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Review

Long-term socio-environmental monitoring of protected areas is a persistent weak point in developing countries: Literature review and recommendations

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ABSTRACT

Protected areas (PAs) are pivotal for biodiversity conservation, particularly in developing countries. However, success in achieving their objectives is variable. The reasons for the inconsistent effectiveness of PAs are well documented and include inadequate resources and conflicting objectives. Despite the proliferation of tools and guidelines for monitoring and evaluation (M&E) of PAs over recent decades, a gap persists between the availability of these resources and their practical application. This review of more than 114 publications on the subject summarizes and critically examines the approaches and tools used for M&E of PAs, in particular in developing countries. It highlights the existing shortcomings and explores the causes behind the ongoing disconnect between theoretical guidance and operational reality. Based on this review, we suggest recommendations to improve the efficacy and sustainability of M&E practices in the PAs of developing countries, with an emphasis on integrating the needs of local communities and adopting a strategy of adaptive management.

1. Introduction

Protected areas (PAs) are the main tool for biodiversity conservation around the globe (Chape et al., 2005; Dudley, 2021; Maxwell et al., 2020; Watson et al., 2014). While some conservation stakeholders have expressed concerns about their efficacy or highlighted aspects that need to be better taken into account—including ecological representativeness, equity, justice and connectivity—PAs are generally acknowledged to be effective in reducing habitat loss and conserving biodiversity (Eklund et al., 2016; Godet and Devictor, 2018; Gray et al., 2016). This has led to efforts to extend the network of PAs worldwide: today they cover about 17 % of the Earth's land surface and 8 % of its seas (UNEP-WCMC, 2021). The post-2020 Global Biodiversity Framework of the Convention on Biological Diversity (CBD) aims to raise this target to 30 % of protected areas or "other effective area-based conservation measures" (OECMs) by 2030 (Working Group on the Post-2020 Global Biodiversity Framework, 2021).

Most biodiversity hotspots are located in developing countries (Fisher and Christopher, 2007; Myers et al., 2000), where the challenges facing PAs are exacerbated by ecological and socioeconomic precarity (Naughton-Treves et al., 2005; Virah-Sawmy et al., 2014). While their core objective is to protect biodiversity, PAs in developing countries are increasingly expected to support numerous ecosystem services, contribute to poverty alleviation by allowing sustainable livelihoods (conditional to better biodiversity outcomes), ensure food security, promote sustainable tourism, and, more recently, to play a role in climate change mitigation and adaptation (Gardner et al., 2018; Naughton-Treves et al., 2005). In accordance with this evolution of PA goals, PAs designated as category V ("Protected landscapes or seascapes") and category VI ("Protected areas with sustainable use of natural resources") (UNEP-WCMC, 2021) now represent 24 % of the total number of PAs and 37 % of their surface area (UNEP-WCMC and IUCN,

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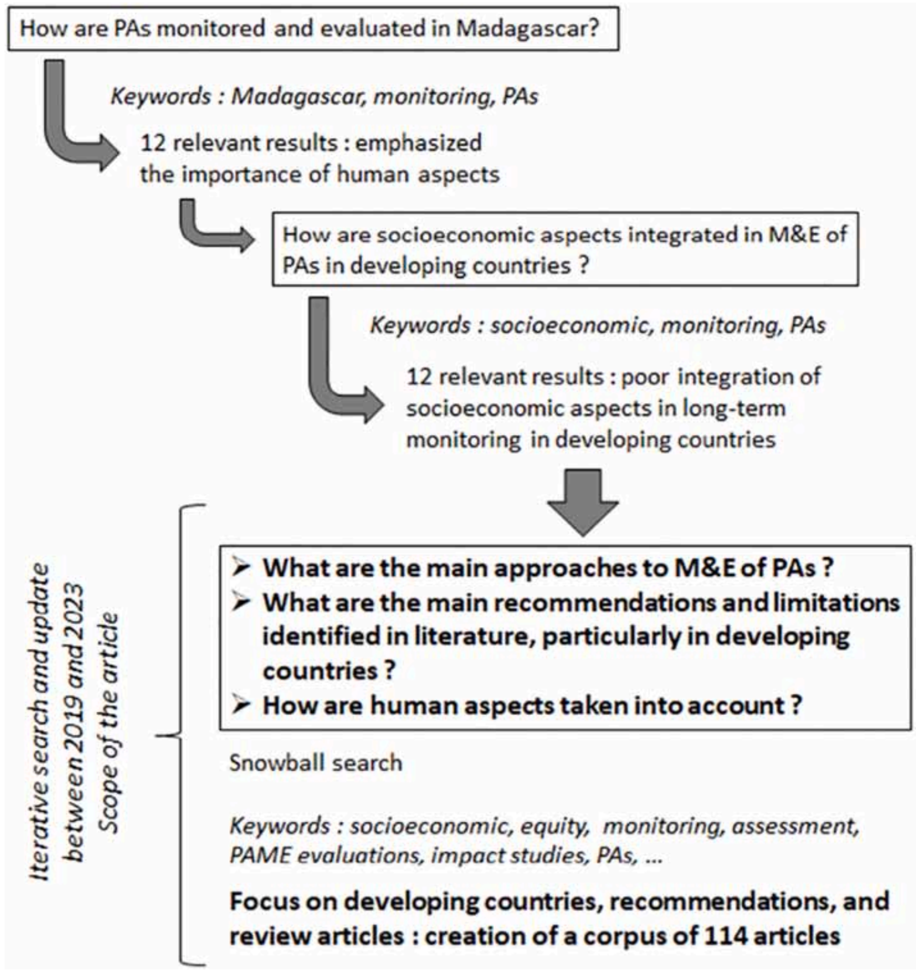

Fig. 1. Methodology and research questions structuring the review.

2023).

While the importance of PAs for biodiversity conservation is recognized, their success in achieving their objectives is relative (Geldmann et al., 2019; Mora and Sale, 2011). In one study, Watson et al. (2014) found that only 20–50 % of PAs were effectively managed. In a review of 158 studies of PA effectiveness, Godet and Devictor (2018) found that about 40 % of these PAs were insufficient or failing. Bruner et al. (2004) and Watson et al. (2014) noted that this situation is particularly acute in developing countries. The reasons for the lack of effectiveness of PAs in developing countries are manifold and have been well documented in numerous studies. Lack of financial and human resources is the main factor affecting PAs (Bruner et al., 2004; Coad et al., 2019; Leverington et al., 2010). The number of PAs has increased faster than the resources allocated to their management (Geldmann et al., 2019). This has resulted in a lack of infrastructure, poor governance and failures in law enforcement (Bruner et al., 2004; Coad et al., 2019; Leverington et al., 2010; Watson et al., 2014). Another key reason behind PA failure is a lack of consideration of the socioeconomic issues faced by local communities, and not involving these communities in the management of an area. This can lead local people to view PAs in a negative light and be reluctant to support them (Hirschnithz-Garbers and Stoll-Kleemann, 2011; Mora and Sale, 2011; Vuola and Pyhälä, 2016). The relationship between a PA and the local community, and the impact of a PA on poverty, is context-dependent and constantly evolving as a result of many factors—not necessarily attributable to the PA—including the local socioeconomic situation prior to the establishment of the PA (Adams et al., 2004; Rodrigues and Cazalis, 2020).

Given the multiplication of objectives PAs are expected to achieve and the relative scarcity of resources, there is a pressing need for effective monitoring and evaluation (M&E) of PAs in developing countries to better understand how to ensure their effectiveness (Gardner et al., 2018; Rakotomanana et al., 2013; Waeber et al., 2016). Monitoring is needed in order to gather data on local socioecological conditions, management practices of a PA, and threats to a PA, which would help deal with the high degree of uncertainty and complexity in these contexts, especially in the face of accelerating global change (Salzer and Salafsky, 2006). Robust M&E is key to planning in an approach of adaptive management (Coad et al., 2015; Hockings et al., 2006; Murray and Marmorek, 2003), which draws lessons from the results of management actions (Hirschnithz-Garbers and Stoll-Kleemann, 2011; Murray and Marmorek, 2003). The M&E process is essential in providing the scientific basis for determining if PAs are effective (Fox et al., 2012; Pressey et al., 2017; Watson et al., 2016), and can also help to efficiently allocate resources, which is particularly important in developing countries with limited means (Bruner et al., 2004; Ferraro and Pattanayak, 2006).

Thus, M&E is of interest to all stakeholders concerned by the management, efficacy and impacts of PAs: scientists, PA managers, environmental NGOs, donors, local populations, and governments (Field et al., 2007; Hockings et al., 2006). For scientists, ecological and socioeconomic monitoring enables PA outcomes (both for biodiversity and development) to be measured, with the collected data allowing meta-analyses on the effectiveness of different aspects. For biologists and ecologists, ecological monitoring provides a baseline for future fieldwork. Monitoring also allows reporting on PA effectiveness to donors, governments and local populations, responding to the growing demand

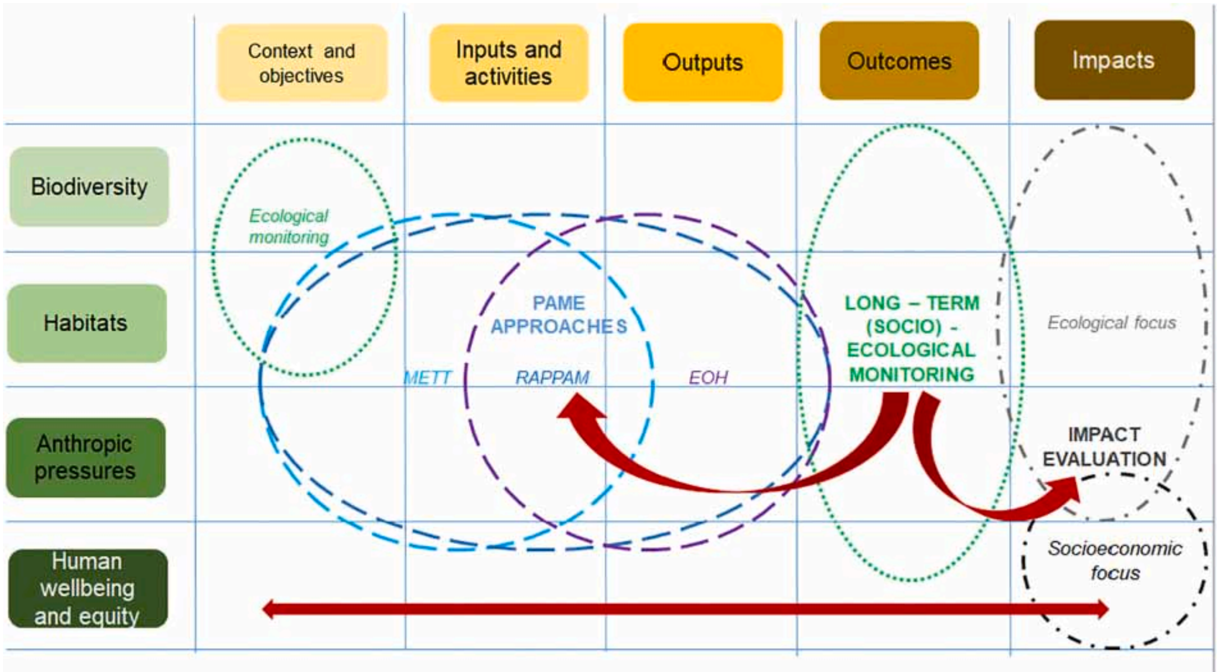

Fig. 2. Categorization of different approaches to monitoring and evaluation of protected areas. *The horizontal axis shows the stage in the management process; the vertical axis shows the aspect evaluated. The circles show the approximate coverage of a tool on these axes. The red arrows show links between elements (long-term monitoring data is needed to inform management effectiveness assessments and impact studies, and human dimensions are needed to assess socioeconomic impacts).* (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

for transparency (Christensen, 2003; Ferraro and Pattanayak, 2006; Jepson, 2005). This increases the legitimacy of a PA, which is essential to ensure both local support and external funding (Bragagnolo et al., 2016; Coad et al., 2015).

In recent decades, many studies have underlined these factors in the importance of M&E. In line with this, a number of recommendations and guidelines have been produced to support the implementation of M&E in protected areas, particularly in developing countries. Most encourage going beyond strictly ecological goals, to encompass socioeconomic objectives in order to ensure the long-term sustainability of a PA. The aim of this study was to provide an overview of M&E approaches and tools developed for PAs, comparing their methods, their objectives, and their current application in developing countries. To this end, we conducted a review of the scientific literature on the subject, including case studies. Based on this review, in this article we summarize the different types of M&E of protected areas, explore their shortcomings, and examine the causes of the gap between the profusion of tools available and the lack of M&E in developing countries. The findings allow us to suggest a number of recommendations for more effective and sustainable M&E in the global south.

2. Method

The study originated from a focus on M&E of PAs in Madagascar that began in 2019, and was then broadened in subsequent years to a review of socioeconomic M&E of PAs in developing countries more generally. The review was expanded using a snowball search method, which consisted of searching for all relevant articles cited by the articles in our original literature review, and a bibliographic watch on the subject conducted iteratively from 2019 to 2023. The corpus retained consisted of 114 publications, of which the abstracts and main findings were analyzed (Fig. 1).

3. Results

3.1. Overview of M&E of protected areas in developing countries

There are different M&E approaches for PAs according to what, how, when and why they evaluate, with specific tools developed according to the objectives and the context of those responsible for carrying out the monitoring (Stem et al., 2005). We categorized these approaches along two axes. One axis is the stage in the PA management process (e.g. context, outcomes, impacts), which is a common taxonomy applied to PAs following Hockings et al. (2004) and refined in subsequent studies such as Mascia et al. (2014) and Maxwell et al. (2020, Table 1). The other axis corresponds to the aspect of the PA being evaluated (e.g. biodiversity, habitats, human equity). Thus, a particular M&E tool evaluates the aspects supported by the PA throughout the stages of the management process. In recent years, in order to measure the new consideration of Sustainable Development Goals (SDGs), the human aspects of a PA have been increasingly considered: to evaluate the well-being of local communities, as well as social equity in the functioning of a PA (in terms of stakeholder participation in decision-making, recognition of customary rights, access to justice, transparency, and distribution of benefits) and the quality of governance (Zafra-Calvo et al., 2019). We categorized M&E approaches in a matrix, indicating if they are well established or still incipient in developing countries (Fig. 2).

3.2. Methods for assessing effectiveness of PAs

A Protected Area Management Effectiveness (PAME) evaluation assesses the entire implementation cycle of a management plan, with indicators on the context of the PA, planning, inputs (the resources deployed), management processes and outputs (the implemented actions) (Hockings, 2003; Hockings et al., 2004, 2006; Mascia et al., 2014). A PAME generally does not include information about outcomes (impacts on ecological and socioeconomic indicators), but it takes into account this information if it is available from ambient monitoring or impact evaluation. This type of assessment can be carried out

Table 1
Overview of the main recommendations for long-term monitoring in the literature.

Recommendations	Main aspects	Main references (by date) (* specific to monitoring in developing countries)
Thoughtful design of the monitoring system	Carry out data mining (integrating preexisting local monitoring systems) and gather baseline data	Caughlan and Oakley, 2001; Danielsen et al., 2003*; Fancy et al., 2009; Bottrill et al., 2011*; Mann-Lang et al., 2021
	Define system boundaries	Ghoddousi et al., 2022
	Define monitoring objectives	Caughlan and Oakley, 2001; Mezquida et al., 2005; Lovett et al., 2007; Fancy et al., 2009; Lindenmayer and Likens, 2010; Bottrill et al., 2011*; Mann-Lang et al., 2021
	Build a conceptual model of the PA (system thinking)	Fancy et al., 2009; Lindenmayer and Likens, 2010; Théau et al., 2018; Gurney et al., 2019*
Integration of human and social dimensions	Monitor human aspects (including governance and equity)	Danielsen et al., 2000*; Stem et al., 2005; Lockwood, 2010; Hirschnithz-Garbers and Stoll-Kleemann, 2011; Ban et al., 2013; Rodríguez-Rodríguez et al., 2015; Corrigan et al., 2018; Gurney et al., 2019*; Ghoddousi et al., 2022
	Monitor links between ecological and human aspects	Hirschnithz-Garbers and Stoll-Kleemann, 2011; Ban et al., 2013; Hicks et al., 2016; Franks et al., 2018; Ferreira et al., 2020; Ghoddousi et al., 2022
	Involve stakeholders	Danielsen et al., 2000*; Danielsen et al., 2003*; Reed et al., 2008*; Danielsen et al., 2009*; Danielsen et al., 2010*; Lindenmayer and Likens, 2010; Convertino et al., 2013; Rodríguez-Rodríguez et al., 2015; Gurney et al., 2019*; Quintana et al., 2020; Mann-Lang et al., 2021; Ghoddousi et al., 2022
Selection of variables, indicators and protocols	Use a protocol to select and prioritize variables and indicators	Caughlan and Oakley, 2001; Mezquida et al., 2005; Niemeijer and de Groot, 2008; Fancy et al., 2009; Lin et al., 2009; Timko and Innes, 2009; Convertino et al., 2013; Rodríguez-Rodríguez et al., 2015; Gurney et al., 2019*; Lee and Abdullah, 2019; Ghoddousi et al., 2022
	Mix quantitative and qualitative variables	Stem et al., 2005; Smallhorn-West et al., 2020*
	Choose simple protocols compatible with statistical requirements	Caughlan and Oakley, 2001; Danielsen et al., 2000*; Danielsen et al., 2003*; Lee and Abdullah, 2019
Data management	Collect data at an appropriate time step and get consistent time series	Caughlan and Oakley, 2001; Rodríguez-Rodríguez et al., 2015; Ahmadia et al., 2015a*; Ghoddousi et al., 2022
	Analyze the data at regular intervals	Caughlan and Oakley, 2001; Danielsen et al., 2003*; Lovett et al., 2007; Fancy et al., 2009; Lindenmayer and Likens, 2010
	Properly store and manage data, maintain consistency	Lovett et al., 2007; Fancy et al., 2009; Bottrill et al., 2011*; Ahmadia et al., 2015*

occasionally or on a recurring basis, with different levels of detail. Depending on the objectives and the evaluation scale, the number of indicators used, as well as the precision of the data collected, varies (Hockings et al., 2009).

A set of PAME evaluation methods have been developed by conservation organizations (Anthony, 2014; Leverington et al., 2010) based on the IUCN-WCPA Management Effectiveness Evaluation Framework (Hockings et al., 2006). These methods can be classified into two categories: methods based on qualitative data or indicator scoring, and those including quantitative data.

Methods based on indicator scoring allow for rapid evaluation and use little long-term data. In developing countries, the two most common methods based on indicator scoring are the Management Effectiveness Tracking Tool (METT) (Stolton et al., 2003, 2019), designed for the evaluation of an individual PA, and the Rapid Assessment and Prioritization of Protected Areas Management (RAPPAM) (Ervin, 2003), suitable for the evaluation of a PA network (Brockington and Wilkie, 2015; Hockings, 2003; Stoll-Kleemann, 2010). The METT and RAPPAM tools represent 67 % of PAMEs in low- and middle-income countries, but account for only 3 % of PAMEs in high-income countries.

Methods using quantitative data, such as UNESCO's Enhancing our Heritage (EoH) toolkit, suitable for monitoring an individual PA, require the establishment of long-term monitoring of the PA, and are oriented toward measuring the results achieved by PA management (Stoll-Kleemann, 2010). However, the EoH tool is rarely used, accounting for only 0.2 % of PAMEs in low- and middle-income countries, and 0.01 % of PAMEs in high-income countries.

While PAME methods provide a conceptual framework for designing assessment mechanisms, these must be adapted to the diverse range of PAs and their management systems (Hockings et al., 2006). Evaluation of management effectiveness is included in the Program of Work on Protected Areas, which was adopted by the Convention on Biological Diversity in 2004 (Leverington et al., 2010), and many institutions and funders have made PAME assessments mandatory. As a result, the development and dissemination of PAME methods have led to the generalization of a minimum level of M&E of PAs throughout the world. This type of M&E is mainly carried out by PA managers, but it can also be relevant for the purpose of scientific research on the effects of PAs and the effectiveness of various management measures.

3.3. *Long-term M&E and participatory monitoring*

Long-term monitoring—referred to as "ambient monitoring" by Mascia et al. (2014)—of a set of ecological and socioeconomic variables provides scientific data on the general context and functioning of a PA and its surroundings, ideally from the time of its creation. It assesses the outcomes resulting from management actions, as well as the pressures on the PA, and trends concerning nature (Mascia et al., 2014; Salzer and Salafsky, 2006). Such monitoring programs are often carried out by researchers, and the results contribute to improved knowledge on the functioning of a PA. Sometimes they are conducted by PA managers, to monitor the status of conservation targets and threats (Leverington et al., 2010; Timko and Innes, 2009).

However, there is a general lack of long-term monitoring of the effects of the biodiversity conservation tools that have been put in place. To address this, researchers have put forward various recommendations over the past 25 years (see in particular Hockings et al., 2006; Likens and Lindenmayer, 2018; Margoluis and Salafsky, 1998). Although these recommendations are diverse, some key points recur regularly (see Table 1 for a summary of the main recommendations). The purpose of these recommendations is to allow the design of both outcome-effective and cost-effective monitoring systems, a particularly relevant goal in the context of developing countries with limited resources. The excessive complexity of monitoring systems has been identified as a major cause of their failure in the global south (Danielsen et al., 2003).

Two aspects of the recommendations seem particularly important to consider: the choice of variables to monitor and the role of stakeholders (PA managers, local communities and researchers) in the monitoring process. In terms of the choice of variables, the authors agree on the importance of selecting variables to monitor that represent the whole system. The approaches proposed for monitoring have evolved over time, with increasingly systemic and integrative methods. For example, Kremen et al. (1994) propose ecological and socioeconomic variables to be monitored in the case of Integrated Conservation and Development Projects (ICDPs) in developing countries. Caughlan and Oakley (2001) and Danielsen et al. (2000) propose a complete protocol for monitoring a PA. Lin et al. (2009) and Niemeijer and de Groot (2008) propose using causal chains to choose the variables to follow. The "essential variables" approach, in particular the "essential biodiversity variables" (Pereira et al., 2013), aims to select variables representing each ecological aspect of the PA. More recently, Ghoddousi et al. (2022) and Gurney et al. (2019) propose taking a systems approach based on Ostrom's socio-ecological systems framework to design monitoring.

Stakeholder involvement in monitoring is also widely discussed in the literature. Several studies show the value of involving local communities in the collection of monitoring data, and make recommendations on how to do this (see Table 1, "Involve stakeholders"). An increasing number of PAs are implementing participatory ecological monitoring, in which local communities are involved in the collection of data (Danielsen et al., 2010). This allows the costs associated with data collection to be reduced (Berkes et al., 1998; Danielsen et al., 2010; Sheil, 2001) and also values the traditional ecological knowledge of communities that have historically managed the area and depend on resources from the PA for their livelihood. As these communities are present in and around the PA on a daily basis, they can collect data regularly and provide early warnings of any problems.

Many authors show the interest of going even further, involving local communities and other stakeholders in the design of the monitoring program in a co-construction process, especially in category V PAs (Dudley et al., 2016; Leverington et al., 2010; Reed, 2008). Several studies recommend involving local communities in the choice of variables to monitor, arguing for the importance of setting up an adaptive and systemic monitoring system that is anchored in local reality (Aswani and Weiant, 2004; Berkes et al., 1998; Fraser et al., 2006). This type of system can be more effective in influencing local management decisions (Danielsen et al., 2010). Two distinct currents can be identified in participatory monitoring recommendations: an "evidence-based approach" that focuses on collecting ecological data, and a "collaborative-learning approach" that encourages local communities to actively engage in the monitoring process as co-managers (Villasenor et al., 2016).

3.4. Impact evaluations

Impact studies help to understand overall trends in a PA's conservation effectiveness and its interdependency with local communities, as well as to compare the effectiveness of PAs with other conservation instruments (Miteva et al., 2012). The ultimate goal of impact studies is to provide answers to the question posed by Ferraro and Hanauer (2015): "Through what mechanisms do protected areas affect environmental and social outcomes?" They are carried out at the level of a region, a country or a set of countries (Craigie et al., 2015; Leverington et al., 2010; Mascia et al., 2014). These studies can be conducted with the aim of scientific research, based on literature reviews (see e.g. Carneiro, 2011; Coad et al., 2015; Mascia et al., 2010; Oldekop et al., 2016; Pullin et al., 2013; Smallhorn-West et al., 2020), on the analysis of available data on PAs (see e.g. Andam et al., 2010; Brockington and Wilkie, 2015; Canavire-Bacarreza and Hanauer, 2013; den Braber et al., 2018; Ferraro and Hanauer, 2014; Mammides, 2020; Timko and Satterfield, 2008), or backed up by M&E conducted over several years (see e.g. Ahmadia et al., 2015a).

4. Shortcomings of M&E of PAs in developing countries

The dissemination of the main PAME tools has led to their widespread use, and PAME evaluations carried out worldwide are shared in the Global Database on Protected Area Management Effectiveness (GD-PAME). However, there is often an assumption that the use of these indicator-scoring tools is sufficient to carry out M&E, despite several authors pointing out shortcomings in these methods. Three main pitfalls have been highlighted. First, they provide little data on biodiversity outcomes (Rodrigues and Cazalis, 2020). Yet measuring these is essential to understand what is really effective in order to conserve biodiversity: several studies have shown that while good scores for indicators of resources deployed and actions implemented are necessary, they are not sufficient for a PA to have good conservation outcomes (see e.g. Carranza et al., 2014; Geldmann et al., 2018; Kapos et al., 2009; Nolte and Agrawal, 2013; Powlen et al., 2021).

Second, PAME evaluations do not give sufficient consideration to the social dimensions of a PA. In a review of social indicators included in 38 PAME methods, Corrigan et al. (2018) found that important aspects of community well-being were missing, and that positive impacts of PAs on local communities and negative impacts of communities on PAs were overrepresented. Ban et al. (2019) found similar results, citing a lack of data on social, health and cultural aspects in evaluations of the impact of marine PAs. Consequently, due to this lack of data, long-term social impacts of PAs remain poorly understood, preventing the establishment of causal links between the implementation and operation of PAs and the socioeconomic status of local communities. Studies on these social impacts have revealed contrasting effects that are closely linked to the context (Ban et al., 2019; Blanco et al., 2020; Carneiro, 2011; Mascia et al., 2010; Palfrey et al., 2021), making a strong argument for monitoring the social impacts of PAs (Gurney et al., 2014). Regarding equity, Moreaux et al. (2018) found that PAME evaluations do not sufficiently include the perspectives of different stakeholders on PA governance. Most PAME evaluations tend to focus on the effectiveness of PAs, not on equity, but Zafra-Calvo and Geldmann (2020) show that to have a positive impact on biodiversity, PAs need to be not only effective but equitable.

Third, PAME evaluations are often carried out on an ad hoc basis, and tend to be subjective and lack quantitative data, making it impossible to assess the impact of PAs in a rigorous way. This was shown by Coad et al. (2015) in a review of PAME evaluations in the GD-PAME database, and by Cook and Hockings (2011) in a study based on interviews. Impact evaluations are thus limited by the unavailability of long-term monitoring datasets (Miteva et al., 2012), as shown by Pullin et al. (2013) in their review of the impacts of PAs on human well-being; by Naidoo et al. (2019) in a study on the socioeconomic impact of PAs on surrounding populations; and by Smallhorn-West et al. (2020) in their study on the ecological and socioeconomic impacts of PAs in the South Pacific.

Fourth, threat monitoring is frequently limited to remote-sensing measurement of land cover change, which does not assess all threats. This produces a skewed picture of PA effectiveness and does not allow a link to be made between PA inputs and ecological outcomes (Ahmadia et al., 2015; Dunham et al., 2020; Geldmann et al., 2019; Rodrigues and Cazalis, 2020).

For all these reasons, Ghoddousi et al. (2022) recommend reserving the term “effectiveness” for both social and ecological outcomes of PAs. This means that to properly evaluate PA effectiveness in terms of conservation and social outcomes, long-term monitoring of ecological and socio-environmental variables is necessary, in addition to PAME evaluations (Ahmadia et al., 2015; Bottrill et al., 2011; Mascia et al., 2014; Pullin et al., 2013). However, despite the numerous recommendations on the need to establish long-term monitoring systems that include variables on human aspects, this type of monitoring is still rarely implemented in PAs (Geldmann et al., 2018; Rodrigues and Cazalis, 2020).

5. Discussion and recommendations

5.1. Root causes: approaches that remain unfavorable to long-term monitoring

The major underlying constraint for PAs around the world is a lack of financial and human resources, and this is particularly the case in developing countries, where governments often disengage from funding PAs (Gardner et al., 2013; Geldmann et al., 2018; Nicoll and Ratsifandrihamanana, 2014; Sheil, 2001; Watson et al., 2014). In 2019, Coad et al. found that less than a quarter of the PAs they studied around the world had adequate human and financial resources. The scarce resources that exist for PAs are often allocated in priority to implementing management actions, leaving very few resources available for M&E (Balmford et al., 2005; Hockings et al., 2009). Of the limited budget left for monitoring, most tends to be used for data collection at the expense of M&E design, analysis, interpretation and use of the data collected (Caughlan and Oakley, 2001). This often means that monitoring objectives are poorly defined and the monitoring system lacks an integrated vision (Dale and Beyeler, 2001; Field et al., 2007; Lin et al., 2009), resulting in a poor choice of variables and indicators to monitor (Niemeijer and de Groot, 2008). The result is M&E that does not adequately reflect the functioning of the PA or assess its impacts and seeks to monitor too many variables with complex protocols, making the cost of monitoring the selected indicators too high (Dale and Beyeler, 2001; Lin et al., 2009; Salafsky et al., 2000; Théau et al., 2018). Another issue is that if data collection is not structured, unnecessary data is collected, or the data collected cannot be adequately analyzed (Caughlan and Oakley, 2001; Field et al., 2007; Hockings et al., 2009). Without a clear M&E design, baselines are often inexistent, statistical considerations are overlooked, and changes in protocols lead to a loss of data integrity over time. The end result of issues such as these is that M&E data lacking scientific validation is not used, and the M&E program may eventually be abandoned. Such cases are viewed as a misuse of scarce resources and contribute to a poor image of PA monitoring (Field et al., 2007; Sheil, 2001).

It should be noted that the lack of long-term socioecological monitoring of PAs involving all stakeholders is not specific to countries with limited financial resources—in fact it is a wider issue, reflecting the absence of a systemic, interdisciplinary, long-term vision of PA management. Beyond problems of resource scarcity, researchers have shown little interest in setting up long-term monitoring systems for PAs, despite the recommendations arguing for this. Project-based cycles and funding is becoming the norm for conservation initiatives, which is incompatible with maintaining long-term monitoring (Field et al., 2007; Gardner et al., 2018; Mascia et al., 2014). This disengagement of researchers from long-term monitoring also stems from current trends in research, which favor frequent, short publications on new discoveries and are not well suited to long-term studies (Gardner et al., 2013; Hulme, 2011). Researchers also tend to focus on the study of spatial rather than temporal phenomena, and to privilege modeling over the collection of field data. Moreover, researchers may frequently change institute during their scientific career, and the departure of the person leading monitoring in a PA is often the reason for its discontinuation (Likens and Lindenmayer, 2018).

This inconsistent research interest in monitoring PAs is an illustration of what has been called the “research–implementation gap” (Knight et al., 2008), i.e. the disconnect between research and conservation actions in the field. Monitoring is then left to managers, who lack the necessary resources and skills, are overwhelmed by daily management problems, and do not have access to the recommendations provided in the scientific literature. Despite growing interest in participatory monitoring and increasing calls for interdisciplinarity, difficulty in accessing and sharing data and methodologies are frequently reported. In studies that have interviewed PA managers, the latter state they lack access to scientific data from research and monitoring, while they recognize the importance of this type of data to inform their management decisions (Cook et al., 2010, 2012; Giehl et al., 2017; Pullin and Knight, 2005; Rafidimanantsoa et al., 2018). This lack of access is particularly significant in developing countries, where insufficient resources, language barriers and a lack of training to interpret scientific results can limit the integration of scientific data in management decisions (Giehl et al., 2017; Gossa et al., 2015). For example, in Madagascar, data from monitoring carried out by foreign research teams on the country’s PAs are seldom communicated to local stakeholders (Pyhälä et al., 2019). Conversely, PA managers often fail to share their experiences outside their structure or to dialogue with researchers (Gardner et al., 2013).

Another factor that affects monitoring of PAs is that those with a background in social science are rare among managers and researchers designing M&E programs (Aldana-Domínguez et al., 2017; Ban et al., 2019; Hirschnitz-Garbers and Stoll-Kleemann, 2011). This means that socioeconomic protocols in M&E are lacking, and those responsible for analyzing the data collected on the functioning of the PA may not have the skills to interpret all its aspects (Ban et al., 2013; Smallhorn-West et al., 2020). The existing tools for monitoring socioeconomic information related to PAs are often incomplete or too expensive to be implemented (Ghoddousi et al., 2022; Moreaux et al., 2018). Socioeconomic data is thus perceived as being more difficult to collect than ecological data, and is also perceived as more expensive, even if this is not actually the case. The result is that the limited financial resources available for M&E tend to be allocated to ecological data (Geldmann et al., 2013; Neugarten et al., 2011). This is problematic, as implementing M&E with local communities requires social science skills, significant investment and long-term fieldwork. Without this, local communities are often not sufficiently integrated into PA management, and M&E indicators are often not meaningful or accessible to them (Fox et al., 2012; Reed, 2008).

5.2. The need for systemic, interdisciplinary socioenvironmental M&E in the global south

Despite these challenges to implementing M&E in developing countries, we argue that a prerequisite to the success of PAs is a true socioecosystem approach, as advocated in particular by Ban et al. (2013) and Ghoddousi et al. (2022). This requires a change in the conventional representation of a PA. Many studies have demonstrated the interdependency between PAs and their surroundings and have argued that PAs need to integrate human activities, yet the Western vision of conservation still tends to prevail, separating humans from a nature that needs to be “protected” (Descola, 2005). But for a PA to be effective, the approach must fully consider the interdependency of ecological and human aspects and must have a long-term vision of PA management. A socioecosystem approach makes it possible to integrate inputs and outcomes of the PA in M&E, allowing a better understanding of which actions lead to which results and to take this into account in an adaptive management strategy (Bennett and Dearden, 2014).

Innovative ways of implementing M&E need to be explored. Collaboration between natural science researchers and PA managers should be strengthened in order to guide PAs in the implementation of long-term M&E, ideally from the moment they are created (Gardner

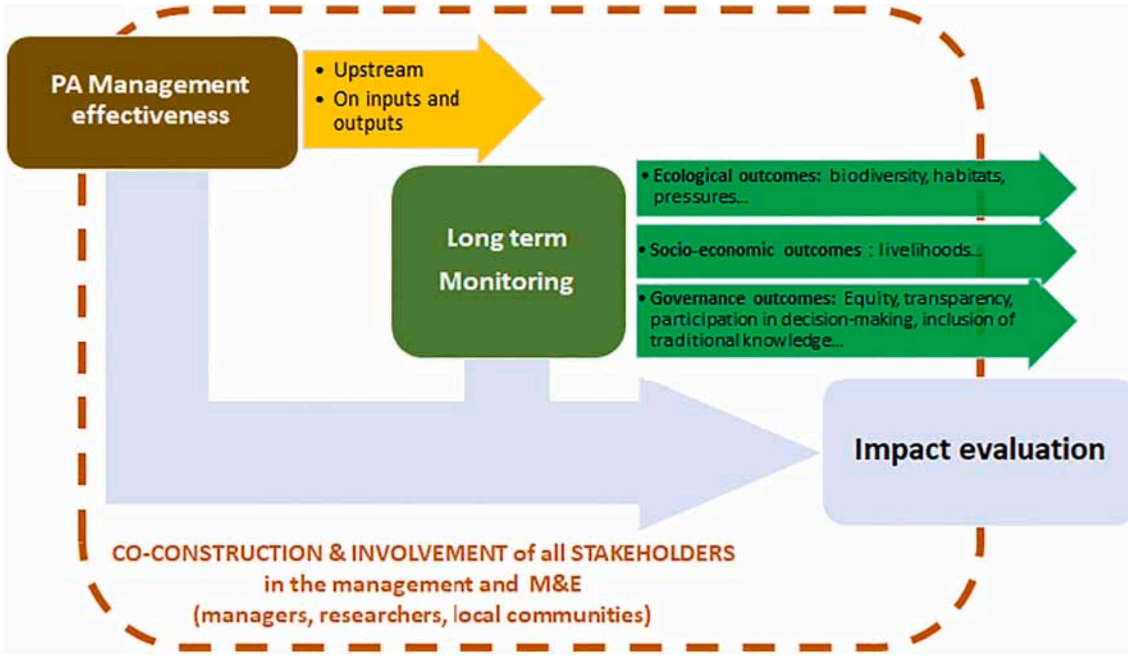

Fig. 3. M&E involving all stakeholders, enabling consistent monitoring of PA management and outcomes.

et al., 2013; Watson et al., 2014). For managers, this would provide methodological support and allow them to set up effective adaptive management. For researchers, this would favor the production of and access to robust and comprehensive monitoring data in an approach in line with sustainability science. To take into account the multiple challenges of PAs, partnerships between managers, local communities and researchers from various disciplines should be established (Hockings et al., 2009; Turnhout et al., 2007). Researchers in social sciences, too rarely enlisted in this context, should equally be involved (Palomo et al., 2014; Virah-Sawmy et al., 2014). Social science tools would make it possible to better take into account the economic and social aspects of PAs, as well as the relationships between local populations and PAs (Ban et al., 2013, 2019; N. J. Bennett et al., 2017; Gardner et al., 2013). Social-learning institutions, steering committees and action-research projects involving managers and researchers from various disciplines can encourage interdisciplinary work and are increasingly valued by research institutions and funders (Cvitanovic et al., 2015; Field et al., 2007; Gardner, 2012; Virah-Sawmy et al., 2014). The co-design of an M&E system can be an opportunity to initiate such interdisciplinary work.

Of the stakeholders involved in this co-design, particular attention must be paid to local communities, which should be actively involved in the process. While communities are increasingly involved in data collection, this is not enough to ensure that they are fully integrated into M&E (Thompson et al., 2020). It has been shown that the quality of monitoring data collected by communities is higher when they have participated in designing the protocols (Danielsen et al., 2014). Participating in M&E also reinforces their feeling of stewardship (Quintana et al., 2020). For participatory socioecological monitoring to be both effective and fair, care must be taken not to create conflict within communities by favoring certain groups; disadvantaged groups should be included, while respecting local social structures and being aware of existing inequalities (Singleton, 2009).

The complementarity of stakeholders in terms of their interest in monitoring, skills and data dissemination channels is an important lever for the implementation of effective M&E (Field et al., 2007; Gardner et al., 2013). Co-building the system increases the sustainability of M&E by ensuring its long-term relevance (Fraser et al., 2006). Indicators cannot be solely science-based because they are a policy tool at the interface between knowledge production and policy (Balmford et al., 2005; Fancy et al., 2009; Gardner et al., 2013; Turnhout et al., 2007). More comprehensive M&E based on equity could help reduce conflicts around PAs and focus attention on environmental justice. Zafra-Calvo and Geldmann (2020), for example, propose a set of relevant indicators to assess equity in the context of PAs.

6. Conclusion

The involvement of different stakeholders in co-constructing M&E allows different knowledge about a PA, and thus a more relevant choice of variables and indicators to be monitored. A process of co-learning between stakeholders, and the construction of a shared representation of the PA, can be as important as the content of the conceptual model itself (Ban et al., 2013; Fancy et al., 2009; Fromont et al., 2022; Salafsky et al., 2000). Companion modeling methods using mental models can help build a shared conceptual model of the PA and determine the variables to monitor (Aubert et al., 2012; Fromont et al., 2022). Such an approach empowers the local community, which takes ownership of the PA, and increases the acceptability of the measures taken and commitment to the PA (Aswani and Weiant, 2004; Fox et al., 2012; Fraser et al., 2006; Gardner et al., 2018; Quintana et al., 2020). Of course, this requires more initial investment compared to ready-made top-down methodologies, but it should result in a more adapted and effective program that is likely to prove less costly in the medium run (Fig. 3). Given that governments often do not supply sufficient financial resources for PAs (Watson et al., 2014), the sustainability of funding and the means to ensure that M&E continues must be discussed upstream (Lovett et al., 2007). An M&E program that involves and is in the interest of all stakeholders has a better chance of being incorporated in the ongoing operations of the PA, and of being sustainable over the long term.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

References

Adams, W.M., Aveling, R., Brockington, D., Dickson, B., Elliott, J., Hutton, J., Roe, D., Vira, B., Wolmer, W., 2004. Biodiversity conservation and the eradication of poverty. Science 306 (5699), 1146–1149.

Ahmadia, G.N., Glew, L., Provost, M., Gill, D., Hidayat, N.I., Mangubhai, S., Purwanto, N., Fox, H.E., 2015. Integrating impact evaluation in the design and implementation of monitoring marine protected areas. Philos. Trans. R. Soc. Lond., B, Biol. Sci. 370 (1681), 20140275 https://doi.org/10.1098/rstb.2014.0275.

Aldana-Domínguez, J., Montes, C., Martínez, M., Medina, N., Hahn, J., Duque, M., 2017. Biodiversity and ecosystem services knowledge in the Colombian Caribbean: progress and challenges. Trop. Conserv. Sci. 10, 1940082917714229.

Andam, K.S., Ferraro, P.J., Sims, K.R., Healy, A., Holland, M.B., 2010. Protected areas reduced poverty in Costa Rica and Thailand. Proc. Natl. Acad. Sci. 107 (22), 9996–10001.

Anthony, D.B., 2014. Review of International Protected Area Management Effectiveness (PAME) Experience, 53.

Aswani, S., Weiant, P., 2004. Scientific evaluation in women's participatory management: monitoring marine invertebrate refugia in the Solomon Islands. Hum. Organ. 63 (3), 301–319.

Aubert, S., Rahajason, F., & Ganomanana, T. (2012). La modélisation d'accompagnement pour le Suivi de l'Impact des Transferts de Gestion à Madagascar. *VertigO - la revue électronique en sciences de l'environnement, Volume 11 Numéro 3*, Article Volume 11 Numéro 3. doi:https://doi.org/10.4000/vertigo.11888.

Balmford, A., Bennun, L., Brink, B. ten, Cooper, D., Côté, I. M., Crane, P., Dobson, A., Dudley, N., Dutton, I., Green, R. E., Gregory, R. D., Harrison, J., Kennedy, E. T., Kremen, C., Leader-Williams, N., Lovejoy, T. E., Mace, G., May, R., Mayaux, P., … Walther, B. A. (2005). The convention on biological diversity's 2010 target. Science doi:https://doi.org/10.1126/science.1106281.

Ban, N.C., Mills, M., Tam, J., Hicks, C.C., Klain, S., Stoeckl, N., Bottrill, M.C., Levine, J., Pressey, R.L., Satterfield, T., Chan, K.M., 2013. A social–ecological approach to conservation planning: embedding social considerations. Front. Ecol. Environ. 11 (4), 194–202. https://doi.org/10.1890/110205.

Ban, N.C., Gurney, G.G., Marshall, N.A., Whitney, C.K., Mills, M., Gelcich, S., Bennett, N. J., Meehan, M.C., Butler, C., Ban, S., 2019. Well-being outcomes of marine protected areas. Nat. Sustain. 2 (6), 524–532.

Bennett, J., Dearden, P., 2014. From measuring outcomes to providing inputs: governance, management, and local development for more effective marine protected areas. Mar. Policy 50, 96–110. https://doi.org/10.1016/j.marpol.2014.05.005.

Bennett, N.J., Roth, R., Klain, S.C., Chan, K., Christie, P., Clark, D.A., Cullman, G., Curran, D., Durbin, T.J., Epstein, G., 2017. Conservation social science: understanding and integrating human dimensions to improve conservation. Biol. Conserv. 205, 93–108.

Berkes, F., Folke, C., Colding, J., 1998. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge University Press.

Blanco, J., Bellón, B., Fabricius, C., de O. Roque, F., Pays, O., Laurent, F., Fritz, H., Renaud, P.-C., 2020. Interface processes between protected and unprotected areas: a global review and ways forward. Glob. Chang. Biol. 26 (3), 1138–1154.

Bottrill, M.C., Hockings, M., Possingham, H.P., 2011. In pursuit of knowledge: addressing barriers to effective conservation evaluation. Ecol. Soc. 16 (2), art14. https://doi.org/10.5751/ES-04099-160214.

den Braber, B., Evans, K.L., Oldekop, J.A., 2018. Impact of protected areas on poverty, extreme poverty, and inequality in Nepal. Conserv. Lett. 11 (6), e12576.

Bragagnolo, C., Malhado, A.C.M., Jepson, P., Ladle, R.J., 2016. Modelling local attitudes to protected areas in developing countries. Conserv. Soc. 14 (3), 163–182.

Brockington, D., Wilkie, D., 2015. Protected areas and poverty. Philos. Trans. R. Soc. Lond., B, Biol. Sci. 370 (1681), 20140271.

Bruner, A.G., Gullison, R.E., Balmford, A., 2004. Financial costs and shortfalls of managing and expanding protected-area systems in developing countries. BioScience 54 (12), 1119–1126.

Canavire-Bacarreza, G., Hanauer, M.M., 2013. Estimating the impacts of Bolivia's protected areas on poverty. World Dev. 41, 265–285.

Carneiro, G., 2011. Marine management for human development: a review of two decades of scholarly evidence. Mar. Policy 35 (3), 351–362.

Carranza, T., Manica, A., Kapos, V., Balmford, A., 2014. Mismatches between conservation outcomes and management evaluation in protected areas: a case study in the Brazilian Cerrado. Biol. Conserv. 173, 10–16.

Caughlan, L., Oakley, K.L., 2001. Cost considerations for long-term ecological monitoring. Ecol. Indic. 1 (2), 123–134.

Chape, S., Harrison, J., Spalding, M., Lysenko, I., 2005. Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philos. Trans. R. Soc. B 360 (1454), 443–455. https://doi.org/10.1098/rstb.2004.1592.

Christensen, J., 2003. Auditing conservation in an age of accountability. Conserv. Pract. 4 (3), 12–18. https://doi.org/10.1111/j.1526-4629.2003.tb00065.x.

Coad, L., Leverington, F., Knights, K., Geldmann, J., Eassom, A., Kapos, V., Kingston, N., de Lima, M., Zamora, C., Cuardros, I., 2015. Measuring impact of protected area management interventions: current and future use of the global database of protected area management effectiveness. Philos. Trans. R. Soc. Lond., B, Biol. Sci. 370 (1681), 20140281.

Coad, L., Watson, J.E., Geldmann, J., Burgess, N.D., Leverington, F., Hockings, M., Knights, K., Di Marco, M., 2019. Widespread shortfalls in protected area resourcing undermine efforts to conserve biodiversity. Front. Ecol. Environ. 17 (5), 259–264.

Convertino, M., Baker, K.M., Vogel, J.T., Lu, C., Suedel, B., Linkov, I., 2013. Multi-criteria decision analysis to select metrics for design and monitoring of sustainable ecosystem restorations. Ecol. Indic. 26, 76–86.

Cook, C.N., Hockings, M., 2011. Opportunities for improving the rigor of management effectiveness evaluations in protected areas. Conserv. Lett. 4 (5), 372–382. https://doi.org/10.1111/j.1755-263X.2011.00189.x.

Cook, C.N., Hockings, M., Carter, R.W., 2010. Conservation in the dark? The information used to support management decisions. Front. Ecol. Environ. 8 (4), 181–186.

Cook, C.N., Carter, R.B., Fuller, R.A., Hockings, M., 2012. Managers consider multiple lines of evidence important for biodiversity management decisions. J. Environ. Manag. 113, 341–346.

Corrigan, C., Robinson, J., C., Burgess, N. D., Kingston, N., & Hockings, M., 2018. Global review of social indicators used in protected area management evaluation. Conserv. Lett. 11 (2), e12397.

Craigie, I.D., Barnes, M.D., Geldmann, J., Woodley, S., 2015. International funding agencies: potential leaders of impact evaluation in protected areas? Philos. Trans. R. Soc. Lond., B, Biol. Sci. 370 (1681), 20140283 https://doi.org/10.1098/rstb.2014.0283.

Cvitanovic, C., Hobday, A.J., van Kerkhoff, L., Marshall, N.A., 2015. Overcoming barriers to knowledge exchange for adaptive resource management; the perspectives of Australian marine scientists. Mar. Policy 52, 38–44.

Dale, V.H., Beyeler, S.C., 2001. Challenges in the development and use of ecological indicators. Ecol. Indic. 1 (1), 3–10. https://doi.org/10.1016/S1470-160X(01)00003-6.

Danielsen, F., Balete, D.S., Poulsen, M.K., Enghoff, M., Nozawa, C.M., Jensen, A.E., 2000. A simple system for monitoring biodiversity in protected areas of a developing country. Biodivers. Conserv. 9 (12), 1671–1705. https://doi.org/10.1023/A:1026505324342.

Danielsen, F., Mendoza, M.M., Alviola, P., Balete, D.S., Enghoff, M., Poulsen, M.K., Jensen, A.E., 2003. Biodiversity monitoring in developing countries: what are we trying to achieve? Oryx 37 (04). https://doi.org/10.1017/S0030605303000735.

Danielsen, F., Burgess, N.D., Balmford, A., Donald, P.F., Funder, M., Jones, J.P.G., Alviola, P., Balete, D.S., Blomley, T., Brashares, J., Child, B., Enghoff, M., Fjeldså, J., Holt, S., Hübertz, H., Jensen, A.E., Jensen, P.M., Massao, J., Mendoza, M.M., Yonten, D., 2009. Local participation in natural resource monitoring: A characterization of approaches. Conserv. Biol. 23 (1), 31–42. https://doi.org/10.1111/j.1523-1739.2008.01063.x.

Danielsen, F., Burgess, N.D., Jensen, P.M., Pirhofer-Walzl, K., 2010. Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement. J. Appl. Ecol. 47 (6), 1166–1168.

Danielsen, F., Jensen, P.M., Burgess, N.D., Altamirano, R., Alviola, P.A., Andrianandrasana, H., Brashares, J.S., Burton, A.C., Coronado, I., Corpuz, N., 2014. A multicountry assessment of tropical resource monitoring by local communities. BioScience 64 (3), 236–251.

Descola, P., 2005. Par-delà nature et culture, vol. 1. Gallimard Paris.

Dudley, N., 2021. Building on Nature 236.

Dudley, N., Phillips, A., Amend, T., Brown, J., Stolton, S., 2016. Evidence for biodiversity conservation in protected landscapes. Land 5 (4), 38.

Dunham, A., Dunham, J.S., Rubidge, E., Iacarella, J.C., Metaxas, A., 2020. Contextualizing ecological performance: rethinking monitoring in marine protected areas. Aquat. Conserv.: Mar. Freshw. Ecosyst. 30 (10), 2004–2011. https://doi.org/10.1002/aqc.3381.

Eklund, J., Blanchet, F.G., Nyman, J., Rocha, R., Virtanen, T., Cabeza, M., 2016. Contrasting spatial and temporal trends of protected area effectiveness in mitigating deforestation in Madagascar. Biol. Conserv. 203, 290–297.

Ervin, J., 2003. Rapid assessment of protected area management effectiveness in four countries. BioScience 53 (9), 833–841.

Fancy, S.G., Gross, J.E., Carter, S.L., 2009. Monitoring the condition of natural resources in US national parks. Environ. Monit. Assess. 151 (1), 161–174.

Ferraro, P.J., Hanauer, M.M., 2014. Quantifying causal mechanisms to determine how protected areas affect poverty through changes in ecosystem services and infrastructure. Proc. Natl. Acad. Sci. 111 (11), 4332–4337.

Ferraro, P.J., Hanauer, M.M., 2015. Through what mechanisms do protected areas affect environmental and social outcomes? Philos. Trans. R. Soc. Lond., B, Biol. Sci. 370 (1681), 20140267 https://doi.org/10.1098/rstb.2014.0267.

Ferraro, P.J., Pattanayak, S.K., 2006. Money for nothing? A call for empirical evaluation of biodiversity conservation investments. PLoS Biol. 4 (4), e105 https://doi.org/10.1371/journal.pbio.0040105.

Ferreira, A.F., Zimmermann, H., Santos, R., von Wehrden, H., 2020. Biosphere reserves' management effectiveness–a systematic literature review and a research agenda. Sustainability 12 (14), 5497. https://doi.org/10.3390/su12145497.

Field, S.A., O'connor, P.J., Tyre, A.J., Possingham, H.P., 2007. Making monitoring meaningful. Austral Ecol. 32 (5), 485–491.

Fisher, B., Christopher, T., 2007. Poverty and biodiversity: measuring the overlap of human poverty and the biodiversity hotspots. Ecol. Econ. 62 (1), 93–101. https://doi.org/10.1016/j.ecolecon.2006.05.020.

Fox, H.E., Mascia, M.B., Basurto, X., Costa, A., Glew, L., Heinemann, D., Karrer, L.B., Lester, S.E., Lombana, A.V., Pomeroy, R.S., 2012. Reexamining the science of marine protected areas: linking knowledge to action. Conserv. Lett. 5 (1), 1–10.

Franks, P., Booker, F., & Roe, D. (2018). Understanding and assessing equity in protected area conservation. 40.

Fraser, E.D.G., Dougill, A.J., Mabee, W.E., Reed, M., McAlpine, P., 2006. Bottom up and top down: analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. J. Environ. Manag. 78 (2), 114–127. https://doi.org/10.1016/j.jenvman.2005.04.009.
Fromont, C., Blanco, J., Culas, C., Pannier, E., Razafindrakoto, M., Roubaud, F., Carrière, S.M., 2022. Towards an inclusive nature conservation initiative: preliminary assessment of stakeholders' representations about the Makay region, Madagascar. PLoS One 17 (8), e0272223. https://doi.org/10.1371/journal.pone.0272223.
Gardner, C.J., 2012. Social learning and the researcher–practitioner divide. Oryx 46 (3), 313–314.
Gardner, C.J., Nicoll, M.E., Mbohoahy, T., Oleson, K.L., Ratsifandrihamanana, A.N., Ratsirarson, J., René de Roland, L.-A., Virah-Sawmy, M., Zafindrasilivonona, B., Davies, Z.G., 2013. Protected areas for conservation and poverty alleviation: experiences from Madagascar. J. Appl. Ecol. 50 (6), 1289–1294.
Gardner, C.J., Nicoll, M.E., Birkinshaw, C., Harris, A., Lewis, R.E., Rakotomalala, D., Ratsifandrihamanana, A.N., 2018. The rapid expansion of Madagascar's protected area system. Biol. Conserv. 220, 29–36.
Geldmann, J., Barnes, M., Coad, L., Craigie, I.D., Hockings, M., Burgess, N.D., 2013. Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. Biol. Conserv. 161, 230–238.
Geldmann, J., Coad, L., Barnes, M.D., Craigie, I.D., Woodley, S., Balmford, A., Brooks, T. M., Hockings, M., Knights, K., Mascia, M.B., 2018. A global analysis of management capacity and ecological outcomes in terrestrial protected areas. Conserv. Lett. 11 (3), e12434.
Geldmann, J., Manica, A., Burgess, N.D., Coad, L., Balmford, A., 2019. A global-level assessment of the effectiveness of protected areas at resisting anthropogenic pressures. Proc. Natl. Acad. Sci. U. S. A. 116 (46), 23209–23215. https://doi.org/10.1073/pnas.1908221116.
Ghoddousi, A., Loos, J., & Kuemmerle, T. (2022). An outcome-oriented, social–ecological framework for assessing protected area effectiveness. BioScience, 72(2), 201–212. doi:https://doi.org/10.1093/biosci/biab114.
Giehl, E.L., Moretti, M., Walsh, J.C., Batalha, M.A., Cook, C.N., 2017. Scientific evidence and potential barriers in the management of Brazilian protected areas. PLoS One 12 (1), e0169917.
Godet, L., Devictor, V., 2018. What conservation does. Trends Ecol. Evol. 33 (10), 720–730.
Gossa, C., Fisher, M., Milner-Gulland, E.J., 2015. The research–implementation gap: how practitioners and researchers from developing countries perceive the role of peer-reviewed literature in conservation science. Oryx 49 (1), 80–87.
Gray, C.L., Hill, S.L., Newbold, T., Hudson, L.N., Börger, L., Contu, S., Hoskins, A.J., Ferrier, S., Purvis, A., Scharlemann, J.P., 2016. Local biodiversity is higher inside than outside terrestrial protected areas worldwide. Nat. Commun. 7 (1), 1–7.
Gurney, G.G., Cinner, J., Ban, N.C., Pressey, R.L., Pollnac, R., Campbell, S.J., Tasidjawa, S., Setiawan, F., 2014. Poverty and protected areas: an evaluation of a marine integrated conservation and development project in Indonesia. Glob. Environ. Chang. 26, 98–107.
Gurney, G.G., Darling, E.S., Jupiter, S.D., Mangubhai, S., McClanahan, T.R., Lestari, P., Pardede, S., Campbell, S.J., Fox, M., Naisilisili, W., Muthiga, N.A., D'agata, S., Holmes, K.E., Rossi, N.A., 2019. Implementing a social-ecological systems framework for conservation monitoring: lessons from a multi-country coral reef program. Biol. Conserv. 240, 108298 https://doi.org/10.1016/j.biocon.2019.108298.
Hicks, C.C., Levine, A., Agrawal, A., Basurto, X., Breslow, S.J., Carothers, C., Charnley, S., Coulthard, S., Dolsak, N., Donatuto, J., Garcia-Quijano, C., Mascia, M.B., Norman, K., Poe, M.R., Satterfield, T., St. Martin, K., & Levin, P. S., 2016. Engage key social concepts for sustainability. Science 352 (6281), 38–40. https://doi.org/10.1126/science.aad4977.
Hirschnithz-Garbers, M., Stoll-Kleemann, S., 2011. Opportunities and barriers in the implementation of protected area management: a qualitative meta-analysis of case studies from European protected areas. Geogr. J. 177 (4), 321–334.
Hockings, M., 2003. Systems for assessing the effectiveness of management in protected areas. BioScience 53 (9), 823–832.
Hockings, M., Stolton, S., Dudley, N., 2004. Management effectiveness: assessing management of protected areas? J. Environ. Policy Plan. 6 (2), 157–174.
Hockings, M., Stolton, S., Leverington, F., Dudley, N., Courrau, J., 2006. Evaluating Effectiveness: A Framework for Assessing Management Effectiveness of Protected Areas. IUCN.
Hockings, M., Stolton, S., Dudley, N., James, R., 2009. Data credibility: what are the "right" data for evaluating management effectiveness of protected areas? N. Dir. Eval. 2009 (122), 53–63.
Hulme, P.E., 2011. Practitioner's perspectives: introducing a different voice in applied ecology. J. Appl. Ecol. 48 (1), 1–2. https://doi.org/10.1111/j.1365-2664.2010.01938.x.
Jepson, P., 2005. Governance and accountability of environmental NGOs. Environ Sci Policy 8 (5), 515–524. https://doi.org/10.1016/j.envsci.2005.06.006.
Kapos, V., Balmford, A., Aveling, R., Bubb, P., Carey, P., Entwistle, A., Hopkins, J., Mulliken, T., Safford, R., Stattersfield, A., 2009. Outcomes, not implementation, predict conservation success. Oryx 43 (3), 336–342.
Knight, A. T., Cowling, R. M., Rouget, M., Balmford, A., Lombard, A. T., & Campbell, B. M. (2008). Knowing but not doing: selecting priority conservation areas and the research–implementation gap. Conserv. Biol., 22(3), 610–617. doi:https://doi.org/10.1111/j.1523-1739.2008.00914.x.
Kremen, C., Merenlender, A.M., Murphy, D.D., 1994. Ecological monitoring: a vital need for integrated conservation and development programs in the tropics. Conserv. Biol. 8 (2), 388–397. https://doi.org/10.1046/j.1523-1739.1994.08020388.x.
Lee, W.H., Abdullah, S.A., 2019. Framework to develop a consolidated index model to evaluate the conservation effectiveness of protected areas. Ecol. Indic. 102, 131–144. https://doi.org/10.1016/j.ecolind.2019.02.034.
Leverington, F., Costa, K.L., Pavese, H., Lisle, A., Hockings, M., 2010. A global analysis of protected area management effectiveness. Environ. Manag. 46 (5), 685–698. https://doi.org/10.1007/s00267-010-9564-5.
Likens, G., Lindenmayer, D., 2018. Effective Ecological Monitoring. CSIRO publishing.
Lin, T., Lin, J., Cui, S., Cameron, S., 2009. Using a network framework to quantitatively select ecological indicators. Ecol. Indic. 9 (6), 1114–1120. https://doi.org/10.1016/j.ecolind.2008.12.009.
Lindenmayer, D.B., Likens, G.E., 2010. The science and application of ecological monitoring. Biol. Conserv. 143 (6), 1317–1328. https://doi.org/10.1016/j.biocon.2010.02.013.
Lockwood, M., 2010. Good governance for terrestrial protected areas: a framework, principles and performance outcomes. J. Environ. Manag. 91 (3), 754–766. https://doi.org/10.1016/j.jenvman.2009.10.005.
Lovett, G.M., Burns, D.A., Driscoll, C.T., Jenkins, J.C., Mitchell, M.J., Rustad, L., Shanley, J.B., Likens, G.E., Haeuber, R., 2007. Who needs environmental monitoring? Front. Ecol. Environ. 5 (5), 253–260.
Mammides, C., 2020. Evidence from eleven countries in four continents suggests that protected areas are not associated with higher poverty rates. Biol. Conserv. 241, 108353.
Mann-Lang, J., Branch, G., Mann, B., Sink, K., Kirkman, S., Adams, R., 2021. Social and economic effects of marine protected areas in South Africa, with recommendations for future assessments. Afr. J. Mar. Sci. 43 (3), 367–387. https://doi.org/10.2989/1814232X.2021.1961166.
Margoluis, R., Salafsky, N., 1998. Measures of Success. Island Press.
Mascia, M.B., Claus, C.A., Naidoo, R., 2010. Impacts of marine protected areas on fishing communities. Conserv. Biol. 24 (5), 1424–1429.
Mascia, M.B., Pailler, S., Thieme, M.L., Rowe, A., Bottrill, M.C., Danielsen, F., Geldmann, J., Naidoo, R., Pullin, A.S., Burgess, N.D., 2014. Commonalities and complementarities among approaches to conservation monitoring and evaluation. Biol. Conserv. 169, 258–267. https://doi.org/10.1016/j.biocon.2013.11.017.
Maxwell, S.L., Cazalis, V., Dudley, N., Hoffmann, M., Rodrigues, A.S.L., Stolton, S., Visconti, P., Woodley, S., Kingston, N., Lewis, E., Maron, M., Strassburg, B.B.N., Wenger, A., Jonas, H.D., Venter, O., Watson, J.E.M., 2020. Area-based conservation in the twenty-first century. Nature 586 (7828), 217–227. https://doi.org/10.1038/s41586-020-2773-z.
Mezquida, J.A.A., De Fernández, J.V.L., Yangüas, M.A.M., 2005. A framework for designing ecological monitoring programs for protected areas: a case study of the Galachos del Ebro Nature Reserve (Spain). Environ. Manag. 35 (1), 20–33.
Miteva, D.A., Pattanayak, S.K., Ferraro, P.J., 2012. Evaluation of biodiversity policy instruments: what works and what doesn't? Oxf. Rev. Econ. Policy 28 (1), 69–92.
Mora, C., Sale, P.F., 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. Mar. Ecol. Prog. Ser. 434, 251–266.
Moreaux, C., Zafra-Calvo, N., Vansteelant, N.G., Wicander, S., Burgess, N.D., 2018. Can existing assessment tools be used to track equity in protected area management under Aichi Target 11? Biol. Conserv. 224, 242–247.
Murray, C., Marmorek, D., 2003. Adaptive Management: A Science-based Approach to Managing Ecosystems in the Face of Uncertainty.
Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403 (6772), 853–858.
Naidoo, R., Gerkey, D., Hole, D., Pfaff, A., Ellis, A., Golden, C., Herrera, D., Johnson, K., Mulligan, M., Ricketts, T., Fisher, B., 2019. Evaluating the impacts of protected areas on human well-being across the developing world. Sci. Adv. 5, eaav3006 https://doi.org/10.1126/sciadv.aav3006.
Naughton-Treves, L., Holland, M.B., Brandon, K., 2005. The role of protected areas in conserving biodiversity and sustaining local livelihoods. Annu. Rev. Environ. Resour. 30 (1), 219–252. https://doi.org/10.1146/annurev.energy.30.050504.164507.
Neugarten, R.A., Wolf, S.A., Stedman, R.C., Tear, T.H., 2011. Integrating ecological and socioeconomic monitoring of working forests. BioScience 61 (8), 631–637.
Nicoll, M., Ratsifandrihamanana, N., 2014. The growth of Madagascar's protected areas system and its implications for tenrecs (Afrosoricida, Tenrecidae). Afrotherian Conserv. 10, 4–8.
Niemeijer, D., de Groot, R.S., 2008. A conceptual framework for selecting environmental indicator sets. Ecol. Indic. 8 (1), 14–25.
Nolte, C., Agrawal, A., 2013. Linking management effectiveness indicators to observed effects of protected areas on fire occurrence in the Amazon rainforest. Conserv. Biol. 27 (1), 155–165.
Oldekop, J.A., Holmes, G., Harris, W.E., Evans, K.L., 2016. A global assessment of the social and conservation outcomes of protected areas. Conserv. Biol. 30 (1), 133–141.
Palfrey, R., Oldekop, J., Holmes, G., 2021. Conservation and social outcomes of private protected areas. Conserv. Biol. 35 (4), 1098–1110. https://doi.org/10.1111/cobi.13668.
Palomo, I., Montes, C., Martin-Lopez, B., González, J.A., Garcia-Llorente, M., Alcorlo, P., Mora, M.R.G., 2014. Incorporating the social–ecological approach in protected areas in the Anthropocene. BioScience 64 (3), 181–191.
Pereira, H.M., Ferrier, S., Walters, M., Geller, G.N., Jongman, R.H.G., Scholes, R.J., Bruford, M.W., Brummitt, N., Butchart, S.H.M., Cardoso, A.C., Coops, N.C., Dulloo, E., Faith, D.P., Freyhof, J., Gregory, R.D., Heip, C., Höft, R., Hurtt, G., Jetz, W., Wegmann, M., 2013. Essential biodiversity variables. Science. https://doi.org/10.1126/science.1229931.

Powlen, K.A., Gavin, M.C., Jones, K.W., 2021. Management effectiveness positively influences forest conservation outcomes in protected areas. Biol. Conserv. 260, 109192 https://doi.org/10.1016/j.biocon.2021.109192.

Pressey, R.L., Weeks, R., Gurney, G.G., 2017. From displacement activities to evidence-informed decisions in conservation. Biol. Conserv. 212, 337–348. https://doi.org/10.1016/j.biocon.2017.06.009.

Pullin, A.S., Knight, T.M., 2005. Assessing conservation management's evidence base: a survey of management-plan compilers in the United Kingdom and Australia. Conserv. Biol. 19 (6), 1989–1996.

Pullin, A.S., Bangpan, M., Dalrymple, S., Dickson, K., Haddaway, N.R., Healey, J.R., Hauari, H., Hockley, N., Jones, J.P., Knight, T., 2013. Human well-being impacts of terrestrial protected areas. Environ. Evid. 2 (1), 1–41.

Pyhälä, A., Eklund, J., McBride, M.F., Rakotoarijaona, M.A., Cabeza, M., 2019. Managers' perceptions of protected area outcomes in Madagascar highlight the need for species monitoring and knowledge transfer. Conserv. Sci. Pract. 1 (2), e6.

Quintana, A., Basurto, X., Van Dyck, S.R., Weaver, A.H., 2020. Political making of more-than-fishers through their involvement in ecological monitoring of protected areas. Biodivers. Conserv. 29 (14), 3899–3923.

Rafidimanantsoa, H.P., Poudyal, M., Ramamonjisoa, B.S., Jones, J.P., 2018. Mind the gap: the use of research in protected area management in Madagascar. Madag. Conserv. Dev. 13 (1), 15–24.

Rakotomanana, H., Jenkins, R. K., & Ratsimbazafy, J. (2013). Conservation challenges for Madagascar in the next decade. *Conservation Biology: Voices from the Tropics. NPH Raven, S. Sodhi and L. Gibson (eds.)*, 33-39.

Reed, M.S., 2008. Stakeholder participation for environmental management: a literature review. Biol. Conserv. 141 (10), 2417–2431. https://doi.org/10.1016/j.biocon.2008.07.014.

Reed, M.S., Dougill, A.J., Baker, T.R., 2008. Participatory Indicator development: what can ecologists and local communities learn from each other. Ecol. Appl. 18 (5), 1253–1269. https://doi.org/10.1890/07-0519.1.

Rodrigues, A.S., Cazalis, V., 2020. The multifaceted challenge of evaluating protected area effectiveness. Nat. Commun. 11 (1), 5147.

Rodríguez-Rodríguez, D., Rees, S.E., Rodwell, L.D., Attrill, M.J., 2015. IMPASEA: a methodological framework to monitor and assess the socioeconomic effects of marine protected areas. An English Channel case study. Environ Sci Policy 54, 44–51. https://doi.org/10.1016/j.envsci.2015.05.019.

Salafsky, N., Margoluis, R., Redford, K., 2000. Adaptive Management: A Tool for Conservation Practitioners.

Salzer, D., Salafsky, N., 2006. Allocating resources between taking action, assessing status, and measuring effectiveness of conservation actions. Nat. Areas J. 26 (3), 310–316.

Sheil, D., 2001. Conservation and biodiversity monitoring in the tropics: realities, priorities, and distractions. Conserv. Biol. 15 (4), 1179–1182.

Singleton, S., 2009. Native people and planning for marine protected areas: how "stakeholder" processes fail to address conflicts in complex, real-world environments. Coast. Manag. 37 (5), 421–440. https://doi.org/10.1080/08920750902954072.

Smallhorn-West, P.F., Weeks, R., Gurney, G., Pressey, R.L., 2020. Ecological and socioeconomic impacts of marine protected areas in the South Pacific: assessing the evidence base. Biodivers. Conserv. 29 (2), 349–380. https://doi.org/10.1007/s10531-019-01918-1.

Stem, C., Margoluis, R., Salafsky, N., Brown, M., 2005. Monitoring and evaluation in conservation: a review of trends and approaches. Conserv. Biol. 19 (2), 295–309.

Stoll-Kleemann, S., 2010. Evaluation of management effectiveness in protected areas: methodologies and results. Basic Appl. Ecol. 11 (5), 377–382.

Stolton, S., Hockings, M., Dudley, N., MacKinnon, K., Whitten, T., 2003. Reporting Progress in Protected Areas a Site-Level Management Effectiveness Tracking Tool. World Bank / WWF Alliance.

Stolton, S., Dudley, N., Belokurov, A., Deguignet, M., Burgess, N.D., Hockings, M., Leverington, F., MacKinnon, K., Young, L., 2019. Lessons learned from 18 years of implementing the management effectiveness tracking tool (METT): a perspective from the METT developers and implementers. Parks 25 (2), 79–92.

Théau, J., Trottier, S., Graillon, P., 2018. Optimization of an ecological integrity monitoring program for protected areas: case study for a network of national parks. PLoS One 13 (9), e0202902.

Thompson, K.-L., Lantz, T., Ban, N., 2020. A review of indigenous knowledge and participation in environmental monitoring. Ecol. Soc. 25 (2) https://doi.org/10.5751/ES-11503-250210.

Timko, J.A., Innes, J.L., 2009. Evaluating ecological integrity in national parks: case studies from Canada and South Africa. Biol. Conserv. 142 (3), 676–688.

Timko, J.A., Satterfield, T., 2008. Seeking social equity in national parks: experiments with evaluation in Canada and South Africa. Conserv. Soc. 6 (3), 238–254.

Turnhout, E., Hisschemöller, M., Eijsackers, H., 2007. Ecological indicators: between the two fires of science and policy. Ecol. Indic. 7 (2), 215–228. https://doi.org/10.1016/j.ecolind.2005.12.003.

UNEP-WCMC, 2021. Protected Planet Digital Report 2021 (December Update). IUCN & NGS. https://livereport.protectedplanet.net.

UNEP-WCMC, IUCN, 2023. Protected Planet: The World Database on Protected Areas (WDPA) (UNEP-WCMC and IUCN). www.protectedplanet.net.

Villasenor, E., Porter-Bolland, L., Escobar, F., Guariguata, M.R., Moreno-Casasola, P., 2016. Characteristics of participatory monitoring projects and their relationship to decision-making in biological resource management: a review. Biodivers. Conserv. 25, 2001–2019.

Virah-Sawmy, M., Gardner, C., Ratsifandrihamanana, A.N.A., 2014. The Durban Vision in Practice: Experiences in Participatory Governance of Madagascar's New Protected Areas, pp. 216–252.

Vuola, M., Pyhälä, A., 2016. Local community perceptions of conservation policy: rights, recognition and reactions. Madag. Conserv. Dev. 11 (2), 77–86.

Waeber, P.O., Wilmé, L., Mercier, J.-R., Camara, C., Lowry, P.P., 2016. How effective have thirty years of internationally driven conservation and development efforts been in Madagascar? PLoS One 11 (8), e0161115.

Watson, J.E.M., Dudley, N., Segan, D.B., Hockings, M., 2014. The performance and potential of protected areas. Nature 515 (7525), 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., 2016. Bolder science needed now for protected areas. Conserv. Biol. 30 (2), 243–248. https://doi.org/10.1111/cobi.12645.

Working group on the post-2020 global biodiversity framework, 2021. First Draft of the Post-2020 Global Biodiversity Framework, p. 12.

Zafra-Calvo, N., Geldmann, J., 2020. Protected areas to deliver biodiversity need management effectiveness and equity. Glob. Ecol. Conserv. 22, e01026 https://doi.org/10.1016/j.gecco.2020.e01026.

Zafra-Calvo, N., Garmendia, E., Pascual, U., Palomo, I., Gross-Camp, N., Brockington, D., Cortes-Vazquez, J.-A., Coolsaet, B., Burgess, N.D., 2019. Progress toward equitably managed protected areas in Aichi target 11: a global survey. BioScience 69 (3), 191–197. https://doi.org/10.1093/biosci/biy143.