nature sustainability

ANALYSIS

https://doi.org/10.1038/s41893-019-0306-2

Well-being outcomes of marine protected areas

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Marine protected areas are advocated as a key strategy for simultaneously protecting marine biodiversity and supporting coastal livelihoods, but their implementation can be challenging for numerous reasons, including perceived negative effects on human well-being. We synthesized research from 118 peer-reviewed articles that analyse outcomes related to marine protected areas on people, and found that half of documented well-being outcomes were positive and about one third were negative. No-take, well-enforced and old marine protected areas had positive human well-being outcomes, which aligns with most findings from ecological studies. Marine protected areas with single zones had more positive effects on human well-being than areas with multiple zones. Most studies focused on economic and governance aspects of well-being, leaving social, health and cultural domains understudied. Well-being outcomes arose from direct effects of marine protected area governance processes or management actions and from indirect effects mediated by changes in the ecosystem. Our findings illustrate that both human well-being and biodiversity conservation can be improved through marine protected areas, yet negative impacts commonly co-occur with benefits.

Many countries have committed to establishing 10% of their marine waters as marine protected areas (MPAs)[1,2] to stem biodiversity declines and safeguard related ecosystem services[3,4]. While conservation effectiveness of MPAs has been demonstrated through ecological studies[5,6], many MPAs have social goals and outcomes that are less well known[7]. Understanding how human well-being may be affected by MPAs is important for social and ethical reasons with potential implications for biological outcomes. MPAs that support positive human well-being are also more likely to achieve their conservation goals because they are more acceptable, desirable and supported by local communities[8–10]. This in turn can increase compliance[11]. Human well-being is an important end goal, with co-benefits for conservation goals and policies (for example, in refs. [12–15]). Ensuring that positive human well-being outcomes are associated with implementation and maintenance of MPAs is important for people and for acceptance and effectiveness of MPAs.

Worldwide, increasing establishment of MPAs[16] has stimulated research on well-being outcomes of MPAs, with a substantial increase in the number of studies in the past decade (Supplementary Fig. 1). The most recent synthesis of impacts of MPAs on human well-being (hereafter 'well-being outcomes'), published a decade ago, focused only on fishing communities due to data constraints[7]. This study found that MPA establishment tends to improve food security and empower local fishing communities, but that effects vary depending on the social and governance context[7,17]. Since this synthesis was conducted, there have been numerous case studies (Supplementary References) that document a broad array of positive and negative social outcomes from MPAs. Given the commitment by countries to establish MPAs[16], understanding their effects on well-being outcomes is crucial.

We performed a systematic literature review on the well-being outcomes of MPAs (Supplementary Tables 1 and 2). We examined social, health, culture, economic and governance domains of human well-being[18], and added an environment domain since environmental health is fundamental to human well-being and vice versa (Supplementary Table 1). Governance as a well-being outcome refers to the experience of local people with the quality of governance processes—including actors such as empowerment, participation, conflict management and accountability[19]. Our analysis allows us to answer questions critical for assessing well-being outcomes of MPAs. Where and how are well-being outcomes of MPAs studied? What domains of human well-being are included in scientific studies? Are well-being outcomes consistent across different groups of people (that is, stakeholders)? What factors influence whether positive or negative outcomes are perceived or experienced? Finally, what well-being outcomes co-occur?

Data on human well-being outcomes of MPAs. We identified 118 peer-reviewed articles (Supplementary References and Supplementary Fig. 1) that investigated one or more existing MPAs, and included information about the measured or perceived impact(s) of the MPA(s) on people (108 articles with quantitative or directional data). The relevant articles studied 121 MPAs distributed globally (Fig. 1a), containing 267 observations of stakeholders (that is, some articles studied multiple stakeholders, as defined in the source paper), each of which described one or more well-being outcomes of MPAs (that is, 606 data points of well-being outcomes).

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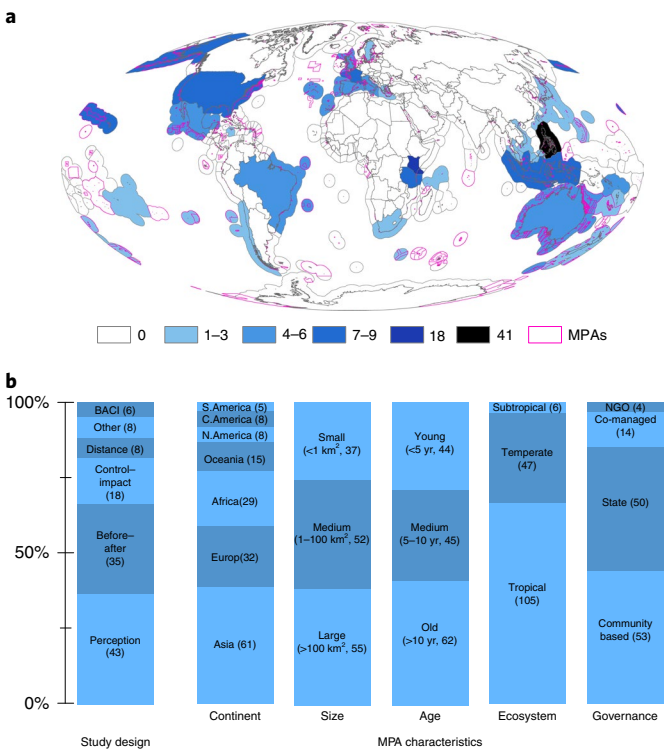

Fig. 1 | Global distribution and characteristics of MPAs. **a**, Global distribution of studies of MPAs included in the analysis, colour coded according to the number of included studies for each country. MPAs shown in pink outline. **b**, Characteristics of the studies and MPAs included in this review. Numbers in parentheses indicate the number of studies (that is, papers) used for study design (out of 118, left column), or the number of MPAs (out of a possible 121; some MPAs had no data about some characteristics). BACI, before–after-control–impact; S., South; C., Central; N., North; NGO, non-governmental organization. MPA data are from ref. [58]; EEZ boundaries are from ref. [59]; country boundaries are from ref. [60], ESRI, DeLorme Publishing Company, Inc.

Coastal communities referred to residents in coastal towns rather than more specific groups such as fisheries or tourism, and recreation was defined as non-extractive personal activities (for example, diving or kayaking). Seventy-five per cent of stakeholder data involved fisheries; of those, 76% were about artisanal and small-scale fisheries, 15% about industrial fisheries and 9% about recreational fisheries, but the sample sizes were too small to be analysed by disaggregated fisheries categories. Further disaggregation, while not provided in the papers, might highlight additional biases in studies (for example, gender and ethnicity)[20]. Most MPAs with relevant data were from Asia (especially the Philippines) and Europe, with a fairly even distribution of MPA size and age categories. The most common types of MPA governance were state-led and community-based, followed by co-managed. Several study designs were used, with those asking stakeholders for their perceptions of social change being the most common, followed by studies before and after MPA establishment and studies using control–impact design (for example, inside and outside of MPAs). The least common study type was the before–after control–impact design (Fig. 1b).

Domains of human well-being considered in MPA studies. All domains of well-being were mentioned in the papers reviewed, whether as the focus of study or in the discussion (Fig. 2). Economic, governance and environment categories were most prevalent, and were often the focus of assessment. Social, health and cultural domains received much less attention, usually in the form of a cursory mention in the discussion. The category mentioned most frequently was economic livelihoods, in which we included fisheries catches and catch per unit effort (CPUE). Categories of cultural diversity and mental health received the least attention. We posit that the uneven consideration of categories is due to a combination of the societal importance placed on economic outcomes and the challenges in measuring social, health and cultural domains. Ten variables across four domains contained sufficient quantitative information to be further analysed for outcomes (Fig. 3): income, number of users, CPUE, catches, cost of activity (only mentioned in relation to fishing regarding increasing fuel costs when distance to fishing grounds increased), stakeholder rights to inform resource management (hereafter 'resource control'), stakeholder support for the MPA, change in spatial use patterns (hereafter 'spatial change'), conflict and community involvement (Supplementary Table 1).

Well-being outcomes of MPAs. Overall, there were more positive (51%) than negative (31%) well-being outcomes reported in the literature (Fig. 3 and Supplementary Table 3). Shifts in the numbers of users differed between stakeholder groups, with more increases for tourism and recreation, and more decreases for fisheries (Supplementary Table 4). The most positive well-being outcomes of MPAs related to community involvement (76% positive), CPUE (73%) and income (65%). The most negative outcomes manifested through increasing costs of activities (100%, though in only 13 instances, all related to increased cost of fishing) and conflict (79%). We interpreted increased conflict as a negative well-being outcome, although conflict is not necessarily negative. Debate and to some extent, conflict, are recognized as critical elements of democratic governance and procedural justice[21], often providing space for a diversity of voices, including those of minority groups[22]. The most ambiguous outcomes (that is, no change, or those that could not be interpreted as negatively or positively affecting people) occurred with shifting spatial usage patterns—mostly of fishing activities—due to the MPA.

Some explanatory variables had a significant influence on well-being outcomes (Fig. 4 and Supplementary Table 5). MPAs that were single zones, no-take, old and had high enforcement indicated more positive well-being outcomes than other categories (Fisher's exact tests and analysis of variance, $P < 0.05$). Study design was also correlated with outcomes, with studies that ascertained stakeholders' perceptions (that did not fall into the other research design categories) exhibiting more negative outcomes than those that objectively measured outcomes. While the data showed that positive well-being outcomes were more prevalent in tropical systems, the correlation was not statistically significant when considering combined outcomes (Fig. 4 and Supplementary Table 5). When analysing specific outcomes (for example, income, CPUE and number of users; Supplementary Table 6), some additional patterns emerged. Ecosystem type was correlated with income, CPUE, support, spatial change and community involvement; no-take zone presence was correlated with income, support and community involvement; and compliance was correlated with resource control, support, spatial change and conflict; for additional correlations, see Supplementary Table 6. However, sample sizes were small when disaggregating outcomes, because most studies only included one or two outcomes.

Co-occurrences of outcomes showed some interesting and unexpected patterns (Fig. 5). As expected, an increase in catches correlated with an increase in CPUE. When catches increased, there was also more conflict (which we interpreted as negative), perhaps due to uneven distribution of benefits. Some co-occurrences, despite showing significant trends, have small sample sizes and are thus difficult to interpret (catches and income; catches and number of users; Fig. 5), and we emphasize that correlation does not mean causation.

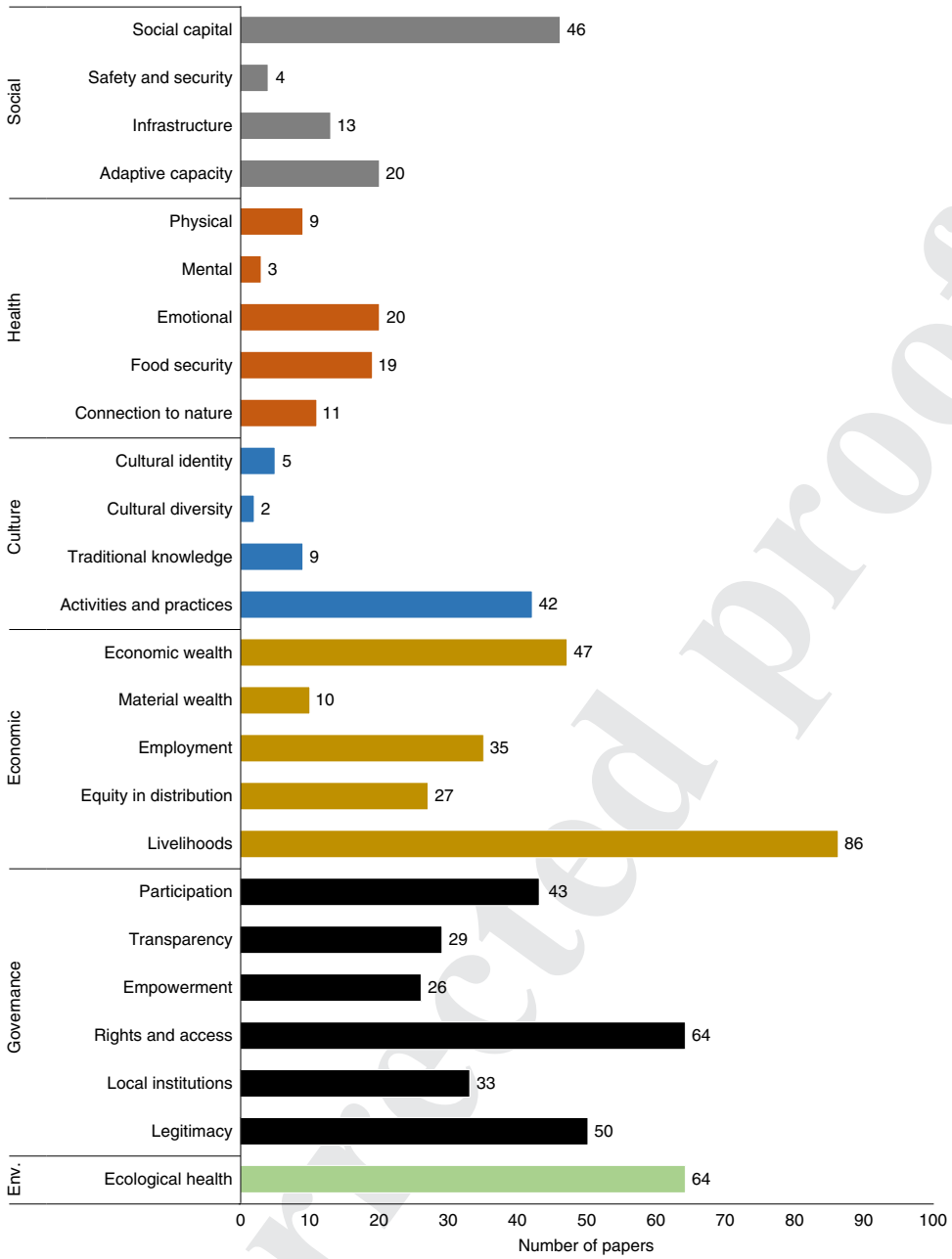

Fig. 2 | Domains and categories of human well-being mentioned in studies reviewed. For the rationale underpinning our categorization scheme, see ref. [18]. Supplementary Table 1 describes details of the domains of human well-being. Env., environmental.

Discussion

Our finding that MPAs have more positive than negative well-being outcomes across diverse stakeholder groups—similar to findings by Mascia et al.[7] for fishers—lends credibility to the potential of MPAs to benefit both biodiversity and people. MPAs are usually established to reduce biodiversity declines and safeguard related ecosystem services[3,4], and research shows that ecologically effective MPAs require five key attributes: no-take, well-enforced, old (>10 yr), large (>100 km^2) and isolated[5]. Similarly, we found that no-take, well enforced and old MPAs also led to more positive well-being outcomes. However, our results indicate that small MPAs had more positive well-being outcomes than large MPAs. Certain aspects of MPA design and management may thus contribute to both positive ecological and positive well-being outcomes, whereas others will require trade-offs. Our findings also highlight that there are both co-benefits and trade-offs among stakeholder groups, leading to questions of equity, justice and power.

The scientific literature on well-being outcomes of MPAs focused on relatively few indicators, mostly in the economic domain, such as income earned or catches, whereas many other potentially relevant indicators in other domains were mentioned but rarely measured (see Supplementary Table 1 for examples of indicator topics for all well-being categories). For instance, indicators of diet and food availability can reveal changes in health of local populations that are dependent on coastal resources. The fact that measurements relate to only a few well-being outcomes is important, because there is a risk that easily quantifiable indicators come to dominate the discourse about well-being outcomes of MPAs. Multidimensional aspects of well-being, notably in relation to values, are particularly difficult to quantify (for example, power and sense of community), but can have important

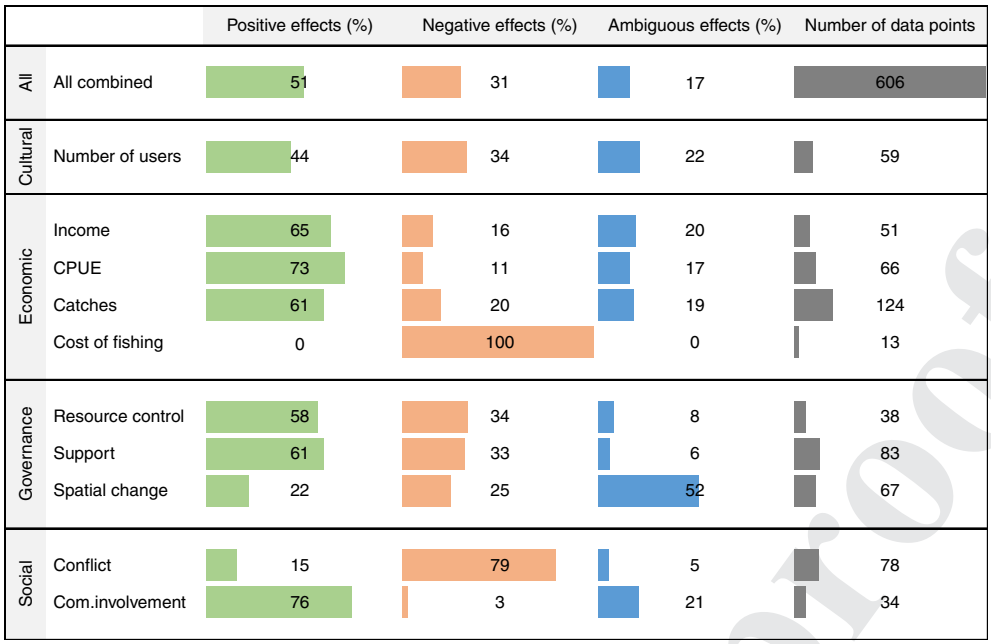

Fig. 3 | Summary of well-being outcomes of MPAs. See Supplementary Table 3 for interpretations of negative, positive and ambiguous outcomes. Sums of percentages may not add up to 100% due to rounding errors. Percentages refer to the percentage of data points that were positive, negative or ambiguous (neither clearly positive or negative, or no change). Data points consist of all measures of well-being by stakeholder group(s) contained in the papers reviewed. Com., community.

implications for the acceptance of and support for MPAs[17,23]. There is a danger that these aspects of human well-being may inadvertently disappear from the problem–decision-making context because they are not being measured or reported if decision-makers are not part of the affected communities (for example, in state-managed MPAs). Furthermore, indicators can become self-perpetuating, with the rationale for using indicators based on past studies. Indeed, we justified some of the indicators we quantified because they were assessed in a previous study[7]. Some indicators that are easily measured, such as equity (for example, examining outcomes by race, gender, age, location or cultural group), are rarely included. Therefore, we encourage those studying the well-being outcomes of MPAs to combine previously tested indicators (see Hicks et al.[24]) with efforts to develop a broader set of indicators that represent holistic domains of human well-being[18,25,26]. Furthermore, qualitative studies are particularly important for providing explanations and contexts for indicators, which alone cannot tell the full story[25,27].

While social scientists are increasingly called on to assess human well-being outcomes of MPAs[28], MPA development and management continues to primarily take place without consistent quantitative or qualitative monitoring of well-being outcomes[29,30]. We need to move towards ensuring the long-term well-being of people and communities that depend on marine systems, and to develop appropriate studies and indicators to capture the multidimensional outcomes of MPAs. Similarly, participatory processes are critical to ensure that those affected by MPAs are involved in making management decisions. Social sciences can provide important methodological and analytical insights for qualitative studies and quantitative monitoring, regarding ways in which stakeholders frame MPAs in their own terms, and how MPAs are continually mediated through cultural values and worldviews, media discourses and perceived trust in science and institutions. A shift within management agencies is starting to occur, as exemplified by the recent management focus on diverse ecological and cultural values[31,32].

The process of creating MPAs that are small, local and managed by communities, has numerous benefits for human empowerment and well-being, notwithstanding environmental outcomes[33–35]. Two main mechanisms for well-being outcomes of MPAs were reflected in the literature: (1) direct effects of MPA governance processes or management actions; and (2) indirect effects mediated by changes in the ecosystem. Direct effects included, for example, conflicts arising during MPA planning processes, community involvement in management, enhancement or displacement of livelihoods, and limitations on access rights (for example, displacement from fishing an area or exclusive access for some users). Indirect effects of MPAs on well-being are generally due to recovering marine systems and include increases in catches, CPUE and income from resource extraction. These indirect effects are influenced by the state and management of ecosystems surrounding the MPA[36]. Some aspects of well-being outcomes may arise with both mechanisms. For instance, conflict can be caused by stakeholder discussions during MPA establishment and management fora, and can also result from new or shifting user groups in the area or changing availability of resources. Ideally, future studies will track human well-being and ecological outcomes simultaneously, so that the relationship between them can be better understood.

We found that MPA implementation more frequently increased rather than decreased conflict. A key source of conflict identified in the reviewed literature related the reconfiguration of stakeholders' resource access, use and rights as a result of MPA implementation. For example, conflict was often related to MPA-mediated displacement of users that increased overlap in the use of marine areas. This was particularly common among fishers employing different types of equipment (for example, in refs. [37,38]). Further, conflict was often documented in relation to MPA decision-making processes during which different stakeholder groups vied for influence and control. In many cases, this conflict occurred between local users (often fishers) and external stakeholders, including conservation organizations (for example, in ref. [39]) and tourism operators (for example, in ref. [40]). Given the power differentials between local users and external stakeholders (particularly in global south contexts), such processes were often documented as further marginalizing local users and contributing

Fig. 4 | Combined well-being outcomes summarized by explanatory variables. See Supplementary Table 3 for interpretations of negative, positive, and ambiguous outcomes. Sums of percentages may not add up to 100% due to rounding errors. Ambiguous refers to no change or unclear directionality of change. Bolded variables are those that show significant ($P < 0.05$) correlations (Fisher's exact tests or analysis of variance) between the variable and synthesized outcomes (Supplementary Table 5). For analyses by disaggregated outcomes, see Supplementary Table 6.

to inequities in resource use or access[41]. However, in some cases it was reported that MPA establishment was seen as a negotiation opportunity for local users to acquire or solidify their rights over a marine area. For example, Cudney-Bueno et al.[42] reported that although there was substantial conflict over the granting of access rights during MPA implementation, fishers' territorial access rights were strengthened through the process. Further, conflict can lead to debate and deliberative decision-making, which are essential for democratic governance and procedural justice[35]. For example, Gurney et al.[41] documented how conflict led to improved governance, whereby MPA management group members fished together in an MPA to highlight lax enforcement by government officials.

Given that MPA processes involve reconfiguring resource use and access, and typically involve a number of competing stakeholder groups, conflict is likely[43]. Conflict also highlights that there are commonly trade-offs among different people in MPA design and management, and that win–win situations are rare and difficult to negotiate. Better understanding the nuances of conflict and

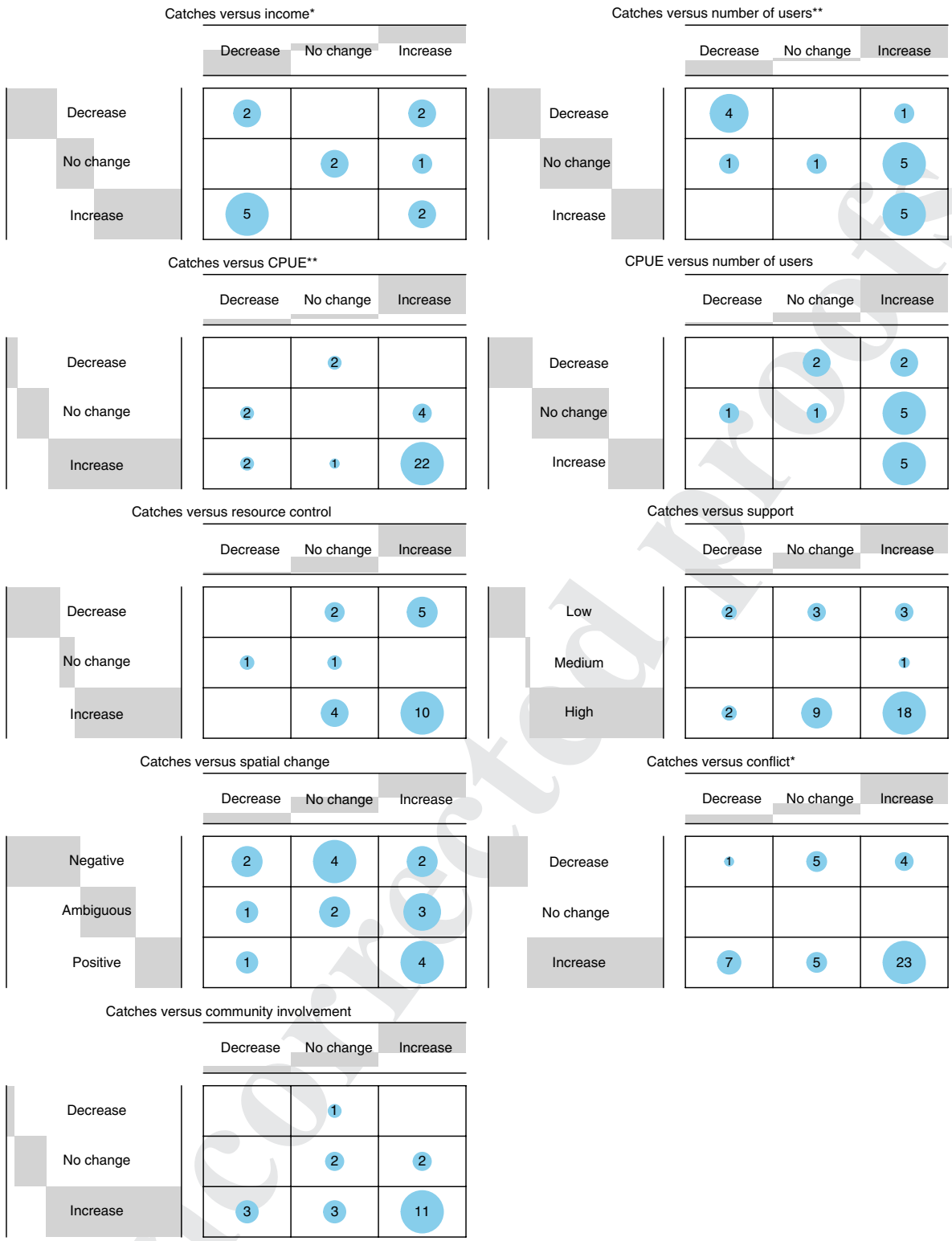

Fig. 5 | Co-occurrence of selected well-being outcome variables. Blue circles are scaled relative to each plot to illustrate the sample size (number inside the circle) of co-occurrences, and the grey bars indicate the sample sizes of the rows and columns. The first variable stated is shown on the *x* axis and the second is shown on the *y* axis. $^{**}P < 0.05$, $^{*}P < 0.1$; Fisher's exact test.

managing expectations might help inform and innovate future MPA design and management processes. Collaboration between resource users may also provide opportunities for dialogue, sense-making and conflict resolution[44]. Involving the community at initial phases in the policy decision-making process can promote deliberation and increase the efficiency of producing workable outcomes[45,46]. However, we need to recognize that access to power is uneven among stakeholders.

An interesting finding was that the design of studies affected whether well-being outcomes appeared more positive or negative.

Studies that measured the perceptions of stakeholders (for example, their self-assessment of impacts through surveys) were more negative than those that attempted to measure objective aspects of human well-being (for example, tracking fisheries landings before and after MPA implementation). Such a discrepancy could be due to the identity of those measuring the outcome (stakeholders versus researchers). Furthermore, different aspects of well-being are captured by subjective and objective measures, with objective measures being less able to capture some aspects of well-being that critically affect people, such as culture, conflict and social relations. Subjective measures do not only reflect perception; they can also be self-reports of observed reality. Perceptions and self-reports clearly matter in their own right, because they can lead to support for, or opposition to, conservation[19,47,48]. Therefore, use of both objective and subjective measures is essential, as they can test and lend validity to each other. Understanding why results of objective measures are sometimes inconsistent with reported perceptions may help identify more acceptable and robust management actions[49].

Our review revealed several research gaps that require attention. There was very little data for some systems (for example, Arctic and subtropical systems), and some regions (for example, South America) and stakeholder groups (for example, recreational users) were understudied. There was a methodological gap in that the most powerful study design, before–after control-impact[50], was also the least prevalent. Furthermore, studies to date predominantly have considered single MPAs. As MPA networks are being established, there is a need to think about assessing well-being outcomes at the scale of networks, rather than single sites, which requires attention to potential mismatches between ecological and social systems. Documenting the objectives of MPAs, and how they relate to well-being and ecological outcomes, is also important, as is understanding the relationship between well-being and ecological outcomes. Limitations of our research include the lack of knowledge of whether the studied MPAs are biased towards positive or negative results. We also considered all indicators of well-being as being important, whereas in reality, some aspects are more important to stakeholders, and this is likely to vary by stakeholder group. A more nuanced understanding of human well-being outcomes of MPAs is critical for creating management measures that benefit people and ecosystems.

Methods

Selection of papers. We carried out a systematic literature review in Web of Science (capturing all dates, with the first article appearing in 1973, last searched on 5 June 2018; Supplementary Table 1) to identify studies that assessed the outcomes of MPAs on human well-being (hereafter well-being outcomes). We included original peer-reviewed journal articles that investigated an existing MPA or MPAs and included information about the measured or perceived impact(s) of the MPA(s) on people. Excluded were studies about: the impact of users on the MPA; opinion papers; modelling studies with hypothetical or predictive data; anticipated impacts; descriptive studies of fishing or tourism effort within an MPA without a temporal comparison; and review papers. Papers included the following research designs: before–after studies; control-impact (or inside–outside) comparisons; before–after control-impact studies; distance from MPAs; studies that assessed people's perceptions that did not fit in the other categories; and other (for example, historical narratives and ethnographic studies).

Qualitative data and analyses on human well-being. We reviewed papers that met our selection criteria for mentions of possible well-being outcomes (that is, qualitative information). We tracked the indicators or phrases mentioned, and summarized them into slightly adapted domains and categories of human well-being reported by Kaplan-Hallam and Bennett[18] (Supplementary Table 1). We used this categorization because it provided a recent review and synthesis of social impacts in conservation and environmental management and was therefore highly relevant to our study. It synthesizes several related relevant frameworks, which we also considered (for example, refs. [25,51–54]). Our modifications were to add 'environment' as a domain to encompass variables relating directly to the ecological system (although we did not track quantitative data for this domain) and to add 'legitimacy' to the governance domain, as this is an important component of governance[55]. Ambiguities between domains of well-being meant that some indicators could fit in multiple domains, so we made a decision about the best fit. For example, 'number of users' can represent the cultural engagement with an activity, and we associated it with the cultural domain. It could also be an indicator of economic outcomes. We graphed the number of papers mentioning each of the domains and categories to provide an overview of the prevalence for different aspects of human well-being.

Quantitative data on human well-being. We collated results of measurements (quantitative data) of the well-being outcomes of MPAs by the most refined yet independent stakeholder group possible, such that a paper could provide multiple data points relating to different levels and types of social aggregation (for example, by village and/or by stakeholder type and/or fishing gear type). We collated data for variables known to be important and that are commonly measured, as identified by Mascia et al.[7]: number of users (for example, number of fishers or number of tourism operators), community organization (that is, number of active civil society organizations exclusively or primarily of that stakeholder group), income and the fisheries-specific measure CPUE. In addition, we tracked other variables that were commonly measured in the reviewed papers: resource control (that is, involvement by stakeholders in governing natural resources within the MPA), support for the MPA, cost of carrying out an activity (for example, fuel costs for fishers or tourism operators), conflict, spatial usage change of the MPA (that is, whether and how spatial usage patterns changed, mostly relating to fishing) and fisheries-specific total catches. We obtained quantitative data from the results of the papers and tables and figures therein using WebPlotDigitizer (https://apps.automeris.io/wpd/) to acquire data from figures or graphs. When multiple years were tracked, we used data from the latest year (that is, longest time since protection). When multiple species were included (for example, CPUE for multiple species), we used the data for the species with the most catches. Since papers used different methods and measures that were not comparable across contexts, we categorized data as increased, no change or decreased. Some papers reported different outcomes for a single category of well-being (support: high or increased, medium or no change, low or decreased; spatial change: displacement; fishing the line; changed pattern; no change). Therefore, we interpreted these measures as illustrating predominantly positive, negative or ambiguous outcomes (Supplementary Table 3). We created a summary of the outcomes by stakeholder–MPA combinations, categorizing them as positive if only positive outcomes were found for a stakeholder group, negative if only negative outcomes existed, and trade-off if both were described for a stakeholder group; we did not consider ambiguous outcomes in this summary.

Data on explanatory variables. We collated information provided in the papers about potential variables that might contribute to the well-being outcome of MPAs on people including characteristics of: the MPAs (country, continent, size and age), governance (community-based, co-managed, state- or NGO-managed), management (no-take or multiple use) and ecosystem protected (tropical, subtropical or temperate). We also included the study design used in the source papers (before–after control–impact, perception, distance from MPA or other). For the sake of visual comparisons, we classified size and age into three categories: small (<1 km^2), medium (1–100 km^2) and large (>100 km^2); and young (<5 yr), medium (5–10 yr) and old (>10 yr). Where details about the MPAs were lacking, we looked up the MPA on https://protectedplanet.net or MPA Atlas to ascertain the size and age. Some MPAs were not listed and thus had incomplete information. To estimate the age of the MPA at the time of the study, we used the designation date and the year the study was performed. If the date of data collection was not provided, we assumed that the data were collected the year before publication. For MPAs that have had major management changes, we used the date of the change to calculate the age, and not the original MPA designation date. Similarly, when papers mentioned that implementation (that is, the management plan) was different from the date of designation, we used the date of implementation. We categorized the stakeholder groups studied (fisheries, coastal communities, tourism, recreation or other). Where the studies provided the data, we also compiled whether the MPAs had high enforcement (yes or no), high compliance (yes or no), and clear boundaries (yes or no).

Quantitative analyses. We summarized the data by calculating the percentage of positive, ambiguous and negative outcomes for the categories of human well-being that had quantitative data (economic, governance, social or cultural). Similarly, we summarized the percentage of positive, ambiguous and negative outcomes by stakeholder group, ecosystems, MPA characteristics, MPA locations, governance and study design. We used Fisher's exact tests (two-tailed, for factor variables) and analysis of variance with Tukey's honestly significant difference post hoc test (for continuous variables, size and age) to assess the statistical significance of the relationship between synthesized outcomes (positive, trade-off or negative) and the explanatory variables. We also examined data within categories or variables with more than two categories, but these analyses did not yield any additional insights. We used Microsoft Excel and R to visualize data, and performed all quantitative analyses in R[56].

We used balloon plots (in the R package gplots[57]) and Fisher's exact tests to gauge co-occurrence of specific outcomes. We examined co-occurrence of economic indicators by comparing the variable with the most data (catches,

$n = 124$) to other economic variables (income, number of users or CPUE) and the two next most-commonly found variables to each other (CPUE and number of users). We excluded cost of activity because of limited data points ($n = 13$). We then repeated the analyses comparing catches to governance variables (resource control, support and spatial change) and social variables (conflict and community involvement). Small sample sizes precluded statistical analyses with multiple variables.

Data availability

The data that support the findings of this study are available in the Supplementary Information.

Received: 11 October 2018; Accepted: 2 May 2019;

References

1. *Aichi Biodiversity Targets* (Convention on Biological Diversity, 2010).
2. *Transforming Our World: The 2030 Agenda for Sustainable Development* (United Nations, 2015); https://sustainabledevelopment.un.org/post2015/transformingourworld
3. Jones, K. R. et al. The location and protection status of Earth's diminishing marine wilderness. *Curr. Biol.* **28**, 2506–2512 (2018).
4. Halpern, B. S. et al. Spatial and temporal changes in cumulative human impacts on the world's ocean. *Nat. Commun.* **6**, 7615 (2015).
5. Edgar, G. J. et al. Global conservation outcomes depend on marine protected areas with five key features. *Nature* **506**, 216–220 (2014).
6. Lester, S. E. et al. Biological effects within no-take marine reserves: a global synthesis. *Mar. Ecol. Prog. Ser.* **384**, 33–46 (2009).
7. Mascia, M. B., Claus, C. & Naidoo, R. Impacts of marine protected areas on fishing communities. *Conserv. Biol.* **24**, 1424–1429 (2010).
8. Chaigneau, T. & Brown, K. Challenging the win–win discourse on conservation and development: analyzing support for marine protected areas. *Ecol. Soc.* **21**, 36 (2016).
9. Diedrich, A., Stoeckl, N., Gurney, G. G., Esparon, M. & Pollnac, R. Social capital as a key determinant of perceived benefits of community-based marine protected areas. *Conserv. Biol.* **31**, 311–321 (2017).
10. Gurney, G. G. et al. Participation in devolved commons management: multiscale socioeconomic factors related to individuals' participation in community-based management of marine protected areas in Indonesia. *Environ. Sci. Policy* **61**, 212–220 (2016).
11. Arias, A., Cinner, J. E., Jones, R. E. & Pressey, R. L. Levels and drivers of fishers' compliance with marine protected areas. *Ecol. Soc.* **20**, 19 (2015).
12. Guidetti, P., Bussotti, S., Pizzolante, F. & Ciccolella, A. Assessing the potential of an artisanal fishing co-management in the marine protected area of Torre Guaceto (southern Adriatic Sea, SE Italy). *Fish. Res.* **101**, 180–187 (2010).
13. Gelcich, S., Godoy, N. & Castilla, J. C. Artisanal fishers' perceptions regarding coastal co-management policies in Chile and their potentials to scale-up marine biodiversity conservation. *Ocean Coast. Manag.* **52**, 424–432 (2009).
14. Jenkins, A., Horwitz, P. & Arabena, K. J. My island home: place-based integration of conservation and public health in Oceania. *Environ. Conserv.* **45**, 125–136 (2018).
15. Pollnac, R. et al. Marine reserves as linked social-ecological systems. *Proc. Natl Acad. Sci. USA* **107**, 18262–18265 (2010).
16. Sala, E. et al. Assessing real progress towards effective ocean protection. *Mar. Policy* **91**, 11–13 (2018).
17. Jones, P. Equity, justice and power issues raised by no-take marine protected area proposals. *Mar. Policy* **33**, 759–765 (2009).
18. Kaplan-Hallam, M. & Bennett, N. J. Adaptive social impact management for conservation and environmental management. *Conserv. Biol.* **32**, 304–314 (2018).
19. Bennett, N. J. *et al.* Local support for conservation is associated with perceptions of good governance, social impacts and ecological effectiveness. *Conserv. Lett.* https://doi.org/10.1111/conl.12640 (2019).
20. Gurney, G. G., Pressey, R. L., Cinner, J. E., Pollnac, R. & Campbell, S. J. Integrated conservation and development: evaluating a community-based marine protected area project for equality of socioeconomic impacts. *Phil. Trans. R. Soc. Lond. B* **370**, 20140277 (2015).
21. Matulis, B. S. & Moyer, J. R. Beyond inclusive conservation: the value of pluralism, the need for agonism, and the case for social instrumentalism. *Conserv. Lett.* **10**, 279–287 (2016).
22. Mouffe, C. Deliberative democracy or agonistic pluralism? *Soc. Res.* **66**, 745–758 (1999).
23. Hill, L. S., Johnson, J. A. & Adamowski, J. Meeting Aichi Target 11: Equity considerations in marine protected areas design. *Ocean Coast. Manag.* **134**, 112–119 (2016).
24. Hicks, C. C. et al. Engage key social concepts for sustainability. *Science* **352**, 38–40 (2016).
25. Breslow, S. J. et al. Conceptualizing and operationalizing human wellbeing for ecosystem assessment and management. *Environ. Sci. Policy* **66**, 250–259 (2016).
26. McKinnon, M. C. et al. What are the effects of nature conservation on human well-being? A systematic map of empirical evidence from developing countries. *Environ. Evid.* **5**, 8 (2016).
27. Charnley, S. et al. Evaluating the best available social science for natural resource management decision-making. *Environ. Sci. Policy* **73**, 80–88 (2017).
28. Pascal, N. et al. Evidence of economic benefits for public investment in MPAs. *Ecosyst. Serv.* **30**, 3–13 (2018).
29. Álvarez-Romero, J. G. et al. Research advances and gaps in marine planning: towards a global database in systematic conservation planning. *Biol. Conserv.* **227**, 369–382 (2018).
30. Fox, H. E. et al. How are our MPAs doing? Challenges in assessing global patterns in marine protected area performance. *Coast. Manag.* **42**, 207–226 (2014).
31. Fox, H. E. et al. Reexamining the science of marine protected areas: linking knowledge to action. *Conserv. Lett.* **5**, 1–10 (2012).
32. Twichell, J., Pollnac, R. & Christie, P. Lessons from Philippines MPA Management: social ecological interactions, participation, and MPA performance. *Environ. Manag.* **61**, 916–927 (2018).
33. Christie, P., White, A. & Deguit, E. Starting point or solution? Community-based marine protected areas in the Philippines. *J. Environ. Manag.* **66**, 441–454 (2002).
34. Gelcich, S. et al. Alternative strategies for scaling up marine coastal biodiversity conservation in Chile. *Marit. Stud.* **14**, 5 (2015).
35. Jupiter, S. D., Cohen, P. J., Weeks, R., Tawake, A. & Govan, H. Locally-managed marine areas: multiple objectives and diverse strategies. *Pac. Conserv. Biol.* **20**, 165–179 (2014).
36. Halpern, B. S. & Warner, R. R. Marine reserves have rapid and lasting effects. *Ecol. Lett.* **5**, 361–366 (2002).
37. Suuronen, P., Jounela, P. & Tschernij, V. Fishermen responses on marine protected areas in the Baltic cod fishery. *Mar. Policy* **34**, 237–243 (2010).
38. Hattam, C. E., Mangi, S. C., Gall, S. C. & Rodwell, L. D. Social impacts of a temperate fisheries closure: understanding stakeholders' views. *Mar. Policy* **45**, 269–278 (2014).
39. Yang, Y.-C., Wang, H.-Z. & Chang, S.-K. Social dimensions in the success of a marine protected area: a case in a Taiwan fishing community. *Coast. Manag.* **41**, 161 (2013).
40. Oracion, E. G., Miller, M. L. & Christie, P. Marine protected areas for whom? Fisheries, tourism, and solidarity in a Philippine community. *Ocean Coast. Manag.* **48**, 393–410 (2005).
41. Gurney, G. G. et al. Poverty and protected areas: an evaluation of a marine integrated conservation and development project in Indonesia. *Glob. Environ. Change* **26**, 98–107 (2014).
42. Cudney-Bueno, R. et al. Governance and effects of marine reserves in the Gulf of California, Mexico. *Ocean Coast. Manag.* **52**, 207–218 (2009).
43. Buchy, M. & Race, D. The twists and turns of community participation in natural resource management in Australia: What is missing? *J. Environ. Plan. Manag.* **44**, 293–308 (2001).
44. Källström, H. N. & Ljung, M. Social sustainability and collaborative learning. *Ambio* **34**, 376–382 (2005).
45. Bruckmeier, K. Interdisciplinary conflict analysis and conflict mitigation in local resource management. *Ambio* **34**, 65–73 (2005).
46. Le Tissier, M., Hills, J., McGregor, J. & Ireland, M. A training framework for understanding conflict in the coastal zone. *Coast. Manag.* **32**, 77–88 (2004).
47. McNeill, A., Clifton, J. & Harvey, E. S. Attitudes to a marine protected area are associated with perceived social impacts. *Mar. Policy* **94**, 106–118 (2018).
48. Bennett, N. J. Using perceptions as evidence to improve conservation and environmental management. *Conserv. Biol.* **30**, 582–592 (2016).
49. Elwell, T. L., Gelcich, S., Gaines, S. D. & López-Carr, D. Using people's perceptions of ecosystem services to guide modeling and management efforts. *Sci. Total Environ.* **637**, 1014–1025 (2018).
50. Underwood, A. On beyond BACI: sampling designs that might reliably detect environmental disturbances. *Ecol. Appl.* **4**, 3–15 (1994).
51. Pomeroy, R. S, Parks, J. E. & Watson, L. M. How is Your MPA doing? A Guidebook of Natural and Social Indicators for Evaluating Marine Protected Area Management Effectiveness. (IUCN: 2004).
52. Mascia, M. B. & Claus, C. A. A property rights approach to understanding human displacement from protected areas: the case of marine protected areas. *Conserv. Biol.* **23**, 16–23 (2009).
53. Leisher, C., Samberg, L. H., Van Buekering, P. & Sanjayan, M. Focal areas for measuring the human well-being impacts of a conservation initiative. *Sustainability* **5**, 997–1010 (2013).
54. Biedenweg, K., Stiles, K. & Wellman, K. A holistic framework for identifying human wellbeing indicators for marine policy. *Mar. Policy* **64**, 31–37 (2016).

55. Adger, W. N. et al. Governance for sustainability: towards a 'thick' analysis of environmental decision-making. *Environ. Plan. A* **35**, 1095–1110 (2003).
56. R Core Team *R: A Language and Environment for Statistical Computing* (R Foundation for Statistical Computing, 2018); http://www.R-project.org/
57. Warnes, G. R. et al. *Various R Programming Tools for Plotting Data* (2016); https://cran.r-project.org/web/packages/gplots/gplots.pdf
58. Protected Planet: The World Database on Protected Areas (WDPA). (UNEP-WCMC and IUCN: accessed October 2018).
59. *Maritime Boundaries Geodatabase: Maritime Boundaries and Exclusive Economic Zones (200NM)* version*10* (Flanders Marine Institute, 2018); https://doi.org/10.14284/312
60. *World Countries* (ESRI, 2016); https://www.arcgis.com/home/item.html?id=ac80670eb213440ea5899bbf92a04998

Acknowledgements

N.C.B. hosted a workshop of co-authors that was made possible by her Lansdowne Scholar Award from the University of Victoria, and the OceanCanada SSHRC Partnership. N.J.B. recognizes the OceanCanada Partnership; G.G.G. recognizes funding from the Australian Research Council and C.K.W. recognizes support from an NSERC Canada Graduate Scholarship.

Author contributions

N.C.B. conceived of the idea, reviewed the literature, led study design, collated quantitative data, carried out analyses and drafted the paper. All authors contributed ideas and to study design, reviewed papers for qualitative information and edited the paper. C.K.W. and T.C.T. reviewed the quantitative data.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information is available for this paper at https://doi.org/10.1038/s41893-019-0306-2.

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