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Effectively Incorporating Small Reserves into National Systems of Protected and Conserved Areas

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Abstract: Received wisdom has argued that large protected areas are superior to small reserves, based on island biogeography theory, economies of scale, and the need to sustain viable populations of top predators and other large ranging or dispersive species. But this position overlooks evidence that, for many species, strategically placed smaller reserves are extremely important, especially in areas highly altered by humans. Many countries are reluctant or unable to designate additional large protected areas. We provide evidence that carefully designed support networks of smaller protected areas can be an important complement to activities to reach the Global Biodiversity Framework's target of 30% of the planet in protected and conserved areas by 2030. We identify seven benefits from small reserves, when correctly located and well-managed: (1) conserving critical habitat of range-limited or relic species; (2) conserving remaining areas of sensitive or threatened habitat in altered ecosystems; (3) conserving habitat for sensitive, time-limited lifecycle stages, such as raptor nesting sites and fish spawning grounds; (4) maintaining and enabling connectivity by providing stepping stones of suitable habitat through inhospitable ecosystems; (5) providing increased protection for critical habitat within Category V protected landscapes and seascapes to boost their overall conservation potential; (6) taking advantage of conservation opportunities at cultural sites, sacred natural sites, and other faith-based sites in transformed landscapes; (7) integrating different management approaches and governance types in a range of connected small reserves to multiply conservation impacts. We propose a typology based on these benefits that can guide steps for policy makers to help plan and monitor small reserves in area-based conservation efforts. Using these principles, the role of small reserves in area-based conservation efforts can be further enhanced.

Keywords: protected area; Global Biodiversity Framework; management effectiveness; connectivity

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1. Introduction

The "*Single Large or Several Small*" (SLOSS) debate has, for decades, discussed whether different sized protected areas offer the most effective in situ conservation option for biodiversity (genes, species, and ecosystems) when overcoming the long-term impacts of habitat fragmentation and loss through human activity [1]. This discussion, often heated and based on a false dichotomy, originated from Jared Diamond's original suggestion [2], which utilized tenets from the theory of island biogeography [3], that a single large reserve (here, synonymous with "protected area") is likely to be more useful than several smaller reserves, even if the total area of the latter is greater.

Clear evidence demonstrates that protecting large amounts of habitat in one area or a smaller number of large reserves can have benefits for species and ecosystem conservation, as these areas are capable of supporting self-sustaining populations of larger species, reducing species extinction risks by reducing the impacts of fragmentation and "edge effects" and sometimes conserving whole ecosystems [4–6]. It is well established that securing large protected areas is particularly important for the maintenance of wilderness and Indigenous cultural values [7] as well as conserving those ecosystems that are considered still relatively 'intact' when considering evolutionary and ecological processes [8], which has been increasingly recognised as important in a time of climate change [9]. The value of large reserves has been repeatedly stressed in the literature in terms of conservation effectiveness (e.g., [10]), return-on-investment [11], and their ability to either resist or 'bounce back' from post anthropogenic disturbances such as those associated with fire and disease [12].

Despite these positives, researchers have increasingly challenged the assumption that large protected areas are the only approach to successful site-based conservation, emphasizing the critical importance of small habitat patches in many situations [13]. While it is clear that many small reserves tend to harbour more generalist and exotic species and are at risk of suffering extinction debt [14], recent syntheses of multiple studies concluded that, for plants, invertebrates, reef fish, amphibians, lizards, small mammals, and birds, a patchwork of smaller, well-managed protected areas, could conserve more biodiversity than a single large protected area of the same size [15]. Sets of small patches were found to harbour more species than large patches, even when considering only species of conservation concern and even if the small patches are very small compared with the large patches [16]. This is especially true if matrix conditions surrounding these reserves are not too inhospitable to native biodiversity [17], as well as in highly altered landscapes where the importance of small patches increases with the degree of ecosystem fragmentation [18]. Small patches are sometimes the only conservation option in highly altered areas, sometimes leading to "concentration effects" as species are driven into remaining suitable habitats, which then provide nodal points for regeneration [19]. As a consequence, most protected area system managers now recognise that a mixture of both large and small protected areas are needed for effective biodiversity conservation [20] and to maintain the existing state of ecology in the area. For example, a US study focusing on return-on-investment for forest protection found larger protected areas were more effective at reducing forest fragmentation, whereas smaller reserves had a higher return on investment (ROI) when prioritizing sites offering protection to more species, showcasing that both approaches are important when considering long-term conservation outcomes [21].

Despite a much more nuanced approach emerging among academic researchers, the importance and benefits derived from smaller protected areas tend to be downplayed [22]. This discrepancy becomes increasingly important in light of the Kunming-Montreal Global Biodiversity Framework (GBF) from the Convention on Biological Diversity and its Target 3, which aims to conserve 30 per cent of land and ocean in protected areas and other effective area-based conservation mechanisms (OECMs) by 2030 ("30 × 30"). Although the numerical target has caveats relating, amongst others, to effectiveness, representation, equity, and connectivity, signatory nations will be under significant pressure to achieve the areal component and this means finding more and larger spaces for nature, often with less consideration of the biodiversity that needs to be protected. There is, consequently, concern that governments will prioritize the quantity rather than quality of protected areas [23] and seek to identify large sites not placed strategically for effective conservation outcomes [24,25], rather than focusing on the most effective options for conservation of biodiversity and ecosystem services [26].

To date, relatively few serious reviews have been undertaken regarding how and when smaller protected areas can provide important benefits to biodiversity. The SLOSS debate usually looks at a single large or several small reserves as if they were trying to do equivalent things. But, small reserves have distinct roles that are not directly comparable with conservation activities aimed at securing large remaining areas of natural habitat. They also have a number of management advantages that help further their usefulness. For example, some management procedures can be more easily implemented in small reserve patches, with their usefulness also increased via more-or-less random factors like individual risk tolerance within populations of mammals and birds [27].

From this perspective, we describe the state of play when it comes to small reserves globally and then provide evidence that, when well-placed and well-managed, many small reserves have been shown to play a positive role in conservation outcomes. We provide a broad typology of the evidence and discuss how this can be interpreted to provide practical guidance for protected area planners developing national or regional conservation systems, particularly those people working in crowded or largely transformed landscapes and seascapes, as well as to inform monitoring efforts around their overall effectiveness.

2. A Typology of Communicating and Planning for the Roles of Small Protected Areas

Despite the fact that most of the area under protection is made up of a relatively small number of very large reserves [28], over half of the global protected area inventory is composed of protected areas of <100 ha [29] and this figure likely underestimates the number of small protected areas because these have a high probability of being accidentally excluded from databases and of having incomplete boundary information [28]. Many small protected areas exist and will continue to exist, as countries practice conservation in crowded landscapes and seascapes, with competing demands on space. The average size of the 2300 reserves managed by the Wildlife Trusts in the UK, for instance, is 39 ha (calculated from [30]). This situation is likely to continue, and the proportion of small reserves may well even increase in the future, so it is important that they are chosen, located, managed, and monitored to get the best possible results.

While some small reserves that have been established may provide little benefit for conservation [31], there are increasing examples where they have played an extraordinary role in enabling biodiversity persistence. Understanding when and how such reserves can benefit overall conservation is particularly important at a time when conservation politics are putting an emphasis on the area under conservation. We, therefore, provide a typology of seven distinct conservation benefits that small protected areas have delivered, based on evidence from around the world, and provide a series of national examples based on the United Kingdom (Table 1). This is then interpreted to provide practical guidance for protected area planners developing national or regional conservation systems, particularly those people working in crowded or largely transformed landscapes and seascapes. This typology is not intended to be comprehensive nor systematic but rather represents our perspective that seven distinct benefits can arise when undertaking small protected area designation.

Benefit 1. Successfully conserving critical habitats of range-limited species. Small reserves are already successfully conserving critical habitats of range-limited species, particularly plants and invertebrates. For example, around 300 2-20 ha micro-reserves to protect rare plant species have been established in otherwise heavily managed areas of Valencia, Spain, some within larger national parks but the majority are outside of these protected areas [32]. Micro-reserves have been set up to protect crop wild relatives in Eastern Europe and central Asia; here, the need is to maintain the disturbed ecological conditions required by these pioneer species [33]. Small marine reserves (0.5–0.8 km^2) on Fiji's main island were found to have greater species richness, density, and biomass of fishes than other areas and to maintain healthier coral ecosystems in ways that increased overall reef resilience [34].

Benefit 2. Conserving small areas of sensitive or threatened habitat in an otherwise altered ecosystem. Small reserves can secure the final fragments of a habitat, still containing a good proportion of the expected species (particularly plants and smaller animals) in conditions where the rest of the landscape has been transformed and there is little possibility of restoration in the medium term. A good example is the Andrew Johnston Big Scrub Nature Reserve in the Northern Rivers region of New South Wales, Australia. The 21-hectare reserve is the largest and most important of the remnants of the Big Scrub, the largest area of lowland subtropical rainforest in eastern Australia, which was intensively cleared for agricultural use in the 19th century—<1% now remains. While very small, it is likely a stronghold for endangered species like White Booyong (*Heritiera trifoliolata*) and Australian Red Cedar (*Toona australis*) [35]. A small area can sometimes be a positive advantage by excluding pressures acting in the wider environment. In New Zealand, small patches of remnant native vegetation provide sanctuaries for land snails, because they preclude development of feral pig populations which are a major predator of snails elsewhere [36].

Benefit 3. Conserving habitat for sensitive, often time-limited, lifecycle stages threatened in the wider landscape or seascape. This included preserving raptor nesting sites and fish spawning grounds. Cabo Roja Salt Flats National Wildlife Refuge on the island of Puerto Rico is only 522 ha but is a critical stopover site for migrating shorebirds in the Caribbean [37] and is part of the Western Hemisphere Shorebird Reserve Network. The Mai Po Marshes nature reserve at 113 ha is a small wetland located in Hong Kong and is an internationally significant wetland that is actually a shallow estuary supporting globally important numbers of wetland birds, which chiefly arrive in winter and during spring and autumn migrations, including over 55,000 migrating birds such as Saunders's gull (Chroicocephalus saundersi), a quarter of the world's Black-faced spoonbill (*Platalea minor*) population, and significant numbers of Spoon-billed sandpiper (*Calidris pygmaea*) [38].

Benefit 4. Maintaining connectivity by protecting stepping stones of suitable habitat in otherwise less hospitable ecosystems. Small reserves, when located strategically within an ecosystem or a series of ecosystems, are an important connectivity component of larger-scale conservation plans, helping ensure maximum coverage of widely dispersed species and providing stepping stones between larger habitat patches. Furthermore, connectivity is increasingly recognised as a dynamic rather than a static process, particularly under conditions of climate change [39]. Methods for assessing the temporal dynamics of connectivity are emerging [40]. Stepping stones can appear and disappear over time [41] through short-term changes such as seasonal flooding to longer term clearing and regeneration of vegetation patches. This raises the possibility of temporary reserves to facilitate the movement of species to adapt to changing climatic conditions or other environmental variation [42].

For example, the Chereninup reserve is a small (897 ha) reserve located in Western Australia seen as critical to a project to restore connectivity between the larger Fitzgerald River and Stirling Ranges National Parks, a global biological hotspot. It is providing core connectivity for endangered species like Black-Gloved (*Notamacropus irma*) and Tammar (*N. eugenii*) wallabies [43]. This protection is considered extremely important when considering the impacts of climate change and the need for some species to have the ability to move to suitable climates or undergo genetic change or phenotypic plasticity [44].

Benefit 5. Providing high levels of protection for critical habitat within broader Category V protected landscapes and seascapes to boost overall conservation potential of the wider area.

While protected landscapes and seascapes often conserve large cultural areas with high biodiversity value, specialised or individual threatened species may need particular areas to be identified where management is more focused on particular conservation outcomes. The effectiveness of Category V protected areas has been less thoroughly studied than more strict protection categories. But, examples exist throughout the world including the conservation of black stork (*Ciconia nigra*) in Lonske Polje Nature Park, Croatia; the endemic, dune-dwelling tree *Icuria dunensis* in Matibane Forest Reserve, Mozambique; and clouded leopard (*Neofelis nebulosa*) and Blyth's tragopan (*Tragopan blythii*) in Khonoma Nature Conservation and Tragopan Sanctuary, India [45].

Benefit 6. Taking advantage of conservation opportunities provided by cultural sites, sacred natural sites, and other faith-based sites in otherwise transformed landscapes. A good example of this is the Tembawang in Borneo, which are planted forest gardens and burial grounds of high spiritual importance to the Dayak people of West Kalimantan. Although previously agricultural, they also contain native biodiversity that has otherwise disappeared in transformed areas of Kalimantan [46]. Another example includes ancient temperate forest fragments that now survive only in Orthodox churchyards over large areas of Ethiopia [47].

Benefit 7. Facilitating the integration of different management approaches and governance types within a range of connected small reserves to multiply the overall conservation impact. This also allows conservation areas to grow incrementally over time, so that a collection of small reserves can sometimes develop into what is effectively or actually a much larger protected area. In southwest England, the Somerset Levels is a low peatland area that was, in the 1980s, the scene of fierce arguments between farmers, peat cutters, and conservationists. Since then, a collection of protected areas has been established by four private organisations and the state nature conservation body; additionally, over 30 Sites of Special Scientific Interest have been designated, many on private land. There are now plans to amalgamate these under an overall 6140 ha reserve, albeit with individual parcels under different governance regimes.

Given these benefits, the IUCN protected area management Category IV Habitat/Species Management Area has evolved over time to have a particular focus on smaller reserves. Category IV protected areas aim to protect particular species or habitats and management reflects this priority. This means that Category IV sites are often, although not invariably, smaller reserves, either habitat fragments or areas designated to protect species outside of an entire ecosystem, which would usually be designated in IUCN I or II protected areas for natural ecosystems or V and VI for ecosystems with significant human intervention [48]. Prior to the revision of the IUCN management categories in 2008, while most protected areas require some form of management, Category IV protected areas were previously defined as sites requiring continual management to retain their biodiversity values. This stipulation has been dropped, although, in many cases, the fact that the protected area is less than an entire functioning ecosystem implies that a relatively high level of management will be needed [48].

Table 1. Seven benefits of small protected areas using UK reserves as examples.

Benefit	Example
1. Conserving critical habitat of range-limited or relic species, particularly plants and invertebrates	Edmonston's chickweed (*Cerastium nigrescens*) has a known global distribution confined to two sites on one of the Shetland Islands, north of Scotland [49], and is protected by Keen of Hamar National Nature Reserve, 42.4 ha.
2. Conserving small areas of sensitive or threatened habitats in an otherwise altered ecosystem.	Radipole Lake is an 83 ha wetland surrounded by housing developments in Weymouth. Long recognised as an important habitat [50], today, despite its largely urban location, it still supports rare UK bird species such as marsh harrier (*Circus aeruginosus*), bearded reedling (*Panurus diarmicus*), and many migrant wetland and wader birds. It, therefore, also acts as a *stepping stone* (4 below).
3. Conserving habitat for sensitive, often time-limited, lifecycle stages threatened in the wider landscape or seascape, such as raptor nesting sites and fish spawning grounds.	Populations of the once-extirpated osprey (*Pandion halietus*) are being rebuilt in the UK through judicious protection of nesting sites, often in small reserves such as Loch Garten, owned by the Royal Society for the Protection of Birds [51]. While ospreys catch fish in the wider environment, continuing persecution means that the protection of nest sites remains critical to their survival in the UK.
4. Maintaining connectivity by protecting stepping stones of suitable habitat in otherwise less hospitable ecosystems—particularly valuable for birds.	Montrose Basin is an enclosed estuary of the river South Esk covering 750 ha, home to over 80,000 migratory birds—including pink-footed geese (*Anser brachyrhynchus*) [52], Arctic terns (*Sterna paradisaea*), knots (*Calidris canutus*), and sedge warblers (*Acrocephalus schoenobaenus*). Birds like the geese stay all winter; others such as the Arctic tern pass through for a few days only on longer migrations.
5. Providing high levels of protection for critical habitat within broader Category V protected landscapes and seascapes to boost overall conservation potential of the wider area.	Ramsey Island, 259 ha, is one of three highly protected island reserves within the wider Pembrokeshire Coast National Park and is an internationally important breeding centre for the Manx Shearwater (*Puffinus puffinus*) alongside other oceanic bird species. Intensive conservation management, including a rat eradication programme, has rebuilt nesting bird populations on the island [53].
6. Taking advantage of conservation opportunities provided by cultural sites, sacred natural sites, and other faith-based sites in otherwise transformed landscapes	St Dennis's churchyard, at 0.02 ha, is the smallest of 27 Local Nature Reserves designated by the local authority in Cambridgeshire. Covered in calcareous grassland, it includes many calcium-loving plant species that have disappeared from the surrounding landscape, including oxslip (*Primula elatior*), classified as near-threatened in the UK. It is one of thousands of churchyards and graveyards managed for wildlife in Britain [54].
7. Facilitating the integration of different management approaches and governance types within a range of connected small reserves to multiply the overall conservation impact.	In the Somerset Levels, abandoned peat cutting areas have been reflooded and are managed by a range of different private and state protected area institutions, with more land likely to become available under government climate change adaptation plans, creating a large ecosystem that is now very important for waterfowl.

3. Discussion

Small reserves are not generally established to protect entire ecosystems, except in cases where the ecosystems themselves are unusually limited (for example on small, remote islands). Nor in all but a few cases would they be used for conserving large, wide-ranging animals or sustaining ecological or evolutionary processes, although they can protect sites of importance for particular stages of the lifecycle of these species (e.g., breeding sites or winter-feeding grounds) and stepping stone habitat patches between larger reserves. But, from this perspective, we have provided examples that demonstrate that, when strategically placed, smaller reserves can be extraordinarily important in securing biodiversity, especially in those landscapes and seascapes that have been highly altered by humans (Table 1). Smaller reserves are likely to be most effective in landscapes and seascapes that have been transformed to a certain extent and a less attractive option where large areas of near-native vegetation still remain [55]. The multiple approaches that protected areas can take to reach their objectives have long been recognised by institutions such as the IUCN [56]. By integrating small reserves consciously into a national system of protected areas, rather than having them scattered more haphazardly across a landscape or seascape, this functionality is further increased.

We do not provide a numerical figure for "large" or "small" and recognise that this is a limitation. But, size is a very relative term here, dependent on geography, ecology, and, to some extent, on ecosystem history and the aims of conservation. Further work is needed on quantifying the optimal sizes of protected areas—and what the bare minimum is for a small reserve—in different situations. We also note that, from this perspective, we do not delve into the challenges associated with representing small landscape elements adequately in mapping assessments, which could impact protected area design. We recognise that common land cover classifications sometimes do not adequately describe the specific and nuanced characteristics of small landscape elements [57,58], which affects the understanding of habitat complexity and biodiversity at a finer scale [59]. While some elements can be identified through remote mapping techniques, other smaller features are likely to be lost. Deeper specific effort is needed to determine how different mapping efforts can address the challenges associated with capturing the complexity of small-scale habitats.

While protecting the most amount of habitat and ensuring that this is intact and connected is a fundamental step towards abating the biodiversity crisis, societal demands and the amount of natural habitat left on the planet means securing small protected areas are going to have to play an increasingly important role in achieving the GBF. Their size means that they can, if necessary, be subject to both intensive management and, in many cases, intensive oversight, which may be important given smaller parcels of land have increased edge effects and additional risks of impacts from wildfires and disease outbreaks. It is becoming clear that small reserves are ideally suited for the privately protected area model, subject to fast purchase, to conserve critically threatened species or habitat fragments due to being quicker to apply than state-led approaches that are often cumbersome and slow-moving [60]. The average size of privately protected areas reported to the World Database on Protected Areas is 10.26 km^2 [61], and many are far smaller. Many countries are now facing critical risks to numerous species that are often confined to or at least only known to inhabit a single site; the Alliance for Zero Extinction focuses on species recorded only from a single location [62]. Rapid expansion of the privately-owned micro-reserve model could help secure many of these species on the edge of extinction, until such time as broader conservation policies can help rebuild populations [63].

Additionally, given CBD's recognition of both protected areas and "other effective area-based conservation measures" (OECMs), there is now considerably more flexibility surrounding how such areas are governed and managed, ranging from de facto management through some form of agrarian reform to full recognition as OECMs or protected areas [64]. It is still too early to tell how effective these different measures will prove to be over time and this is likely to change in different countries. But, given the urgency of the problems facing many range-limited, highly threatened species, it is important to make full use of all the area-based conservation tools available [65].

In many countries, small reserves draw on a volunteer network for both management and monitoring and those near centres of populations have the advantage of ease of access. As such, they provide ideal sites for teaching, both formally with school or university students and informally through signage, interpretation, and by providing the chance for the general public to explore nature on their own. Today, few budding naturalists have the chance to explore nature (biodiversity but also concepts such as geodiversity, landscapes, and seascapes) by heading off into the wilderness and most will have their early independent taste of this nature through small, urban, or peri-urban reserves.

Within the context of the GBF, our belief is that small reserves need to be specifically integrated into conservation planning efforts, both under GBF Target 3 and also Target 1, which deals with overall strategic planning to reduce biodiversity loss, and Target 4, which addresses species extinction. They can be best integrated by utilising a typology such as the one outlined above to determine which benefit(s) will be derived from their gazettement and, when implemented, which they should be monitored against. This can be assisted by a number of clearly identifiable steps:

- Applying gap analysis to identify species outside the current protected and conserved area network and assessing these to see which could have their threats substantially reduced by protecting one or more of their sites.
- Using biodiversity action plans for target species to identify cases where a key part of the lifecycle is vulnerable—for example, fish spawning areas, bird nest sites, and winter feeding grounds—and arranging localised protection to ensure that these functions are maintained.
- Within connectivity plans, identifying places where small-scale protection can assist migration pathways or the more general dispersal of species and where small reserves could be integrated into large conservation units.
- Looking for opportunities to boost potential conservation effectiveness in managed landscapes, including under non-traditional management regimes.

4. Conclusions and Recommendations

Within the context of the GBF, a key policy recommendation is for the inclusion of small reserves, fulfilling one or more of the roles identified in our typology, within systematic conservation planning exercises. Governments and donors should consider the option for purchasing small reserves, possibly privately protected areas, in sites containing rare or endemic species.

A great deal remains to be learned about the long-term success of small reserves, including what constitutes sufficient connectivity between protected areas for different species, how the location of reserves can maximise success, and what long-term management strategies work. Determining the optimal size, and minimal useful size, of reserves still needs further elaboration for different ecosystems. Further researchand advice is needed on the management of small reserves. Finally, given concerns about species loss and the island biogeography effect, long-term monitoring is needed to evaluate their impacts over time. Much of this information is probably already available from individual sites but needs to be synthesised and converted into practical advice for conservation planners and managers.

Despite these shortfalls in knowledge, we believe our typology of seven distinct conservation benefits from small protected areas can help protected area planners to develop effective national or regional conservation systems. This is particularly this case for people working in crowded or largely transformed landscapes and seascapes.

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