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Area based conservation tools have mixed effects across all SDGs but research may overstate effects

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Marine Protected Areas (MPAs) are important tools in marine conservation. However, MPAs have unforeseen consequences, including complex adverse outcomes for human coastal communities through impacts such as dispossession of people to resource access. Here we searched the literature for evidence of MPA effects across the Sustainable Development Goals (SDGs), collected information on these effects and the forms of evidence used to document these effects. Our analysis indicated that MPAs can have both positive and negative effects across each of the 17 SDGs, and that many papers rely on secondary data over primary data to assess those effects. For SDGs 1 (End Poverty), 2 (No Hunger), and 5 (Gender Equality) we found that papers highlighting benefits of MPAs were usually more reliant on secondary information than papers emphasizing adverse impacts. Given the importance of local contexts, MPAs are better used as precision interventions rather than broad policy tools for achieving large-scale marine sustainability.

Area-based conservation measures such as Marine Protected Areas (MPAs) and Other Effective area-based Conservation Measures (OECM) are promoted as the primary global tool for conserving nature and associated ecosystem services throughout a range of national, regional and international ocean policies[1,2]. In particular, area-based conservation measures received a stand-alone target in The Kunming-Montreal Global Biodiversity Framework (GBF), adopted during the fifteenth meeting of the Conference of the Parties (COP 15) in 2022. Global MPA and OECM coverage increased from 1.8 million km^2 in 1990 to 28 million km^2 in 2021[3], and will continue to increase with numerous governments having formally committed to designate at least 30% of the ocean for biodiversity by 2030 (30 × 30) under Target 3 of the GBF[4]. However, Target 3 of the GBF also emphasizes the importance of equitable governance, inclusive participation, fair distribution of costs and benefits, and recognition of the rights of affected communities. The relationship between the GBF and the 2030 Agenda for Sustainable Development (Sustainable Development Goals) is intended to be mutually constructive (CBD-GBF, 2020, Section D). An understanding of how area-based conservation measures influence progress towards the Sustainable Development Goals is therefore an important aspect of widespread and growing conservation area designation. Research to date has shown that area-based conservation measures can produce both positive and negative impacts on sustainable development[5], local livelihoods[6], and biodiversity[7], from increasing fish biomass and catch potential (positive) to causing livelihood impacts and displacement (negative). This mixed evidence has often run against narratives promoting area-based conservation measures as not only useful for biodiversity conservation and recovery (which is often their main goal), but also as potential pathways for sustainable development through the delivery of co-benefits such as food security and economic resilience[8–10].

This narrative of co-benefits is why many governments and environmental Non-Governmental Organizations (eNGOs) advocate for area-based conservation measures (and often specifically MPAs) as part of nature-based solutions for conservation and climate change, as well as contributing to the achievement of other development goals[8,11]. For example, some governments are integrating MPAs into Blue Economic Growth Strategies, and implementing MPAs towards the fulfillment of the United Nations Sustainable Development Goals (SDGsa) and other policy priorities[12–15]. MPAs are also promoted for specific strategic development initiatives. For example, MPA designation or extension has also been identified as a strategic compensation measure to offset the potential negative ecological impacts of offshore wind (OFW) development[16]. This makes it particularly important to understand the effects of these conservation measures on development goals, both for achieving these goals

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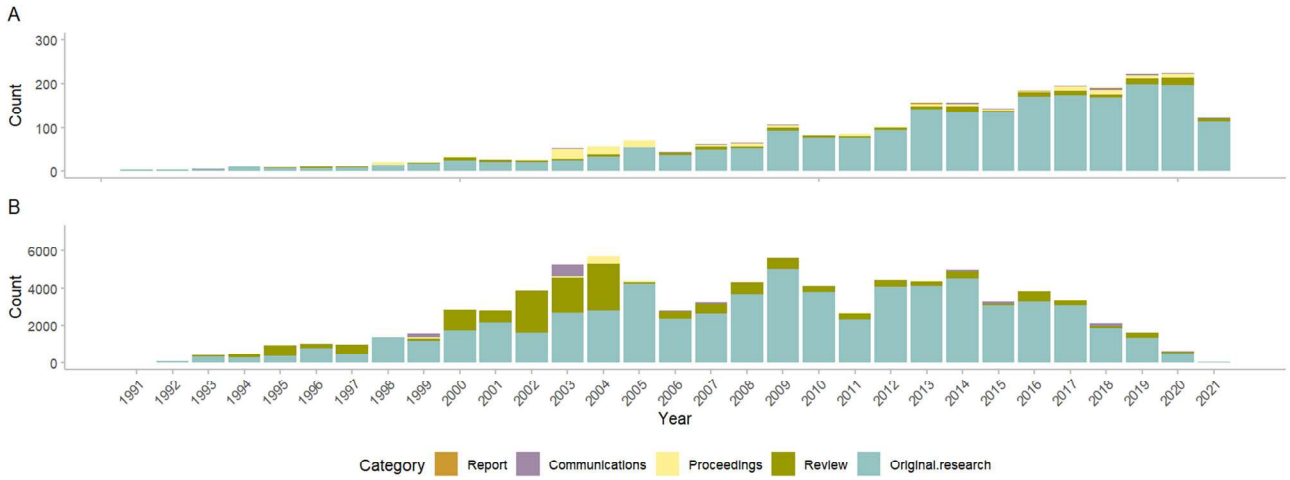

Fig. 1 | Publications linking MPAs to SDGs over time. Noted links between MPAs and SDGs in the literature ($n = 2508$) showing the number of different types of publications by year (**A**), and the number of citations each type of publication received (**B**) by publication year. All values represent the time of data collection (in 2021).

and for maintaining trust and partnerships with the local communities that must agree to their implementation[12].

To date, no study has collated available evidence of contributions of MPAs and area-based conservation towards the SDGs as a whole. While existing reviews focus on some aspect of these, such as reviewing how MPAs contribute to marine biodiversity[17], benefits rendered to people through ecosystem services[18], and the consequences on well-being[6], the SDGs provide one of the most formally recognized comprehensive ways to conceptualize societal and development dimensions, signed by all UN member states[19,20].

This study analyses the literature documenting the impacts of area-based conservation measures across the different SDG dimensions. The study focused on the impact of MPAs, but to ensure coverage of the literature related to MPAs our search included broader terms used to denote areas managed under area-based conservation measures referred to, for example, as 'sanctuary', 'reserve', 'no-take zone'. It should be noted that our literature search may include literature based on study regions that do not fall under the IUCN definition of an MPA[1] dependent on area-specific levels of extraction and biodiversity protection, and therefore could be considered OECMs.

We specifically focus on the impacts to SDGs 1 (No Poverty), 2 (Zero Hunger), and 5 (Gender Equality). These are commonly used as benchmarks to assess development progress within and among countries[21], and have been listed among the most important SDGs by world leaders and decisionmakers, especially in the Global South[22–24]. Arguably, they also represent some of the SDG areas that best capture the main theme of the SDGs: "no one left behind"[25]. Perhaps partly because of the global and sub-global importance of SDGs 1, 2, and 5, some of the social promises of MPAs have focused on these goals as well[9,26]. Indeed, some MPAs are advertised as anti-poverty, gender-equity, and food security measures[26,27]. However, given these SDGs are socioeconomic in scope and the co-benefits of MPAs are often assumed to flow through biophysical effects[18,28], there is a priority to document the kinds of evidence that underpin claims of the links of MPAs to these SDG areas. We consider claimed and documented effects of MPAs across these SDG dimensions and focus on understanding the evidence used to reach conclusions about observed outcomes.

Results

Literature search of MPA effects across SDGs

We identified 4867 documented or claimed links between MPAs and SDGs made in the literature, as determined by linking literature claims and results with every SDG targets. These links were recorded from MPAs across the world, from every populated continent as well as some studies with a global focus (see Datasets 2 and 3). These 4867 links were found in 2508 papers including original research, reviews, proceedings, communications, and other reports from 1991 to 2021 (to allow time to consider corresponding citations). We found an increase in the number of papers publishing links between MPAs and SDGs over time (Fig. 1A), from 3 papers in 1991 (all in original research articles) to 225 papers in 2020 (across all types). Overall, the greatest number of papers were original research articles ($n = 2176$), followed by reviews ($n = 157$, Fig. 1A).

By 2021, reviews had an outsized impact, making up over half the citations on articles written in some years, and otherwise always making up a larger proportion of citations relative to the number of articles written (Fig. 1B). On average, original research articles were cited 30 times (65,941 citations across 2176 papers links to SDGs) and reviews were cited 98 times (15,392 citations across 157 papers links to SDGs). Not all papers in our database had recorded citations, accounting for the difference in number of original research papers reported in our citation count versus our paper count.

The literature we analyzed included positive and/or negative impacts of MPAs across every SDG, connected to 50 of all 169 SDG targets (Fig. 2; Table 1). Most links ($n = 2012$) focused on the influence of MPAs on SDG 14 (Life Below Water), and this goal was also found to have the highest proportion of targets identified as affected by MPAs (6/10 targets), while SDG 1 (No Poverty) had the second highest proportion of targets affected by MPAs (4 of 7 targets), and SDG 11 (Sustainable Cities and Communities) and SDG 14 (Life on Land) both had the third highest proportion of targets (5 of 10 targets and 6 of 12 targets, respectively). All other SDGs had fewer than half of their targets identified as being affected by MPAs.

We found that across the published literature, the same causal processes by which MPAs are credited with generating benefits to SDGs have also been credited with generating adverse effects (Table 1). For example, one prominent process by which the published literature reports that MPAs can have benefits is through limiting environmental stressors allowing for increases in productivity, diversity and resilience of local ecosystems, which benefits SDGs 1 (No Poverty), 2 (Zero Hunger), 3 (Good Health and Well-being), 6 (Clean Water and Sanitation), 8 (Decent Work and Economic Growth), 12 (Responsible Consumption and Production), 13 (Climate Action), and 14 (Life Below Water). However, limiting environmental stressors often restricts access to local resources, which has adverse consequences for SDGs 1 (No Poverty), 2 (Zero Hunger), 3 (Good Health and Well-being), 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 8 (Decent Work and Economic Growth), 9 (Industry, Innovation, and Infrastructure), 10 (Reduced Inequalities), and 16 (Peace, Justice, and Strong Institutions). Relatedly, many papers point out that MPAs may simply displace impacts, such redirecting water pollution (SDG 6), increasing spatial conflicts for alternative uses (SDG 7) and other economic and infrastructure activities (SDGs 8 and 9). Some adverse effects have also

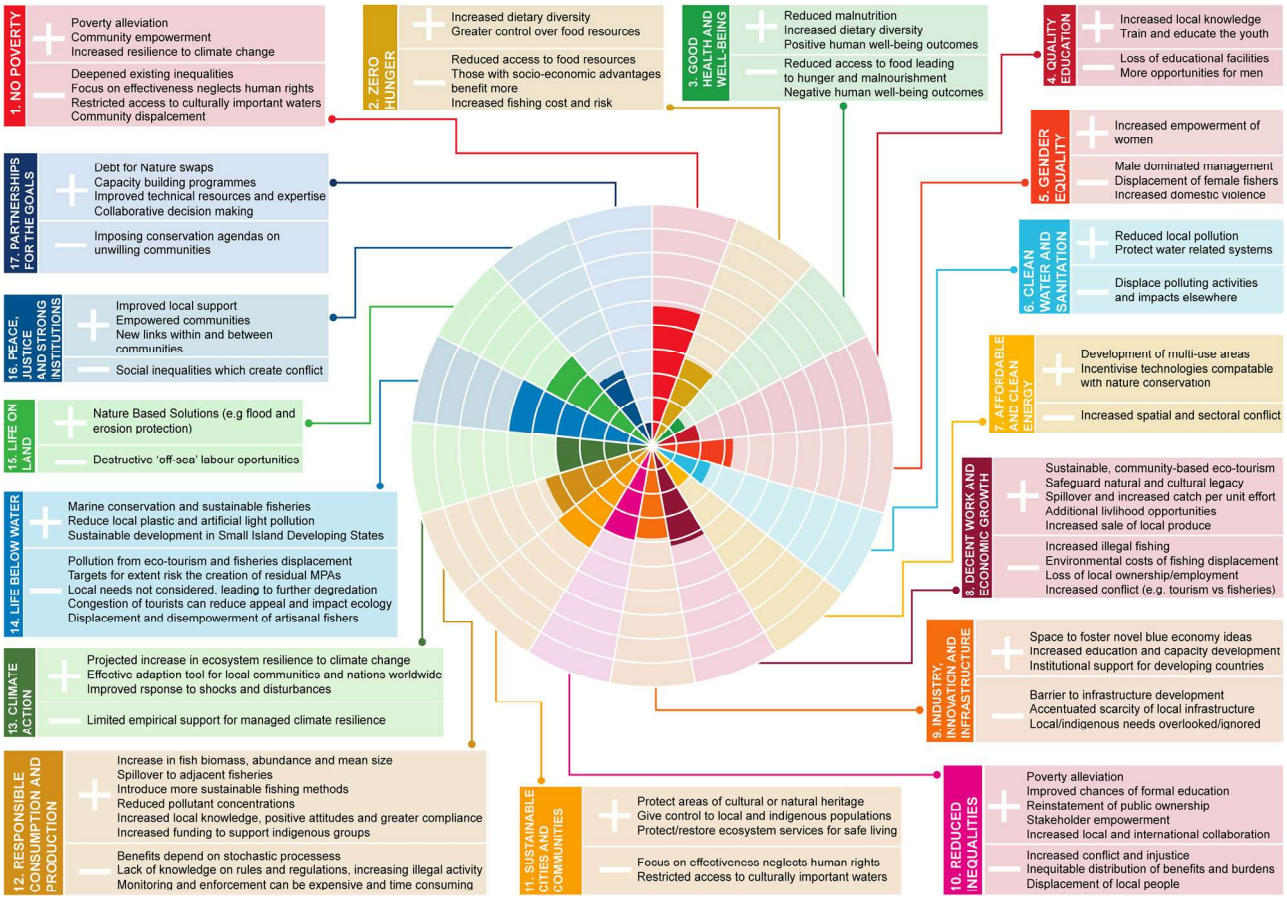

Fig. 2 | Effects of MPAs on SDGs. Highlighted cells in the radial plot illustrate the proportion of SDG targets influenced by MPAs. Examples are given of the positive (+) and negative (–) influences.

been credited with MPAs not achieving their objectives as MPA benefits are dependent on effective management and external factors (e.g. environmental variation and other diffuse stressors); communities might plan for promised benefits that do not materialize. This negative effect has been pointed out across SDGs, including SDGs 1, 12, 13, and 14.

The remaining SDGs can be positively or negatively affected through how MPAs are planned, designed, governed, and managed. That is, the establishment and process of MPAs regulate impacts across many SDGs rather than the outcomes of MPAs. MPAs managed collaboratively and with active focus on co-development, community training and education were cited to improve SDGs 4 (Quality Education), 5 (Gender Equality), 7 (Affordable and Clean Energy), 9 (Industry, Innovation, and Infrastructure), 10 (Reduced Inequalities), and 16 (Peace, Justice, and Strong Institutions).

However, published papers point out that MPAs are also managed in ways that negatively affect SDGs. Published papers indicate that MPAs can establish or reinforce coercive, colonial or otherwise unequal power relationships. These unequal power relationships can enhance inequities or inadequately communicate rules that unintentionally lead locals to commit newly "illegal" actions, affecting SDGs 4, 5, 10, 12, 13 and 16. In particular, since closures are often near communities (as this makes them easier to manage), closures often disproportionately negatively affect women, who often harvest close to communities (SDG 5). Further, by restricting local access to resources, local people can become more vulnerable to climate impacts (SDG 13).

Evidence assessment across all SDGs

To explore the evidence used to make claims on links, we evaluated a subsample of papers (n = 340), and found a mix of positive, negative, or mixed effects of MPAs on SDGs varied by SDG. The SDGs that had the most papers showing positive impacts were SDGs 15, 17, 16, 12, and 13. The SDG with the majority of papers showing negative impacts was SDG 5. The SDGs with most papers showing both positive and negative were SDGs 10 and 8. The remaining SDGs had a mix of papers showing positive, negative, and both (Fig. 3A).

Across the SDGs, we note that many studies ($n = 102$, 30%) focus at multi-site scales, global scales ($n = 18$, 5%) or are conceptual arguments (i.e. did not collect data but were based on models or conceptual analysis, $n = 59$, 17%, Fig. 3B). Across the SDGs we found less than half of studies focused on local case studies ($n = 161$, 47%). We also observe that across the SDGs, there is an almost even split of studies relying on secondary data ($n = 148$, 44%) compared with primary data ($n = 153$, 45%) and the remainder ($n = 39$, 11%) use both or don't use data at all to link MPAs to SDGs (even if they analyze data for other purposes in their study, Fig. 3C). We found that studies rely on secondary data equal to or more so than primary data (that is, over half of studies rely on secondary data) for 9 of the 17 SDGs (SDGs 2, 6, 7, 9, 11, 13, 14, 16, 17). We note that of the studies that relied on primary data, very few studies used local knowledge ($n = 8$, 2%), and only in a few SDGs (SDG 3, 4, 5, 8, 12, and 14). Similarly, we found that 14 papers (4%) across the SDGs either assume a directional (either positive or negative) link between MPAs and SDGs (where the link is first assumed in the methods) and 69 papers (20%) amplified pre-existing results (where studies initially made links between MPAs and SDGs in the introduction, discussion, or conclusion of the paper). In contrast, we found 122 papers that first connect MPAs and SDGs in the results (36%). Finally, we found 135 papers (40%) that did not follow a typical structure (i.e. opinion articles or research articles that did not follow a standard format).

Table 1 | Documented links between MPAs and SDG targets

	SDG	Positive Links	Negative Links
1	No Poverty	- reduce exposure to to extreme events (SDG 1.5) - economic opportunities through ecotourism, fishing (SDG 1.1, 1.2) - economic opportunities increase community empowerment (SDG 1.4)	- inequitable benefits (SDG 1.1) - displaced communities (SDG 1.1, 1.2, 1.5) - limit access to resources (SDG 1.4) - limit local roles in decision-making (SDG 1.4) - coercive and forced displacement with uncertain rights of return (SDG 1.4)
2	Zero Hunger	- increased productivity, diversity, and resilience of ecosystem for food production (SDG 2.1, 2.2, 2.4)	- restrict local access to local resources (SDGs 2.1, 2.3) - leads to poverty traps increasing poaching and decreasing resilience (SDG 2.3) - those who are already advantaged will benefit while others will not (SDG 2.1,2.3)
3	Good health and well-being	- increased food and nutrition (SDG 3.2. SDG 3.4)	- displacement of resource use entrenches food insecurity (SDG 3.2) - increased access to polluted seafood have outsized negative effects on infant health (SDG 3.4)
4	Quality education	- hiring youth in conservation programs for training (SDG 4.4, 4.7)	- limiting activities can create fewer opportunities for youth (SDG 4.4) - community displacement can lead to loss of educational and social facilities (SDG 4.7)
5	Gender equality	- can provide opportunities for women in leadership (SDG 5.5, 5.a)	- management can be male dominant (SDG 5.1, 5.5) - protection prioritizes male fisheries and women can increase food insecurity (SDG 5.5,5.a)
6	Clean water and sanitation	- reduce activities which cause water pollution (SDGs 6.3, 6.6)	- displace activities causing pollution (SDG 6.3) - protected areas cannot protect against development outside of boundaries, giving false sense of protection (SDG 6.6)
7	Affordable and clean energy	- compatibility with clean energy development (SDG 7.b)	- spatial conflicts with potential energy sites (SDG 7.b)
8	Decent work and economic growth	- increased marine productivity leading to higher incomes (SDGs 8.1, 8.2, 8.4, 8.5, 8.9)	- loss of resource access and income (SDG 8.1, 8.2, 8.4, 8.5, 8.9) - displaced environmental impact leads to loss of employment and income (SDG 8.1, 8.2, 8.4, 8.5, 8.9) - foreign run eco-tourism displaces local economies (SDG 8.5, 8.9)
9	Industries, innovation and infrastructure	- provide inspiration for innovation in blue economy (SDG 9.5) - Indigenous protected areas employ more Indigenous people in research and development (SDG 9.5, 9.a)	- incompatibilities with infrastructure (SDG 9.1, 9.a) - local and Indigenous priorities often not considered and fails to protect important areas (SDG 9.5, 9.a)
10	Reduced inequalities	- increased ecosystem production can lead to poverty alleviation (SDG 10.1) - education and capacity building initiatives (SDG 10.2, 10.3)	- displacement of communities, loss of income for the poorest (SDG 10.1, 10.2, 10.3) - benefits captured by those already well-off and others excluded (SDG 10.1, 10.2, 10.3, 10.6) - limited voice of small island states in international conservation discussions (SDG 10.6)
11	Sustainable cities and communities	- protecting culturally important sites (SDG 11.4) - giving greater control to local communities (SDG 11.b)	- people get displaced from their homes (SDG 11.1) - limit local input and access to important sites (SDG 11.4, 11.b)
12	Responsible consumption and production	- increased sustainable use of resources (SDG 12.2, 12.4) - cooperation includes knowledge sharing (SDGs 12.8, 12.a, 12.b)	- realization of resource sustainability due in part of chance and not just protected area establishment and operation (SDG 12.2) - protected areas often placed in areas not facing threat, limiting their potential (SDG 12.2) - poor management and communication can lead to increased illegal activity (SDG 12.8, 12.a, 12.b)
13	Climate action	- increase resilience to hazards (SDG 13.1) - participation of stakeholders increases capacity for adaptation (SDG 13.3)	- limiting access to resources can make people more vulnerable to hazards (SDG 13.1) - uncertainty around the effectiveness of protected areas in addressing climate change and hazards, including in level of protection and enforcement (SDG 13.3)
14	Life below water	-reduced pollution (SDG 14.1) - fisheries restoration and marine conservation (SDG 14.2, 14.4, 14.5) - contribution to sustainable development through tourism opportunities in small island states (SDG 14.7).	- ecotourism adds pollution (SDG 14.1) - displace fisheries (SDG 14.4, 14.b) - disempower local communities and undermine coastal management (SDG 14.2) - “paper parks” create illusion of protection while continued degradation (SDG 14.2, 14.5)
15	Life on land	- flooding and erosion protection (SDG 15.5)	- enhance poaching and trafficking where enforcement low (SDG 15.7, 15.c) - displace destructive efforts elsewhere (SDG 15.5)
16	Peace, Justic and strong institutions	- decentralized and locally-controlled MPAs can increase local support and community links (SDGs 16.5, 16.6, 16.7) - protected areas allow for an entry way to global conservation planning for developing nations (SDG 16.8)	- existing disparities can be enhanced through protected area establishment, increasing conflict (SDG 16.5, 16.6, 16.7)
17	Partnerships for the goals	- promote collaborative decision-making and internation collaboration (SDG 17.16) - “debt for nature swaps” help debt reduction (SDG 17.4)	- entrench colonial dynamics and limit sovereignty of small islands, including in debt-for-nature swaps (SDG 17.4)

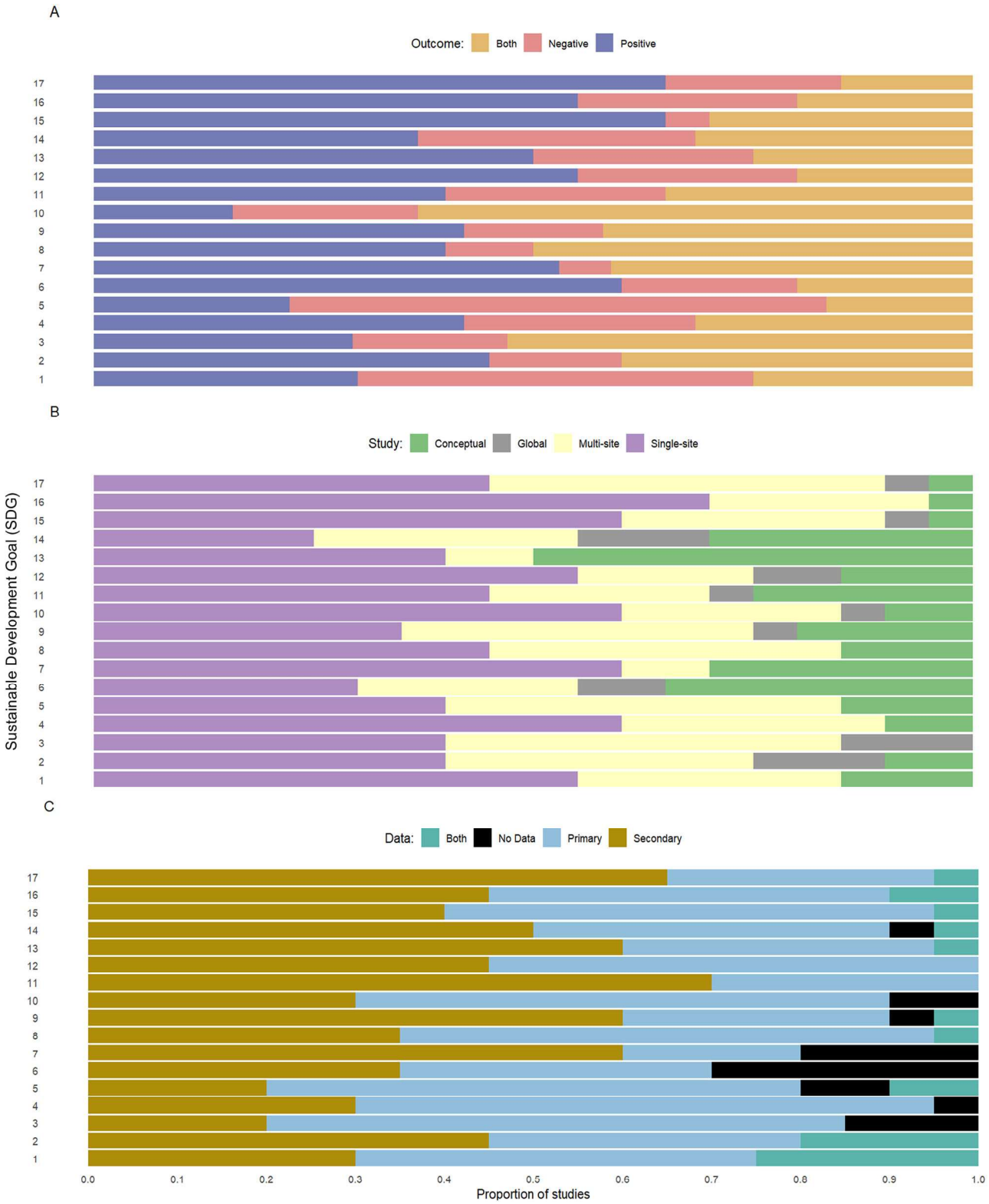

Fig. 3 | Evidence underpinning the links between MPAs and the SDGs. Literature derived evidence was characterized to identify **A** the proportion of literature which identified the positive and/or negative impacts of MPAs, **B** the scale of study from which evidence was extracted (e.g., localized study, multi-site, global, or conceptual study); **C** whether the data used by the study was of primary or secondary origin.

In depth evidence assessment of SDGs 1, 2, and 5

We reviewed the full literature to examine links between MPAs and SDGs 1, 2, and 5, as well as the evidence used in this literature. We found that the literature linking MPAs on SDGs 1, 2, and 5 based on data analysis show a mix of effects on these SDGs (Fig. 4). For papers showing links between MPAs and SDG 1, we found that individual papers mostly documented mixed effects (both positive and negative, 43% of 54 papers), with papers documenting only positive effects or only negative effects being less common (31% and 26%, respectively, Fig. 4A). For papers showing links between MPAs and SDG 2, we found that individual papers most often

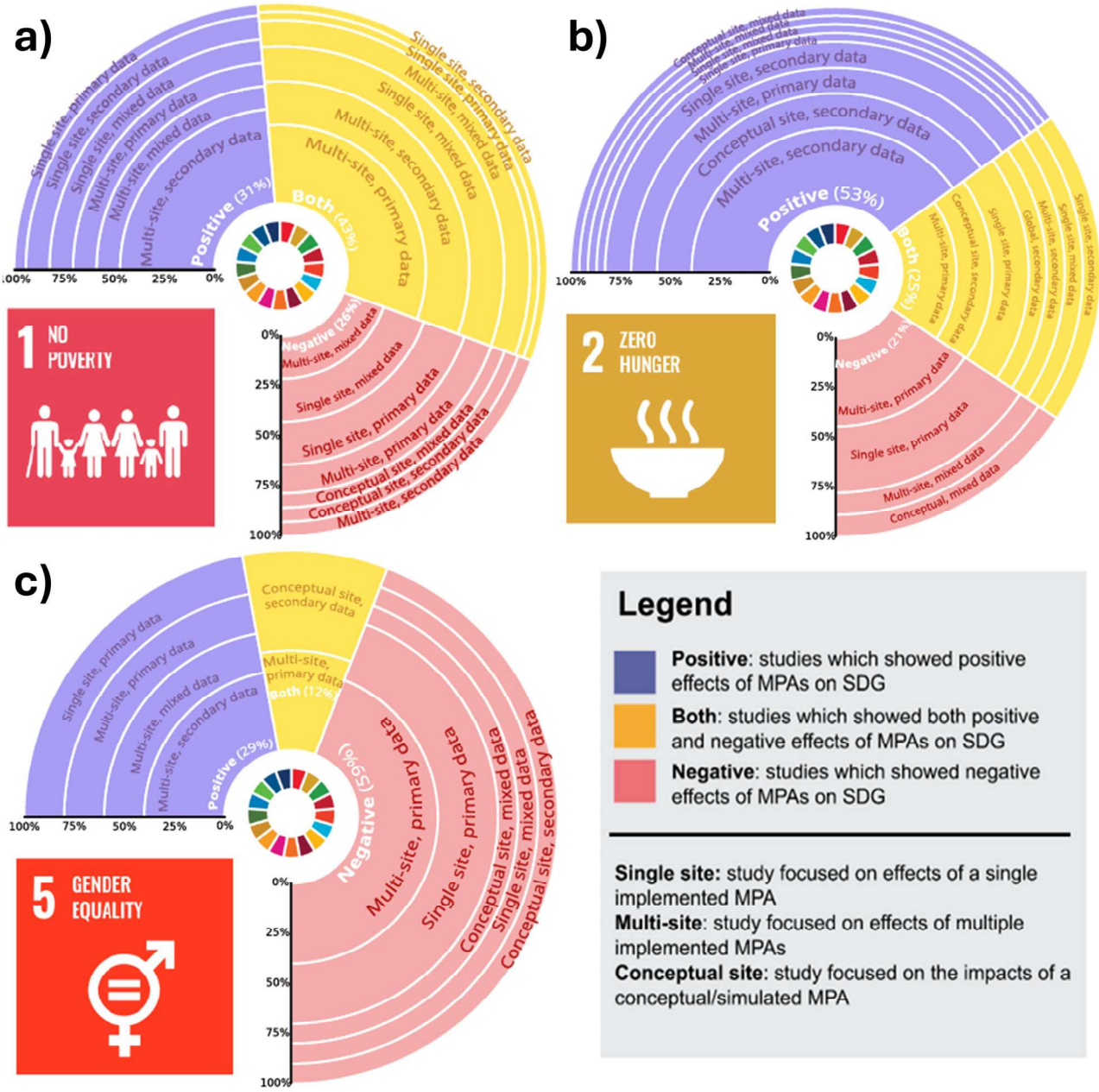

Fig. 4 | Effects of MPAs on SDGs 1, 2, and 5. The kinds of effects of MPA on SDG 1 (**A**), SDG 2 (**B**), and SDG 5 (**C**) and the kinds of evidence (e.g. primary, secondary) and scale of assessment (e.g. single site, multi-site) documenting these effects in the literature.

documented solely positive effects (53% of 43 papers), while fewer showed mixed effects and only negative effects (26% and 21%, respectively, Fig. 4B). For literature showing links between MPAs and SDG 5, we found that individual papers most often documented solely negative effects (59% of 17 papers), with papers that documented only positive effects or mixed effects were less common (29% and 12%, respectively, Fig. 4C).

Of the 54 papers linking MPAs with SDG 1 through data analysis, we found that 18 of these were based solely on secondary data. Combining these with the 53 papers making claims about MPAs without conducting their own analysis, we estimate that 59% of studies that purport a relationship between MPAs and SDG 1 relied on previous work or made recommendations or opinions about the relationship based on secondary data. Of the 43 papers linking MPAs with SDG 2 through data analysis, 21 rely solely on secondary data. Combining these studies with the 77 studies that did not conduct their own analysis, we found that 73% of papers rely on previous studies to link MPAs with SDGs. For the 17 papers linking MPAs with SDG 5 through data analysis, we found that 4 studies were solely reliant on secondary data. Adding this to the 10 studies that claimed relationships between MPAs and SDG5 without conducting their own analysis, we estimate that 52% of the 27 studies that claimed relationships between MPAs and SDG 5 rely on previous studies.

Across SDGs 1, 2, and 5, we found that papers documenting solely positive effects through analysis of MPAs were often (though not always) reliant on secondary data with no primary data collection (59% for SDG 1, 70% for SDG 2, 40% for SDG 5). In comparison, we found studies that found solely negative effects through analysis more often utilized primary data (86% for SDG 1, 100% for SDG 2, 90% for SDG 5, though two of the studies link MPAs and SDG 5 in the discussion rather than its own results). We also analyzed the abstracts of papers that did not conduct analyses (that is, no primary or secondary data, such as opinion articles and reviews) to assess whether papers were written to be generally supportive or cautionary of MPAs (and therefore highlight benefits or risks). Combining our results of

papers reliant on secondary data with our results of abstract framing for papers that did not conduct data analysis, we estimate that 41% of studies that linked MPAs and SDG1 without original analysis (papers with no primary data or no data at all) asserted positive effects of MPAs on SDG 1, while 31% asserted negative effects. We also find that 62% of studies that made claims without original analysis stated or assumed positive relationships between MPAs and SDG 2, while 13% asserted negative effects. Finally, we estimate that 29% of studies that made claims without original data on links between MPAs and SDG 5 assumed positive relationships, while 50% of papers that made claims without original data asserted negative effects.

We found that papers documenting solely positive effects were mostly conducted at multi-site scales. We found that literature focused on SDG 1 documenting positive effects were predominantly multi-site studies (71%) while only 43% of papers focused on negative effects were multisite while a further 43% were single-site studies. We found that literature focused on SDG 2 documenting only positive effects were mostly multi-site studies (57%) while papers focused on negative effects were similarly mostly based on multi-site (56%). We found that literature focused on SDG 5 documenting only positive effects were predominantly conducted at multi-site scales (80%), while 40% of papers documenting only negative effects were conducted at multi-sites scales (with a further 40% at single sites).

Discussion

MPAs are tools available for addressing conservation and, in some cases, development goals. We found that they have displayed mixed effects across every SDG, and across many of the SDG targets. MPAs need to be strategically designed and implemented with a greater awareness of their potential impacts to wider societal objectives, so that trade-offs can be effectively considered and care can be taken to avoid promoting some goals at the detriment of others[5,19,20]. Our results of these mixed effects that MPAs pose across all SDGs suggest that MPAs are better employed as precision instruments where the capacity and context favours them rather than broad policy tools to address large scale conservation and development goals, because so many of their risks are a product of how they are designed and implemented[12,29–31]. To further this argument, MPAs are interventions that have local scale repercussions, even when their implementation may be in the context of a wider network or national objective, which affect specific communities and geographies rather than national and international scales[32]. These results reinforce that caution and full consideration of the elements of GBF Target 3 (e.g. equitable governance) is required in the context of 30 × 30 implementation, because of the potential for these broad uses of the MPA tool to impact key dimensions of sustainable development. Sustainable development criteria are often absent from MPA monitoring programs and infrequently used to measure MPA success[33,34]. To achieve scenarios where MPA targets also contribute to progress in sustainable development, as is set out in the GBF, our results suggest that MPA need to be strategically designed, not assumed, to do so. While 30 × 30 is often celebrated for its bold quantitative goals, measuring success must be approached with the recognition that MPAs themselves are not policy objectives, rather that they are interventions which may support policy objectives when implemented effectively and equitably in consideration of their possible direct and indirect impacts to societal needs and objectives.

Our findings suggest that the literature documenting impacts of MPAs on SDGs may overrepresent benefits relative to risks for several reasons. First, many studies on benefits are conducted at scales larger than specific interventions, which may mask negatives at specific sites. Second, more studies are focused on SDGs where biophysical dynamics benefit people, and fewer are focused on areas of procedural and equitable social effects, where risks are often documented. Finally, we found that papers documenting benefits are more prone to rely on secondary data and amplify existing work compared to papers documenting risks.

We found that across SDGs, many studies focus on effects of MPAs at scales larger than a specific intervention. While this scale of analysis might fit with broader regional, national, and international planning, it necessarily misses important local context that can regulate whether risks or benefits materialize. This is important for two reasons: first, there may be broad disciplinary differences in how benefits and risks are studied, with risks often studied by social scientists and benefits by ecologists and conservation biologists[30,31]; second, while effects of MPAs are often designed and studied at aggregate scales, they are often communicated to communities with promises at local scales[30,32]. For the former, aggregation can help establish generalities that cater to how biophysical and conservation scientists and global policy delegates understand biophysical processes, while the site-specific focuses on context which is often investigated by political and social researchers. However, because of the relative prestige that biophysical sciences and quantitative approaches have, they may be promoted above the site specific focus of case-studies. This may allow for a proliferation of logic-models that assume if the natural environment is more productive people will benefit, rather than research which considers broader trade-offs to explicitly recognize the adverse impacts of MPAs on people[35–37]. Some of these dynamics may play out even in cases where MPA benefits to SDGs 1, 2, and 5 are communicated over risks, even if they tend to focus at broader scales.

If there are cases where documenting impacts of MPAs are often done at aggregate scales and then communicated to specific communities, this scale mismatch raises serious concerns (as explored by some documents such a ref. 32). Applying expected population-level responses (where data including a well-functioning MPA with strong productivity gains can offset data from another site where productivity gains are minimal) to specific site settings is a statistical fallacy called the "ecological fallacy"[38]. That is, using population level characteristics to make claims about individual interventions is a statistical artifact that is not representative of how an individual MPA may affect SDG concerns. At scales relevant to impacted communities (where SDG impacts often materialize) the benefits of one MPA do not necessarily balance out the negatives of another. That is, population level measures may create statistical artefacts that are not relevant at community scales. We suggest that planning for MPAs at local scales should focus on context, societal objectives, and lessons learned at local scales.

Our results indicate that relatively little research is focused on SDG areas that have to do with social, procedural and equitable dimensions (as determined by the number of papers connected to these SDG dimensions). Since so many of the risks posed by MPAs are procedural, then understanding the processes employed by MPAs may provide more insights into effective strategies into avoiding or mitigating risks[29,30]. Some research is already focused here, and early synthesis suggests that ocean interventions that focus on local control, equity, and power may be best at avoiding adverse side-effects and mitigating risks[12,34]. Another option may be bypassing the use of externally-implemented MPAs and relying on other interventions, such as locally controlled OECMs, seasonal closures, or fisheries cooperatives with local control. Further, our results specifically focused on spatial approaches, whereas marine protection includes temporal tools (e.g. seasonal fishing closures) and informal customary institutions (e.g. local taboos). We see an opportunity to explore the potential of these types of OECMs rather than automatically defaulting to spatial tools in addressing marine conservation and development goals.

Our results indicate that much research on MPA impacts on the SDGs rely on secondary data and previous research. For SDGs 1 and 2, this reliance on previous work is demonstrated to be stronger for papers highlighting benefits of MPAs instead of risks. In addition, there are also review papers entirely focused on the benefits of MPAs (e.g. ref. 18) and we are unaware of similar literature reviews and systematic studies entirely focused on risks, though some document both benefits and risks (e.g. ref. 6). Despite the frequency of articles documenting or arguing for the positive effects of MPAs on these SDGs, our results indicate these studies base their conclusions on primary data (either solely or in combination with secondary data) between 10 and 43% of the time or otherwise are recycling data in new analysis or citing previous studies through reviews. In particular, the recycling of information through literature reviews, models, and best practice documents may inflate the documentation of MPA benefits in ways that are

disproportionate to their actual frequency. There may be instances where the frequency of risks is overinflated more than benefits, and more directed research documenting the inflation of benefits vs. risks is needed to definitively address this. However, we caution that the importance of risks as "controlling variables" (as discussed below) may counteract any numerical difference in benefits and risks, and can also be good planning practice[34].

Outside of the potential problems of understanding the effects of MPAs with an overreliance on secondary data, we also note how few studies utilize data that reflects the voices of affected communities. While many studies employed surveys, interviews, and focus groups, these were often conducted with staff and managers of MPAs rather than affected communities. Additionally, these studies tend to be both structured and interpreted through the lens of the researcher. We estimated that only 2% of studies involve local knowledge and frame research from local perspectives (and none of these studies address SDGs 1, 2, or 5). Where these studies and assessments are carried out by researchers aligned with proponents, this may call into question the framing and interpretation of the research. Even in contexts where researchers are unaligned with proponents there may be questions of to what extent results reflect local perspectives and realities and instead are filtered through the lens of the analyst. The MPA Guide – a framework to categorize types of MPAs and connect them to their intended goals through procedural considerations – has "enabling conditions" calling for integrating knowledge and perspectives of local communities as necessary for MPAs to succeed[12]. We call for increased research framed by and reflecting local communities.

Our review of the literature raises additional theoretical concerns that may further justify the suggestion that current literature may overrepresent benefits relative to risks. First, many risks of MPAs are immediate and are subject to planning, management, and environmental variation, whereas benefits take longer to be realized and are dependent on good planning and management. Second, many studies implicitly assume that MPAs are well functioning while recent estimates indicate that many MPAs are not adequately protected to provide benefits. Finally, some studies documenting benefits use questionable causal logic, attributing social benefits to the success of MPAs while in reality the success of the MPA might be dependent on social benefits, though we do not know if this practice is more prevalent in literature documenting benefits rather than risks.

Our findings reveal a range of causal structures behind the risks and benefits of MPAs, but also reinforces previous work in highlighting many benefits related to boosted marine productivity and diversity versus risks that include reduced local decision-making, control, and access of resources[5,6,30,31,33]. That is, while many of the risks of MPAs seem to accrue immediately (as part of socio-political forces around decision-making and sovereignty), the benefits take longer to materialize since they rely on the successful environmental restoration of habitat and species[28,31]. We suggest more research is needed to understand the dynamics between early and later effects to better understand when risks and potential benefits might be realized.

First, early risks may be generally more likely to materialize than later benefits, since events farther in the future are more uncertain[20,39]. More substantively, there is growing evidence that later outcomes of MPAs are dependent on earlier planning, capacity building, and implementation stages[29,30]. Because the risks are often related to representational and management concerns (such as whose priorities are represented and taking part in planning and process and implementation), later outcomes will likely be influenced by these stages, and could benefit those who had leadership roles and leave out those who did not[11,30,34]. In contrast, when benefits of MPAs are associated with the outcomes of MPAs (rather than planning and process), they are probably less important at affecting earlier planning and implementation stages. This cumulative disadvantage - whereby disadvantages beget future disadvantages - are widespread in social and socio-ecological systems[34]. However, there are also cases where the kinds of enabling conditions that allow for positive ecological outcomes have negative social effects (such as when planning and enforcement is imposed on a community externally[31]), and cases where locals do not share conservation concerns, so inclusive planning does not lead to conservation outcomes[30]. In short, simplistic formulas for MPAs delivering benefits and avoiding risks may not exist, but understanding contextual factors and causes is needed to better inform decision makers as to how management interventions have cross-policy implications.

Regardless, we argue there is one dynamic that can largely regulate whether benefits or risks materialize. Recent estimates indicate up to a quarter of global MPAs have zero conservation efforts, and a further third are so limited in restricting activities to include extractive industries (such as mining and industrial fishing) that could likely compromise the effectiveness of the MPA and negate the potential for benefits[40]. Some studies point out that some MPAs are necessarily compromised in effectiveness in order to get the buy-in from powerful groups (such as oil and gas industries) in order to be established[12,34,41]. If MPAs are not adequately protected we suspect they might generate negatives for communities affected by them without any potential for positives – they can limit local input and access, make historic extractive activities illegal, but simultaneously fail to deliver on their promises. We argue that this point further implies that the published literature on MPAs may overemphasize the benefits of MPAs in the real world because many studies are done assessing or assuming MPAs with functioning management and capacity[29,40]. For example, recent research highlighting potential impacts of nature-based solutions to SDGs broadly (e.g. refs. 42,43), assume interventions towards conserving, restoring, or managing ecosystems are effective and work as intended, producing co-benefits.

On a final point about the links between MPAs and SDGs, we noted that causality in the published literature was sometimes confused. Though we did not conduct the study with the explicit aim of understanding how the literature understands causal relationships between MPAs and SDGs, we did note some cases that could signal the need for explicit research focused on whether MPAs impact SDGs or whether SDG progress impacts MPA implementation and outcome. Some papers we reviewed demonstrated a "reverse causality" problem (sensu[44]), or a "simplified causality" problem. Reverse causality problems and simplified causality problems occur when authors attribute MPAs as interventions with effects on SDGs, when in fact progress or characteristics of the SDG area made for better or more sustainable MPA implementation, management, or outcome. This is a fundamental problem when documenting the effects of MPAs since the direction of attribution is opposite what is claimed, and the article making the claim may erroneously report an effect of an MPA. For example, some studies attributed or implied that MPAs benefitted women through raising their roles in leadership, when in fact gender-norms may have allowed or preferred female leadership and led to MPAs with female-led executive (e.g. ref. 45). In other cases, authors credit MPAs for providing new opportunities for innovation and market diversification, when in fact market innovation may be unaffected by MPA existence and may instead provide alternative opportunities for people potentially affected by MPAs and make MPAs more acceptable (e.g. refs. 46,47). Though we cannot say whether or not these "reverse causal" problems are more prevalent in the literature showcasing positive versus negative effects of MPAs, we do highlight this as another potential problem in understanding the evidence as provided by the literature. We note that goals associated with the social dimensions of the SDGs are not traditionally the focus of MPAs and data is not always collected on these dimensions, so properly evaluating the causal relationship between MPAs and SDGs may be difficult. Properly evaluating these links, and incorporating them as measures of MPA success, will require targeted monitoring and evaluation processes be planned in MPAs at the outset and not assessed retroactively[35].

Though MPAs are often championed as a necessary tool of a sustainable future, we caution that MPAs are complex interventions with both positive and negative impacts. An exploration of risks and trade-offs should be central to MPA design, to ensure that social, governance, economic, and ecological priorities are explicitly considered[48]. Reviewing the published literature around the dimensions of sustainable development as outlined by the SDGs reveals that the co-benefits of MPAs are often assumed or

determined without primary data or strong causal understanding. Assessing the evidentiary bases of the studies looking at the effects of MPAs suggests that some of the benefits are disproportionately emphasized in frequency given the recycling of data and references. We suggest MPAs, and other area-based conservation tools, should be implemented with greater care, the potential positive effects reviewed with greater rigor, the often-unexplored risks explicitly considered and planned against, and both considered in local context with locally-partnered evaluation to ensure their contributions towards sustainability goals. Doing so will require more than a change in scale of focus, but rather address the capacity constraints (such as limited resources and mismatched donor priorities) that often limit local planning and implementation needed for enhancing benefits and limiting risks.

Methods

Overview

We undertook a three-part systematic mapping review of the literature linking MPAs and SDG areas. First, we conducted a systematic search of the literature across every SDG target (Supplementary Table 1). We conducted searches specific to each SDG and terms related to MPAs. Each of the 17 goals contains a collection of targets (from 5 to 17 targets). Second, we collected a random subsample of papers within each SDG goal (across all 17 goals) to explore the kinds of evidence provided in each paper to make claims about how MPAs affect the SDGs. Third, we reviewed every paper collected relevant to the impacts of MPAs on SDG 1 (End Poverty), SDG 2 (Zero Hunger), and SDG 5 (Gender Equality) to thoroughly explore the evidence of impacts to these SDG areas relevant to social and economic development priorities.

Literature search and screening

We performed an extensive search for literature focused on links between MPAs and the SDGs, accessible via Google Scholar and Web of Science. We conducted a systematic search for literature[49] for each of the 17 SDGs by combining search terms for MPAs with search terms in alignment with each SDG. Search terms and datasets can be found in a public data repository[50]. Search terms for MPAs were adapted from search terms from previous reviews on MPAs[6,17,51–54]. Since our systematic mapping of evidence was concerned with addressing the question "what are the effects of MPAs across the SDGs?" we scoped our search according to PICO criteria (Population of interest, Intervention, Comparator of interest, Outcome of interest), and applied these to establish systematic and repeatable inclusion and exclusion criteria when screening papers for data collection[55]. Our search included terms for impacts across all SDG areas (our Population of interest), from MPAs and area-based conservation measures (our Intervention of interest), and all forms of area based conservation tools were eligible. We excluded papers that discussed benefits of nature that were not a result of explicit area based conservation. Our Comparator of interest were sites not protected by MPAs or other area based conservation, though we did not include papers that only looked at these effects without also looking at the effects of MPAs. Our Outcome of interest were consequences related to the SDGs. Given this focus on effects, we excluded articles that focused solely on inputs, planning, processes, or recommendations for improving MPA design. However, because part of our analysis concerned the types of evidence used, we retained studies regardless of whether they included explicit comparisons between protected and unprotected sites.

We looked at all available papers until July 2021. We initially found 6675 papers, with some papers linked to multiple SDGs. We found 12 046 links between papers and SDGs. This included peer reviewed papers, government reports and management reports from MPAs. We recorded where papers were original research, conference proceedings, reviews, short communications (opinion pieces), and reports (grey literature) for government and intergovernmental agencies. For peer reviewed sources found through Web of Science we recorded the number of citations each paper received up to the time we downloaded the data.

In order to generate a list of papers relevant to the SDGs, we screened our list of papers through a filtering process involving multiple steps. First, papers were filtered by title, so that papers clearly not related to SDGs were removed. Second, we read the abstracts of each paper to ensure that the paper at least addressed an SDG target and MPAs. This second stage resulted in 2508 papers, including 4867 links across the SDGs (Supplementary Fig. 1).

While we endeavored to conduct a rigorous literature search, some biases may still shape our results. Namely, our search focused on English language articles, which may not capture the regional variation of MPA effects. These language effects can compound with potential for publication biases and paradigm biases that often emphasize positive effects (that is, some studies showing effects are more likely to be published in English, and this can compound with publication biases that focus on the same, while much of the MPA literature has also focused on positive effects)[55–57]. Our inclusion of grey literature in the scope of our literature collection process was intended to counter some of these biases, since non-peer reviewed articles often face less pressure to show effects. We also explicitly included a wide temporal range of articles in part to counter biases that may be found in more recent articles (including current paradigms or emphasis on some kinds of effects). Overall while we attempted to address these biases, some limitations remain (especially regarding language bias). In addition, since our approach was focused on mapping evidence and less so on synthesizing evidence, our approach is stronger at pointing out the range of work done and weaker at estimating true effects (such as only considering studies that have evaluated effects according to causal inference-based approaches, such as those studies with robust counterfactuals).

In order to answer the question of which SDG areas may be affected by MPAs, and if the literature suggests that any SDG area is uniformly affected (positively or negatively) from MPAs, we screened our list of papers further. We searched for the kinds of effects that MPAs can have across the SDGs, and documented if any SDG is universally positively or negatively affected by MPAs. We listed up to five papers that document a link, and recorded the kind of link described in the papers, where "link" refers to a statement, finding, or assertion about the influence of MPAs on a given SDG target. We recorded direct statements from the papers and/or findings that make links between MPAs and the specific SDG target. Where we did not find clear links, we conducted dedicated word searches across papers that corresponded to the exact wording within an SDG target.

The result was an overview of the proportion of targets within each SDG that the literature indicates can be affected by MPAs, and the kinds of positive and negative effects that MPAs can have on SDGs. We chose not to quantify the proportion of targets positively vs negatively impacted, since literature searches can only provide representative samples of the focus of past research (and associated issues like identifying gaps in research), and are not a representative sample of reality[58]. That is, while the published literature may be expansive enough to cover whether MPAs have impacts across the SDGs, they are likely not a representative sample to quantify the likelihood of effects of MPAs across the SDGs.

Evidence assessment overview across SDGs

The initial literature review documented how the literature characterizes the effects of MPAs across SDG areas. We then took subsamples of the literature to explore how evidence is collected and used to justify the effects of MPAs across the SDGs. To do so we categorized the kinds of data collection (e.g. collecting primary vs secondary data, details provided below) to observe patterns of how evidence is used within each SDG. Given the amount of peer reviewed articles collected in the previous step (the initial literature search), we used a random number generator to select 20 papers within each SDG area. We chose a subsample of $n = 20$ for each SDG because this sample size is suggested to be reasonable for ensuring adequate power and avoiding false detections of differences in categorical variables[59], and our assessment was focused on counts of the kinds of evidence used in each SDG. This totaled a review of 340 articles in which to assess the evidence used to make claims about MPAs.

More importantly, our sample size of 20 was large enough to capture at least 15% of the literature found linked to the social SDGs, which were the

focus of our analysis. We do not claim our results are conclusive about data quality within each SDG but rather assess patterns across the SDGs. However, the sample of 20 represented a smaller or larger proportion of available papers, depending on the SDG (Supplementary Table 2). The proportion of relevant literature reviewed in this process per SDG varied from 1% of papers for SDG 14 ("Life Below Water") to 74% of available papers (e.g. SDG 5 "Gender Equality"). We note that papers related to SDG 14 were outliers in terms of the number of papers exploring it, but many of the papers in SDG 14 were focused on ecological rather than societal outcomes. SDGs with higher proportions of relevant papers captured by this subsample were related to social dimensions (health, education, gender, poverty, hunger, inequalities, partnerships) and lower proportions related to economic and ecological dimensions (economic growth, ocean and land conservation and development, infrastructure, consumption and production) and policy (climate policy, institutions). Our results, based on this subsample, are therefore more likely to represent the literature of how MPAs impact social goals.

From each paper we collected the following information: whether the study documented the MPA having a positive, negative, neutral, or mixed effect on the SDG; the study type (including original research, reviews, perspectives and communications, and reports); the kind of data the paper's evidence is based on (primary data, secondary data, a reliance on both, or if the paper did not use data); the scale of the analysis (whether it was a study of an individual MPA, multi-site, global, or conceptual); the kind of evidence relied on (quantitative data, qualitative, expert knowledge, literature review, local knowledge, project evaluations of a specific MPA, and mixed collection of evidence).

As a supplement, we also recorded whether the paper's conclusions about MPAs influence on SDGs was based on analysis done in the study (and therefore found in the results of the paper), or simply a claim and a citation to other studies. That is, some papers made claims about MPA associations with SDGs without conducting their own analysis, instead citing previous work. Some papers were not written using standard structure (Introduction, Methods, Results, Discussion) and so were not included in the analysis on where in the paper the link between MPAs and SDGs was made. We documented these categories as an indicator of how much the literature produced multiple lines of evidence towards impacts of MPAs on SDGs and how much the literature amplified previous work.

While it is sometimes acknowledged that higher quality evidence comes from studies that follow causal inference designs (e.g. comparisons against a comparative site without interventions, quasi-experimental designs) we did not explicitly record information on causal evidence as part of our evidence assessment. We made this decision for a few reasons. First, the work on causal designs for MPAs is still relatively nascent and new research indicates that even work that includes counterfactual comparisons (i.e. sites without MPAs) may not adequately compare against representative and appropriate counterfactuals[60], and we determined that making this specific level of assessment for each study was untenable given the size of our database. Second, some fields of study (such as ethnographic fields) are place based and not focused on comparative studies, and we did not want to introduce biases in our assessment that favored some forms of evidence and some fields over others. Third, some studies do not lay out clear causal paths by which MPAs are assumed to affect SDGs, making the recording of causal designs difficult. For example, some studies may assume that MPAs affect an SDG, when in fact they record how progress in the SDG can influence MPA establishment or managed. Some studies point to this as "reverse causality problems" and we do note some instances of this.

In depth evidence assessment of SDGs 1, 2, and 5

Finally, we read all papers in full for the SDGs our analysis is focused on (SDG 1 (Poverty, $n = 118$), SDG 2 (Hunger, $n = 134$), and SDG 5 (Gender, $n = 27$)) to determine how many conducted original analyses on the link between MPAs and SDGs. We also limited our analysis to papers written in English, given our limited capacity and high likelihood to misinterpret papers if we relied on translation software. The result were 67 papers for SDG 1 (Poverty), 47 for SDG 2 (Hunger), and 17 for SDG 5 (Gender). From this list of papers we collected the same information on the evidence and analysis done as recorded in the Evidence Assessment (see above at Evidence Assessment Overview across SDGs).

The papers that did not conduct their own analysis were instead analyzed through qualitative content analysis (similar to ref. 61) to explore how MPAs are framed in their abstracts. Particular attention to framing was placed on the use of positive versus negative language around MPAs (including their tone), as well as causal attribution and treatment recommendations[61]. This analysis was conducted on the abstracts to judge whether the paper was generally supportive of MPAs (written assuming positive impacts), cautious (written assuming negative impacts), or unclear (written making no clear distinction of impacts). Our in-depth analysis allowed us to explore the evidence used to make claims in a more comprehensive and definitive sense for SDG 1 (Poverty), SDG 2 (Hunger), and SDG 5 (Gender).

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

All data for this article can be found in Figshare (https://doi.org/10.6084/m9.figshare.30547874.v1). In addition, tables showing our search terms and specific links of literature to SDG targets are also found in this Figshare repository.

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Author contributions

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Competing interests

The authors declare no competing interests.

Additional information

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