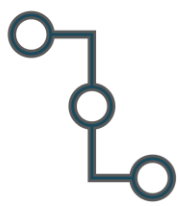
Assessing Progress Toward an Effectively Managed, Well-connected & Representative Global Protected Area Network


Heather Gough
FACULTY OF NATURAL RESOURCES MANAGEMENT, LAKEHEAD UNIVERSITY | THUNDER BAY, ONTARIO

ASSESSING PROGRESS TOWARD AN EFFECTIVELY MANAGED, WELL-CONNECTED, AND REPRESENTATIVE GLOBAL PROTECTED AREA NETWORK

by

Heather Gough

An Undergraduate Thesis Submitted in
Partial Fulfillment of the Requirements for the
Degree of Honours Bachelor of Environmental Management

Faculty of Natural Resources Management

Lakehead University

April 2022

________________________ ________________________

Major Advisor Second Reader

LIBRARY RIGHTS STATEMENT

A CAUTION TO THE READER

This HBEM thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

The reader should be aware that the opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, the faculty or Lakehead University.

MAJOR ADVISOR COMMENTS

ABSTRACT

Gough, H. Assessing Progress Toward an Effectively Managed, Representative, and Well-Connected Global Protected Area Network. April 2022. Pp. 37.

Keywords: biodiversity; CBD Aichi targets; connectivity; conservation; effective management; protected areas; representativeness.

Protected areas are a cornerstone of conservation efforts to prevent biodiversity loss. Aichi Target 11 of the Convention on Biological Diversity called for the area of protected areas to be increased to 17% of terrestrial and inland water and 10% of coastal and marine areas. It also called for those protected areas to be effectively managed, representative, and well-connected by 2020. These three qualities are crucial to conserving biodiversity within protected areas. This literature review has critically assessed the status of each of these qualities for the global protected area network.

This review examined why these qualities are vital to biodiversity conservation, how they are measured, their current extent of implementation, what the gaps in the data are, and what barriers are impeding their progress. Overall, studies indicate that the quality of protected areas has not kept up with the quantity. Approximately one-fifth of protected areas have effective management, just over half of the protected areas could be considered connected, and approximately one-third of ecosystems have adequate representation. This is to the detriment of effective biodiversity conservation.

For protected areas to realize their potential in biodiversity conservation, the qualities of the current and expanding protected area network need to be improved. It is recommended that efforts be concentrated toward increased collaboration and communication, increased financial resources, improved data quality, and the use of systematic conservation planning.

CONTENTS

TABLES

FIGURES

ACKNOWLEDGMENTS

I would like to thank my supervisors Dr. Dzhamal Amishev and Dr. Kevin Crowe, and my second reader Dr. Jian Wang, for all their advice and support. I would like to express my gratitude to my partner, Marc-André Gosselin for being a walking thesaurus, and his encouragement throughout my studies. Finally, I would like to extend my sincere appreciation to my parents and Judy Flavin for their unwavering support and belief in me.

INTRODUCTION

Human activity is bringing about global changes to land surfaces, oceans, and the atmosphere (Lewis & Maslin 2015). Land-use change leading to habitat degradation is one of the principal, direct drivers of biodiversity loss (Leader-Williams *et al.* 2010:349). In its Global Risks Report, the World Economic Forum (2020) listed biodiversity loss as one of the top five risks to humanity. The loss of biodiversity threatens the role that ecosystems play in providing essential services: nutrient and water cycling, pollination and seed dispersal, soil formation and retention, and climate regulation (Diaz *et al.* 2006). These services, in turn, provide food, fuel, fibre, and potable water which contribute to human health and quality of life (Diaz *et al*. 2006).

Protected areas are a cornerstone of conservation planning and an important element of preventing biodiversity loss (Geldmann *et al*. 2015, Dudley *et al.* 2004, Jones *et al*. 2018). In recent decades, there have been increased efforts by the global community to extend protected area coverage.

The loss of biodiversity is recognized as a global issue requiring a coordinated effort (Secretariat of the CBD 2000). In 1992, the United Nations Conference on Environment and Development in Rio De Janeiro developed the first global agreement on the conservation and sustainable use of biodiversity (Secretariat of the Convention on Biological Diversity 2000). This agreement, the Convention on Biological Diversity (CBD), has since been ratified by 175 countries (Secretariat of the CBD 2000). The agreement requires that each country develop a national biodiversity strategy and action plan and commit to creating protected areas for the conservation of biodiversity (Secretariat of the CBD 2000).

To move towards the objectives of the Convention on Biological Diversity, a strategic plan for 2011-2020 and 20 Aichi Targets were set at the Nagoya conference in 2010. Target 11 specifically called for protected areas to be increased and improved by 2020. The target stated that at least 17% of terrestrial and inland water and 10% of coastal and marine areas are to be conserved through effectively managed, representative, and well-connected systems of protected areas (Secretariat of the Convention on Biological Diversity 2010).

There has been considerable progress and success in meeting global targets for protected areas in terms of percentage-area covered. As of 2020, 16.6% of terrestrial and inland water areas and 7.7% of coastal and marine areas have been included in protected areas (Figure 1) (UNEP-WCMC and IUCN 2021). The protected area added in the last decade accounts for 42% of the total area, with marine areas accounting for nearly 90% of that recently added area (UNEP-WCMC and IUCN 2021). However, the progress towards these areas being managed effectively, well-connected, and representative has been slower (UNEP-WCMC and IUCN 2021). This is to the detriment of these areas achieving biodiversity conservation objectives. (Barnes *et al*. 2018, Mammides *et al*. 2021)

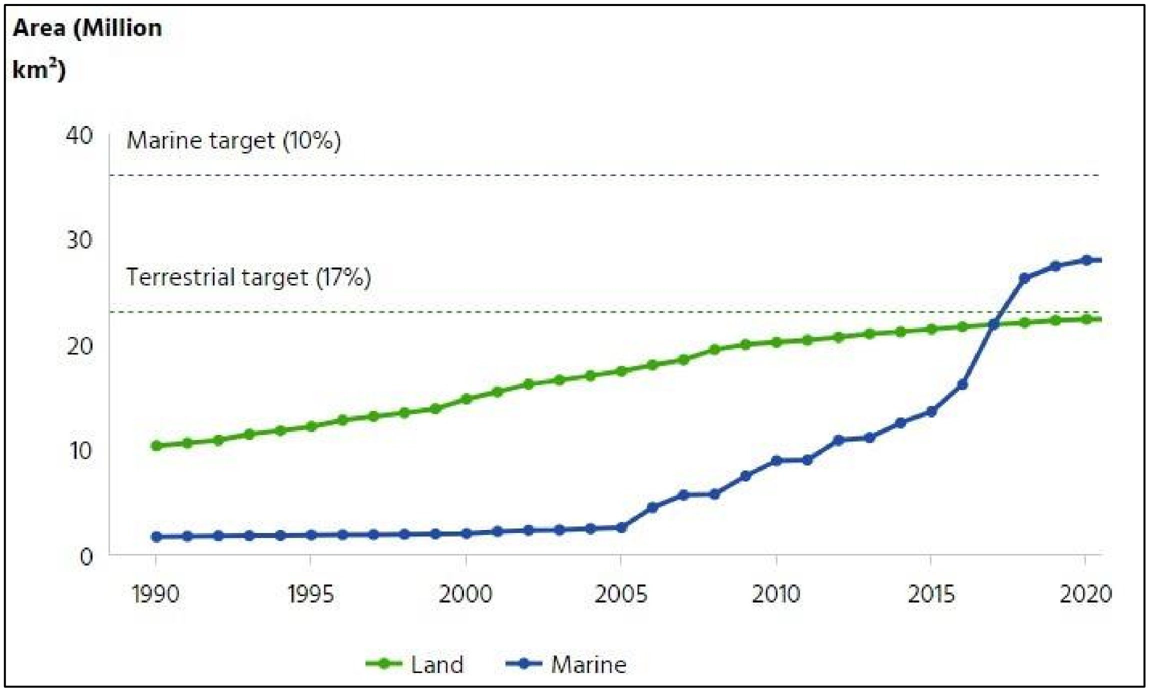


Figure 1. Change in coverage of marine and terrestrial protected areas and OECMs from 1990 to 2020. (UNEP-WCMC and IUCN 2021)

There is concern that the targets focus on quantity and undermine quality (Visconti *et al*. 2019). It is possible to reach percentage area targets while perpetuating biases that subvert biodiversity conservation goals (Visconti *et al*. 2019). Large areas, areas not immediately threatened, or areas with minimal biodiversity could be selected (Visconti *et al*. 2019). Studies have also shown that protected areas are biased towards higher elevations, steeper slopes, and lands of lower productivity, lower economic worth and low human density (Rodrigues *et al.* 2004, Venter *et al*. 2017, Hazen & Anthatten 2004). When designating protected areas, the conservation of biodiversity has often been secondary to other motivations such as low value for resources and benefits for recreation and tourism, among others (Pressey 1994). The targets have enabled protected areas that are important to conservation to be downsized or degazetted and replaced with areas of a similar size but less conservation value (Visconti *et al.* 2019).

Management effectiveness, connectivity and representativeness are measures of the quality of protected areas. Management effectiveness measures how well protected areas are preserving their values and attaining their goals and objectives (Leverington *et al*. 2010). Connectivity indicates the extent that a landscape either helps or hinders the movement of organisms across areas of habitat, which aids in the persistence of viable populations in increasingly fragmented landscapes (Belise 2005, Saura *et al*. 2018). Representativeness at the global scale is often interpreted as even coverage of the world's ecoregions (Mammides *et al*. 2021). Striving towards representativeness recognizes that it may not be possible to save everything and concentrates efforts on preserving a representative sample of all ecosystem types (Chauvenet *et al*. 2020).

Although the targets for protected area coverage have nearly been achieved, biodiversity is still in decline (Butchart *et al*. 2010). Studies have shown greater richness and/or abundance of species inside some individual protected areas than outside but this outcome is not universal for all protected areas (Mora & Sale 2011). Watson *et al.* (2015) found that some nations have successfully increased the effectiveness of their protected areas and the representation of underrepresented ecosystems with positive outcomes for threatened species. However, they considered protected areas overall to be inefficient due to poor location and management. They point to issues of corruption, poor governance, and insufficient financial resources for enabling habitat loss and resource exploitation to persist within protected areas.

This thesis will review the literature concerning effective management, connectivity and representativeness within the global network of protected areas. It will summarize and identify: i) why these qualities are vital to conserving biodiversity within protected areas, ii) how these qualities are measured, iii) to what extent the current global network is managed effectively, well-connected, and representative, iv) the gaps in the data, and v) the barriers to progress. The thesis concludes with recommendations to improve progress towards Aichi Target 11.

METHODS AND MATERIALS

This undergraduate thesis is a literature review. This review aims to assess management effectiveness, connectivity and representativeness in the global network of protected areas; provide an overview of their status; and make recommendations for improvement moving forward.

Peer-reviewed journal articles were examined along with selected studies cited in the articles. Keyword searches included: “global protected areas”, “management effectiveness”, “representativeness”, and “connectivity”.

Websites for the International Union for Conservation and Nature (IUCN), the Convention on Biological Diversity (CBD), and the Protected Planet were also consulted to consider international policies and progress towards the protection of biodiversity through the establishment of conservation areas.

LITERATURE REVIEW

MANAGEMENT EFFECTIVENESS

What are protected areas managed for?

The International Union for Conservation of Nature (IUCN) has helped to coordinate the global community's protected area actions (Leroux *et al*. 2009). To help with communication and reporting, it categorized protected areas (Table 1) and for each category set different levels of protection, management approaches, and intensity of land use for other purposes (Leroux *et al.* 2009). While there are various management objectives, the main purpose for all IUCN protected areas is to conserve nature (Jones *et al*. 2018).

Table 1. A summary of the IUCN definitions for protected area categories. There are six management categories with one sub-division, classified according to their management objectives. The table has been adapted from Leroux *et al.* 2009, Dudley 2008, and IUCN 2021.

Category	Title	Description
Ia	Strict nature reserve	• Characteristics: Exceptional ecosystems, strictly protected. • Objectives: To protect biodiversity and/or geological or geomorphological features. • Human uses: Strictly controlled and limited visitation. Scientific research and monitoring.
Ib	Wilderness area	• Characteristics: Often large, unmodified, or somewhat modified areas. • Objectives: To preserve their natural condition. • Human uses: Public access allowed but limited to maintain wilderness qualities. Use by indigenous communities to maintain traditional lifestyle. No permanent or significant human habitation.

II	National park	• Characteristics: Large, natural, or near natural. • Objectives: To protect large-scale ecological processes with characteristic ecosystems or species. To promote education and recreation. • Human uses: Cultural, spiritual, scientific, educational, and recreational opportunities.
III	Natural monument or feature	• Characteristics: Typically small, can be a landform, sea mount, marine cavern, geological feature, or living feature. • Objectives: To protect a specific natural monument. • Human uses: High visitation and tourism.
IV	Habitat/species management area	• Characteristics: Variable size, often small. Areas that have already undergone considerable modification. Often fragments of an ecosystem. • Objectives: To prioritize the protection of targeted species or habitats, through conservation or restoration. • Human uses: Active management or interventions.
V	Protected landscape or seascape	• Characteristics: Distinct area for ecological, biological, scenic, or cultural value that was shaped by human-nature interactions over time. • Objectives: To maintain a balanced human-nature interaction. To protect and sustain the area's values. To provide socio-economic opportunities through recreation and tourism. • Human uses: Traditional management practices. Recreation and tourism.
VI	Protected areas with sustainable use of natural resources	• Characteristics: Commonly large, mostly natural. A share of the area is under sustainable natural resource management. • Objectives: To protect natural ecosystems with concurrent sustainable natural resource use. • Human uses: Low-level nonindustrial use of natural resources.

Why is effective management vital to conserving biodiversity in protected areas?

A protected area must be managed for the long-term conservation of nature (Visconti *et al.* 2019). If biodiversity values are to be maintained, then the negative impacts of threats need to be mitigated with effective management (Di Minin & Toivonen 2015). However, many protected areas have inadequate management and resources and thus contribute to the widespread phenomenon of "paper parks", where protected areas exist in name only. These "paper parks" are areas protected through legislation but lacking resources for implementation, and threats to biodiversity continue within them (Figueiredo 2007). Many protected areas are not meeting their basic objectives (Watson *et al.* 2014). For example, Clark *et al.* (2013) conducted a study in South Asia that found habitat conversion rates inside protected areas to be indistinguishable from rates on unprotected land. They asserted that substantially enhancing the management of protected areas is urgently needed.

How is management effectiveness measured?

Protected Area Management Effectiveness (PAME) assessments are used to evaluate the strengths and weaknesses of management in protected areas (Ervin 2003, Leverington *et al*. 2010). Many different methodologies for these assessments have been developed by independent organizations and used throughout the world (Leverington *et al*. 2010). Most methodologies are questionnaires with a scoring system and are completed by protected area managers, government agency employees, or donor institutions (Geldmann *et al*. 2015). The questions are usually qualitative and rely on the assessor's knowledge and judgment (Cook *et al*. 2014).

Assessments can improve the management of protected areas. Ervin (2003) found they can do this by determining discrepancies between the plans and intentions for protected areas and actual conditions. Also, they identify threats and pressures on areas and valuable insights into their scope and prevalence are gained. This information can then be used by policymakers to adjust strategies and allocate funds to address threats and improve outcomes.

Leverington *et al.* (2010) performed a cross-analysis to compare the findings of completed assessments. They summarized the overall mean score for each protected area's management effectiveness. They also summarized trends, analyzed the strengths and weaknesses of management, and determined which areas of management are most correlated with successful outcomes.

<u>To what extent is the current global protected area network managed effectively?</u>

Leverington *et al.* (2010) collected and compiled data from more than 8000 PAME assessments from around the world. When considering the 3184 most recent assessments, they found that 13% of the assessed areas had inadequate management, 65% had basic management, and 22% had sound management (Figure 2). The study found that many protected areas had low scores for adequate resourcing, communication and community relations, resource management, and management planning and adaptive management.

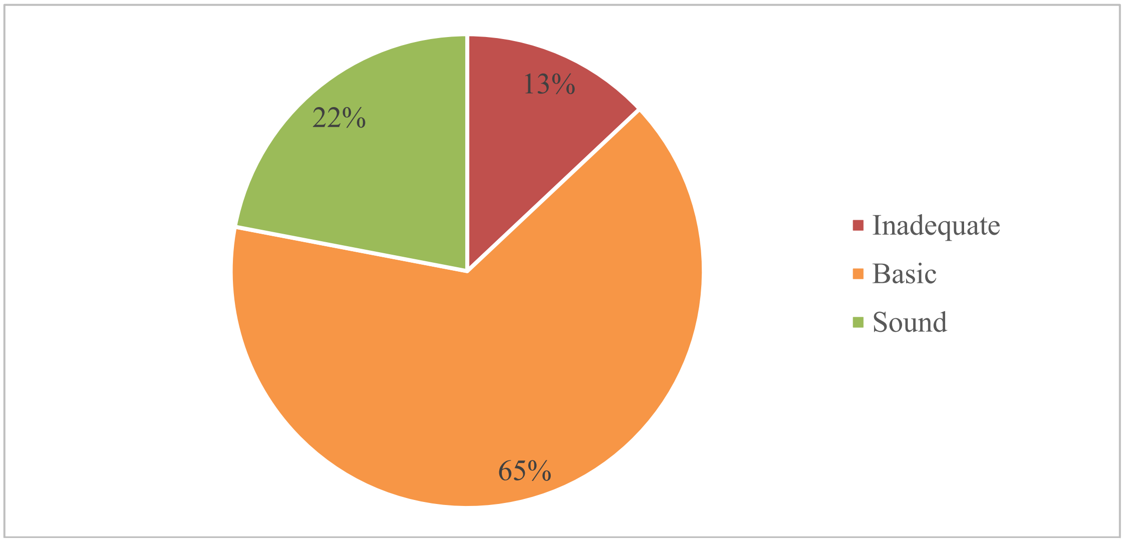


Figure 2. Scores for protected area management based on 3184 PAME assessments. Adapted from Leverington *et al*. 2010.

Leverington *et al.* (2010) note that the results do not reflect a random sample of protected areas. The study was likely biased towards lower performance parks as there was a prevalence of protected areas under development aid programs that have program requirements for management assessments.

Geldmann *et al.* (2015) examined how management and governance of protected areas change over time. They used the management effectiveness tracking tool (METT), a type of PAME assessment, multiple times for the same protected areas. METT collects information on objectives, threats, budgets, staffing, size, designations, and management. Their analysis of METT assessments for 722 protected areas found that 70% of the protected areas had improved METT scores, while 25% had decreased scores and 5% showed no change.

<u>What are the gaps in the data?</u>

There are no data for the management effectiveness of most protected areas. PAME assessments have been conducted for only 11% of protected areas (UNEP-WCMC and IUCN 2021). Moreover, the metrics used for PAME assessments measure management inputs and outputs with minimal information pertaining to biodiversity outcomes (Visconti *et al.* 2019).

<u>What are barriers to progress in management effectiveness?</u>

The main reason for the poor performance of protected areas generally is inadequate funding and resources, particularly in the developing world (Bruner *et al*. 2001, Watson *et al*. 2014).

PAME assessments provide valuable insights into needed improvements and enable policymakers to apply adaptive management (Ervin 2003). If more funding was allocated to PAME assessments, their findings could be used to improve management effectiveness in individual protected areas and within the global network as a whole.

CONNECTIVITY

<u>Why is connectivity vital to conserving biodiversity in protected areas?</u>

Connectivity refers to the extent that a landscape either helps or hinders the movement of organisms across areas of habitat (Belise 2005). Habitats have become increasingly fragmented by human activity that changes landcover types (Santini *et al.* 2016). Connectivity among fragments has been shown to affect population persistence (Santini *et al*. 2016). The connectivity of protected areas enables gene flow, migration, and species range shifts (Saura *et al*. 2018). These are large-scale ecological and evolutionary processes that help to maintain viable populations. (Saura *et al*. 2018). Conversely, species that have been confined to increasingly small and isolated habitat patches are more vulnerable to stochastic events and face a higher likelihood of local extinction (Santini *et al*. 2016).

Managing a landscape for increased connectivity often involves the creation of landscape corridors or stepping-stone reserves (Krosby *et al*. 2010). A meta-analysis that assessed the effectiveness of corridors found them to be overall effective in facilitating movement and dispersal, with corridors generally increasing migration between habitat patches by 50% compared to isolated patches (Gilbert-Norton *et al.* 2010). This analysis found that all taxa, other than avian species, were likely to use corridors. The study also found natural landscape corridors facilitated movement better than manipulated corridors and recommended protecting natural landscape corridors over efforts to create corridors.

Saura *et al.* (2017) maintain that connectivity of protected areas is particularly urgent in the context of climate change. They point to projections that predict some protected areas will become uninhabitable for certain species that currently occupy them. They found that species will need to move locations to those that match their environmental requirements. They assert that connectivity is the key to facilitating these movements and preventing protected areas from becoming climatic traps.

How is connectivity measured?

The methods used to measure connectivity vary depending on the scale of the study. Santini *et al.* (2016) found that connectivity studies have largely focused on single species, as the movement of species is very much species-specific and landscape dependent. They indicate that single-species studies have been conducted with local, long-term field studies. They also found that multi-species approaches have been formulated to assess connectivity at the landscape scale. They indicate that these approaches estimate potential connectivity based on simplified metrics of species' characteristics, assumptions, and algorithms.

To measure the connectivity of the protected area network at the global scale researchers have used graph theory (Santini *et al.* 2016, Saura *et al.* 2017). These researchers applied a range of dispersal distances that reflect the dispersal abilities of terrestrial mammals with different sizes of home range. Santini *et al* .(2016) applied this method to analyze protected area connectivity at country and continental scales across the globe. While Saura *et al.* (2017) applied a similar method to assess intra- and inter-protected area connectivity for the world's terrestrial ecoregions. For the spatial data of protected areas, these analyses used the World Database on Protected Areas (WDPA). This database includes national sites, sites under regional agreements, and sites under international conventions and agreements (Saura *et al.* 2017).

To what extent is the current global protected area network well-connected?

Saura *et al.* (2017) found that protected, connected lands represent 63% of protected lands when a median dispersal distance of 10 km is used. At a time when terrestrial protected areas covered 14.7% of the world's ecoregions, this analysis found that only 9.3% of the area was protected and connected.

The study by Saura *et al.* (2017) found a great range of variability in protected area connectivity by ecoregion. Their results highlight that some ecoregions have yet to be afforded any protected area and therefore were found to have 0% protected area connectivity. Conversely, other ecoregions have extensive protected area networks and were found to have up to 100% protected area connectivity. According to the results of this study, areas with the greatest levels of protected, connected lands include: the tundra and taiga of Alaska, the moist forests of Brazil and Venezuela, Europe, Greenland, the Tibetan plateau in China, most ecoregions adjacent to the Caribbean Sea in Central America, and in several ecoregions in Southern Africa, and in Western-Central and Tropical Australia. In contrast, this study revealed areas with the lowest levels of protected, connected lands include most of North America, southern South American, Northern Africa, and most of Asia.

Santini *et al.* (2016) found that there is a need to enhance connectivity across country borders, particularly among several countries in Asia and North and South America. They also found the spatial arrangement of protected areas to vary greatly from one continent to the next. They highlighted Europe and Africa to exemplify two extremes. They found that in Europe, where human population density is generally high, protected areas occur at high densities and are typically small. In Europe, they determined that dispersal is largely dependent on inter-protected area connectivity, and dispersal distance is a strong determinant of connectivity. They found that in Africa, protected areas are typically large and distant from one another. In Africa, they determined that dispersal is largely dependent on intra-protected area connectivity, as the distance between protected areas is often too large for even long-distance dispersers. On this continent, they concluded that dispersal ability has little bearing on connectivity, as species can disperse and persist within large protected areas.

What are the gaps in the data?

The WDPA provides the most extensive and accurate dataset on global coverage of protected areas (Hazen & Anthamatten 2013). However, the data submitted to the WDPA are almost exclusively from national governments (Bingham *et al.* 2021). While these governments record the data for protected areas that they manage, private protected areas are under-reported (Bingham *et al.* 2021). With minimal reporting on private protected areas, the WDPA dataset does not allow for a comprehensive picture of connectivity (Bingham *et al.* 2021).

What are barriers to progress in connectivity?

Santini *et al.* (2016) suggest that setting quantifiable targets for connectivity could help focus efforts on improvement. They recommend that targets could be set by using protected area networks with high connectivity as a reference and setting their level of connectivity as a target for others. Alternatively, they also suggest a simulation model could be used to determine the maximum potential level of connectivity for a network of protected areas, and targets could be set based on that.

REPRESENTATIVENESS

Why is representativeness vital to conserving biodiversity in protected areas?

Ecological representation ensures that biodiversity features are included within the protected area network, thus safeguarding their persistence (Kuempel *et al.* 2016). Efforts focus on preserving a representative sample of all ecosystem types (Chauvenet *et al.* 2020). By maximizing the representation of a diversity of ecological systems in protected areas, a greater number of species and habitats can be protected (Aycrigg *et al.* 2015). Also, the resilience of species and habitats to global change is enhanced (Aycrigg *et al.* 2015).

How is representativeness measured?

Representativeness at the global scale is typically considered in terms of ecoregion, biomes, or realms (Mammides *et al*. 2021, Woodley *et al.* 2012). Ecoregions represent distinct assemblages of communities and species (Mammides *et al*. 2021).

To assess the representation of ecosystems in global protected areas at a finer scale than ecoregions, Sayre *et al.* (2020) developed a higher resolution (250 m) map of world ecosystems that integrates climate, terrain, and vegetation data. The data were further stratified by the biogeographic realm, as similar ecosystems on different continents contain different species compositions. The study mapped 431 global ecosystems, of which 278 were used in their assessment of representation. The researchers excluded highly converted ecosystems and ecosystems deemed too small to count (< $10 km^2$ globally). The researchers overlaid the world ecosystems map with the

WDPA map and conducted a gap analysis. The gap analysis included all protected areas, with all levels of IUCN designation, as well as protected areas that do not have an IUCN category designation.

To what extent is the current global protected area network representative?

Sayre *et al.* (2020) found that 33% of ecosystem types had a protection level greater than 17% and 38% of ecosystem types were between 8.5% and 17% protected. The proportion of ecosystems with less than 5% coverage was 14% (Figure 3).

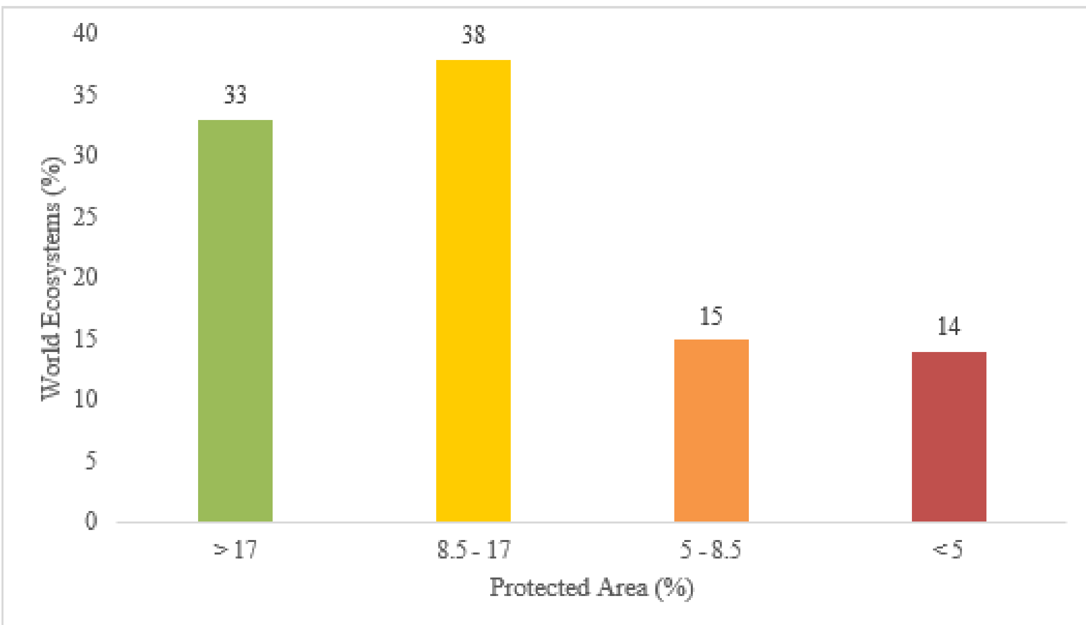


Figure 3. Protected area percent coverage of world ecosystems. Adapted from Sayre et al. 2020.

The results from the Sayre *et al.* (2020) study indicate that global ecosystems and species are insufficiently represented within the global network of protected areas Their analysis found that only one-third of ecosystem types had more than 17% of their area included in a protected area. Also, they found that the eight ecosystem types with the greatest proportion protected were all snow and ice classes.

Kuempel *et al.* (2016) evaluated the increase in ecological representativeness relative to the increase in protected areas coverage over time. Their study analyzed the protected areas of 66 countries over two decades, and found that for 64 countries, the increase in representativeness was not statistically different from a random distribution.

<u>What are the gaps in the data?</u>

There is disagreement on how to define representation (Hazen & Anthamatten 2013). Trying for equal representation of all ecoregions or ecosystems will not likely achieve the greatest levels of protection for biodiversity because ecoregions and ecosystems vary greatly in biodiversity, ecological function, and threats to ecosystems (Hazen & Anthamatten 2013). Alternative approaches to representativeness have been suggested, such as targeting protection of key biodiversity areas or threatened species (Hazen & Anthamatten 2013, Venter *et al.* 2014). Threatened species are currently under-represented in protected areas (Venter *et al.* 2014). Only 15% of threatened vertebrates are adequately covered within protected areas, and 17% of threatened vertebrates have zero representation in protected areas (Venter *et al*. 2014). Sites that contain threatened, restricted-range, or site-endemic species have been identified as key biodiversity areas and the most important places for conserving biodiversity (Butchart *et al.* 2012). However, as protected area coverage has expanded over time, the proportion of protected areas covering key biodiversity areas has declined (Butchart *et al.* 2012). For representation targets to be more impactful, the definition of representation needs to be broadened to incorporate these prioritization schemes (Hazen & Anthamatten 2013).

What are barriers to progress in representativeness?

Mammides *et al.* (2021) point out that the progress towards an ecologically representative protected area network has been hindered by a lack of coordination between countries that contain the same ecoregions. The authors highlight that nearly half of the world's ecoregions are in more than one country, and transboundary coordination has thus far been insufficient. Moreover, they find that the uneven representation can be attributed to the amount of land available for protection within countries and differing percentages of protected areas among countries.

Progress towards ecological representation has also been hindered because it has not been prioritized over other motivations for protected area designation. Baldi *et al.* (2017) found that protected area designation has primarily been driven by opportunities provided by isolation and low population density. They found the secondary driver has been a preference for areas that are attractive to tourism. Lastly, they found representativeness has had a relatively minor effect in shaping the distribution of protected areas. From this, they infer that representativeness has not been prioritized in the distribution of protected areas, contrary to conservation agendas.

RECOMMENDATIONS

1. Increase collaboration and communication

Increased collaboration and communication between countries are recommended to improve management, connectivity, and representation. Management effectiveness could be improved through sharing best management practices. Since many protected areas face similar threats, protected area managers would be better supported by sharing successes and failures of management strategies (Di Minin & Toivenen 2015). Representation could also be improved through timely reporting of national conservation plans, and for countries to consider the plans of others when planning the expansion of protected areas (Mammides *et al.* 2021). Similarly, transboundary collaboration is recommended to improve the connectivity of the protected area network (Santini *et al.* 2016).

2. Increase financial resources

A lack of financial resources is the principal limitation to effective management (Di Minin & Toivenen 2015). Countries need to adequately invest in protected areas to achieve their objectives (Watson *et al.* 2014). Investment can be supported through better recognition of the benefits of protected areas, such as increased socio-economic well-being of citizen. It can also be facilitated through better recognition of return on investment, considering contributions to the economy in tourism, the value of ecosystem services, and the costs associated with degraded ecosystems. Inadequate funding and resources are particularly pronounced in developing countries and international donors need to increase funding here (Di Minin & Toivenen 2015).

3. Improve data quality

Private protected areas make a significant contribution to the global protected area network, but they are not recognized or included in reports (Bingham *et al.* 2021). It is difficult to draw conclusions on the current global protected area network with an incomplete data set (Bingham *et al.* 2021). To move forward, we need to understand what currently exists.

4. Utilize systematic conservation planning

It is recommended that systematic conservation planning be used to help fill the gaps in ecosystems and threatened species representation in the global network of protected areas (Polak *et al.* 2016). It is commonly regarded as the most effective approach for protected area network design (Smith *et al.* 2006). However, its application has been limited (Smith *et al.* 2006). Systematic conservation planning is a target-driven process, that can aim to maximize both ecosystems and threatened species representation while minimizing costs (Smith *et al.* 2006, Polak *et al.* 2016). These models can incorporate trade-offs and cost-benefit analyses to support decisions in protected area expansion (Polak *et al.* 2016).

CONCLUSION

The global community has made great progress in expanding the protected area network (UNEP-WCMC and IUCN 2021). However, area alone is not a reliable indicator of successful conservation. The qualities of effective management, connectivity and representativeness are crucial to successful biodiversity conservation, yet they have been left behind. These qualities require drastic improvement if protected areas are to make a genuine contribution to halting biodiversity loss. The global community can work towards improving the quality of protected areas and biodiversity outcomes through increased international cooperation, increased financial resources, improved data quality and strategic placement by use of systematic conservation planning (Di Minin & Toivenen 2015, Watson *et al.* 2014, Bingham *et al.* 2021, Polak *et al.* 2016). The global network of protected areas has the potential to provide security for humans and all living organisms (Watson *et al.* 2014). By achieving effective management, connectivity, and ecological representation, its potential can be realized.

This review looked at the qualities of protected areas from a global perspective. Due to the broad scale of this analysis, the complexities at local or regional levels were not addressed. The studies highlighted in this report provide an impression of the quality deficiencies that protected areas face. However, it was by no means exhaustive in its analysis of all studies that have been undertaken on this subject. This review also did not address equitable management. There are both benefits and burdens placed on local communities with the designation of protected areas (Calvo *et al.* 2017). While social equity is an important aspect of the long-term sustainability of protected areas, it was considered beyond the scope of this research.

LITERATURE CITED

Aycrigg, J.L., Tricker, J., Belote, R.T. … Aplet, G.H. 2015. The next 50 years: opportunities for diversifying the ecological representation of the national wilderness preservation system within the contiguous United States. Journal of Forestry. 114 (3): 396-404.

Baldi, G., Texeira, M., Martin, O.A., Grau, H.R. & Jobbagy, E.G. 2017. Opportunities drive the global distribution of protected areas. PeerJ. 5:e2989.

Belise, M. 2005. Measuring landscape connectivity: the challenge of behavioural landscape ecology. Ecology 86(8): 1988-1995.

Bingham, H., Fitzsimons, J.A., Redford, K.H., Mitchell, B.A., Bezaury-Creeel, J., Cumming, T.L. 2017. Privately protected areas: advances and challenges in guidance, policy, and documentation. Parks. 23(1): 13-28

Bishop, K., Dudley, N., Phillips, A., Stolton, S. 2004. Speaking a common language: the uses and performance of the IUCN system of Management categories for protected areas. Cardiff University, Cambridge.

Bruner, A.G., Gullison, R.E., Rice, R.E. & da Fonseca, G.A.B. 2001. Effectiveness of Parks in Protecting Tropical Biodiversity. Science. 291: 125-128

Bunn, A.G., Urban, D.L. & Keitt, T.H. Landscape connectivity: A conservation application of graph theory. Journal of Environmental Management. 59: 265-278

Butchart, S.M., Walpole, M., Collen, B. … Watson, R. 2010. Global biodiversity: indicators of recent declines. Science. 328: 1164-1168

Butchart, S.H.M., Scharlemann, J.P.W., Evans, M.I., … Woodley, S. 2012. Protecting important sites for biodiversity contributes to meeting global conservation targets. PLoS ONE 7(3): e32529.

Calvo, N.F., Pascual, U., Brockington, D. … Burgess, N.D. 2017. Towards an indicator system to assess equitable management in protected areas. Biological Conservation. 211 (A): 131-141.

Clark, N.E., Boakes, E.H., McGowan, P.J.K., Mace, G.M. & Fuller, R.A. 2013. Protected areas in South Asia have not prevented habitat loss: a study using historical models of land-use change. PLoS ONE 8(5): e65298

Cook, C.N., Carter, R.W. & Hockings, M. 2014. Measuring the accuracy of management effectiveness evaluations of protected areas. Journal of Environmental Management 139: 164-171

Chauvenet, A.L.M., Watson, J.E.M., Adams, V.M. … Possingham, H.P. 2020. To Achieve Big Wins for Terrestrial Conservation, Prioritize Protection of Ecoregions Closest to Meeting Targets. One Earth 2: 479-486.

Diamond, J. 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biological Conservation, 7, 129–146.

Diaz, S., Fargione, J., Chapin, F.S., Tilman, D. 2006. Biodiversity loss threatens human well-being. PLoS Biol 4(8):e277.

Di Minin, E. & Toivonen, T. 2015. Global protected area expansion: creating more than paper parks. BioScience. 65 (7): 637-638.

Dudley, N. 2008. Guidelines for Applying Protected Area Management Categories. IUCN, Gland, Switzerland

Dudley, N., Hockings, M. & Stolton, S. 2004. Options for guaranteeing the effective management of the world's protected areas. Journal of Environmental Policy & Planning 6, 131–142.

Ervin, J. 2003. Rapid Assessment of protected area management effectiveness of four countries. BioScience. 53(9): 833-841

Figueiredo, C.C.M. 2007. From paper parks to real conservation: case studies of national park management effectiveness in Brazil. PhD dissertation. Ohio State University. Ohio. Pp 382.

Geldmann, J., Coad, L., Barnes, M. … Burgess, N.D. 2015. Change in protected area management effectiveness over time: a global analysis. Biological Conservation 191: 692-699

Gilbert-Norton, L., Wilson, R., Stevens, J.R. & Beard, K.H. 2010. A meta-analytic review of corridor effectiveness. Conservation Biology. 24(3): 660-668.

Hazen, H.D. & Anthamatten, P.J. 2004. Representation of ecological regions by protected areas at the global scale. Physical Geography, 25:6, 499-512

Hockings, M., Stolton, S., Leverington, F., Dudley, N., Courrau, J. 2006. Evaluating effectiveness: A framework for assessing management effectiveness of protected areas. 2nd edition. IUCN, Gland, Switzerland and Cambridge, UK. XIV + 105pp.

Jones, K.R., Venter, O., Fuller, R.A. … Watson, J.E.M. 2018. One-third of global protected land is under intense human pressure. Science. 360: 788-791

Krosby, M., Tewskbury, J., Haddad, N.M. & Hoekstra, J. 2010. Ecological connectivity for a changing climate. Conservation Biology. 24(6): 1686-1689.

Kuempel, C.D., Chauvenet, A.L.M. & Possingham, H.P. 2016. Equitable representation of Ecoregions is slowly improving despite strategic planning shortfalls. Conservation Letters. 0(0): 1-7

Leader-Williams, N., Adams, W.M. & Smith, R.J. 2010.Trade-offs in conservation: deciding what to save. Blackwell Publishing Ltd. West Sussex. 397 pp.

Leroux, S. J., Krawchuk, M.A., Schmiegelow, F. … Petkova, M. 2009. Global protected areas and IUCN designations: Do the categories match the conditions? Biological Conservation 143: 609-616.

Leverington, F., Costa, K.L., Pavese, H., Lisle, A., Hockings, M. 2010. A global analysis of protected area management effectiveness. Environmental Management. 46:685-698

Leverington F. & Hockings M. 2004. Evaluating the effectiveness of protected area management: the challenge of change. In: Barber CV, Miller KR, Boness M (eds) Securing protected areas and ecosystem services in the face of global change. IUCN, WCPA,WRI, Gland, Switzerland, pp 169–214

Lewis, S.L. & Maslin, M.A. 2015. Defining the Anthropocene. Nature. Vol 519: 171-180.

Mammides, C., Goodale, E., Elleason, M., Corlett, R.T. 2021. Designing an ecologically representative global network of protected areas requires coordination between countries. Environ. Res. Lett. 16 : 121001

Mora,C. & Sale, P. 2011. Ongoing global biodiversity loss and the need to move beyond protected areas: a review of the technical and practical shortcomings of protected areas on land and sea. Marine Ecology Progress Series. 434: 251-266.

Polak, T., Watson, J.E.M., Bennet, J.R., Possingham, H.P., Fuller, R.A. & Carwardine, J. 2016. Balancing ecosystem and threatened species representation in protected areas and implications for nations achieving global conservation goals. Conservation Letters. 9 (6): 438-445.

Rodrigues, A.S.L., Andelman, S.J., Bakaar, M.I. … Yan., X. 2004. Effectiveness of the global protected area network in representing species diversity. Nature 428: 640-643.

Santini, L., Saura, S. & Rondinini, C. 2016. Connectivity of the global network of protected areas. Diversity and Distributions 22: 199-211

Saura, S., Bastin, L., Battistella, L., Mandrici, A. & Dubois, G. 2017. Protected areas in the world's ecoregions : How connected are they? Ecological Indicators. 76: 144-158.

Saura, S., Bertzky, B., Bastin, L., … Dubois, G. 2018. Protected area connectivity: shortfalls in global targets and country-level priorities. Biological Conservation 219: 53-67

Sayre, R., Karagulle, D., Frye, C. … Possingham, H. 2020. An assessment of the representation of ecosystems in global protected areas using new maps of world climate regions and world ecosystems. Global ecology and conservation 21: e00860

Secretariat of the Convention on Biological Diversity. 2000. Sustaining Life on Earth: How the Convention on Biological Diversity Promotes Nature and Human Well-Being. Québec: Retrieved from: https://www.cbd.int/doc/publications/cbd-sustain-en.pdf

Secretariat of the Convention on Biological Diversity. 2010. Strategic Plan for Biodiversity 2011-2020 and the Aichi Targets. Quebec. Retrieved from: https://www.cbd.int/doc/strategic-plan/2011-2020/Aichi-Targets-EN.pdf

Smith, R.J., Goodman, P.S. & Matthews, W.S. Systematic conservation planning: a review of perceived limitation and illustrations of the benefits, using a case study from Maputaland, South Africa. Oryx. 40 (4): 400-410.

UNEP-WCMC and IUCN. 2021. Protected Planet Report 2020. UNEP-WCMC and IUCN: Cambridge UK; Gland, Switzerland

Venter, O., Magrach, A., Outram, N., Klein, C.J., Di Marco, M. & Watson, J.E.M. 2017.Bias in protected-area location and its effects on long-term aspirations of biodiversity conventions. Conserv Biol.;32:127–34.

Venter, O., Fuller, R.A., Segan, D.B. … Watson, J.E.M. 2014. Targeting global protected area expansion for imperiled biodiversity. PLOS Biology. 12 (6): e1001891.

Visconti, P., Butchart, S. H., Brooks, T. M. … Watson, J. E. 2019. Protected area targets post-2020. Science. 364(6437), 239– 241.

Watson, J.E.M., Dudley, N., Segan, D.B. & Hockings, M. 2014. The performance and potential of protected areas. Nature. 515: 67-73.

Watson, J.E.M., Darling, E.S, Venter, O., Maron, M., Walston, J., Possingham, H.P., Dudley, N., Hockings, M., Barnes, M. & Brooks, T.M. 2015. Bolder science needed now for protected areas. Conservation Biology. 30 (2): 243-248.

Woodley, S., Bertzky, B., Crawhall, N., Dudley, N., Londono, J.M., MacKinnon, K., Redford, K. & Sandwith, T. 2012. Meeting Aichi Target 11: What does success look like for protected area systems? Parks. 18.1: 23-36.

World Economic Forum. 2020. Global Risk Report. Retrieved from: https://www.weforum.org/reports/the-global-risks-report-2020