of cities. A nativist attitude which sees these refugees as “invasive” would undermine the conservation potential that cities offer.

Consider, for example, the case of the Red-crowned Parrot (*Amazona viridigenalis*) in the Los Angeles suburbs, featured in the documentary *Urban Ark Los Angeles* (Wanigatunga 2017). The species was introduced as a pet, but escaped and released birds ended up forming large wild flocks. Since these parrots are not indigenous to the area, are considered a nuisance, and have spread rapidly, they would fit many definitions of “invasive”. Yet, the negative evaluation associated with species classified as “invasive” would not be appropriate in this case, because the species is endangered in its ancestral territories in Mexico. The thriving population in Los Angeles might be the species’ best chance for survival. Promoting species conservation requires treating the Red-crowned Parrot as a refugee rather than an invader. The Red-crowned Parrot is a clear example of a species whose best conservation hope is outside their historical range. Such cases are becoming more frequent as ecological changes continue to occur rapidly (table 1).

A similar situation is faced by the Yellow-crested Cockatoo (*Cacatua sulphurea*), which experienced severe declines of its native populations due to habitat loss and capture for international pet trade (BirdLife International 2021 b). As with the Red-crowned Parrot, the release or escape of pet birds resulted in the establishment of this species in Hong Kong and Singapore, both significant trade hubs in Asia (Andersson et al. 2021). These locations now support substantial feral populations of a species that would otherwise be threatened with extinction (Gibson and Yong 2017). Another example of potential ecological refugees is the case of the tree species Dawn Redwood (*Metasequoia glyptostroboides*) and Monterey Pine (*Pinus radiata*), which are both considered endangered in their native ranges due to habitat loss, overexploitation, and a disease caused by an introduced fungal parasite (pine pitch canker) (Farjon 2013 b). While the former is popularly cultivated as an ornamental tree in parks and arboreta, the latter is the most widely cultivated pine species in the world, appreciated for its wood, seeds, and needles, and also used as an ornamental plant in urban as well as cultivated regions (Templeton et al. 1997). Thus, both species maintain stable populations in their invaded areas due to anthropogenic activity (Gibson and Yong 2017, Roy et al. 2020, Simpson et al. 2022).

Therefore, we argue that the prevalent practice of labeling species in a new range as non-native or even invasive, which often leads to policies aimed at eradicating them, can be seen as counterproductive (Kendle and Rose 2000). A more effective conservation mindset in these scenarios is to see cities as refugia and range-shifting species as ecological refugees. Cases like these show that conservation goals like preventing anthropogenic extinction might oppose traditional invasive species management in novel ecosystems.

TABLE 1: Some examples of species that are endangered in their native habitats but successful in invaded urban ranges, thus being considered as potential refugee species. IUCN (International Union for Conservation of Nature) status: vulnerable (VU), endangered (EN), critically endangered (CR).

SPECIES	COMMON NAME	GROUP	NATIVE RANGE	IUCN STATUS IN NATIVE AREAS	MAIN THREATS	POTENTIAL REFUGEE AREA	CONDITIONS FAVORING POPULATION IN THE REFUGEE	REFERENCES
<i>Amazona viridigenalis</i>	red-crowned amazon, red-crowned parrot	bird	NE Mexico	EN	habitat loss, trapping for international trade (pet)	USA (Los Angeles, Miami, Jacksonville, Orlando)	habitat availability and abundant food sources	BirdLife International (2021 a), Simpson et al. (2023)
<i>Cacatua sulphurea</i>	yellow-crested cockatoo	bird	Indonesia (Lesser Sunda Islands, Sulawesi), Timor-Leste	CR	habitat loss, trapping for international trade (pet)	Hong Kong, China, Singapore	habitat and food availability and further protection by law	BirdLife International (2021 b), Andersson et al. (2021), Gibson and Yong (2017)
<i>Proteus anguinus</i>	olm, cave salamander, white salamander	amphibian	Bosnia and Herzegovina, Croatia, Slovenia	VU	habitat loss, pollution	Belgium, France, Hungary, Austria, Italy (introduced population according to the IUCN)	potentially, due to habitat availability	IUCN SSC Amphibian Specialist Group (2022), Gibson and Yong (2017), Carnevali et al. (2020), Essl et al. (2020)
<i>Pelodiscus sinensis</i>	Chinese softshell turtle	reptile	China, Japan, Taiwan, Vietnam	VU	overexploitation (fishing and harvesting aquatic resources)	Guam, Okinawa, Singapore, Thailand, USA (California, Hawaii, Massachusetts, Virginia)	potentially, due to the abundance of food resources for this highly carnivorous species	Asian Turtle Trade Working Group (2000), McKeown (1996), Gibson and Yong (2017), Ikeda et al. (2021)
<i>Macaca arctoides</i>	stump-tailed macaque, bear macaque	mammal	NE India, S China, mainland SE Asia	VU	habitat loss, overexploitation (hunting)	Hong Kong (introduced population according to the IUCN), Mexico (Catemaco Lake, Veracruz), Cuba	potentially, due to the absence of competitors and natural enemies	Chetry et al. (2020), Gibson and Yong (2017), Gonzalez-Oliva et al. (2024)
<i>Metasequoia glyptostroboides</i>	dawn redwood	plant	China (Hunan, Hubei, Chongqing)	EN	habitat loss, overexploitation (logging and wood harvesting)	UK, USA (e.g., North Carolina), South Africa	popularly cultivated as an ornamental tree in parks and arboreta	Farjon (2013 a), Jonnes (2016), Gibson and Yong (2017), Robinson et al. (2020), Simpson et al. (2023)
<i>Pinus radiata</i>	monterey pine	plant	Mexico (Baja California, Guadalupe Islands, Monterey), USA (California)	EN	habitat loss, disease caused by the introduced fungal parasite known as pine pitch canker (<i>Fusarium circinatum</i>)	Argentina, Australia, Chile, Kenya, New Zealand, South Africa, Spain, Uruguay, UK, Northern Ireland	extensive cultivation as timber plantation in temperate areas (overcoming and displacing of native forests)	Farjon (2013 b), Arroyo and Hoffmann (1994), Gibson and Yong (2017), Earle (2018), Roy et al. (2020), Randall et al. (2023)

Conclusion

Traditional invasive species management relies on concepts that may be outdated, where dichotomies like native/alien play a central role. This is not to say that we should not worry about invasive species, which could cause serious ecological harm. However, effective, non-alarmist communication is needed among academics, stakeholders, policy makers, and the general public to address the issue in the contexts of global change and resulting novelty. In other words, socially engaged ecological management is needed rather than relying on species' geographic origins as a guide to their value.

In a rapidly changing world, the introduction of the concept of novel ecosystems denotes not only the rise of novelty in ecological systems, but also of novelty in our attitudes towards environmental transformations. Calling for such a change in attitudes is optimistic, and also realistic. It provides a way for conservation and invasive species management to engage in more progressive politics, with alternative ways to imagine the future.

In a way, the concept of novel ecosystems does what conservation has always done – it draws attention to threatened values in nature and calls for their protection. But what kind of nature is desired and worthy of effort is at the centre of the debate. Our examination into invasive species and their place in novel ecosystems shows that “degraded” systems and their “invaders” can be expressed and understood in new conservation terms. It is not to disregard what we lose as the planet changes, but to acknowledge those losses and changes, then find the gains and keep going. We will have to embrace some degree of ecological novelty, invasive species included.

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