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REVIEWS

How far have we come? A review of MPA network performance indicators in reaching qualitative elements of Aichi Target 11

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Abstract

Effective networks of marine protected areas (MPAs) are explicitly recognized and called for in international biodiversity conservation strategies such as the Aichi Targets. While various indicators have been proposed to assess effectiveness of individual MPAs, no comprehensive set of indicators exists for MPA networks, particularly for Aichi Target 11. The qualitative elements of this target recognize the value of social, economic, governance, and ecological factors in achieving effective biodiversity conservation. Here, we used a systematic literature review to identify indicators of MPA network effectiveness. We reviewed 64 publications, identifying 48 indicators that could be aligned with the qualitative elements. Results showed that assessments of MPA network effectiveness predominantly focused on effective management while neglecting equitable management and integration into the wider land and seascape. Indicators tended to focus on ecological characteristics, overlooking social, economic, and governance dimensions. Key challenges in addressing these gaps include identifying conflicting priorities and objectives in adjacent marine and land areas that interfere with cooperation and knowledge sharing, and ensuring diverse areas with distinct social and ecological contexts are considered. This study provides the first review of indicators for assessing MPA networks and adds to the literature assessing whether current and future targets can be met.

KEYWORDS
conservation policy, conservation strategies, monitoring and evaluation, multidisciplinary, social–ecological conservation

1 | INTRODUCTION

The protection of global marine and coastal ecosystems has garnered increased scientific and political interest in the last decade, driven by international targets such as the Convention on Biological Diversity's (CBD) Aichi Target 11 (Sala et al., 2018). Aichi Target 11 calls for "… at least 17 per cent of terrestrial and inland water areas, and

10 per cent of coastal and marine areas of particular importance for biodiversity and ecosystem services [to be conserved through] effectively and equitably managed, ecologically representative, well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape" (CBD 2011). The amount of area each country sets aside for terrestrial protected areas and marine protected areas (MPAs) is the principal indicator for determining effectiveness of this approach (Adams, Iacona, & Possingham, 2019; Gannon et al., 2017). While focusing on the area alone makes it more straightforward to assess and may help bolster political will, such a simple measure falls short as a proxy for protected area effectiveness (Claudet et al., 2020; Coad et al., 2019; DeSanto, 2013; Zupan et al., 2018). The six qualitative elements of Aichi Target 11 (hereafter *qualitative elements*; "areas of importance for biodiversity conservation and ecosystem services," "ecological connectivity," "equitable management," "effective management," "integration into the wider land and seascape," and "ecological representation") are designed to ensure that established protected areas are effective beyond consideration of the quantitative target by providing a conceptualization of how MPA networks should attain biodiversity conservation (Geldmann et al., 2020; Rees, Foster, Langmead, Pittman, & Johnson, 2018).

Aichi Target 11 contributes to a growing awareness that conservation strategies need to move beyond protecting individual, isolated areas (Adams et al., 2019; CBD 2011). This is particularly relevant for marine systems, which is the focus of this research. MPAs are established to safeguard threatened marine ecosystems and species from destructive human activity (CBD 2011). A collection of individual MPAs intentionally arranged into an organized group is considered an MPA network. MPAs within a network thereby operate in a cooperative and synergistic manner (IUCN-WCPA 2008). As a result, an MPA network is thought to be more than the sum of its parts (Grorud-Colvert et al., 2014). MPA networks are essential biodiversity conservation tools designed to improve marine biodiversity protection by encompassing spatial scales that better reflect species' life history distributions (Green et al., 2007). They can help mitigate the impact of climate change through the application of network design elements such as replication, representation, and connectivity (McLeod, Salm, Green, & Almany, 2009). MPA networks may also enable cost sharing and collaboration among communities and conflict relief in high-use areas (White, Alino, & Meneses, 2005). Aichi Target 11 also promotes conservation beyond boundaries by recognizing the crucial role of governance, economic, social, and ecological factors working in concert to influence ecological outcomes (Gill et al., 2017; Hill, Johnson, & Adamowski, 2016; Yates, Clarke, & Thurstan, 2019). Implementing effective MPA networks requires careful consideration of these factors, also known as dimensions that underlie the social and ecological links within the ecosystem (McGinnis & Ostrom 2014). Therefore, here, we define effectiveness as the degree to which MPA networks demonstrate characteristics related to the six Aichi Target 11 qualitative elements (Gannon et al., 2017; Woodley et al., 2012).

Monitoring and evaluation are important steps in deciphering whether a conservation approach is reaching its objective(s) (Conservation Measures Partnership 2013; Heink & Kowarik 2010). This process makes use of indicators to track progress of the project and understand the impacts of the intervention and whether objectives are being attained (Conservation Measures Partnership 2013). An indicator is a variable used to describe or measure the status of a particular characteristic of a system over time, such as change in abundance of a species (Hockings et al., 2006; Pomeroy, Parks, & Watson, 2004; Woodcock et al., 2017). Evaluations of MPA effectiveness exist for a range of objectives, from effectiveness of community management on livelihoods, fisheries, or agricultural practices to the benefits provided by MPAs for ecosystem health and biodiversity (Coad et al., 2013). Evaluating the effectiveness of MPA networks will require assessing individual MPA contributions, as well as those specifically associated with MPA networks. For instance, the well-established ecological benefits of individual (fully protected) MPAs (Lester & Halpern 2008; Sala & Giakoumi 2017) and the factors such as size, age, socioeconomics, and governance that influence effectiveness across various scales (Charles & Wilson 2008; Claudet et al., 2008; Mizrahi, Diedrich, Weeks, & Pressey, 2018) have been validated in MPA networks (Grorud-Colvert et al., 2014; Lowry, White, & Christie, 2009). As such, individual MPAs may provide relevant insights for MPA networks (IUCN-WCPA 2008).

While many studies proposed indicators that can help assess the effectiveness of individual MPAs (Woodcock et al., 2017), indicators for measuring network-specific elements (e.g. connectivity, representativeness) are infrequently used in practice (see Gannon et al., 2017), (Geldmann et al., 2020). Furthermore, a synthesis of indicators that can be used for evaluating effectiveness of MPA networks in achieving Aichi Target 11 (e.g., equity, land–sea integration) is still needed (Geldmann et al., 2020). Here, we draw upon several existing MPA evaluation frameworks to organize indicators and ensure a practical connection to existing evaluation initiatives (Gannon et al., 2017; Leverington, Costa, Pavese, Lisle, & Hockings, 2010; Pomeroy et al., 2004). These frameworks were developed over time, in consultation with global participants; as such, they provide a context and structure for indicator organization. Furthermore, these frameworks apply

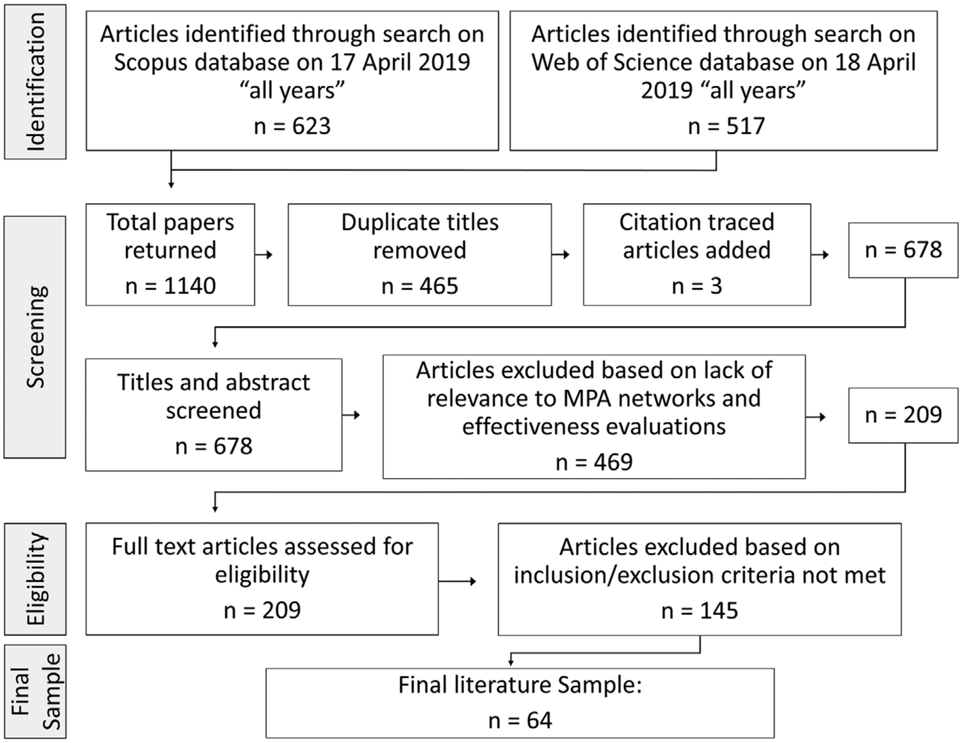

FIGURE 1 Flowchart outlining the literature search and review process based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) four-phase flow diagram for systematic reviews (Moher et al., 2009)

guidance for assessing management effectiveness, which details six management stages that outline the iterative process inherent in effective protected area management (Hockings et al., 2006). Finally, the frameworks provide a categorization of indicators based on the social, ecological, economic, and governance dimensions previously discussed.

The purpose of our literature review was to identify existing indicators from the MPA network evaluation literature, then characterize the use of these indicators in evaluating MPA network effectiveness toward achieving Target 11. MPA networks are multifaceted, and demonstrate complex social and ecological relationships influencing, and being influenced by, these conservation measures (Corrigan, Robinson, Burgess, Kingston, & Hockings, 2017; Rees et al., 2018). We explored how indicators are used to measure each qualitative element, including the dimensions (social, ecological, economic, and governance) and six management stages (context, planning, process, input, output, and outcome) they are associated with. We identified the gaps in the types of indicators used to evaluate MPA networks and their diversity and distribution in evaluating the qualitative elements. The gaps identified through this review will enable further inquiry into the best approach to evaluate networks of MPAs.

2 | METHODS

We conducted a systematic literature review to identify indicators used to assess MPA network effectiveness in achieving the qualitative elements (Moher et al., 2009). We searched peer-reviewed publications using Web of Science core collection database (1900 to April 2019) and Elsevier's Scopus database (1995 to April 2019) (see Table S1 for the search terms used). In addition, we used the citation tracing method (i.e., reviewing citations within selected publications) to add relevant publications that were not captured in the original literature search. For all selected publications, we reviewed titles and abstracts to ensure that studies evaluated or discussed the effectiveness of some aspects of an MPA network or system of MPAs. To avoid the introduction of subjective error through interpretation, we accepted what each study identified as an MPA network, not further evaluating whether it fit our definition.

Publications that discussed MPA network design or the status of an area prior to MPA network implementation were excluded (Figure 1) as we wanted studies that specifically assessed the network after implementation. We coded each of the final publications selected for (1) geographic location of the study, (2) one or more of the six Aichi Target 11 qualitative elements evaluated (Table 1, Figure 2), (3) one or more of the dimensions covered by the research

TABLE 1 Description of the six Aichi Target 11 qualitative elements used in this review; abbreviations used in some figures are in parentheses

Aichi Target 11 qualitative element	Description
Areas of particular importance for biodiversity and ecosystem services (areas of importance)	Areas of importance are considered "geographically or oceanographically discrete areas that provide important [biodiversity and ecosystem] services to one or more species/populations of an ecosystem or to the ecosystem as a whole, compared to other surrounding areas or areas of similar ecological characteristics, or otherwise meet the criteria as identified in annex I to decision IX/20" (CBD 2008).
Effectively managed	Effective management describes the extent to which management achieves goals and objectives designated for a particular area (Hockings et al., 2006). This includes design issues relating to both individual sites and protected area systems; adequacy and appropriateness of management systems and processes; effective public participation and social policy processes, and delivery of protected area objectives (Woodley et al., 2012).
Equitably managed (equity)	Equitable management highlights the impact and benefit of conservation actions on human well-being and social systems, including the fair distribution of economic benefits and livelihood opportunities (distributional equity); the process for involvement and inclusion of stakeholders in planning, implementing, and administering (procedural equity); and the process of acknowledging and accepting the legitimacy of rights, values, interests, and priorities of different actors and respecting their human dignity (recognitional equity) (Juffe-Bignoli et al. 2014; Schreckenberg et al., 2016).
Ecologically representative (representative)	Representativeness is considered the inclusion of areas that represent the entire suite of "different biogeographical subdivisions of the global oceans and regional seas that reasonably reflect the full range of ecosystems, including the biotic and habitat diversity of these marine ecosystems" (CBD 2008). Representative includes the element of replication to ensure risk is minimized in the event of unforeseen or catastrophic events (Rees et al., 2018).
Well-connected (connectivity)	Connectivity in relation to MPA networks concerns the "linkages whereby protected sites benefit from larval and/or species exchanges, and functional linkages from other network sites" (CBD 2008).
Integrated into wider landscape and seascape (integrated)	In recognition that protected areas cannot work in isolation, this element identifies the importance of integrating MPAs with other conservation and management tools, such as fisheries management or land use plans for land-based sources of pollution. Other considerations for this element include potential cumulative impacts stemming from climate change, ocean acidification, ocean noise, and pollution (Juffe-Bignoli et al. 2014; Rees et al., 2018).

(ecological, social, economic, or governance, Table 2), (4) the stages being evaluated in the process of effective management (i.e., context, planning, inputs, process, and outputs) as proposed in Hockings et al., 6) framework for the assessment of protected area management effectiveness, and (5) the variable(s) used to evaluate each element of the MPA network. Finally, (6) we hierarchically organized each variable into an indicator, noting that some variables were already indicators.

We consider a variable as a factor, trait, or condition that noticeably responds to a management action and can therefore be used to measure the effect of that action. Although variables may or may not be explicitly identified as such in the publications, we considered each measurement of a qualitative element as a variable (Pelletier et al., 2005). The distribution of pink sea fans in southwest U.K. waters (Pikesley et al., 2016), for example, is considered a variable for assessing MPA network connectivity. We hierarchically classified each site-specific variable into indicators to reduce redundancy of site-specific variables and match indicators at a similar scale of measurement (Leverington et al., 2010). The variable "distribution of pink sea fans," for example, was organized into the indicator "species distribution" (see Table S2 for categorization). This hierarchical classification was based on existing frameworks designed to assess individual MPAs (Leverington et al., 2010; Pomeroy et al., 2004) and MPA networks (Gannon et al., 2017).

We counted the number of times each element was assessed, the indicators used to assess it, and the dimensions and management stages associated with each indicator. Finally, we identified gaps in indicators used in the literature (to date) by evaluating the composition of the indicators, specifically the dimensions and management

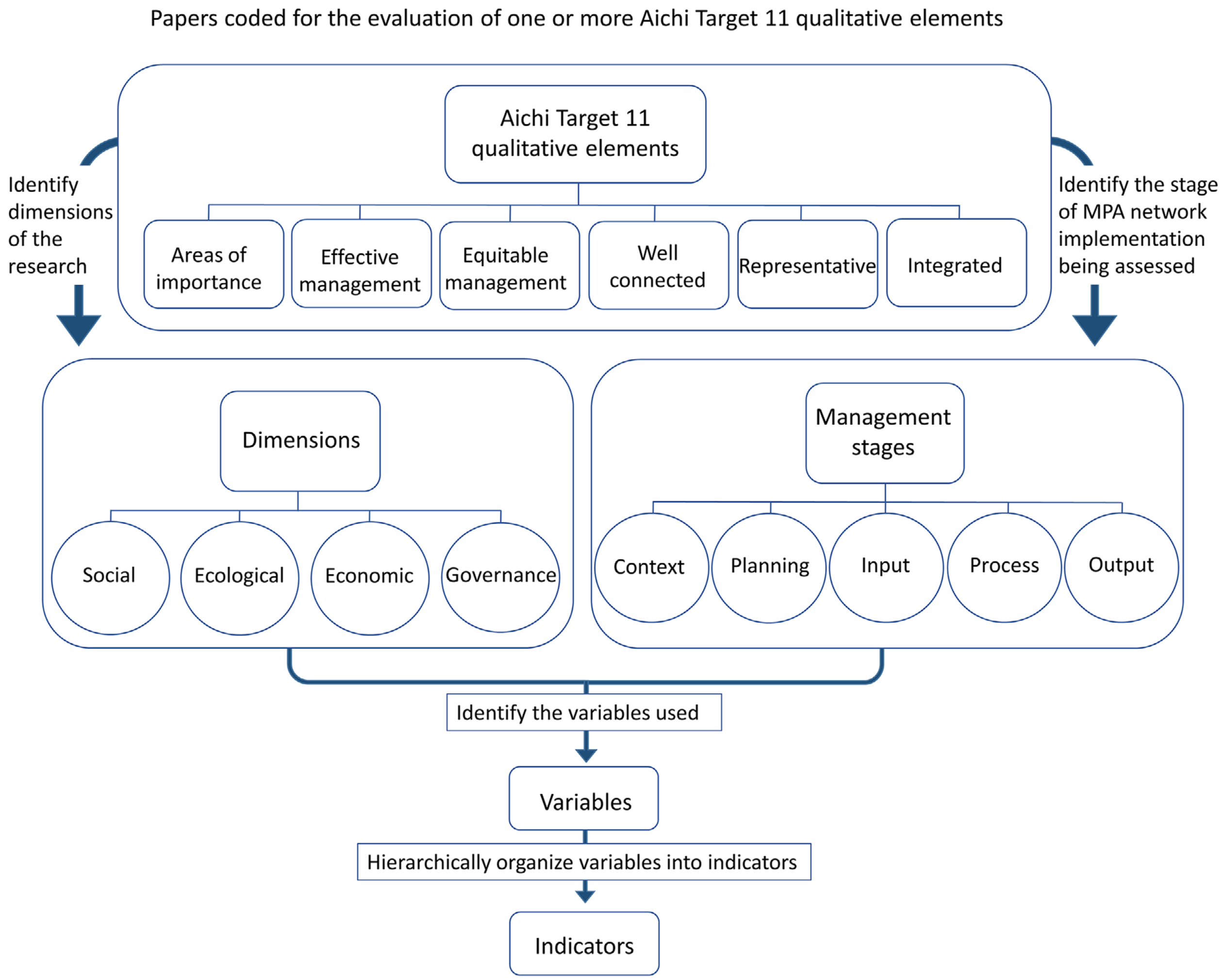

FIGURE 2 Organizational structure of the decision-making process. Papers were first coded for the Aichi Target 11 qualitative elements they evaluated, then each paper was assigned to one or more dimensions in which the research was associated and to a management stage based on where in the process of MPA network management and implementation the research was taking place (following Hockings et al., 2006). The factor(s) that were used to measure change were identified as variables. The variables were then hierarchically assigned to indicators based on Leverington et al. (2010), Pomeroy et al. (2004), and Gannon et al. (2017)

stages associated with each indicator. We then developed a flow diagram (SankeyMATIC, Bogart 2016) to show the structure and distribution of the suite of indicators measuring the qualitative elements. This diagram reflects the frequency each indicator is linked to the management stages, dimensions, and qualitative elements.

To support our general findings on the suite of indicators and to help highlight gaps in how indicators are used to measure effectiveness, we calculated Shannon (H') diversity and evenness (E). These metrics are commonly used in community ecology to characterize species diversity, which we adapted to look at the diversity of indicators across qualitative elements. Shannon diversity incorporates total number and distribution of individuals and is sensitive to rare species, which is necessary to capture the rare presence of indicators for some dimensions. To calculate Shannon's diversity, we used the formula: $H' = -\sum n_i/N \times \ln(n_i/N)$, where n_i is the number of indicators used to evaluate each individual quantitative element i and where N is the total number of indicators used across all qualitative elements. A high diversity score means that many different indicators are used to evaluate a specific qualitative element, while a low score means that one or a few indicators are used to evaluate an element. We also calculated Shannon evenness (E) to quantify the distribution of indicators used to measure each qualitative element, as $E = H'/\ln(S)$, where S refers to the indicator richness, the number of different indicators used to measure a qualitative element (Verberk, 2011). A higher evenness score indicates that a given qualitative element is assessed by a wide variety of indicators, with no indicator dominating the evaluations. A low evenness score means that few (or one) indicators are used predominantly to evaluate this element. These matrices show how the indicators were

TABLE 2 Description of the terminology used in this paper

Term	Description
Variable	An observed (quantifiable) factor, trait, or condition that responds to a local change such as implementation of a management action (Pelletier et al., 2005).
Indicator	An indicator is a suite of one or more qualitative or quantitative variables (social, environmental, etc.) used to measure the status or change over time of a particular characteristic of interest in an ecosystem (Pomeroy et al., 2004).
Dimension	Dimensions are the ecological, governance, social, and economic factors inherent in social–ecological systems that influence and are influenced by a management action (Pomeroy et al., 2004). • The ecological dimension is important to understand the state of the system, the species or habitats of interest so that an intervention can proceed in an appropriate manner suitable to the needs of the species. • The governance dimension includes aspects that help maintain or influence legislation, management, and decision making. • The social dimension includes aspects of compliance, perceptions, and participation and engagement in resource management. • The economic dimension includes financial resources and capital necessary to implement and achieve conservation initiatives.
Management stage	Six management stages are considered important in the progress toward effective management of MPAs. They outline an adaptive process inherent in effective protected areas (context, planning, process, input, output, and outcome) design, implementation, and management (Hockings et al., 2006). • Context refers to the underlying conditions associated with a protected area, including status and threats, and target species; the needs, abilities, and desires of the stakeholders. • Planning refers to establishing a clear objective, and issues of design, including preferred strategies or approaches to achieve the objective(s). • Input refers to the resources (financial, personnel, material) needed for the project to come to fruition. • Process relates to how the actions undertaken to achieve results—the adequacy of approaches in relation to the management objectives. • Output pertains to the goods and services produced to realize the MPA objectives. • Outcome relates to the highest level of results in relation to long-term objectives—fully achieving Aichi Target 11.

distributed across each Aichi Target 11 qualitative element. All analyses and figures, unless specified otherwise, were done using R (R core team 2019) with package vegan 2.5-6 (Oksanen et al., 2019) and ggplot2 version 2_3.3.2 (Wickham, 2016).

3 | RESULTS

Our review identified 64 papers that discussed the effectiveness of an MPA network or system of MPAs in reaching one or more qualitative elements. Our analysis of those papers identified 223 variables, organized into 48 headline indicators that can help assess the effectiveness of MPA networks in achieving Aichi Target 11 qualitative elements. Each indicator identified from the literature matches one or more qualitative elements. We found an uneven distribution in the assessment of Aichi Target 11 qualitative elements in the literature. MPA networks were predominantly evaluated for management effectiveness. Ecological indicators identified in our study are closely aligned with those of individual MPAs (Leverington et al., 2010; Pomeroy et al., 2004) and with indicators previously identified for MPA networks (Gannon et al., 2019). Publications reviewed focused on 34 MPA networks from 15 countries (Figure 3, Table S3), and four regions including the Mediterranean Sea (n = 5), Northeast Atlantic (n = 2), Western Pacific (n = 1), Persian/Arabian Gulf (n = 1), and three studies located in an area beyond national jurisdiction (ABNJ), the OSPAR network. Several studies were global in scope (n = 5). We found that MPA networks in Australia were assessed most often (n = 14), followed by the United States (n = 11) (Figure 3). Several networks were assessed multiple times by various researchers, including the Great Barrier Reef and the Hawai'ian MPA networks (see Table S3 for the list).

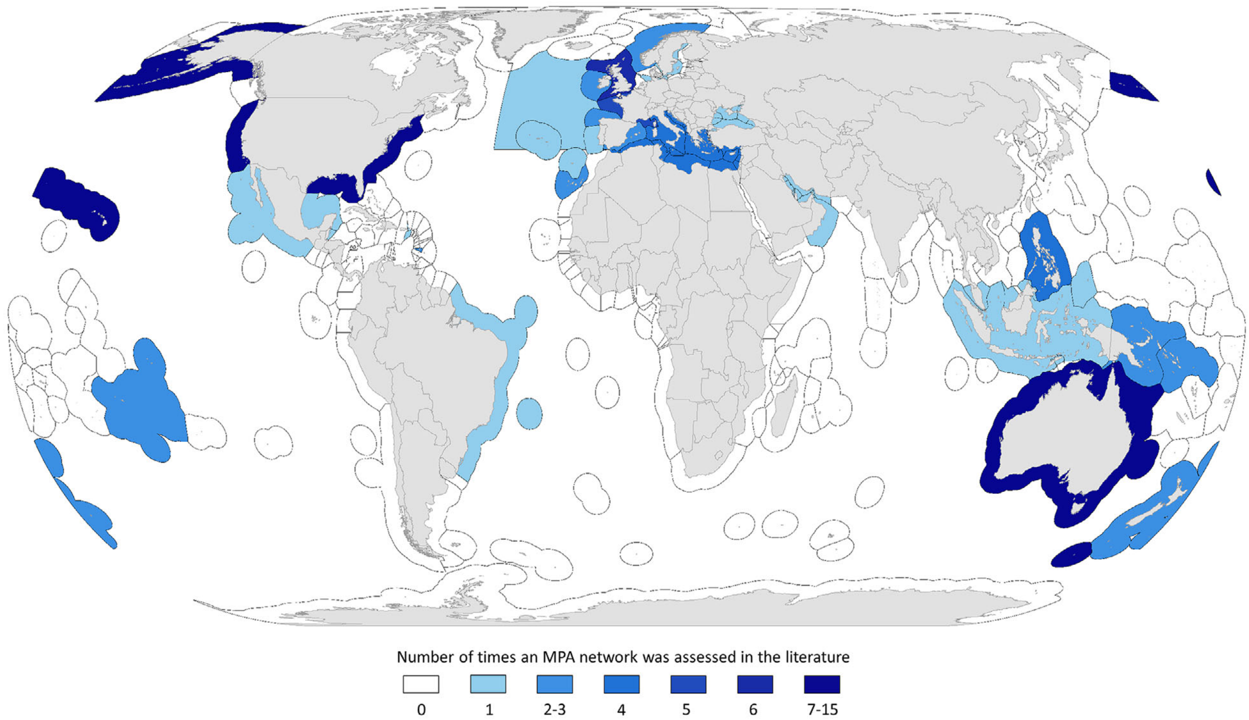

FIGURE 3 Exclusive economic zones (EEZs) of countries and regions that have MPA networks evaluated in our literature review. Color grades represent the number of times an MPA network was studied in the countries associated with the EEZ; OSPAR area beyond national jurisdiction (ABNJ) is also depicted, having been assessed once

3.1 | Aichi Target 11 qualitative elements

"Effective management" was the qualitative element assessed most thoroughly. This element was assessed 153 times, 69% of all indicators identified were used to evaluate this element (Figure 4). Indicators used to evaluate effective management were associated with all dimensions and all management stages though disproportionately assessed ecological and governance dimensions (48% and 40%, respectively) over social and economic dimensions (7% and 5%, respectively; Figure 5). Output and process-associated indicators made up half of indicators used in evaluating effective management (31% and 21%, respectively), while outcome, context, planning, and input made up the remainder (16%, 14%, 10%, and 8%, respectively, Figure 5).

Evaluations of "Equitable management" were limited. "Equitable management" was evaluated twice, with two indicators (Figure 4). The indicators were used to assess the social and governance dimensions of this element (Figure 5), with a focus on the context and outcome stages of management (Figure 5). The social indicator "Perception of MPA effects on livelihood" measured the context of fishers' satisfaction with the process of implementing an MPA network (distributional equity). The governance indicator "Level of stakeholder support and satisfaction in

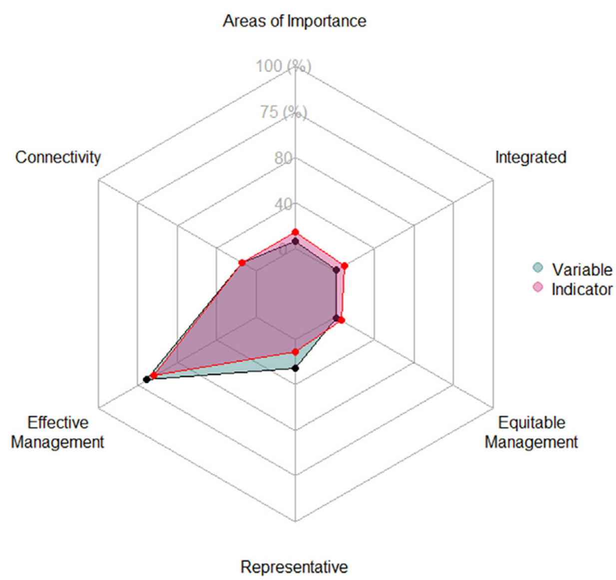

FIGURE 4 Proportion of indicators used to assess each Aichi Target 11 qualitative element. The blue line represents the proportion of times each qualitative element was evaluated in the studies reviewed. Qualitative elements were assessed a total of 223 times; this corresponds to the number of variables identified in the papers we reviewed. The red line represents the proportion of indicators used to assess each qualitative element. A total of 48 headline indicators were identified

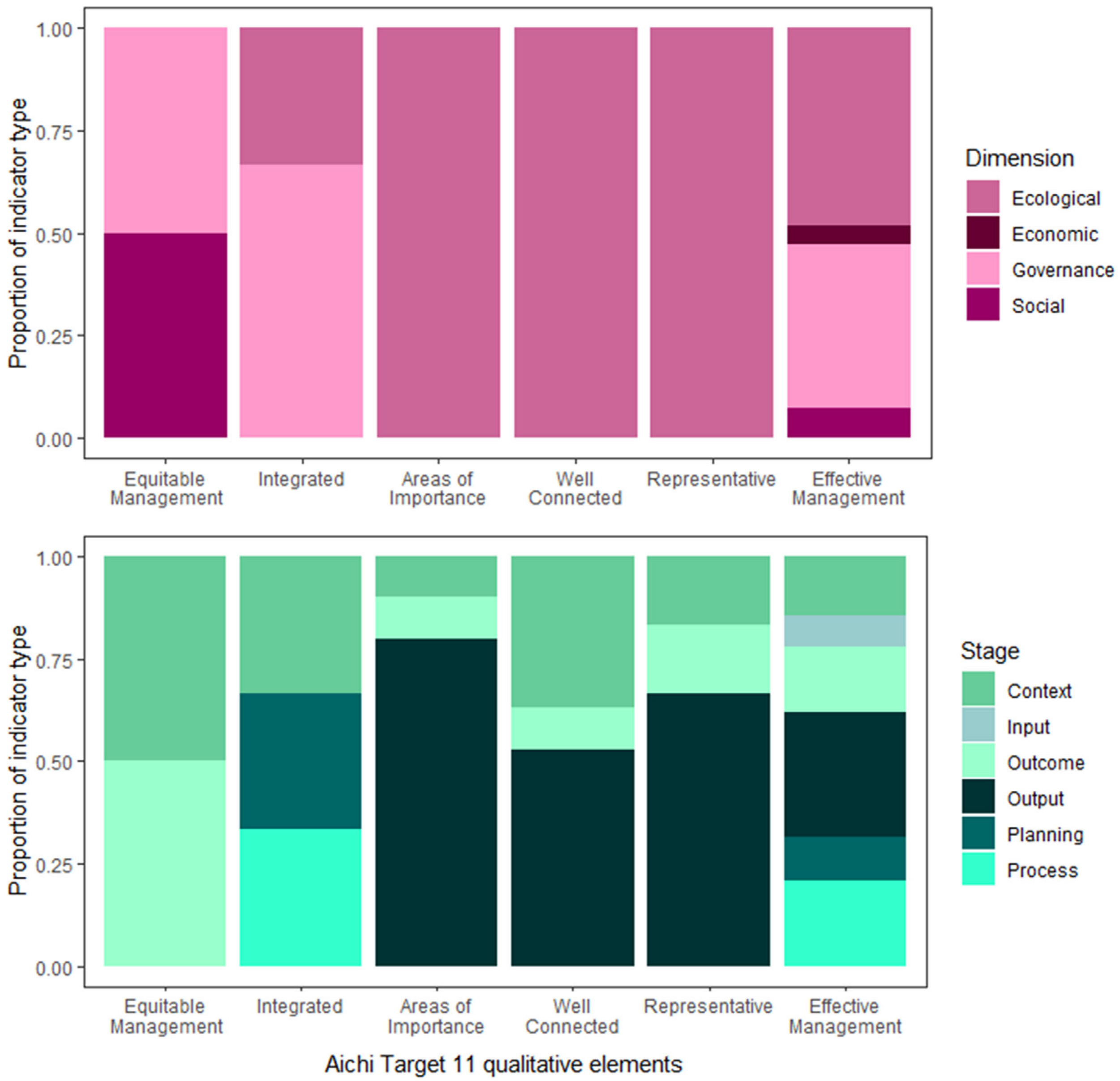

FIGURE 5 Proportion of indicators associated with the different dimensions (top) and management stages (bottom) used to measure each qualitative element. The various dimensions are represented in top panel , the management stages are represented in bottom panel.

management" assessed perceptions of stakeholders about the effect of MPA network implementation in California (recognitional equity) (Figure 6, Table S2). Indicators used to assess procedural equity and other aspects, such as equitable distribution of benefits, human well-being were missing in this review.

"Areas of importance for biodiversity conservation" was assessed 10 times using five indicators (Figure 4). All of the indicators were used to assess the ecological dimension of this element (Figure 5). These indicators also most commonly focused on outputs (80% of the indicators for this element; Figure 5) to evaluate effectiveness of MPAs in covering key species and biodiversity areas. Indicators measured ecological outcomes (10%) for species' richness in areas of importance covered by an MPA. Indicators measuring ecological context (10%) focused on distribution patterns of focal species in order to make decisions on appropriateness of spatial arrangements (Péron et al., 2013).

"Ecological connectivity" was evaluated 19 times. All five indicators used to evaluate this element focused in the ecological dimension (Figure 5). Output (53%), context (37%), and outcome (11%) were the management stages evaluated (Figure 5). Ecological connectivity indicators focused on species and habitat distribution and dispersal, and spatial arrangement of protected areas in a network (Figure 6; Table S2).

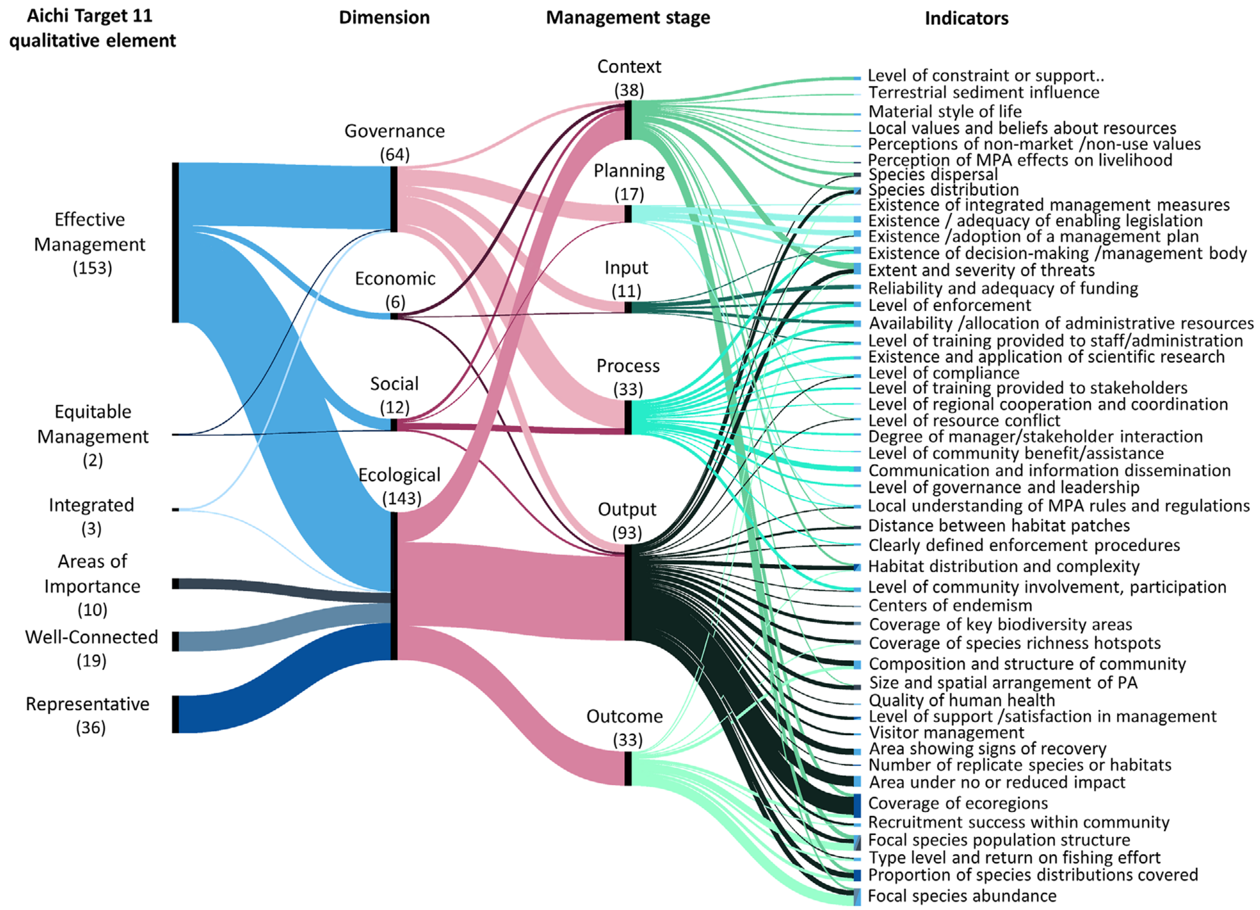

FIGURE 6 Flow diagram describing the use of indicators in evaluating the Aichi Target 11 qualitative elements with their associated dimensions and management stages. For definitions of the Aichi elements, see Table 1. The colors are a visual aid to decipher the Target 11 qualitative elements, dimensions, management stages, and indicators, and correspond with color scheme in Figures 5 and 7. Each node, represented by a rectangle, represents a qualitative element, dimension, management stage, or indicator, as described in the diagram. The thickness of each line and node is proportional to the number of times (number in parentheses) an indicator was used to assess this component. Dimensions describe the governance, social, economic, and ecological factors that influence MPA networks. Management stages describe where in the process of MPA network implementation the indicators are being used (for definitions, see Table 2). The colors on the indicator nodes represent the Aichi Target 11 qualitative elements that each indicator was used to measure

"Ecological representation" was assessed 36 times using four indicators (Figure 4). These indicators were used to measure output (67%), outcome (17%), and context (17%) stages of implementation solely within the ecological dimension (Figure 5). The indicator "Number of replicate habitats" was not previously associated with indicators from existing frameworks. This indicator was used to evaluate the effectiveness of a representative system in minimizing risk of negative impacts (Fernandes et al., 2005).

"Integration into the wider landscape and seascape" was assessed three times (Figure 4). One ecological indicator was used to evaluate the influence of terrestrial sediments on an MPA. Two governance indicators were used to measure planning and process stages of integrated and transboundary management (Figure 6; Table S2), "Level of regional cooperation and coordination" and "Existence of integrated management measures in management plans." The indicators used to evaluate integration were not identified in existing frameworks. Indicators used to assess integrated practices regarding the land–sea connection, and those to assess social aspects of integration such as community cohesion or knowledge sharing are largely missing.

3.2 | Indicator dimensions and management stages

Indicators were primarily associated with ecological and governance dimensions (20 and 19 indicators, respectively), while indicators associated with economic and social dimensions were more limited (four and five indicators, respectively; Figure 6). Outputs and outcomes were predominantly evaluated with ecological indicators. Input was the management stage assessed the least and only

TABLE 3 Shannon diversity and evenness of indicators for each qualitative element assessed

Qualitative element	*S* Indicator richness	*N* Indicator abundance	*H* 'Shannon diversity	*E* Shannon evenness
Areas of importance	5	12	1.42	0.88
connectivity	5	19	1.49	0.93
Effective management	35	153	3.29	0.92
Equity	2	2	0.69	1
Integrated	3	3	1.10	1
Representative	4	36	0.85	0.61

evaluated in terms of governance and economics of effective management. Ecological indicators were used to assess context, output, and outcome stages of five of the six Aichi Target 11 qualitative elements (Figure 6). Governance indicators were also used in the evaluation of five of the six management stages. Social indicators were used to assess context, input, process, and output stages of effective management and equitable management, while economic indicators were used to assess context, input, and output stages of effective management.

3.3 | Indicator diversity

Results from measuring diversity of each suite of indicators that represent an Aichi Target element (Table 3) allowed us to quantify how the indicators were distributed across each qualitative element (Table 3, Figure 7). Shannon diversity (*H*') confirmed that "effective management," which was evaluated the most, had the greatest abundance and largest diversity of indicators (*H*' = 3.29). In contrast, "equitable management" was evaluated the least and had the lowest diversity of indicators (*H*' = 0.69). Diversity of indicators used to assess "representativeness" was also low (*H*' = 0.85; Table 3). Diversity of indicators used to assess "connectivity," "'areas of importance," and "integration" were moderate with respect to the suite of indicators used to evaluate the qualitative elements (*H*' = 1.49, 1.42, and 1.10, respectively). Evenness scores range between 0.6 and 1. The small sample sizes, however, reduces the reliability of these findings.

3.4 | Unique indicators

Several studies used indicators not yet recognized in the MPA evaluation frameworks we used (Gannon et al., 2019; Leverington et al., 2010; Pomeroy et al., 2004). Three of these indicators relate to the element of integration: "Existence of integrated management measures," "Level of regional cooperation and coordination," and "Level of terrestrial sediment influence." One indicator relates to ecological representation: the "Number of replicate species or habitats" and one relates to the social dimension of effective management: "Level of compliance." "Level of compliance" was used three times to assess the influence of MPA networks on changing levels of compliance and poaching and, conversely how levels of compliance influence effectiveness of MPA networks. Finally, 18 indicators used in the referenced frameworks were not mentioned in the literature we reviewed (see Table S5). These missing indicators include community social, cultural, economic, and governance indicators as well as indicators measuring ecosystem services.

3.5 | Leading indicators

The indicators most commonly used could form the basis of a core suite of indicators to evaluate MPA networks effectiveness (Table 4). Chief among these was "Coverage of ecoregions" used 23 times to evaluate representativeness. Another indicator for representativeness that was used more often than others was "Proportion of species distributions covered by MPAs" (Table 4). "Focal species abundance" and "Focal species population structure" were the principal indicators for effective management (used 15 and 13 times, respectively), followed by "Area under no or reduced impact" and "Extent and severity of threats" (used 10 and 11 times, respectively). Principal connectivity indicators include "Species distribution," "Size and spatial arrangement of PAs," and "Species dispersal" (used 6, 5, and 4 times, respectively). "Coverage of species richness hotspots" and "Coverage of Key Biodiversity areas" were the principal indicators for areas of importance, used four and three times each, respectively. Indicators for equitable management and integration were limited, each used once (Table 4).

4 | DISCUSSION

Despite the recent progress in designing and implementing MPA networks (Gannon et al., 2019), marine

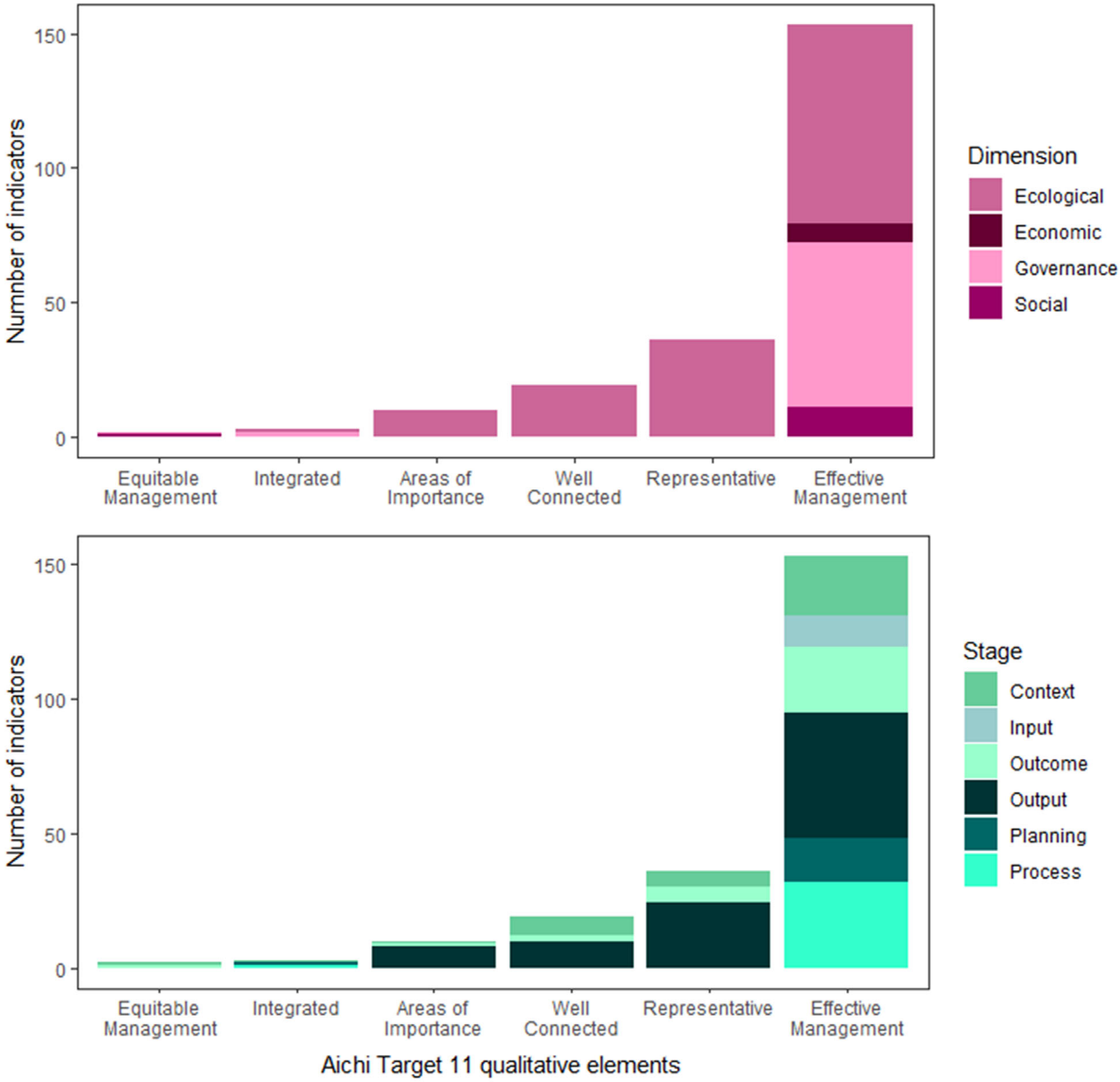

FIGURE 7 Abundance and diversity of the types of indicators used to measure each qualitative element. The number of indicators representing dimensions are shown in top panel; the number of indicators representing implementation stages are shown in bottom panel. Indicators for effective management show the greatest abundance and diversity while equitable management has the least

ecosystem health continues to decline (IPBES, 2019). Assessing whether MPA networks are effective tools for biodiversity conservation is of fundamental importance to help guide future conservation strategies (Grorud-Colvert et al., 2014). In addition to the 10% areal target, the qualitative elements of Aichi Target 11 provide guidance on how to safeguard marine biodiversity and ecosystem services. These qualitative elements shift the narrative of conservation success from an ecological focus toward the incorporation of human dimensions by acknowledging the relationship between the protection of biodiversity and human well-being (Adams et al., 2019; Corrigan et al., 2017; Rees et al., 2018). Our review of peer-reviewed publications found strong evidence of an uneven evaluation of effectiveness across the qualitative elements, with many MPA network evaluations not addressing most elements. While we should not expect an even distribution of indicators across those elements, focus on the assessment of one element raises the risk of MPA networks not meeting their expected goals. Such narrow focus may also distract from recognizing politically motivated implementation or infringements to social justice, which lead to distrust, conflict, and viola-

TABLE 4 Leading indicators for each qualitative element identified from this review

Qualitative element	Indicators	Count
Equitable management	Level of stakeholder support and satisfaction in management	1
	Perception MPA effects on livelihood	1
Integrated	Existence of integrated management measures in management plans	1
	Level of regional cooperation and coordination	1
	Terrestrial sediment influence	1
Areas of importance	Coverage of key biodiversity areas	3
	Coverage of species richness hotspots	4
Well connected	Size and spatial arrangement of PAs	5
	Species distribution	6
	Species dispersal	4
Representative	Coverage of ecoregions	23
	Proportion of species distributions covered by MPAs	11
Effective management	Focal species abundance	15
	Focal species population structure	13
	Extent and severity of threats	11
	Area under no or reduced impact	10

tions (Dehens & Fanning 2018; DeSanto, 2013), and other unintended consequences (Geldmann et al., 2020; Weeks et al., 2014).

In our study, we found effective management as being the most wholly assessed qualitative element (Figure 6). Indeed, effective management has generally become the most evaluated qualitative element in conservation (Pelletier, 2011), for which there are numerous frameworks used throughout the world (Leverington et al., 2010). Effective management provides a means to encourage transparency and accountability (Pelletier, 2011), and can help reduce the risk of creating "paper parks" (Di Minin & Toivonen 2017; Gill et al., 2017). However, an area that is effectively managed may not be effective at conserving biodiversity if, for example, it has limited biological significance to start with (Devillers et al., 2015). Ineffectiveness could also come about if the individual components are not connected to one another in a functionally coherent manner (Woodley et al., 2012), are biologically connected to areas with conflicting objectives (Mackelworth et al., 2019), or lack adequate personnel or financial capacity to ensure goals and objectives are able to be met into the future (Coad et al., 2015).

4.1 | Gaps and challenges

We showed here that while evaluations of management effectiveness are complex and contain a myriad of indicators, they still poorly incorporate the social and economic dimensions (see Figure 6). Missing these factors may enhance the risks of creating MPA networks that generally underperform relative to their promise (Di Minin & Toivonen 2017). In working toward the post-2020 agenda, the conservation community will benefit from knowing how MPA networks are being measured toward this (holistic) target. Our review found that indicators used to evaluate input and planning toward MPA network implementation are limited. Input-related indicators reflect capacity, including personnel and funding for management. Planning-related indicators reflect how the mechanisms to achieve management occurs (Hockings et al., 6), such as design, and legislation or policy that enable the process to move forward in a clear and transparent manner. Appropriate input and planning–related indicators are imperative to successful conservation initiatives.

Effective management will also benefit from improved economic and social indicators (see Figure 5). Indeed shortage in capacity and financial resources have been identified as critical impediments to attaining the post-2020 conservation goals (Coad et al., 2015; Gill et al., 2017). We found four indicators evaluating economic factors among MPA networks covering a range of spatial scales, however just one evaluated the adequacy of funding to implement a national system of MPAs (Gerhardinger, Godoy, Jones, Sales, & Ferreira, 2011). Evaluations considering both market and non-market values need to be mainstreamed into MPA network effectiveness evaluations (Davis, Vianna, Meeuwig, Meekan, & Pannell, 2019). Furthermore, while social dimensions such as well-being, equity, cultural contexts, and indigenous engagement are enjoying increased attention, means to measure the impact of MPA networks on these elements and their influence on MPA success are yet underrepresented (Corrigan et al., 2017). Incorporating these dimensions onto a cohesive monitoring and evaluation framework, albeit daunting, will be necessary to achieve a post-2020 agenda (Addison et al., 2018).

Equitable management has been receiving increased attention (Hill et al., 2016; Law et al., 2018; Rees et al., 2018) including the development of indicators to evaluate this element (Campbell & Gray 2018; Moreaux, Zafra-Calvo, Vansteelant, Wicander, & Burgess, 2018; Schreckenberg, Franks, Martin, & Lang, 2016; Zafra-calvo et al., 2017). We, however, found only two evaluations of equity. These two instances focused on procedural and recognitional equity of stakeholder support and participation in conservation actions (see Table 1 for definitions). The indicator of recognition "Level of stakeholder support and satisfaction in management" does not specifically address potential discrimination, inclusion, and respect for human rights, as equity frameworks would suggest (Schreckenberg et al., 2016). The other indicator used to assess distributional equity in MPA networks, "Perception of MPA effects on livelihood," assessed the perception of MPA effects on livelihood, but not the sharing of benefits among actors, or mitigation of potential impacts as called for in equity frameworks (Franks & Small 2016; Schreckenberg et al., 2016). Our results corroborate those of Moreaux et al. (2018) who found that the existing assessment tools cannot adequately evaluate equity in protected areas as they do not capture the complex underlying relationships fundamental to this element. Evaluation of equity is resource intensive and cumbersome, and often results cannot be comparable across sites within a network (Moreaux et al., 2018).

It is well known that protected areas managed in isolation without consideration of issues happening in surrounding areas such as pollution, habitat destruction, and overfishing reduces success of the protected area (Agardy, Davis, & Sherwood, 2011). There has been a surge in funding allocated to integrating and mainstreaming protected areas with agricultural sectors (Bacon et al., 2019). The increased commitments by countries toward this element have been met with major limitations (Maxwell et al., 2020). Conflicting priorities, contradictory objectives, and competing interests across different sectors and adjacent regions (Álvarez-Romero et al., 2011; Gannon et al., 2019) as well as the lack of indicators for assessing the integration of protected areas into the wider landscape and seascape challenge the realization of this element (Bacon et al., 2019). We identified three indicators used to evaluate integration (Figure 6). These unique indicators focused on governance and land–sea interactions, yet they did not consider measures of integrated practices, community cohesion, knowledge sharing, or distribution of land-based impacts (Jupiter et al., 2017; Partelow, von Wehrden, & Horn, 2015).

Another challenge is identifying a suite of indicators that addresses areas of particular importance for ecosystem services. We identified several indicators that captured aspects of areas of importance for biodiversity conservation, while indicators used to evaluate ecosystem services were absent from the literature we reviewed. The gap in assessments may be due to the lack of a generally accepted approach to measure the suite of services provided by an ecosystem (Gannon et al., 2019). Many ecosystem services do not have a comprehensive suite of indicators to measure them. Indicators that do exist are often inadequate to fully represent the complexity of benefits provided to, and used by, society (Brown et al., 2014; McMichael et al., 2005), especially in the marine realm (Townsend et al. 2018).

We identified several leading indicators used to evaluate MPA networks, but recognize that these are unlikely to be comprehensive and will require further refinement. We recognize the indicators missing or underrepresented in this review (Table S5) may characterize fundamental components of terrestrial protected area and MPA networks and hence help assess whether or not these networks are meeting their objectives. In particular, recent initiatives identifying indicators for equitable management (Zafra-calvo et al., 2017) and integration (Bacon et al., 2019) will help identify priority indicators for evaluation of MPA networks against the qualitative elements (Geldmann et al., 2020). Our findings can also be complemented in the future by using other sources, such as gray literature (e.g., technical reports), local management plans, regional strategies, national action plans, and expert opinions, to identify and categorize a core suite of headline indicators to evaluate MPA networks effectiveness.

4.2 | General implications and future work

Our study adds to the growing literature looking at MPA networks effectiveness. Other reviews of MPA networks have focused on site-specific objectives (Davis, Naumann, McFarland, Graf, & Evans, 2014; Sciberras, Rodríguez-Rodríguez, Ponge, & Jackson, 2013) or on planning and design (Abesamis, Corrigan, Drew, Campbell, & Samonte, 2006). Evaluating effectiveness in the way we did has both advantages and limitations. Each qualitative element was treated independently, allowing for targeted evaluation of progress and may provide insight into the individual contributions of these elements to the whole. In reality, the qualitative elements should work interdependently to successfully conserve biodiversity. The complex and dynamic relationships inherent in protected area networks warrants a holistic, system-level approach to fully appreciate the interactions between the various elements that influence success (Mahajan et al., 2019; Marshall et al., 2016). Assessing the independent and combined contributions of each element and their associated dimensions as a system will have implications for both management and policy. Future work will also benefit from resolving the geographic imbalance in MPA networks identified for this review. Including the management stages that indicators are associated with helps to identify the underlying mechanisms of effectiveness—how and why an MPA network is effective. Knowing the management stages associated with indicators can provide insight to identify entry points for targeted interventions, thereby improving successful outcomes for future iterations of the intervention. This adaptive approach is essential to ensure MPA networks are delivering successful conservation outcomes (Geldmann et al., 2020; Hockings et al., 6). The various perspectives regarding ecological and social contexts, and matters of governance from different geographic provinces will ultimately provide insight into the factors that influence MPA network success (Di Marco et al., 2017; Venter et al., 2018). Indicators missing or underrepresented in this review (Table S5) may characterize fundamental components of MPA networks and hence help assess whether or not these networks are meeting their objectives. Our findings could be complemented in the future by using other sources, such as the gray literature (e.g., technical reports), local management plans, regional strategies, national action plans, or expert opinions. Indeed countries appear to be shifting away from quantitative areal commitments in favor of the qualitative elements (Adams et al., 2019; Bacon et al., 2019), which acknowledges the relationship between the protection of biodiversity and human well-being (Rees et al., 2018). This is likely to come through implementation and integration of other effective area-based conservation measures (OECMs; CBD 2018). While we did not include OECMs in this review. We note the importance of these measures for conservation, particularly with respect to governance and social dimensions in attaining an effective, representative, and equitable global protected area estate (Bacon et al., 2019; Corrigan et al., 2017).

5 | CONCLUSION

It is not surprising that ecological outputs are most often assessed to determine MPA network effectiveness since MPAs are meant to protect biodiversity and ecological processes. However, achieving ecological outcomes often depends on an array of social, economic, and governance factors (Ban et al., 2019; Brueckner-Irwin, Armitage, & Courtenay, 2019; Yates et al., 2019). Evaluating these factors may help understand root causes of stakeholder cooperation and acceptance, and improve concerns of legitimacy (Dehens & Fanning 2018) and equitable sharing of benefits (Franks & Small 2016; White et al., 2005). Indeed, linked social and ecological dynamics were recognized as influencing conservation effectiveness in some of the literature reviewed (Van Lavieren, Klaus, Lavieren, & Klaus, 2013).

Our review highlighted an imbalance in the assessment of protected areas' effectiveness in conserving and protecting areas of high biodiversity importance in a sustainable manner. Here, we provided, to the best of our knowledge, the first systematic review of indicators used to assess MPA networks. This is a first step toward providing guidance for assessing MPA networks on a global scale. We found that current assessments of MPA networks are largely built on assessments used for individual MPAs. This is perhaps unsurprising as individual MPAs contribute to MPA networks and MPA network assessments have developed from the assessment of individual MPAs. However, MPA networks were envisioned to recognize the larger systems in which individual MPAs exist. This may require assessment criteria that includes structure for interacting systems that does not treat MPA networks as a form of individual MPAs or a collection of independent MPAs. Our results indicate that the monitoring and evaluation of MPA networks largely overlook the qualitative elements of equity in management and how MPA networks are integrated into the wider landscape and seascape. Additionally important social and economic attributes are seldom measured in MPA networks performance evaluations. Assessment of MPA network performance using a more suitable and balanced suite of indicators will be key to ensure that MPA networks can help protect marine ecosystems more effectively.

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AUTHORS' CONTRIBUTIONS

RD, NB and MM contributed to the conception of the research. GS and JC provided invaluable insight and context. MM led the writing of the manuscript, produced the figures and analyzed the data. All co-authors contributed to preparation, editing and refining the concepts and text in the manuscript. All authors have seen and approved the final manuscript.

ETHICS STATEMENT

No ethical approval was required for this research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

Data for this review can be found at" https://doi.org/10.5683/SP2/FPYIVC, Scholars Portal Dataverse, V1. Mairi; Ban, Natalie; Devillers, Rodolphe; Singh, Gerald; Claudet, Joachim, 2020, "Data from: How far have we come? A review of MPA network performance indicators in reaching qualitative elements of Aichi Target 11", or upon request from the authors.

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REFERENCES

Abesamis, N. P., Corrigan, C., Drew, M., Campbell, S., & Samonte, G. (2006). Social resilience: A literature review on building resilience into human marine communities in and around MPA networks. MPA Networks Learning Partnership, Global Conservative Program.

Adams, V. M., Iacona, G. D., & Possingham, H. P. (2019). Weighing the benefits of expanding protected areas versus managing existing ones. *Nature Sustainability*, *2*, 404–411.

Addison, P. F. E., Collins, D. J., Trebilco, R., Howe, S., Bax, N., Hedge, P., … McQuatters-Gollop, A. (2018). A new wave of marine evidence-based management: Emerging challenges and solutions to transform monitoring, evaluating, and reporting. *Ices Journal of Marine Science*, *75*, 941–952.

Agardy, T., Davis, J., & Sherwood, K. (2011). Taking steps toward marine and coastal management: An introductory guide. UNEP Reg. Seas Rep. Stud.

Álvarez-Romero, J. G., Pressey, R. L., Ban, N. C., Vance-Borland, K., Willer, C., Klein, C. J., & Gaines, S. D. (2011). Integrated land-sea conservation planning: The missing links. *Annual Review of Ecology, Evolution, and Systematics*, *42*, 381–409.

Bacon, E., Gannon, P., Stephen, S., Seyoum-Edjigu, E., Schmidt, M., Lang, B., … Gidda, S. B. (2019). Aichi Biodiversity Target 11 in the like-minded megadiverse countries. *Journal of Nature Conservation*, *51*, 125723.

Ban, N. C., Gurney, G. G., Marshall, N. A., Whitney, C. K., Mills, M., Gelcich, S., … Breslow, S. J. (2019). Well-being outcomes of marine protected areas. *Nature Sustainability*, *2*, 524–532.

Brown, C., Reyers, B., Ingwall-King, L., Mapendembe, A., Nel, J., O'Farrell, P., … Bowles-Newark, N. J. (2014). *Measuring ecosystem services: Guidance on developing ecosystem service indicators*. Cambridge, UK: UN Environment Programme World Conservation Monitoring Centre.

Brueckner-Irwin, I., Armitage, D., & Courtenay, S. (2019). Applying a social-ecological well-being approach to enhance opportunities for marine protected area governance. *Ecology and Society*, *24*, art 7.

Campbell, L. M., & Gray, N. J. (2018). Area expansion versus effective and equitable management in international marine protected areas goals and targets. *Marine Policy*, *100*, 192–199.

CBD. (2008). Decision adopted by the Conference Of the Parties to the Convention on Biological Diversity at its ninth meeting ix/20. *Marine and coastal biodiversity*. UNEP/CBD/COP/DEC/IX/20. Bonn.1–12.

CBD. (2011). *Strategic plan for biodiversity 2011–2020: Provisional technical rationale, possible indicators and suggested milestones for the Aichi Biodiversity Targets*. Japan: Nagoya.

CBD. (2018). Decision adopted by the Conference of the Parties to the Convention on Biological Diversity "14/8. Protected areas and other effective area-based conservation measures." Conf. Parties to Conv. Biol. Divers. Fourteenth Meet. Agenda item 24 CBD/COP/DEC/14/8 30 November 2018, 1–19.

Charles, A., & Wilson, L. (2008). Human dimensions of marine protected areas. *ICES Journal of Marine Science Journal du Conseil*, *66*, 6–15.

Claudet, J., Loiseau, C., Sostres, M., Zupan, M., Claudet, J., Loiseau, C., … Zupan, M. (2020). Article underprotected marine protected areas in a Global Biodiversity Hotspot ll underprotected marine protected areas in a global biodiversity hotspot. *One Earth*, *2*, 380–384.

Claudet, J., Osenberg, C. W., Benedetti-Cecchi, L., Domenici, P., García-Charton, J. A., Pérez-Ruzafa, Á., … Planes, S. (2008). Marine reserves: Size and age do matter. *Ecology Letters*, *11*, 481–489.

Coad, L., Leverington, F., Burgess, N. D., Cuadros, I. C., Geldmann, J., Marthews, T. R., … Hockings, M. (2013). Progress towards the Cbd protected area management effectiveness targets. *Parks*, *19*, 13–24.

Coad, L., Leverington, F., Knights, K., Geldmann, J., Eassom, A., Kapos, V., … Kapos, V. (2015). Measuring impact of protected area management interventions: Current and future use of the Global Database of Protected Area Management Effectiveness. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*, 20140281.

Coad, L., Watson, J. E. M., Geldmann, J., Burgess, N. D., Leverington, F., Hockings, M., … Di Marco, M. (2019). Widespread shortfalls in protected area resourcing undermine efforts to conserve biodiversity. *Frontiers in Ecology and the Environment*, *17*, 259–264.

Conservation Measures Partnership. (2013). Classification of conservation actions and threats. *Classif. Conserv. Actions Threat, Version 2.0, 2016*. http://cmp-openstandards.org/wp-content/uploads/2014/03/CMP-OS-V3-0-Final.pdf.

Corrigan, C. J., Robinson, C., Burgess, N. D., Kingston, N., & Hockings, M. (2017). Global review of social indicators used in protected area management evaluation. *Conservation Letters*, *11*, 1–9.

Davis, K. J., Vianna, G. M. S., Meeuwig, J. J., Meekan, M. G., & Pannell, D. J. (2019). Estimating the economic benefits and costs of highly-protected marine protected areas. *Ecosphere*, *10*, Article e02879.

Davis, M., Naumann, S., McFarland, K., Graf, A., & Evans, D. (2014). Literature review, the ecological effectiveness of the Natura 2000 Network. ETC/BD Rep. to EEA. Paris.

Dehens, L. A., & Fanning, L. M. (2018). What counts in making marine protected areas (MPAs) count? The role of legitimacy in MPA success in Canada. *Ecological Indicators*, *86*, 45–57.

DeSanto, E. M. (2013). Missing marine protected area (MPA) targets: How the push for quantity over quality undermines sustainability and social justice. *Journal of Environmental Management*, *124*, 137–146.

Devillers, R., Pressey, R. L., Grech, A., Kittinger, J. N., Edgar, G. J., Ward, T., & Watson, R. (2015). Reinventing residual reserves in the sea: Are we favouring ease of establishment over need for protection? *Aquatic Conservation: Marine and Freshwater Ecosystems*, *25*, 480–504.

IPBES (2019): *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. S. Díaz, J. Settele, E. S. Brondízio E.S., H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany. 56 pages.

Fernandes, L., Day, J., Lewis, A., Slegers, S., Kerrigan, B., Breen, D., … Stapleton, K. (2005). Establishing representative no-take areas in the Great Barrier Reef: Large-scale implementation of theory on marine protected areas. *Conservation Biology*, *19*, 1733–1744.

Franks, P., & Small, R. (2016). *Understanding the social impacts of protected areas : A community perspective*. IIED Research Report. IIED, London.

Gannon, P., Dubois, G., Dudley, N., Ervin, J., Ferrier, S., Gidda, S., … Shestakov, A. (2019). Editorial essay: An update on progress towards Aichi biodiversity Target 11. *Parks*, *25*, 7–18.

Gannon, P., Seyoum-Edjigu, E., Cooper, D., Sandwith, T., Dias, Souza, de, B. F., … Gidda, S. (2017). Status and prospects for achieving Aichi biodiversity target 11: Implications of national commitments and priority actions. *Parks*, *23*, 13–26.

Geldmann, A. J., Deguignet, M., Balmford, A., Burgess, N. D., Dudley, N., Hockings, M., … Watson, J. E. M. (2020). Essential indicators for measuring area-based conservation effectiveness in the post-2020 global biodiversity framework. *Preprints*, 1–8 https://doi.org/10.20944/preprints202003.0370.v1.

Gerhardinger, L. C., Godoy, E. A. S., Jones, P. J. S., Sales, G., & Ferreira, B. P. (2011). Marine protected dramas: The flaws of the Brazilian national system of marine protected areas. *Environmental Management*, *47*, 630–643.

Gill, D. A., Mascia, M. B., Ahmadia, G. N., Glew, L., Lester, S. E., Barnes, M., … Fox, H. E. (2017). Capacity shortfalls hinder the performance of marine protected areas globally. *Nature*, *543*, 665–669.

Green, A., Smith, S. E., Lipsett-Moore, G., Groves, C., Peterson, N., Sheppard, S., … Bualia, L. (2007). Designing a resilient network of marine protected areas for Kimbe Bay, Papua New Guinea. *Nat. Conserv. Pacific Isl. Ctries. Rep.*

Grorud-Colvert, K., Claudet, J., Tissot, B. N., Caselle, J. E., Carr, M. H., Day, J. C., … Walsh, W. J. (2014). Marine protected area networks: Assessing whether the whole is greater than the sum of its parts. *Plos One*, *9*, 1–7.

Heink, U., & Kowarik, I. (2010). What are indicators? On the definition of indicators in ecology and environmental planning. *Ecological Indicators*, *10*, 584–593.

Hill, L. S., Johnson, J. A., & Adamowski, J. (2016). Meeting Aichi Target 11: Equity considerations in marine protected areas design. *Ocean & Coastal Management*, *134*, 112–119.

Hockings, M. M., Stolton, S., Leverington, F., Dudley, N., Courrau, J., Valentine, P., … Leverington, F. (2006). *Evaluating effectiveness: A framework for assessing management effectiveness of protected areas* (2nd ed.). Gland, Switzerland and Cambridge, UK: IUCN.

IUCN-WCPA. (2008). *establishing resilient marine protected area networks: Making it happen*.

Juffe-Bignoli, D., Burgess, N., Bingham, H. et al. 2014. *Protected planet report 2014*. UNEP-WCMC: Cambridge, UK. 1–69. ISBN:978-92-807-3416-4.

Jupiter, S. D., Wenger, A., Klein, C. J., Albert, S., Mangubhai, S., Nelson, J., … Watson, J. E. M. (2017). Opportunities and constraints for implementing integrated land-sea management on islands. *Environmental Conservation*, *44*, 254–266.

Van Lavieren, H., Klaus, R., Lavieren, H. Van, & Klaus, R. (2013). An effective regional marine protected area network for the ROPME Sea Area: Unrealistic vision or realistic possibility? *Marine Pollution Bulletin*, *72*, 389–405.

Law, E. A., Bennett, N. J., Ives, C. D., Friedman, R., Davis, K. J., Archibald, C., & Wilson, K. A. (2018). Equity trade-offs in conservation decision making. *Conservation Biology*, *32*, 294–303.

Lester, S. E., & Halpern, B. S. (2008). Biological responses in marine no-take reserves versus partially protected areas. *Marine Ecology Progress Series*, *367*, 49–56.

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.

Lowry, G. K., White, A. T., & Christie, P. (2009). Scaling up to networks of marine protected areas in the Philippines: Biophysical, legal, institutional, and social considerations. *Coastal Management*, *37*, 274–290.

Mackelworth, P. C., Teff Seker, Y., Vega Fernández, T., Marques, M., Alves, F. L., D'Anna, G., … Holcer, D., (2019). Geopolitics and marine conservation: Synergies and conflicts. *Frontiers in Marine Science*, *6*, 1–17.

Mahajan, S. L., Glew, L., Rieder, E., Ahmadia, G., Darling, E., Fox, H. E., … McKinnon, M. (2019). Systems thinking for planning and evaluating conservation interventions. *Conservation Science and Practice*, *1*, 1–8.

Di Marco, M., Chapman, S., Althor, G., Kearney, S., Besancon, C., Butt, N., … Watson, J. E. M. (2017). Changing trends and persisting biases in three decades of conservation science. *Global Ecology and Conservation*, *10*, 32–42.

Marshall, N. A., Bohensky, E., Curnock, M., Goldberg, J., Gooch, M., Nicotra, B., … Tobin, R. C. (2016). Advances in monitoring the human dimension of natural resource systems: An example from the Great Barrier Reef. *Environmental Research Letters*, *11*, 114020.

Maxwell, S. L., Cazalis, V., Dudley, N., Hoffmann, M., Ana, S. L., Stolton, S., … Watson, J. E. M. (2020). Area-based conservation in the 21st century. *Preprints*, 1–42. https://doi.org/10.20944/preprints202001.0104.v1

McGinnis, M. D., & Ostrom, E. (2014). Social-ecological system framework: Initial changes and continuing challenges. *Ecology and Society*, *19*, 30.

McLeod, E., Salm, R., Green, A., & Almany, J. (2009). Designing marine protected area networks to address the impacts of climate change. *Frontiers in Ecology and the Environment*, *7*, 362–370.

McMichael, A., Scholes, R., Hefny, M., Pereira, E., Palm, C., & Foale, S. (2005). Ecosystem services and human well-being. In G. Gallopin, R. Kasperson, M. Munasinghe, L. Olivé, C. Padoch, J. Romm, & H. Vessuri (Eds.), *Ecosystems and human well-being: A framework for assessment* (pp. 113–194). Washington, DC: Island Press.

Di Minin, E., & Toivonen, T. (2017). Global protected area expansion: Creating more than paper parks. *Bioscience*, *65*, 637–638.

Mizrahi, M., Diedrich, A., Weeks, R., & Pressey, R. L. (2018). A systematic review of the socioeconomic factors that influence how marine protected areas impact on ecosystems and livelihoods. *Society & Natural Resources*, *1920*, 4–20.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., Altman, D., Antes, G., … Tugwell, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Plos Medicine*, *6*(7), 1–6.

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 ? *Biological Conservation*, *224*, 242–247.

Oksanen, J., Blanchet, F. G., Friendly, M., Kindt, R., Legendre, P., Mcglinn, D., … Maintainer, H. W. (2019). Package "vegan." *Community Ecology Package*, *2*, 1–297.

Partelow, S., von Wehrden, H., & Horn, O. (2015). Pollution exposure on marine protected areas: A global assessment. *Marine Pollution Bulletin*, *100*, 352–358.

Pelletier, D. (2011). Indicators_ Constructing and validating indicators of the effectiveness of marine protected areas. In C. Joachim (Ed.), *Marine protected areas: A multidisciplinary approach* (pp. 247–290). Cambridge, UK: Cambridge University Press.

Pelletier, D., García-Charton, J. A., Ferraris, J., David, G., Thébaud, O., Letourneur, Y., … Galzin, R. (2005). Designing indicators for assessing the effects of marine protected areas on coral reef ecosystems: A multidisciplinary standpoint. *Aquatic Living Resources*, *18*, 15–33.

Péron, C., Grémillet, D., Prudor, A., Pettex, E., Saraux, C., Soriano-Redondo, A., … Fort, J.Ô (2013). Importance of coastal marine protected areas for the conservation of pelagic seabirds: The case of vulnerable yelkouan shearwaters in the Mediterranean Sea. *Biological Conservation*, *168*, 210–221.

Pikesley, S. K., Godley, B. J., Latham, H., Richardson, P. B., Robson, L. M., Solandt, J. L., … Witt, M. J. (2016). Pink sea fans (Eunicella verrucosa) as indicators of the spatial efficacy of marine protected areas in southwest UK coastal waters. *Marine Policy*, *64*, 38–45.

Pomeroy, R. S., Parks, J. E., & Watson, L. M. (2004). *How is your MPA doing? A guidebook of natural and social indicators for evaluating marine protected area management effectiveness*. Gland, Switzerland and Cambridge, UK: IUCN.

R core team. (2019). R*: A language and environment for statistical computing. Version 3.6.1*. Vienna, Austria: R Found. Stat. Comput.

Rees, S. E., Foster, N. L., Langmead, O., Pittman, S., & Johnson, D. E. (2018). Defining the qualitative elements of Aichi Biodiversity Target 11 with regard to the marine and coastal environment in order to strengthen global efforts for marine biodiversity conservation outlined in the United Nations Sustainable Development Goal 14. *Marine Policy*, *93*, 241–250.

Sala, E., & Giakoumi, S. (2017). No-take marine reserves are the most effective protected areas in the ocean. *ICES Journal of Marine Science*, *75*(3), 1166–1168.

Sala, E., Lubchenco, J., Grorud-Colvert, K., Novelli, C., Roberts, C., & Sumaila, U. R. (2018). Assessing real progress towards effective ocean protection. *Marine Policy*, *91*, 11–13.

Schreckenberg, K., Franks, P., Martin, A., & Lang, B. (2016). Unpacking equity for protected area conservation. *Parks*, *22*, 11–28.

Sciberras, M., Rodríguez-Rodríguez, D., Ponge, B., & Jackson, E. (2013). Criteria for assessing ecological coherence of MPA networks : A review. Report prepared by the Marine Institute and the Agence des Marines Protegees for the Protected Area Network Across the Channel Ecosystem (PANACHE) project. INTERREG programme France (Channel) – England (2007 – 2013) funded project.

Townsend, M., Davies, K., Hanley, N., Hewitt, J. E., Lundquist, C. J. & Lohrer, A. M. (2018). The challenge of implementing the marine ecosystem service concept. *Frontiers in Marine Science*, *5*, 1–13.

Venter, O., Magrach, A., Outram, N., Klein, C. J., Possingham, H. P., Di Marco, M., & Watson, J. E. M. (2018). Bias in protected-area location and its effects on long-term aspirations of biodiversity conventions. *Conservation Biology*, *32*, 127–134.

Verberk, W. (2011). Explaining general patterns in species abundance and distributions. *Nature Education Knowledge*, *3*, 38.

Weeks, R., Pressey, R. L., Wilson, J. R., Knight, M., Horigue, V., Abesamis, R. A., … Jompa, J. (2014). Ten things to get right for marine conservation planning in the Coral Triangle. *F1000Research*, *3*(91), 1–21.

White, A. T., Alino, P. M., & Meneses, A. T. (2005). Creating and managing marine protected areas in the Philippines. Fisheries Improved for Sustainable Harvest Project, Coastal Conservation and Education Foundation, Inc. and University of the Philippines Marine Science Institute, Cebu City, Philippines.

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. New York, NY: Springer-Verlag.

Woodcock, P., O'Leary, B. C., Kaiser, M. J., Pullin, A. S., Leary, B. C. O., Kaiser, M. J., & Pullin, A. S. (2017). Your evidence or mine? Systematic evaluation of reviews of marine protected area effectiveness. *Fish Fish*, *18*, 668–681.

Woodley, S., Bertzky, B., Crawhall, N., Dudley, N., Londoño, J. M., MacKinnon, K., … Sandwi, T. (2012). Meeting Aichi Target 11: What does success look like for protected area systems? *Parks*, *18*(1), 23–36.

Yates, K. L., Clarke, B., & Thurstan, R. H. (2019). Purpose vs performance: What does marine protected area success look like? *Environmental Science & Policy*, *92*, 76–86.

Zafra-calvo, N., Pascual, U., Brockington, D., Coolsaet, B., Cortes-vazquez, J. A., Gross-Camp, N., … Burgess, N. D. (2017). Towards an indicator system to assess equitable management in protected areas. *Biological Conservation*, *211*, 134–141.

Zupan, M., Fragkopoulou, E., Claudet, J., Erzini, K., Horta e Costa, B., & Gonçalves, E. J. (2018). Marine partially protected areas: Drivers of ecological effectiveness. *Frontiers in Ecology and the Environment*, *16*, 381–387.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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