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Editorial

Emerging Paradigms for Biodiversity and Protected Areas

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Despite significant investments in protected areas, biodiversity continues to show the negative influence of human domination of earth's ecosystems with population reductions across many taxa (Dirzo et al. 2014) [1]. Biodiversity loss ("biosphere integrity") is one of two "core planet boundaries", and currently exceeds the "safe operating space for humanity" as an intrinsic biophysical process that regulates the stability of the Earth system: it is at high risk, "beyond the zone of uncertainty" that human perturbations will destabilize the Earth system at a planetary scale (Steffen et al. 2015) [2]. Shifts towards globalization and increased emphasis on ecosystem services pose further challenges to biodiversity and its conservation (Cimon-Morin et al. 2013) [3]. Particularly threatened are organisms that require large, undisturbed areas where natural patterns and processes can occur freely (Laliberte & Ripple 2004) [4]. Such areas are increasingly under-protected. The amount of area under traditional protection varies by country but globally is about 15%, short of the 25–75% required to capture vulnerable biodiversity (Juffe-Bignoli et al. 2014) [5]. Habitat fragmentation is an ongoing process isolating remaining areas of high quality habitat (Haddad et al. 2015) [6]. For example, 50% of the continent of Europe is within 1.5 km of transportation infrastructure (Torres et al. 2016) [7]. A summary of 35 years of studies of habitat fragmentation caused by infrastructural development has shown that it has reduced biodiversity by 13–75% in various regions across the globe (Lawton 2018) [8]. The Global Human Footprint in terrestrial systems increased 9% from 1993 to 2009 with 75% of the surface experiencing measurable pressures (Venter et al. 2016) [9]. Using these same measures, one-third of protected land is influenced by intense human activity (Jones et al. 2018) [10].

The increasing drumbeat of alarm that protected areas, as special and valuable as they are, have not been an adequate answer to the biodiversity crisis is supported by a plethora of studies. Protected areas are often located in the wrong places to protect the greatest diversity (Jenkins et al. 2015) [11], are systematically biased in location (Margules & Pressey 2000) [12], are too small, scattered, and disconnected to protect diversity under changing climatic conditions (McGuire et al. 2016) [13], and internally and at landscape scales are often mismanaged such that biodiversity establishment goals are not achieved (Belote et al. 2016 [14]; Joppa & Pfaff 2009 [15]). Protected areas alone, unless increased in area and landscape-level management practices beyond those currently considered political acceptability, are unlikely to reduce decline let alone stimulate recovery and provide resilience in response to climate changes. On the positive side, there has been a vast increase in research and practical engagement in systematic conservation planning, habitat connectivity, and socioeconomic and cultural mechanisms (Sinclair et al. 2018) [16], and widespread international biodiversity and protected areas initiatives (IUCN 2005 [17], 2017 [18]; UNEP 2010 [19]).

The global map of marine and terrestrial protected areas illustrates the impressive scope and extent of effort that has been invested to create the protected areas estate (Figure 1). There are approximately 200,000 significant terrestrial and 12,000 marine sites globally, covering 15.4% and 8.4%, respectively (World Database on Protected Areas (WDPA)). These numbers are underestimates of the actual amount

that is secured from overuse or conversion; for example, in the continental United States (US) alone there are nearly as many as in the WDPA. Yet, in the US there are many multiple use lands that are not specifically managed for biodiversity. On the other hand, the WDPA percentages overestimate the amount of protected area that is permanently secured and effectively managed primarily for biodiversity protection, particularly in the marine realm; only 3.6% of the oceans are formally protected and many of these are not effectively managed (Baillie & Zhang 2018 [20]; Edgar et al. 2014 [21]). Despite inadequate coverage and management, it is evident that humanity has highly valued nature conservation. Much time and resources are dedicated to protected areas but not all of that effort is efficiently spent (Armsworth et al. 2011) [22]. It is clear from databases such as the WDPA and Protected Areas Database of the United States (PADUS), that despite challenges cataloging, classifying, and providing data for protected areas (DellaSala et al. 2001 [23]; Rissman et al. 2017 [24]) a vast amount of international, national, and local effort has been expended for protected areas.

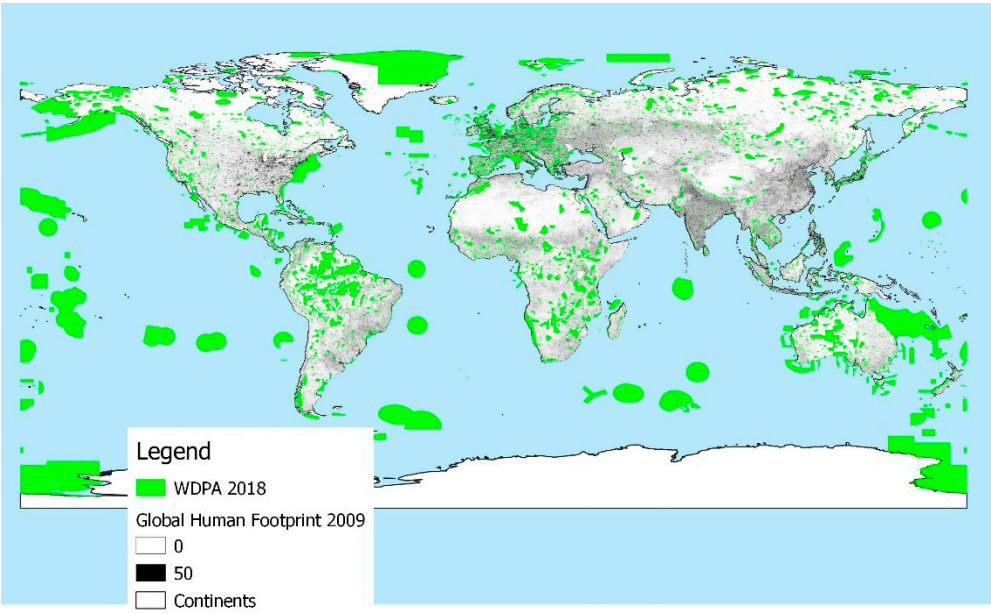

Figure 1. Largest protected areas of the world across marine and terrestrial ecosystems in relation to areas of human land use transformation, the Global Human Footprint. WDPA 2014, Accessed from Protected Planet October 2018. Global terrestrial Human Footprint maps for 2009 from Dryad Digital Repository; HF values stretched from 0 (min) to 50 (max). https://doi.org/10.5061/dryad.052q5.2 (Venter et al. 2016) [9].

The effort has not kept pace with the scale of the task—as much as 50% of the planet needs to be managed for biodiversity (Wilson 2016) [25]. Protected areas alone will likely not accomplish the task. Managing the landscape as a binary problem—protected and not—is too simplistic. A more nuanced view is needed to achieve lasting biodiversity benefits, a view reflected in this special issue. Namely, mechanisms would see the continued establishment of systematically selected protected areas; management of the areas themselves and across political and jurisdictional boundaries improved by meaningful inclusion of the ideas, experience, leadership, and biocultural heritage of local and Indigenous peoples; enhanced quality of life of people; measurements of protected area biodiversity values and ecosystem services provided to society; and, improvements to the habitat quality of the landscape matrix and connectivity made a priority.

The papers in this special issue respond to these unprecedented challenges and imperatives and reflect three broad categories of emerging topics for biodiversity and protected areas. First, there is the topic of database inclusiveness; accuracy, accessibility, and curating is a basic need for assessing protected areas distribution and function. Second, there are issues of social justice and protected areas, in particular the need to reconcile past and on-going 'wrong-doings' that exclude Indigenous and

other local peoples from protected areas themselves and from engagement in their establishment, management and benefits despite their long tenure in those areas and development of their cultures based on local biota. By including Indigenous and local people in management, protected area function may be enhanced. Third, there are challenges in protected area planning and management, within their boundaries and at the landscape scale. National and International politics and policies likewise influence function. Papers in this special issue cut across these topics.

1. Protected Areas Databases

Basic tenets of ecological inquiry are to first ask 'where, what, and how much'. Mapping of protected areas and including them in databases so they may be accessed and used in analyses, including those designed to assess biodiversity coverage, has been a vital function of several conservation initiatives. The World Database on Protected Areas, Protected Areas Database of the United States, Canada's Conservation Areas Reporting and Tracking System (Vanderkam 2016) [26], and National Conservation Easement Database are examples of comprehensive attempts to gather, standardize, and serve spatial data and protection attributes. Despite these efforts, standardized data on management interventions and changes in biodiversity inside and outside of protected areas "do not currently exist for any global sample of PAs, but need to be created" if the relationship to biodiversity outcomes is to be understood (Geldmann et al. 2018) [27].

What seems like a simple task of compiling public information into protected areas databases has not been simple for several reasons. First, there is the question of what to include in a protected areas database, i.e., what constitutes 'protection'. Classification systems of protected areas differ, such as the International Union for the Conservation of Nature (IUCN) Global Protected Areas Programme (Dudley et al. 2010) [28], and the GAP system of the United States Geological Survey (Dudley et al. 2010 [28]; Scott et al. 1993 [29]). This is why, for example, the World Database of Protected Areas includes about 200,000 global records, and the Protected Areas Database of the United States includes roughly the same amount (196,000) for the lower 48 states alone, i.e., the PADUS is more inclusive than the WDPA. Even though guidance exists for defining protected areas, such as for international tracking towards numerical targets under the Convention on Biodiversity's Aichi Target 11, it is up to signatory nation states and their sub-national jurisdictions to interpret the guidance for reporting purposes (MacKinnon et al. 2015) [30], and these interpretations may vary significantly, often for political purposes and sometimes triggering perverse consequences such as a proliferation of 'paper parks' that lack demonstrable conservation impact (Barnes et al. 2018) [31]. Second, there is the problem of obtaining accurate polygons or point locations for protected areas. The government and private entities who acquired, map, and manage the protected areas are responsible for providing those data. Metadata of protected area databases describe problems that pertain to lack of accuracy (such as https://gapanalysis.usgs.gov/padus/data/metadata/). In the United States, compilation of digital map data on public protected areas began in earnest in the 1990s (Scott et al. 1993 [29]). Thus it has been an ongoing project. Obtaining private protected area map data encounters reluctance on behalf of providers to share because of privacy concerns (Rissman et al. 2017) [24].

In this special issue, several authors address the issue of databases. Clements et al. [32] identify the emerging phenomenon of private lands conservation as a concern for database development and management. They review reporting procedures from three countries and recommend a process by which data can be reviewed according to 10 principles and subsequently included in the WDPA. Fundamental to their approach is the problem of equity in relation to reporting requirements and management, in particular for private landholders who may not currently receive the benefits of participating in reporting processes. Zurba et al. [33] address these issues in relation to Indigenous Protected and Conserved Areas (IPCAs), and raise the additional, perplexing legal and ethical issue of what may constitute 'Indigenous-led' when it comes to establishing and reporting on IPCAs, and the limitations and hesitations that Indigenous communities may have with reporting and tracking IPCAs within an imposed framework, particularly when they may receive no benefits for doing so.

Furthermore, they may risk being co-opted in the service of national or international quantitative targets for biodiversity protection, and thus inadvertently contribute to the colonial enterprise. Baldwin and Fouch [34] illustrate the role of small protected areas in conserving biodiversity and the special challenges of spatial data at these fine scales. They describe the area distribution of protected areas in the United States and find that they are, on average, very small (median 16 ha, mean 1648 ha). Additionally they identify potential errors of inclusion and exclusion, and hypothesize such errors may disproportionately influence mapping of small areas. Similarly to Clements et al. [32], they note that database errors probably do not accrue to large public ownerships, but rather smaller, private protected areas. In order to accurately assess how well the protected areas estate meets biodiversity goals, a base requirement is accurate, complete, and accessible data on coverage and effectiveness of protected areas.

2. Social Justice and Protected Areas

Protected areas are commonly assumed to be at the 'wild' end of a human domination gradient. This view undoubtedly arises from the history of protected area establishment in that remote 'rocks and ice' areas were systematically selected for conservation due to their low economic value, among other reasons. As human populations and activities proliferate in more remote areas, conservationists have had to grapple with new realities. Many protected areas are now embedded in human dominated landscapes (Figure 2).

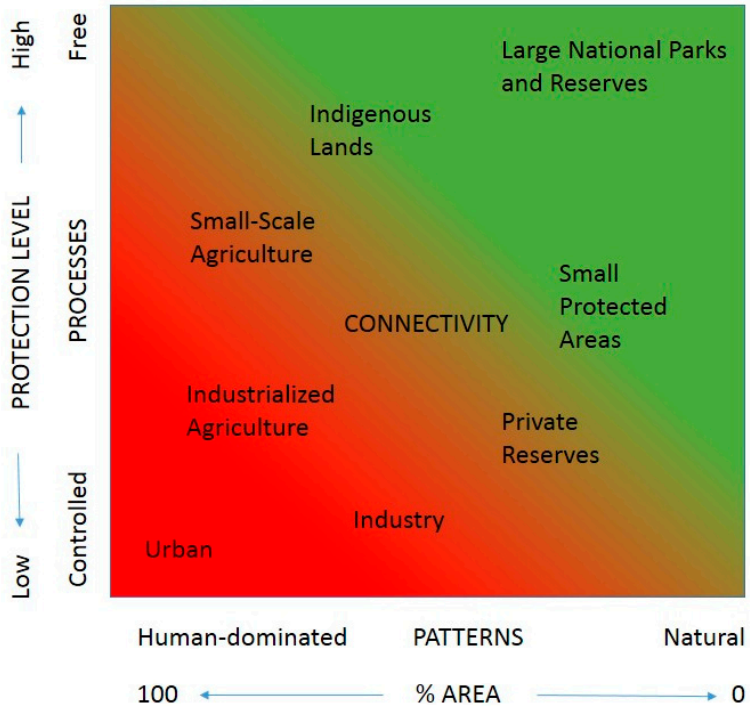

Figure 2. A gradient view of protected areas adapted from a human modification gradient (Theobald 2004) [35]. There are protected areas in virtually every human landscape context. Connectivity is noted in capital letters in the center in the portion of the gradient.

An emerging view is that people living in or near protected areas are not by default a threat to biodiversity and can be management partners. Their wellbeing needs to be part of the conservation equation, especially since poverty near protected areas creates a negative dynamic and can actually be alleviated by progressive management (DeFries et al. 2004) [36]. People have cultures and practices that arose from natural ecosystems, places, and organisms and these histories can become part of the conservation puzzle.

Conservation biology started in the 1980s as a discipline focused on the non-human world and anthropogenic threats to diversity. As realities of conservation have become more apparent, the field

has become much more inclusive of research on humans in and around protected areas as more than mere threats but in some ways, mechanisms for conservation (Klein et al. 2008 [37]; Powell et al. 2009 [38]). Thinking about the matrix in which protected areas sit, and how human activities outside protected areas can influence their effectiveness, contributes to a holistic view of landscapes moving from discrete areas of management and protection to working across the entire gradient of land uses (Anderson et al. 2012 [39]; Cushman et al. 2010 [40]). A view that protected areas are at one end of a management spectrum with intervening areas managed across a gradient of human activities has emerged so that a holistic, landscape view of habitat and permeability becomes more in focus. More area needs to be set aside, but the emerging view is that people's livelihoods and wellbeing be considered as part of the conservation equation if biodiversity protection is to be sustainable, and at the same time these matrix activities can be managed and directed to be less harmful and even beneficial for core protected areas.

In their assessment of global biodiversity hotspots, Cunningham and Beazley [41] point out the imperative to attend to both the wellbeing of the people who live there and the establishment of more protected areas. They identify that most hotspots in which protection has not yet reached 17% are located in countries that are struggling economically and also dealing with war, famine, social unrest, and rapid sea level rise. Half of these hotspots have population densities above the global average. They argue that it is unrealistic and unethical in terms of international equity to assume that protected area targets will be met in many of these regions without extensive assistance from the global community, that wealthy nations have a responsibility to address threats to biodiversity from their consumption of trade goods produced in hotspots outside their boundaries, and that novel approaches to biodiversity conservation should support human-nature coexistence in and beyond protected areas.

Special attention to social justice around protected areas is critical in relation to Indigenous communities, many of whom have experienced and continue to be at risk of dispossessions of their lands, livelihoods and wellbeing for conservation and development purposes. Despite international and national efforts around rights and reconciliation, such as the United Nations Declaration on the Rights of Indigenous Peoples, the Truth and Reconciliation Commission of Canada, and the ICCA[1] Consortium (Borrini-Feyerabend & Campese 2017) [42], meaningful engagement and partnership with Indigenous communities in protected area establishment and management is far from the norm. In this issue, McCarthy et al. [43] posit that the knowledge of Indigenous communities is too often ignored in management of protected areas due to cultural and other assumptions. Their study documents high levels of awareness of biodiversity and positive attitudes towards conservation within the local population near a National Park in Mongolia. Improved communication will more meaningfully engage local and Indigenous communities and help to overcome trust issues; however, as they and others point out, it is better to see Indigenous and local communities as collaborators and/or leaders, if possible, rather than solely as recipients or providers of knowledge, and certainly rather than adversaries—a view that is echoed throughout conservation literature (Colchester 2004) [44].

Zurba et al. [33] position Indigenous leadership (sovereignty) and collaborative governance of protected areas as a potential means of conservation through reconciliation. Indigenous-led Protected and Conserved Areas (IPCAs) express traditional values, responsibilities and Indigenous laws and worldviews, through land stewardship that encompasses the understanding of humans and non-humans as one community whose health is intertwined. In a similar vein, Ekblom et al. [45] show that the cultural connection to landscapes for people in Sub-Saharan Africa through ecosystem memories, landscape memories, and place memories is a powerful conservation dimension. Biocultural heritage connects identity, social cohesion, and practice with social and political negotiation and is thus, they argue, foundational to promoting stewardship.

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[1] ICCA is not an acronym. "It is an abbreviation for 'territories and areas conserved by indigenous peoples and local communities' or 'territories of life'." (https://www.iccaconsortium.org/index.php/discover/).

IPCAs exemplify the nexus of social justice, protected areas and biodiversity conservation. Through the lens of implementing IPCAs in Canada, Zurba et al. [33] examine wicked problems in relation to Aboriginal and Treaty Rights, Aboriginal title, building a nation-to-nation relationship with Canada, Aichi Target 11, and other international Indigenous rights and biodiversity conservation initiatives. Not the least of these is the exclusionary 'wilderness' paradigm pervasive in parks and protected areas, particularly in the global north and west but increasingly exported around the world, which has thus far proven difficult to supplant despite new more inclusionary paradigms that link Indigenous and other local peoples with conservation lands. Attention to both on-the-ground practices and high-level considerations is critical for equitable and just relations between Indigenous and conservation communities. These relations are necessary for protected areas and other arrangements that serve biodiversity conservation and reconciliation, and thus de-colonize institutions, peoples, and non-human nature. Complementary to the social justice imperative to uphold the rights of Indigenous peoples to their lands and its governance is the recognition that it is essential to meeting conservation goals in a practical sense: Indigenous lands, globally, intersect at least 40% of all protected areas, account for 37% of all remaining ecologically intact landscapes, and encompass >65% of the remotest and least inhabited anthropogenic biomes (Garnett et al. 2018) [46].

3. Protected Areas Planning and Management

Management of protected areas is conceptualized in three spatial categories: (1) management within the boundaries; (2) transboundary or ecosystem management at the landscape scale (Grumbine 1994) [47]; and (3) regional to global management of the establishment, legal status, and distribution of protected areas. Within-boundary management is first priority as a protected area cannot effectively contribute to landscape-level biodiversity processes as a functional core unless populations and communities within its boundaries are intact (Noss et al. 2002) [48]. Source populations for metapopulation dynamics depend on core areas of good habitat, and thus protected areas management should provide propagules for feeding processes at the landscape scale (Hunter & Gibbs 2007) [49]. By the same token, conditions outside of protected areas influence those inside, and landscape-level planning and management should improve within-area conditions. For example, population viability for wide ranging carnivores who have core habitat inside reserves is improved by restoring connectivity (Carroll 2006) [50]. Thinking at the systems level and not just about wildlife, it is impossible to consider landscape-level management and improve matrix conditions without considering human enterprise, as millions of people live and make their livings on the edges of protected areas and within them (DeFries et al. 2007 [51]; DeFries et al. 2010 [52]). Finally, management of the entire protected areas estate through regional, national, and global politics, priorities, and agreements requires a global level of cooperation through entities such as the International Union for the Conservation of Nature. With increasing globalization, attention to transboundary and ecosystem management at biome and continental scales is warranted to attend to large-scale regulating and supporting services and planetary boundaries associated with biodiversity.

In this issue, papers show the complexity of protected areas management and linkages between within-area problems and those external, and how spatial scale of influence extends far beyond the landscape matrix to global governance systems. Belote [53] focuses on the important issue of legal management status of protected areas and the risk of having status diminished, due to changes in national political leadership. His policy-based analysis examines impacts of proposed legislation that would demote 29 Wilderness Study Areas in the United States, and thereby reduce their protections. Since core wilderness areas are the bedrock of effective protected area networks, such policy-based demotions would lead to habitat declines in cores, and degrade overall biodiversity function (Soule & Terborgh 1999) [54]. On the other hand, Pasha et al. [55] describe a system to improve standards for management of wild tigers within areas. They propose that sites be audited against a broadly accepted set of standards and discuss the challenges in implementing such standards across a wide range of protected areas and within a tight community of tiger conservation professionals. Tiger reserves are

critically important for the continuance of that species, are scattered across many countries, and have differing management jurisdictions, priorities, and goals (Seidensticker et al. 1999) [56]. Standards and oversight of reserves might help.

Size, distribution, and isolation of protected areas is a central question. While large protected core areas remain the backbone of conservation, a very large number of small areas have been created. Baldwin and Fouch [34] show that there is a very large number of small protected areas that may have been protected for some local value, but whose cumulative biodiversity function is essentially unknown. Small protected areas are very numerous and may provide significant habitat in the matrix, stepping stones for dispersal, and protect localized, rare ecosystems but such spatially scaled research is only now emerging. Ekblom et al. [45] show that there are many small areas in Sub-Saharan Africa protected as sacred sites that also provide habitat for important species diversity. Local conservation is often focused on small natural areas near where people live and work in particular near where conservationists work (Baldwin & Leonard 2015) [57]. While they may not fulfill expectations as large core areas for biodiversity at the ecoregion scale, they may be important for many social, ecological, and economic reasons. More research is needed on small protected areas and how they contribute to overall biodiversity goals, yet it appears they are highly valued.

On the other end of the size spectrum are large protected areas. A small number of countries hold the global legacy of the last of the wild: >70% of the world's remaining wilderness is in five countries—Russia, Canada, Australia, US and Brazil (Watson et al. 2018) [58]. While most of these lands and seas are not officially protected, Wulder et al. [59] in this issue illustrate that large intact areas in Canada's boreal forest region are functioning as de facto protected areas, relatively free from development pressure, and that Canada is in a fairly unique position, globally, to expand the area under its protection, seizing this 'generational opportunity'. Along with formal protections, Wulder et al. [59] elaborate collaborative opportunities through commitments from industry, and provincial and territorial land stewards, and the contributions of First Nations and private protection programs. Consistent with Watson et al., such protections should be established in a way to slow the impacts of industrial activity on large landscapes or seascapes, acknowledge that protecting the livelihoods of Indigenous people can conserve biodiversity just as well as strictly protected areas can, and recognize local Indigenous community rights to land ownership and management. McCarthy et al. [43] examine how Indigenous people living alongside the protected area could improve the management of the protected area itself. They and Zurba et al. [33] show that Indigenous peoples have a good understanding of biodiversity management, and suggest that their systematic inclusion may result in better management outcomes.

Climate and land use change remain the greatest threats to biodiversity and protected areas. Tabor et al. [60] show that combined climate and deforestation risks within the humid tropical biome result in 2 million hectares at extreme risk, which therefore should be prioritized for conservation action. Hamad et al. [61] show that land use changes precipitated by war and economic sanctions have served to fragment forest patches in Iraq, which indicates the tight linkage between social and ecological systems that needs to be observed for the future of biodiversity conservation.

A unique global mechanism for biodiversity conservation based on climate change mitigation is proposed by Githiru and Njambuya [62]. They suggest that REDD+, the United Nations climate change mitigation scheme whose goal is to reduce emissions from deforestation and forest degradation in developing countries, can be harnessed for biodiversity conservation. Other authors caution that globally centralized forest governance should be evaluated in light of desire to give local people, including Indigenous people, more control over natural resources (Phelps et al. 2010) [63]. Githiru and Njambuya [62] address this by urging that bottom-up approaches be included in nested, polycentric schemes, concluding "the power of globalization enables a rural farmer in Kenya to play a role in global climate change mitigation, while a social worker in downtown New York can help conserve Elephants in Africa."

Emphasizing the increasing pressures on protected areas from outside their boundaries, Cunningham and Beazley [41] evaluated conservation threats in global biodiversity hotspots based on changes in human population density and protected area coverage. Over a 20-year timeframe (1995–2015), average population densities in the hotspots increased by 36%, double the global average. The Aichi Target 11 protected area goal of 17% was achieved in only half of the hotspots. In 2015, 15 of 36 global biodiversity hotspots remained in the highest threat category (i.e., population density exceeding global average, and protected area coverage less than 17%). Only two hotspots achieved a target of 50% protection, a scientifically defensible target for the hotspots, which are rich in endemic species and limited to less than 30% of their original habitat extent. They conclude that although conservation progress has been made in most global biodiversity hotspots additional efforts are needed to slow and/or reduce increases in population density and achieve protected area targets, and that such conservation efforts are likely to require support from the global community.

Globalization and externalization of cost are major drivers of biodiversity declines (Weinzettel et al. 2018) [64] as acknowledged by Cunningham and Beazley [41] and by Githiru and Njambuya [62]. There are growing trends and tensions in framing conservation policy in terms of ecosystem services rather than biodiversity (Cimon-Morin et al. 2013 [3]; Kusmanoff et al. 2017 [65]) with implications across boundaries at local to global scales. At the same time, if synergies can be found, these global processes may offer opportunities that support local biodiversity conservation, such as funding for protected area establishment and management, either for internal operations or reducing threats from outside (Angelsen 2008) [66]. Githiru and Njambuya's [62] calls for the polycentric approach of the nested REDD+ process are intended to address some of the globalization-driven biodiversity problems. They argue that such approaches have the potential to harness resources for protected area management and biodiversity conservation by using the appeal of greenhouse gas emissions as a global commodity, and that using carbon to build polycentric policy frameworks and infrastructure could facilitate future development of a similar system for biodiversity. Consistent with Cimon-Morin et al. (2013) [3], while there remain tensions and gaps, site complementarity for ecosystem services and biodiversity through systematic conservation planning could increase the efficiency for both. Global synergies could be derived particularly for large-scale regulating and supporting services such as carbon and climate regulation, which are considered to be at a maximum in intact ecosystems, potentially providing local funding in support of global conservation imperatives.

4. Summary

Protected areas are the gem of biodiversity conservation as they are areas set aside for natural pattern and process to prevail, relatively free from human intervention. Currently at about 15% coverage world-wide, they need to be two- to five-times more extensive if they are to meet science-based estimations of 25–75% protection and more effectively managed to maintain current levels of biodiversity. The scale of biodiversity loss is so great that the protected area estate alone is currently not equal to the task. Human activity dominates the surface of the land, has extensive impacts on the ocean, and dominates many ecosystems (Doney 2010 [67]; Venter et al. 2016 [9]). It is impossible to imagine the future of biodiversity without a profound human component as a major selective force, shaping patterns and processes for millennia, if the earth can bear it.

It may be best to view large core protected areas as one highly concentrated end of a gradient of biodiversity conservation measures with every other part of the landscape managed with a lesser degree of biodiversity benefits in mind. As such it is critical to imagine the losses to biodiversity conservation function should management or designation changes occur within existing protected areas that weaken their ability to meet conservation goals. Adding to the protected areas estate using the tools and techniques of systematic conservation planning is a major goal for governments and conservation organizations throughout the globe (Moilanen et al. 2009) [68]. Even so, the matrix in which protected areas sit contributes to their isolation or connectivity, and thus cannot be ignored (Crooks & Sanjayan 2006) [69].

Human activities in the matrix that would improve connectivity and help meet local conservation goals such as representation of rare endemics can be guided through economic incentives, management partnerships, local-scale conservation planning for small protected areas, agro-ecological programs, wildlife laws and enforcement, and environmental education. Compatible low-intensity human uses that provide complementary bio-cultural conservation and ecosystem services can supplement protected areas and serve to buffer them from external threats. While few examples exist specific to protected areas management outcomes, hundreds of examples around the world support that in human dominated landscapes habitat conditions can be improved by targeted programs and volunteer spirit (Hunter 1990 [70]; Lindenmayer & Hobbs 2004 [71]; Stubbs 2014 [72]; Vandermeer & Perfecto 2007 [73]).

As the planet continues to undergo massive, human-caused changes in climate, biogeography, and ecosystem function, it is important to continue research on mechanisms for biodiversity conservation. The existing protected areas estate is a tribute to the past commitment to conserve biodiversity, yet may reflect a different paradigm than needs to be employed to meet new protection goals. Today, we know more about the 'where' and 'why' for establishment of new protected areas than ever before (Margules & Pressey 2000 [12]; Steffen et al. 2015 [2]). We know less than we should about the 'how' and new scholarship is reflecting a plethora of plausible mechanisms. The papers in this special issue, although not exhaustive by any means, provide a window into emerging topics for biodiversity and protected areas.

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