Ecological irreplaceability in the era of nature positive

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Abstract

As global biodiversity continues to decline beyond safe limits, the ambition to halt and reverse nature loss has crystallized in the form of absolute net outcome goals, most notably within the Global Biodiversity Framework and the Nature Positive movement. Achieving these goals demands a fundamental shift in conservation planning: from minimizing losses to ensuring gains. We argue that central to this shift is the concept of ecological irreplaceability – the recognition that some species, habitats, and ecological features cannot be restored, recreated, or replaced within ecologically relevant timeframes. Here, we define ecological irreplaceability and outline its increasingly critical role in biodiversity policy, including spatial planning and biodiversity offsetting. We argue that ecological irreplaceability must serve as a first filter in identifying "no-go" zones for development, and present initial guidance for translating this concept to guide conservation decisions. Embedding irreplaceability into planning and policy would safeguard the ecological foundations upon which nature positive outcomes depend, and restore credibility to

conservation mechanisms that have too often permitted the cumulative and irreversible loss of biodiversity.

Introduction

Loss of nature has exceeded safe limits [1]. The risk of mass species extinctions and ecosystem collapse has continued to grow as nature is further depleted [2]. Accordingly, ambition to move beyond conservation goals and targets that merely slow biodiversity declines, and instead seek to halt and even reverse losses, is increasing. Such 'absolute' net outcome goals for biodiversity [3] are evident in the goals of the Global Biodiversity Framework [4], the global Nature Positive movement [5], and even jurisdictional environmental impact policy (e.g., England's new Biodiversity Net Gain requirements [6]; Australia's introduction of a Nature Positive Bill [7]).

As a case in point, the Global Biodiversity Framework, agreed to by 196 nations in 2022 under the Convention on Biological Diversity, sets a goal of absolute increase for many elements of nature against a fixed baseline [4]. Goal A calls for 'substantial' absolute increases in the extent, and improvements in the condition, of natural ecosystems, as well as increases in the abundance of native wild species to healthy and resilient levels, and no further extinctions or declines of genetic diversity. Goal B requires an absolute halting of declines and restoration of ecosystem functions and services. These ambitious, but necessary, goals set a clear challenge in the context of ongoing economic development and sustainability imperatives: we can no longer destroy what we cannot replace.

What is ecological irreplaceability?

The concept of irreplaceability has existed in spatial conservation planning since the early 1990s in a different form – as a means of describing (and quantifying) the importance of a site, place or area to the achievement of a representation target applied across a larger region [8,9]. For example, to ensure representation of a minimum percentage of a particular ecosystem within a protected area network, a site that is included in most computational solutions would be considered highly irreplaceable. While this remains a valuable concept in conservation planning, it is quite distinct from the concept of what ecological features can actually be replaced on-the-ground, if physically destroyed.

Here, we outline a concept of 'ecological irreplaceability' in the context of absolute (not relative) net outcome goals, and consider how might we start to identify – and even map – what is truly irreplaceable in the context of its influence on our ability to meet the GBF goals, and for organisations to legitimately contribute to a nature positive future [10]. We argue that this concept is foundational to conservation decision-making and spatial planning, if we are to achieve maintenance or improvement of biodiversity.

In a perfect world, the absolute improvements in biodiversity to which we have committed would be achieved through a combination of no further losses of biodiversity, coupled with investment in ecological restoration and species recovery to reverse past declines [11]. However, ongoing and, in some cases intensifying, pressures on biodiversity lead to difficult trade-offs [12]. The recognition of this is reflected in Target 1 of the GBF: to ensure that all areas are subject to spatial plans that reduce the loss of areas of high biodiversity importance [4]. In this context, the best we can hope for is to achieve these outcomes in net terms, with unavoidable losses counterbalanced by ecologically equivalent gains elsewhere [13,14].

The acceptance that counterbalancing – or offsetting – of some losses will be necessary does not mean that it is possible to achieve for all biodiversity. Indeed, many ecological features, if lost, simply cannot be replaced. If spatial planning is to achieve absolute gains of biodiversity, then we must first understand and describe the areas and ecological features important for biodiversity, which could, if lost, be recreated – and which cannot. In effect, this operationalises the 'avoidance' component of the mitigation hierarchy [15,16], by explicitly defining which species/habitats/locations *must* be avoided, if the absolute net outcome objective is to be achieved.

Here, we define biota, ecological elements, and the places upon which they depend, as 'ecologically irreplaceable' if they are biologically, physically, and/or technically, very difficult and/or impossible in an ecologically-relevant time frame to restore, recreate, or replace, and therefore are essential for maintenance and/or recovery of focal biodiversity (e.g., a species, habitat, or ecological community). Vegetation associations or habitat elements are ecologically irreplaceable if there is no clear evidence of an ability to restore, re-create, or replace them within a timeframe relevant to the threat to the environmental feature in question. For example, old-growth forest is, by definition, unable to be re-created; regrowing or replanting such forests would require hundreds of years to converge on the composition, function, and structure of primary forest [17,18] (Fig. 1). For threatened species dependent on such forest, such a time delay stretches beyond the time frame within which they face extinction.

Ecological irreplaceability also occurs where a species or ecosystem is dependent on particular abiotic conditions that cannot be replicated elsewhere, or re-created if destroyed (Fig. 1). For example, riffle zones – shallow, fast-flowing sections of rivers – are defined by non-manipulable geological and hydrological factors such as stream gradient, substrate type, and natural flow regimes. Similarly, subterranean geological structures create environments relied upon for roosting and breeding by some species of bats and stygofauna [19]. For many such species, there is no known way to replicate these habitats artificially.

Using ecological irreplaceability in conservation planning and decision making

For a goal of maintaining or improving biodiversity in an absolute sense, the concept of ecological irreplaceability must be central to decision-making and planning for biodiversity protection. By definition, such a goal cannot be achieved if ecologically irreplaceable elements are destroyed. Such elements must be preserved, and any losses of biodiversity that are ecologically replaceable fully counterbalanced, if nature positive-aligned goals, such as absolute net gain, are to be achieved [13,20].

Ecological irreplaceability is a simple concept, and its centrality to achieving or preserving the option to achieve nature positive outcomes is logically self-evident. However, it has rarely been used to guide conservation planning and attempts to define and map ecological irreplaceability are uncommon. A recent example is that of the UK government, which has enshrined the concept of ecological irreplaceability in its Biodiversity Net Gain legislation. It defines irreplaceable habitat as habitat that "is very difficult (or takes a very long time) to restore, create or replace once it has been destroyed", due to factors such as age, uniqueness, species diversity or rarity [6].

Here, we provide guidance on how it can be operationalised and then translated to maps and other guidance to enable its use as a first filter when identifying places and features that must be preserved if nature positive is to be possible.

First, the concept of ecological irreplaceability is species- or ecosystem-specific. A given ecological feature can be irreplaceable for one species, but replaceable for another. For example, old, natural tree hollows take more than a century to form; longer in parts of the world where primary cavity-excavating birds are absent [21]. Such hollows perform critical functions in the life history of many vertebrate species. However, while for some species, these functions can be effectively replicated through the use of artificial structures (e.g. nest boxes), other species avoid such structures, or have poorer outcomes if forced to use them [22] (Fig. 1). For this latter group, natural tree hollows are ecologically irreplaceable, and their destruction would preclude the maintenance or improvement of the species' population.

Second, there is a temporal element to irreplaceability. While some features may eventually re-form in restored habitats, this might take decades or even centuries. Clearly, such timeframes of replacement are not ecologically relevant to biota already facing extinction or collapse. One way to set ecologically relevant time frames within which features must be able to be re-created to be considered replaceable is with reference to IUCN threat listing criteria. A Critically Endangered species/community has a 20% probability of extinction in 10 years (or 5 generations, whichever is longer (100 years max.), an Endangered species has a 20% probability of extinction in 20 years (or 5 generations, whichever is longer (100 years max.), and a Vulnerable species has a 20% probability of extinction in 100 years [23]. When defining ecologically irreplaceable features or habitats for threatened species, these respective timeframes within which there is a substantial risk of extinction could provide a guide, depending on the threatened status of the species.

Third, some forms of ecological irreplaceability may arise primarily from a lack of ecological knowledge [24]. A feature of importance to a particular species or ecosystem, thought to be irreplaceable due to a lack of evidence that it can be re-created and its function fully restored, may in the future be found to be replaceable, either through improved knowledge or technological advances. However, given the consequences of inadvertently destroying an ecological feature subsequently revealed to be irreplaceable, features should be presumed to be irreplaceable unless there exists sound evidence or ability to replace them within ecologically relevant time frames for all species or ecosystems to which they are critical.

Finally, while some features might be hypothetically replaceable with enough resourcing and investment, the practical feasibility of such actions being done is low. If required at scale, many ecological restoration actions can prove cost-prohibitive [25]. As such, a demonstration that necessary resources and arrangements for the replacement of ecological features are realistically available – and indeed that the necessary actions would be required, should an ecological feature be destroyed – is also core to consideration of ecological replaceability. This requires appropriate policy, governance, and administrative institutions. For example, the requirement for ongoing maintenance of artificial nest boxes, potentially for hundreds of years, precludes their use to replace permanently destroyed natural hollows, due to the effort and costs involved, and exacerbated by the administrative arrangements that would be necessary to ensure the maintenance occurs [22].

We propose that ecological irreplaceability act as a first filter in describing and mapping 'no-go' zones for protection in conservation planning exercises, if the goal is to achieve nature positive outcomes, or absolute net gains. We recognise that the location of all ecologically irreplaceable elements may not be readily mapped. For example, in dense forest ecosystems, it is still not tractable to map every tree with cavities suitable for nesting and denning by endangered mammals and birds. In such cases, a detailed definition of irreplaceable elements could be developed to ensure they can be identified and protected during an impact assessment and development approval process.

However, many irreplaceable habitats likely can be mapped, and as remote sensing and drone technologies improve, many more will be mapped soon. For example, building on the work of Tillin and colleagues [20], the state of Victoria, Australia, has defined and mapped ecologically irreplaceable marine biotopes based on intrinsic limitations in recovery potential and environmental specificity [26]. This guidance deems a biotope irreplaceable when restoration is either unfeasible – owing to the absence of proven, scalable methods or insurmountable environmental constraints – or when recovery is exceptionally slow, typically exceeding 25 years. Secondary factors such as rarity and environmental uniqueness further constrain restoration success, particularly where biotopes are geographically restricted or dependent on distinctive physical, geological, or hydrodynamic conditions [20,26].

An alternative approach in the face of uncertainty over what is replaceable, is to instead map those ecological features for which there is established evidence of replaceability. As evidence accrues that further elements or habitats are practically re-creatable in ecologically appropriate time frames, additional features can be added. Such a precautionary approach is most likely to safeguard against irreversible losses and would be particularly appropriate when dealing with already-threatened biota.

Conclusion

Unfortunately, the last two decades has seen policies and government decisions that allow almost any habitat, no matter how irreplaceable, to be legally destroyed [27,28]. Often, this has been justified with recourse to some form of offsetting or compensation mechanism [29]. This has contributed to ongoing biodiversity loss and widespread scepticism about the ability of offsets and compensation programs to lead to a true net gain. If nature positive policy and law reforms are to be more than mere rhetoric [30], then a genuine appreciation, quantification and application of irreplaceability concepts must be front and centre and properly administered. Equally, such concepts must set limits to the application of offset or compensation, if such approaches are to play a positive role in a nature-positive future [13,31].

Despite being a simple concept, ecological irreplaceability is very rarely used to underpin conservation planning and decision-making. In the hitherto dominant frame of loss-minimisation in which conservation planning has typically operated, it was not necessarily called upon. But this has changed. Humanity has now set itself much more ambitious goals, in recognition that we have already depleted much of our biodiversity beyond acceptable/safe limits. Using what we cannot replace as an absolute constraint is a necessary step towards achieving the outcome goals of the Global Biodiversity Framework, and a nature positive future.

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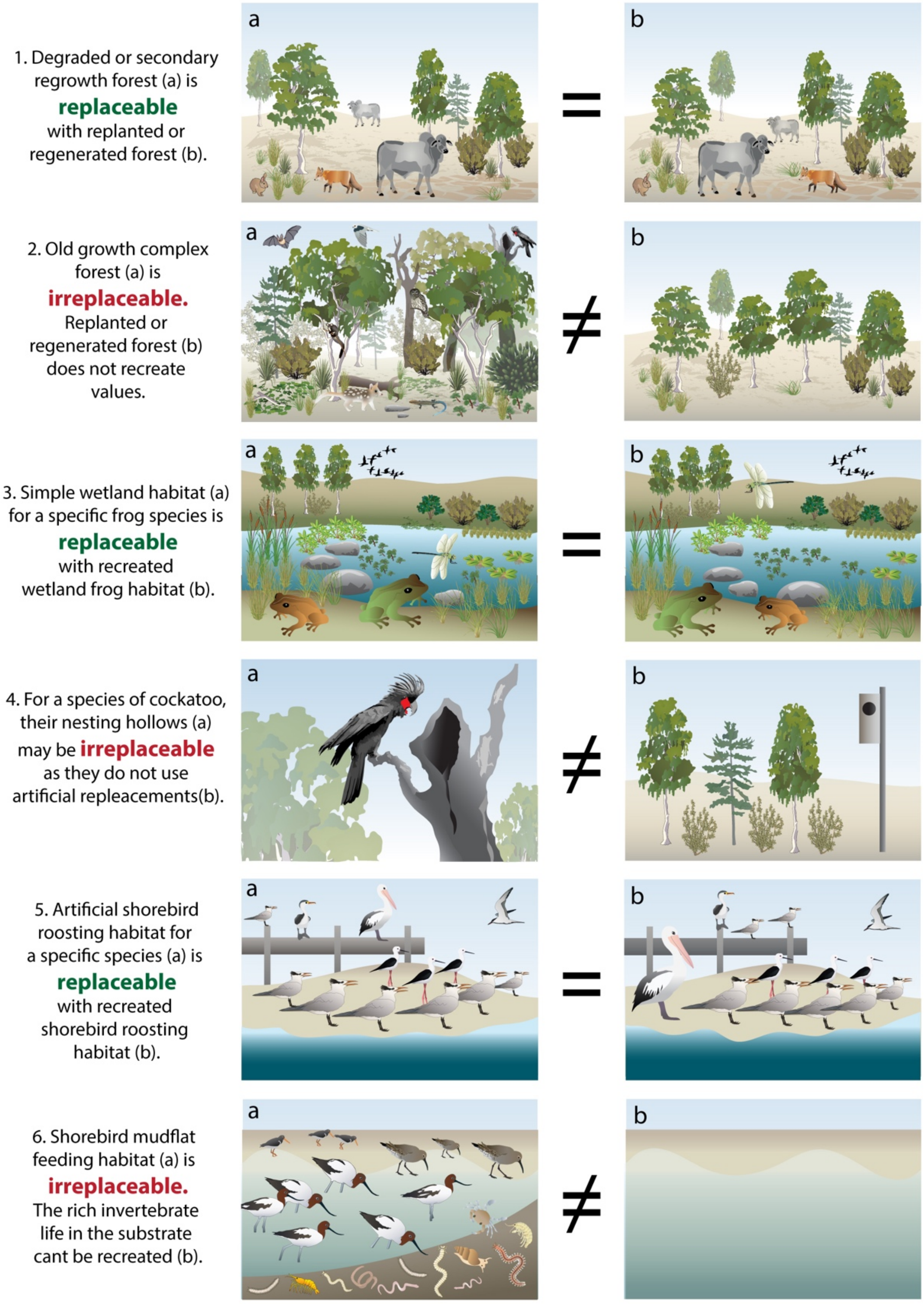

Figure 1: *Examples of ecosystems and habitat elements may be able to be re-created, but many cannot. Habitats on the left show (a) show existing ecosystems and features, which either can or*

cannot be successfully re-created in the corresponding righthand habitats (b). For example, replanting or regenerating forests can replace many aspects of secondary forests, but generally are unable to replicate the characteristics of old growth forests within ecologically-relevant timeframes; some simpler habitat elements required by particular species can successfully be practically re-created, but for other species such replacement has not been successfully demonstrated; even for one species, some aspects of their habitat might be replaceable, while others are not. Illustration Jaana Dielenberg, with symbols courtesy Integration and Application Network (ian.umces.edu/media-library) and NESP Resilient Landscapes Hub (nesplandscapes.edu.au).

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