Shared principles for area-based biodiversity conservation

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Abstract

Recent international agreements have strengthened and expanded commitments to protect and restore native habitats. Nevertheless, biodiversity conservation is hindered because how such commitments should be implemented has been strongly debated. By bringing together researchers on both sides of the habitat fragmentation debate, we identify three incontrovertible principles for area-based biodiversity conservation. Such principles are related to habitat geographic coverage, amount, and connectivity. They emerge from our fundamental agreement that, while large areas of nature are important and must be protected, conservation or restoration of multiple small habitat patches is also critical for global conservation, particularly in regions with high land use. We contend that the many area-based conservation initiatives expected in the coming decades should follow the principles we propose. Considering the importance of biodiversity for maintenance of ecosystem services, we suggest that this would bring unequivocal societal benefits.

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Abstract page

Recent international agreements have strengthened and expanded commitments to protect and restore native habitats. Nevertheless, biodiversity conservation is hindered because how such commitments should be implemented has been strongly debated. By bringing together researchers on both sides of the habitat fragmentation debate, we identify three incontrovertible principles for area-based biodiversity conservation. Such principles are related to habitat geographic coverage, amount, and connectivity. They emerge from our fundamental agreement that, while large areas of nature are important and must be protected, conservation or restoration of multiple small habitat patches is also critical for global conservation, particularly in regions with high land use. We contend that the many area-based conservation initiatives expected in the coming decades should follow the principles we propose. Considering the importance of biodiversity for maintenance of ecosystem services, we suggest that this would bring unequivocal societal benefits.

Main Text:

The 2022 United Nations Biodiversity Conference (COP 15) addressed five "horsemen of the biodiversity apocalypse": climate change, pollution, invasive species, overexploitation, and land use change. Policies to regulate land use are especially important because habitat loss and degradation continue (Riva *et al.* 2022) and contribute the most to ongoing biodiversity loss (Haddad *et al.* 2015; Fahrig 2017). At the same time, such policies are especially delicate because the complexity of species responses to habitat change has spurred a heated debate regarding the importance and influence of habitat fragmentation (Fletcher *et al.* 2018; Fahrig *et al.* 2019). Unanswered questions include how often does habitat fragmentation exacerbate or interact with the effects of habitat loss on biodiversity?

Because different contexts can determine different answers to such questions, deciding which habitat is most valuable based on its pattern and amount has proven difficult. Managers and policy makers might therefore believe that scientists cannot agree on how biodiversity should be preserved in the face of widespread and increasing global land use. We contend that ongoing debates should not distract from shared principles based on decades of research in biodiversity conservation. To identify and articulate such principles, we intentionally brought together researchers from both sides of the habitat fragmentation debate (Fletcher *et al.* 2018; Fahrig *et al.* 2019). The three resulting principles relate to the geographic coverage, abundance, and connectivity of native habitat areas (or "patches") (Fig. 1):

1) To protect Earth's biodiversity, we must protect and restore native habitats in all biomes and ecoregions (Fig. 1.1). This will safeguard the unique contribution of each biome and ecoregion to the Earth's biological heritage (Olson *et al.* 2001). Widespread geographic cover of native habitats is a prerequisite for any effort in global biodiversity conservation.

2) Protecting as much native habitat as possible is our best way to safeguard biodiversity (Fig. 1.2). This requires protecting both the remaining large native ecosystems and the many small native patches in human-dominated regions. Considering the socio-economic costs of habitat restoration, effort should be

focused on preserving native habitats. Restoration is an important tool in regions that are already extensively transformed by humans.

3) Habitat patches must be functionally connected (Fig. 1.3). Connectivity ensures access to sufficient and complementary resources when remnant habitat patches are too small for a single patch to sustain a species. Connectivity is also fundamental when patches are larger, as migration between them decreases population extinction risk, facilitates re-colonization, and may allow species to shift their ranges in response to shifting climate.

These principles are not exhaustive. For instance, they do not cover issues of habitat quality (Betts *et al.* 2022) or overexploitation within protected areas (Plumptre *et al.* 2014). Furthermore, when detailed information is available, the principles might be superseded by actions tailored to a well-known system. Still, biodiversity is poorly understood across most of the Earth (Hortal *et al.* 2015), such that the design of *ad hoc* actions in most ecosystems and/or for most species is not possible. Given the dominant role of habitat change in the current biodiversity crisis, and unresolved biodiversity knowledge shortfalls, the application of effective, "coarse-filter" (Schwartz 1999) general principles will largely benefit biodiversity. Therefore, we argue that the three simple principles we propose should be at the core of conservation action in response to the recent Global Biodiversity Framework, complementing the broader Targets and Goals identified in the Kunming-Montreal meeting of the Conference of the Parties (COP 15).

Putting disagreement into context

Highlighting these three principles (Fig. 1) is important because ecologists and conservation biologists have long discussed how best to manage native habitat to sustain biodiversity. Earlier discussions revolved around SLOSS (Diamond 1975; Simberloff & Abele 1976) – should conservation prioritize 'a Single Large *o* r Several Small' habitat patches? Through time, SLOSS matured into a debate around the effects of habitat fragmentation relative to effects of habitat amount. And more recently, the debate has been on whether habitat fragmentation has positive or negative effects on biodiversity (Fletcher *et al.*2018; Fahrig *et al.* 2019). The problem is, while disagreement is healthy in an academic setting, it fails to provide pragmatic solutions for management and policy making, when those solutions exist.

Still, the extensive body of literature addressing these topics has not been sufficient to reach consensus on them. Some scientists have concluded that landscapes containing many small patches of native habitat can sustain rare and/or habitat specialist species (Shafer 1995; Fahrig *et al.* 2019), whereas others have suggested that reduced patch sizes inevitably depauperate biodiversity even if the total amount of habitat remains unchanged (Fletcher *et al.* 2018; Bateman & Balmford 2023). Underlying different perspectives are several factors determining our understanding of patterns in species occurrence and biodiversity. Some of these factors are contextual to different ecosystems, including biogeographical differences (Betts *et al.*2019; Banks-Leite *et al.* 2022) or intraspecific variation (Bellotto-Trigo *et al.* 2023), and some theoretical, including issues of spatial scaling (Fahrig 2023; Riva & Fahrig 2023a). Authors even differ in what they consider relevant habitat, from "*at least 100-1000 ha* " (Balmford 2021) to "*smaller than 1 ha* " (Riva & Fahrig 2023b).

The existence of different schools of thought might cast doubt on the generality of the principles we propose, yet this is a misconception. Embracing the principles we outline (Fig. 1) instead helps to put disagreements into perspective. For instance, there is no debate about the need to conserve habitat: the effects of increasing native habitat on biodiversity are overwhelmingly positive. It is true that large areas of nature are important and must be protected (Haddad *et al.*2015; Bateman & Balmford 2023), as much as it is true that ensuring the conservation or restoration of multiple small habitat patches is fundamental for global conservation, particularly in extensively modified regions (Arroyo-Rodríguez *et al.* 2020; Riva & Fahrig 2022). These are neither incompatible nor competing strategies; they are complementary approaches to protect biodiversity across all regions. Disagreement can be translated into a false dichotomy between the protection of large or small patches, a mistake that must be avoided at all costs for the sake of biodiversity conservation because both are important.

The risks of ignoring these principles are clear. Habitat existing as small patches is often deemed less valuable

than large swaths of habitat in less modified regions (Bateman & Balmford 2023), which is inadvertently leading to widespread cumulative loss of habitat from millions of small patches across the globe. For instance, smaller (< 1000 ha) forest patches are more likely to suffer a given amount of habitat loss than larger (> 10,000 ha) patches (Riva *et al.* 2022). While the recent agreement of the parties involved in COP 15 is agnostic on patch area, policies that protect only patches larger than a minimum size are widespread [see (Riva & Fahrig 2023b) for examples in Mexico, US, Canada, Australia, and Europe]. Such policies hinder biodiversity conservation because they fail to protect biodiversity in highly-modified regions where protection is clearly needed. Similarly, suggesting that habitat protection should occur primarily in biodiversity-rich regions and/or large habitat patches (Bateman & Balmford 2023) risks neglecting extensive areas of the planet with unique flora and fauna but also large anthropogenic footprints (Haddad *et al.* 2015). Finally, failing to maintain small habitat patches reduces landscape connectivity among larger patches due to the loss of "stepping stones" (Terborgh 1974), where small patches distributed through a landscape can facilitate movement between larger patches.

At the same time, very large tracts of native habitat are now limited to a few regions (Haddad *et al.* 2015), and their conversion to human land uses is placing many species – most of which have not yet been identified to science (Hortal *et al.* 2015) – at risk. For instance, continued deforestation in the Amazon has been predicted to trigger an ecosystem state-shift. This biome persists thanks to feedback between vegetation and climate (Albert *et al.* 2023). Losing 20% of the Amazonian forest could trigger a shift from forest into savanna, a death-knell for the forest-dependent species of the Amazon (Albert*et al.* 2023). Similarly, while the few remaining extensive grasslands worldwide sequester large amounts of carbon and host unique species, they remain poorly protected and continue to shrink (Scholtz & Twidwell 2022). Beyond biodiversity, loss of these extensive natural habitats would bring significant losses to the economic, cultural, and ecological identity of large regions (Scholtz & Twidwell 2022; Albert *et al.* 2023).

Protecting biodiversity with people and for people

While the principles we propose are essential to sustain biodiversity, conservation is destined to fail unless the rights and needs of people also enter the equation. This implies that the three principles, even if best for biodiversity, cannot be always applied. Tradeoffs with other priorities in landscape management must also be considered. For instance, the provision of food, water, shelter, and energy to humans often implies the sacrifice of large areas of native habitat. How can we sustain biodiversity, while at the same time supporting the needs of an increasing global human population?

Careful planning that does not affect the total area reserved to nature can optimize conservation investments. For example, natural habitats can be maintained within agricultural landscapes to sustain several crucial services (e.g., pollination, pest control, and nutrient retention). In the Midwestern US, removing from crop production sub-field areas that are consistently under-yielding makes conservation possible across millions of hectares (Basso & Antle 2020). Avoiding growing food in such locations can reduce the total surface of land needed to feed humanity. As a further example, restoration of small ([?] 0.16 ha) forests in oil palm plantations can enhance biodiversity and multiple ecosystem services without compromising yield (Zemp *et al.* 2023).Thus, it is possible to reduce the area allocated to land used by people and increase land for nature, while also guaranteeing the services that people rely on.

Because area-based conservation actions are intertwined with socio-political dynamics and ethics (Richardson *et al.*2023), they require integrating biodiversity policy with other human goals, e.g., the United Nations sustainable development goals such as "Zero hunger" and "Clean water and sanitation". In some regions this can result in situations where actions to sustain wilderness are not always desirable for people. For instance, human-wildlife conflicts are more likely in human-occupied regions containing significant wilderness areas. This complicates global conservation of large carnivores, especially in the global South where regulations on land use have large impacts on the ability of many people to gain a living.

Conservation action must therefore be implemented equitably, not only for ethical reasons, but also because a loss of social legitimacy often causes nature reserves to be disregarded both legally and practically. Consid-

eration of aspects beyond – but dependent on – biodiversity must therefore be central in the dialogue around how to implement area-based conservation efforts. This dialogue requires weighing different conservation, ethical, social, and economic priorities, but we stress that the principles we champion here must be central to the process of weighing these different priorities. This is because failing to halt biodiversity loss entails a risk of societal collapse as most ecosystem services supporting human societies would disappear (Tilman *et al.* 2014).

Coda

National and international policies have embraced the principle of conserving 30% of land and water by 2030. To protect biodiversity, this so-called '30x30' must be achieved in each ecoregion, through conservation of the large habitat areas that resemble wilderness, combined with protection and restoration of many small habitat patches in ecoregions severely affected by human activities. In fact, in highly human-modified regions, reaching area targets will be possible only through protection of small patches and habitat restoration. In such regions, conservation and restoration of many small areas is essential to get to 30x30, and such areas may represent the greatest net gains for area-based habitat conservation going forward.

More broadly, realizing 30x30 and other ambitious, collective, area-based plans will be possible only through coordination (Eckert*et al.* 2023) and if we promptly recognize common ground among researchers working on biodiversity conservation. Ongoing disagreements such as the fragmentation debate are secondary to the general principles we outline in this letter, and we are confident that they will be resolved as data accumulate and science progresses. In the meantime, to address a global biodiversity emergency, proactive implementation of shared principles will bolster our chances of preserving the Earth's biodiversity heritage.

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Figures

Fig. 1. Three shared principles for area-based biodiversity conservation. (1) To protect Earth's biodiversity, we must protect and restore native habitat in all biomes and ecoregions. Shown are Earth's 14 biomes (Olson *et al.* 2001). (2) Protecting as much native habitat as possible is our best way to safeguard biodiversity, and requires protecting both smaller and larger patches. For instance, while in some tropical biomes forest may exist in large, continuous patches, other biomes have been reduced to highly fragmented habitat. Green circles represent habitat patches separated by anthropogenic land use in two adjacent biomes (lime and blue background); the fading, green area on the bottom-left corner of the inset represents a large expanse of wilderness. (3) Habitat patches must be functionally connected. Habitat connectivity can increase with stepping stone habitat (a), corridors (b), or by reducing distances between patches (i.e., increasing patch density in the landscape) (c).