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Sharks, rays and marine protected areas: A critical evaluation of current perspectives

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Abstract

Marine protected areas (MPAs) are increasingly advocated for the conservation and management of sharks and rays. However, substantial uncertainty remains regarding which species can benefit from MPAs. Meanwhile, area-focused protection targets have spurred recent and rapid gains in the creation of large MPAs, many of which carry vague objectives set by a diverse group of stakeholders with potentially different notions of "success." Here, we capture and critically evaluate current views on the use of MPAs for shark and ray conservation. Through interviews with scientists, MPA managers, fisheries experts, conservation practitioners, advocates and policy experts (n = 53), we demonstrate a variety of perspectives regarding: (a) the effectiveness of MPAs as a tool for shark and ray conservation; (b) which factors influence the success of MPAs for sharks and rays; and (c) the desired outcomes of these MPAs. While MPAs created specifically for sharks and rays were viewed to be slightly more effective than regular MPAs as a tool for shark and ray conservation, both were generally considered insufficient in isolation. Despite greater emphasis on social success factors (e.g., local support) over biophysical success factors (e.g., size), biological outcomes (e.g., increased abundance) were prioritized over social outcomes (e.g., livelihood benefits). We argue that a stronger focus on achieving social outcomes can enhance the potential for MPAs to benefit sharks and rays. In revealing current thinking regarding the drivers and indicators of MPA success for sharks and rays, the results of this study can inform efforts to conserve and manage these species.

KEYWORDS
effectiveness, factors, marine protected areas, outcomes, shark and ray conservation, success

1 | INTRODUCTION

Chondrichthyans (hereafter, "sharks and rays") are among the most threatened groups of species in the oceans—currently, nearly a quarter of species are at elevated risk of extinction (Dulvy et al., 2014). The life history characteristics of many sharks and rays (e.g., slow growth, late age at sexual maturity, low fecundity) make them particularly vulnerable to overfishing (Cortes, 2002; Musick, 1999), a threat which has driven severe and widespread population declines in many species (Dulvy et al., 2014, 2016; Graham, Andrew, & Hodgson, 2001). Despite efforts to combat these declines, each year, tens of millions of sharks are caught and traded in international markets (Simpfendorfer & Dulvy, 2017). Ongoing global population declines have generated considerable uncertainty in the future status of sharks and rays (Dulvy et al., 2017) and highlight the urgent need for more effective conservation strategies.

Marine protected areas (MPAs) are a widely used tool for the protection of biodiversity, management of fisheries and, more recently, are increasingly advocated as a strategy for protecting or restoring shark and ray populations (Bonfil, 1999; Davidson & Dulvy, 2017). By protecting critical habitats for reproduction and feeding, MPAs can play an important role in the conservation of shark and ray populations (Escalle et al., 2015; Norse, 2010). Here, we use the term MPA to refer to any spatial protection within which extractive activities are either partially restricted or fully prohibited. Areas that fall under the MPA umbrella include marine reserves, sanctuaries, parks, no-take zones or areas, fishery exclusion zones, fishery reserves and closed areas. Though most MPAs are small in size, the last decade has seen an increase in the creation of large, remote, pelagic MPAs (Lubchenco & Grorud-Colvert, 2015). Indeed, in the space of only 5 years, this trend nearly doubled the total global area of protected ocean (McCauley, 2014). For many of these MPAs, shark and/or ray conservation is an explicit goal (Koldewey, Curnick, Harding, Harrison, & Gollock, 2010; Davidson, 2012; Dulvy, 2013). The establishment of nationwide Shark Sanctuaries has also increased in popularity—as of 2015, 29% of the total ocean area protected was designated exclusively for shark conservation (Marine Conservation Institute, 2016). At the time of writing, 15 countries had implemented laws banning shark fishing within their exclusive economic zones, with Palau being the first to declare a national Shark Sanctuary in 2009.

The recent and rapid gains in MPAs have been primarily driven by area-focused protection targets of international agreements (e.g., Convention on Biological Diversity Aichi Target 11), which have led to protected area designations that are made opportunistically instead of systematically (Baldi, Texeira, Martin, Grau, & Jobbagy, 2017). The often hasty planning processes associated with meeting area-focused targets have led to vague objectives (Agardy, 2017). Meanwhile, substantial uncertainty remains regarding which shark and ray species can benefit from large-scale spatial protections (Davidson & Dulvy, 2017; De Santo, 2013; Pala, 2013). Further, we continue to see declines in shark populations within some large MPAs (Graham, Spalding, & Sheppard, 2010; White, Myers, Flemming, & Baum, 2015). In the face of the recent and rapidly increasing trend of large MPAs and Shark Sanctuaries, and notwithstanding recent assessments of Shark Sanctuaries and their regulations (Ward-Paige, 2017; Ward-Paige & Worm, 2017), there is a need to take a step back and evaluate (a) whether shark and ray-focused MPAs are perceived to be achieving their desired outcomes, and (b) what the people driving the establishment of MPAs perceive as desired outcomes, including the means for achieving them.

The design, establishment, monitoring and management of an MPA involve a diverse group of stakeholders with potentially different notions of "success" (Murray, 2005). Understanding the perceptions of those involved is important for determining whether thinking is aligned, and can provide insights to guide future planning by identifying lessons learned. While the literature on stakeholder perceptions of MPAs is extensive, most research has focused on perceptions of end users (e.g., Bennett & Dearden, 2014) and, less frequently, environmental managers (Cvitanovic, Marshall, Wilson, Dobbs, & Hobday, 2014; McClanahan, Davies, & Maina, 2005). Perceptions research in shark conservation, however, remains limited. Among the few studies exploring perceptions towards sharks and strategies for their conservation (Gallagher, Cooke, & Hammerschlag, 2015; Shiffman & Hammerschlag, 2016; Tsoi, Chan, Lee, Ip, & Cheang, 2016), our study is the first to capture perspectives of stakeholders with different types of involvement in shark and ray conservation and MPA processes. Reflecting on these varied perspectives in the context of the current science on drivers and indicators of MPA effectiveness can help to identify potential synergies or disconnects between science, practice and among stakeholders.

Here, we capture and critically evaluate current views and priorities relating to the use of spatial protections for shark and ray conservation and management. Specifically, we explore perceptions regarding (a) the effectiveness of MPAs as a tool for shark and ray conservation; and (b) the desired outcomes and success factors of MPAs for sharks and rays. By conducting surveys with scientists, MPA managers, fisheries experts, conservation practitioners, advocates and policy experts, we aim to contribute to understanding of the current perspectives regarding the drivers and indicators of MPA success and evaluate whether these reflect advances in scientific understanding.

2 | METHODS

2.1 | Survey instrument

Survey questionnaires containing closed and open-ended questions were used to record the range of perceptions, experiences and opinions surrounding the use of MPAs for shark and ray conservation

and management. For the purpose of our interviews, we defined an MPA to be any spatial protection (including Shark Sanctuaries) within which extractive activities are partially restricted or completely prohibited.

The survey included three sections (Supporting Information Appendix S1), with the first section containing the three questions of primary interest to this study. These questions were designed to elicit views regarding: (a) the effectiveness of MPAs as a tool for shark and ray conservation (Q1); (b) factors that influence the success (hereafter, "success factors") of MPAs for sharks and rays (Q2); and (c) desired outcomes of MPAs for sharks and rays (Q3). The second section of the survey recorded participants' current or previous involvement with a specific MPA and was intended to provide context and identify potential "lessons learned" through personal experience. The third section of the survey included questions designed to collect background information on participants such as field of expertise, level of experience and demographic information.

We used a 10-point scale to explore the perceived effectiveness of MPAs as a tool for shark and ray conservation. Separate questions were used to explore perceived effectiveness of (a) MPAs designated specifically for sharks and/or rays (hereafter "shark and ray-focused MPAs"); and (b) MPAs designated primarily for other reasons (hereafter "regular MPAs"). In each case, participants were asked an open-ended follow-up question which allowed them to provide explanation for why they chose a particular score. For the questions regarding success factors (Q2) and desired outcomes (Q3), participants were asked to provide up to three responses and rate, on a scale from 1 to 10, each success factor's relative strength of influence on the success of MPAs created to protect sharks and rays, and each outcome's relative importance to shark and ray conservation. We used a rating approach instead of a ranking approach to allow differences among responses to be assessed at a finer scale and to allow respondents to allocate equal scores to multiple responses.

2.2 | Sampling

The survey was administered over the phone with MPA managers, scientists, fisheries experts, conservation practitioners, advocates and policy experts (n = 53) from September 2017 through February 2018 (response rate was 43%). Eligible participants were considered to be those having expertise and experience in shark and ray conservation, fisheries, advocacy and policy, who currently or previously had been involved in the design, establishment, monitoring and/or management of one or more MPAs that contribute to shark and ray conservation (based on their location in an area where sharks and rays occur). Potential interviewees, identified through online searches and from a review of the academic and grey literature, were invited via e-mail to participate in the study. Further participants were identified through snowball sampling and through the established networks of the research team. Given that our aim was to interview as many people as possible within the budgeted time period, we used purposive sampling to obtain the best possible spread across categories such as agency type (government, non-government, academic institution) and country location of MPAs with which participants were currently or previously involved (Figure 1). We classified participants into one of six stakeholder types based on their self-defined area of expertise, and based on whether they had been involved with one or more shark and ray-focused MPAs, or only regular MPAs (Table 1).

FIGURE 1 Marine protected areas (MPAs) discussed by survey participants (n = 53) during interviews to understand current views on the use of MPAs for shark and ray conservation

Stakeholder type	Regular MPAs	Shark and ray-focused MPAs	Total
Advocate	3	3	6
Conservation practitioner	7	7	14
Fisheries expert	1	1	2
MPA manager	3	4	7
Policy expert	0	4	4
Scientist	9	11	20
Total	23	30	53

Note. MPA: marine protected areas.

TABLE 1 Survey sample breakdown showing expertise and experience of survey participants (n = 53). Participants were classified based on their self-defined area of expertise ("stakeholder type") and based on whether they had been involved with one or more shark and ray-focused MPAs, or only regular MPAs

2.3 | Data coding and analysis

Responses to open-ended questions (i.e., success factors, desired outcomes) were coded into broadly defined categories (Supporting Information Table S1a and b) and classified as one of two response types; those relating to human perception and activity (e.g., enforcement, support/buy-in, management) were classified as social, whereas those relating to the environment were classified as biological (for outcomes—e.g., population/biomass, ecosystem) or biophysical (for success factors—e.g., biological significance, size, location). As an example of the coding used, desired outcomes such as "community buy-in," "local support" and "community participation" were all coded to the social outcome category *support/buy-in*. To explore whether perceptions differed with experience, we examined whether perceptions regarding effectiveness, success factors and desired outcomes differed based on the type of MPA that participants had been involved with.

We used a paired sample t test to explore differences in perceived effectiveness between shark and ray-focused MPAs and regular MPAs, and a general linear model to explore whether perceived effectiveness was related to the type of MPAs that respondents had been involved in (i.e., shark and ray-focused MPAs vs. regular MPAs). We used linear mixed effects models to test (a) whether "success factor" scores (describing each success factor's relative strength of influence on success) differed between social and biophysical factors; and (b) whether "desired outcome" scores (describing each outcome's relative importance to shark and ray conservation) differed between social and biological outcomes. In both cases, scores were treated as a continuous dependent variable, and response type (social vs. biophysical/biological) was treated as a categorical independent variable (fixed effect). Given that participants rated up to three responses to each question regarding success factors and outcomes, we a priori set respondent as a random effect to account for the non-independence of scores provided by the same person. We verified that the data were normally distributed by examining quantile plots of model residuals, and formally tested the assumption using the Shapiro–Wilk normality test. The assumption of equal variances was verified using the Breusch–Pagan test. Analyses were conducted using the "lme4" package within the statistical computing software R (version 3.5.1, R Core Team, 2018).

3 | RESULTS

A total of 53 individuals comprising 21 nationalities were interviewed from various agencies including 12 management organizations (three non-government, nine government), three environmental consulting firms, one dive tourism operator, eight research institutions, 17 non-governmental organizations and two intergovernmental organizations (one regional, one international). Overall, 57% of participants (n = 33) had been involved with at least one shark and ray-focused MPA. A total of 34 MPAs from 20 countries were discussed during the interviews, including seven Shark Sanctuaries (Federated States of Micronesia, Cayman Islands, French Polynesia, St. Maarten, Bonaire, Saba, Kiribati) (Figure 1, Supporting Information Table S2).

3.1 | Perceived effectiveness of MPAs as a tool for shark and ray conservation

A number of participants did not provide a score for the effectiveness of either shark and ray-focused MPAs (n = 13) and/or regular MPAs (n = 20) as tools for shark and ray conservation, stating that effectiveness depends on the context: "The effectiveness of any [management/conservation] measure is always going to depend on a complexity of other factors and how well designed for the task at hand it is" (Respondent #34). Overall, participants perceived shark and ray-focused MPAs to be somewhat effective (mean ± SD = 6.7 ± 1.7) as a tool for shark and ray conservation (Figure 2a), and the type of MPAs with which participants had experience (shark and ray-focused vs. regular) did not relate to their perceived effectiveness of either shark and ray-focused MPAs ($F_{1,31}$ = 0.088, p = 0.36) or regular MPAs ($F_{1,31}$ = 0.087, p = 0.77). Where the effectiveness of both shark and ray-focused MPAs and regular MPAs was scored by participants (n = 32), the former were perceived to be slightly more effective on average (mean ± SE = 6.5 ± 0.30) than the latter (mean ± SE = 5.8 ± 0.35; paired t test: t = 2.87, df = 31, p = 0.007) as a tool for shark and ray conservation (Figure 2). Participants shared a variety of perspectives regarding the effectiveness of MPAs for sharks and rays, commenting that effectiveness is context-dependent, complicated by the mobility of target species and constrained by a lack of monitoring, enforcement, compliance and sociocultural acceptance (Table 2).

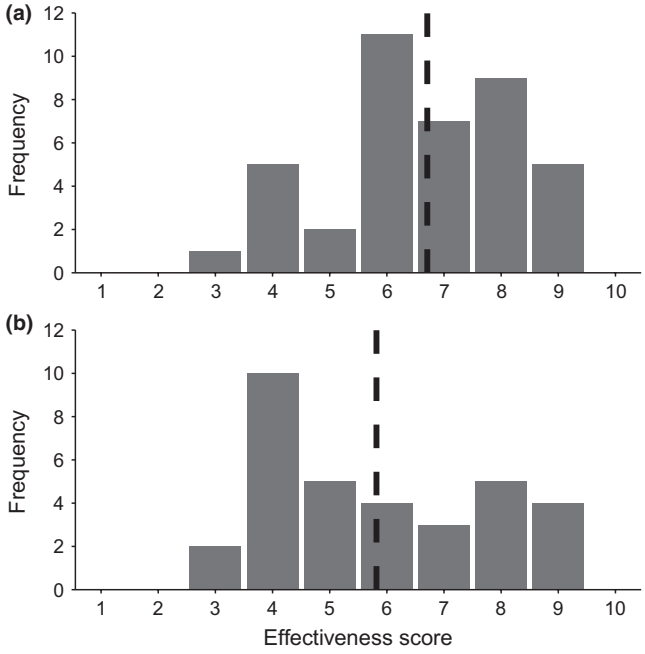

FIGURE 2 Frequency distribution of scores describing the perceived effectiveness of (a) shark and ray-focused marine protected areas (MPAs) (n = 40) and (b) regular MPAs (n = 33) as tools for shark and ray conservation

3.2 | Factors perceived to influence the success of shark and ray-focused MPAs

When asked which factors have the potential to influence the success of MPAs for sharks and rays, all 53 participants provided responses (n = 193 responses) which, once coded, encompassed a total of 47 factors and 28 coded categories (Supporting Information Table S1a). Greater emphasis was placed on the social determinants of MPA success (71%, n = 137 responses) over the biophysical determinants of success (29%, n = 56 responses), with the most common responses relating to support/buy-in (19% of responses), enforcement (17%), biological factors (10%), size of the protected area (8%) and management (6%) (Figure 3a, Supporting Information Table S1a). Other factors mentioned less frequently (i.e., in 5% or fewer cases) included design (5%), location (4%), education, outreach and awareness (4%), and compliance (4%). Among participants who listed both biophysical and social factors (n = 29), social factors scored significantly higher than biophysical factors in terms of how strongly they were perceived to influence the success of MPAs for sharks and rays (χ = 7.04, p = 0.007). The relative emphasis placed on different success factors was similar among participants with experience in shark and ray-focused MPAs and those with experience in regular MPAs (Figure 3b,c).

A recurring theme in the responses was that factors do not act in isolation: "What factors [influence success] depends on other factors in all circumstances." (Respondent #34). Other comments by participants emphasized that success factors depend on the context: "In a place where shark fishing is intense, enforcement is important" (Respondent #38). Among participants who mentioned MPA design as a factor influencing success, several commented that spatial protections must be designed "…in relation to the biology of the species" (Respondent #34). Others also highlighted the importance of incorporating baseline research into effective MPA design: "Understanding what you're trying to protect is key" (Respondent

TABLE 2 Comments by participants (n = 53) regarding the effectiveness of marine protected areas (MPAs) as a tool for shark and ray conservation

Quote	Respondent no.
"Effectiveness very much depends on the circumstances in the area where the MPA is selected and the reasons why it is selected. It depends on enforcement and compliance, depends on whether it affects local livelihoods, whether its culturally invasive. It depends on the other factors that are impacting sharks and rays in the region. I want to believe that MPAs can be effective, but in my experience, [they] are not very effective. If they are large enough and still cover important habitat, can still be very effective – if they are enforced properly"	38
"I think ultimately it's about managing the fisheries, it's the fisheries that is the largest threat. So to me, addressing the fisheries is the most important thing to do for their conservation…I think MPAs can work in certain situations, they can definitely enhance it, but really it's going to be very place specific. Whereas if you address the fishery you'll cover a much wider area and actually address the threat itself"	32
"At present, I don't think they [MPAs] are terribly effective because of lack of monitoring and compliance. Either the MPAs are too large or you don't have social/cultural acceptance… at this point they are only marginally effective"	4
"I don't feel that currently MPAs are particularly effective at fisheries management or mortality reduction directly, they can be part of a broad suite of fisheries management tools but an MPA as a stand-alone tool is not necessarily affecting mortality. The large-scale Shark Sanctuaries… are effectively just retention bans and they don't necessarily mandate safe release or affect post-release mortality"	11
"Effectiveness is limited by mobility of target species. Many sharks and rays are highly mobile relative to other fish species. Need large protected areas to protect these animals. In most cases, MPAs that have been declared are probably not big enough to protect one individual 100% of the time. MPAs are as good as the extent to which they can cover individual home ranges for that species"	40

Note. MPA: marine protected areas.

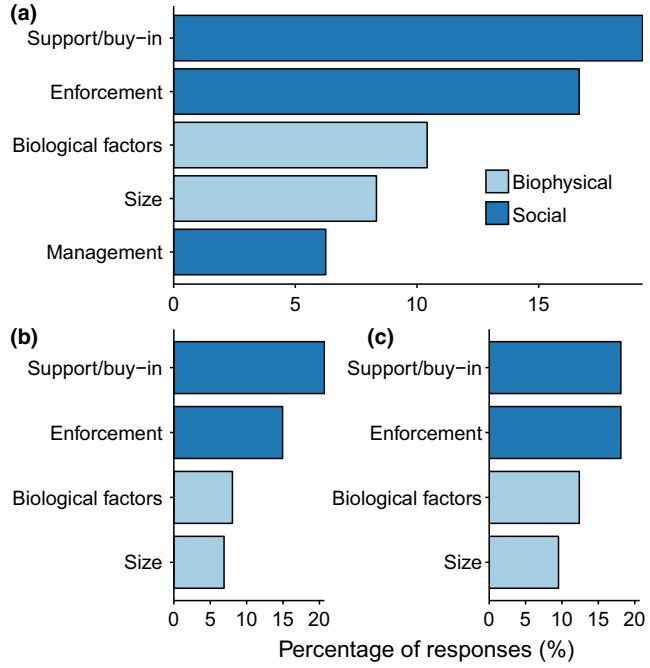

FIGURE 3 Factors perceived to influence the success of shark and ray-focused marine protected areas (MPAs), showing (a) the most commonly cited factors overall (in >5% of cases), and differences between (b) participants with experience in at least one shark and ray-focused MPA (n = 30) and (c) participants with experience only in regular MPAs (n = 23). Relative frequency (percentage of responses) was calculated based on the number of times each factor was mentioned relative to the total number of responses (n = 53 participants, 193 responses) [Colour figure can be viewed at wileyonlinelibrary.com]

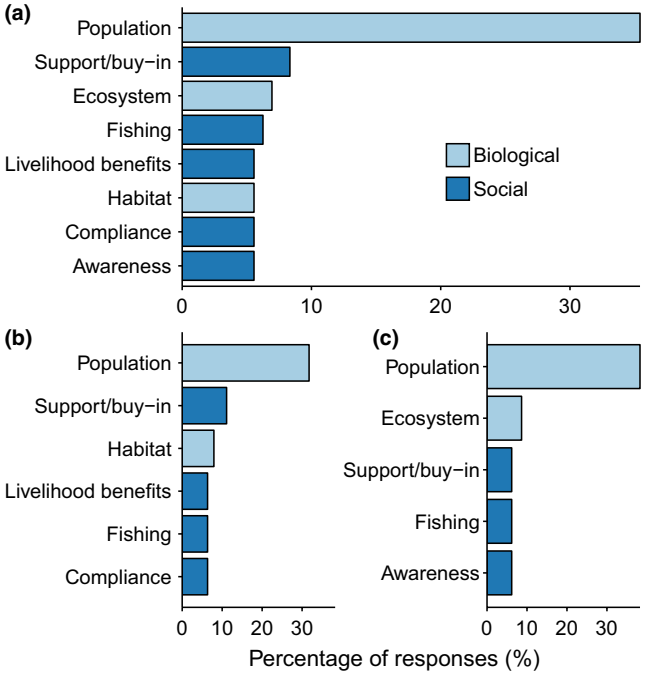

FIGURE 4 Desired outcomes of marine protected areas (MPAs) designated to protect sharks and rays, showing (a) the most commonly cited outcomes overall (in >5% of cases), and differences between (b) participants with experience in at least one shark and ray-focused MPA (n = 30) and (c) participants with experience only in regular MPAs (n = 23). Percentage was calculated based on the number of times each outcome was mentioned relative to the total number of responses provided (n = 53 participants, 165 responses) [Colour figure can be viewed at wileyonlinelibrary.com]

#4). One participant emphasized that "…compliance always, by necessity, includes not just enforcement, but engagement, stewardship, etcetera" (Respondent #34). Another highlighted the importance of compliance: "It's all well and good to put lines on a map and restrict people's behaviour within those lines but it's worthless if you don't have the monitoring and compliance structures in place to enforce the rules…" (Respondent #4).

3.3 | Desired outcomes of shark and ray-focused MPAs

When asked to list the most important desired outcomes of MPAs for sharks and rays, all 53 participants provided responses (n = 146 responses) which, once coded, encompassed a total of 56 outcomes and 25 coded categories (Supporting Information Table S1b). Greater emphasis was placed on biological outcomes (60%, n = 87 responses) over social outcomes (40%, n = 59 responses), with the most frequently mentioned outcomes relating to population/biomass (35% of responses), support/buy-in (8%), the ecosystem (7%) and fishing (6%) (Figure 4a, Supporting Information Table S1b). Responses such as "increased numbers," "persistence of populations," "level of compliance," "reduced fishing effort" and "increased ecosystem health" were common (Supporting Information Table S1b). Among participants who listed both biological outcomes and social outcomes (n = 33), biological outcomes scored significantly higher than social outcomes in terms of their perceived importance to shark and ray conservation (χ = 5.53, p = 0.019). While all participants placed a strong emphasis on population outcomes, support/buy-in featured more strongly among participants with experience in regular MPAs (Figure 4b,c). One participant emphasized the importance of local support as an outcome of MPA establishment: "If people respond favourably towards the establishment of an MPA, then that's an indication that it's successful" (Respondent #4). Another participant highlighted the potential issues that can arise when population outcomes are used as the basis for evaluating MPA effectiveness: "I've seen a lot of ways these things can be done badly… There are so many ways that people can misinterpret what might have happened" (Respondent #34).

4 | DISCUSSION

While MPAs are increasingly advocated as a tool for shark and ray conservation, current discussions around the goals, effectiveness and measures of success of MPAs remain vague. Given that shark and

ray conservation efforts and MPA processes involve a diverse group of people with potentially different notions of success, understanding their perspectives can contribute to a better understanding of (a) current thinking and priorities relating to the use of MPAs for shark and ray conservation; and (b) whether current views reflect the best available science on drivers and indicators of MPA success. Through semi-structured interviews with 53 MPA managers, fisheries experts, scientists, conservation practitioners, advocates and policy experts, we demonstrate a variety of perspectives regarding: (a) the effectiveness of MPAs as a tool for shark and ray conservation; (b) factors that influence the success of MPAs created for sharks and rays; and (c) the desired outcomes of these MPAs. Overall, MPAs were viewed to be somewhat effective as a tool for shark and ray conservation, with shark and ray-focused MPAs perceived to be only slightly more effective than regular MPAs. Despite greater emphasis on social success factors (e.g., support/buy-in, enforcement) over biophysical success factors (e.g., size, design), biological outcomes (e.g., population, habitat and ecosystem outcomes) were emphasized over social outcomes (e.g., buy-in, livelihood benefits).

4.1 | Perceived effectiveness of MPAs as a tool for shark and ray conservation

Overall, shark and ray-focused MPAs were perceived to be moderately effective as a tool for shark and ray conservation, and only slightly more effective than regular MPAs. In explaining the reasons behind the effectiveness scores provided, participants concentrated on two related points. The first point raised by participants is that the effectiveness of MPAs for sharks and rays is complicated by issues relating to the highly mobile and migratory nature of many species. Indeed, species movement ranges are often either unknown or so large that spatial protections are not a feasible conservation strategy in isolation (e.g., Heupel et al., 2015). For spatially restricted populations (e.g., some reef shark species) or those displaying high residency (e.g., the tiger shark *Galeocerdo cuvier* in the Galapagos), however, the potential effectiveness of spatial protections may be enhanced (Acuña-Marrero et al., 2017; Chapman, Feldheim, Papastamatiou, & Hueter, 2015; Speed, Field, Meekan, & Bradshaw, 2010; White et al., 2017). The second point raised by participants is that most MPAs are small and have not been established with specific consideration given to sharks or rays. As such, most do not cover the species' home ranges, although MPA benefits may still arise if core habitat use areas, especially those that support key life stages or functions (e.g., breeding, feeding and gestation), are protected (Hooker et al., 2011). Recognizing that most existing MPAs have been established for other reasons than to protect sharks and rays, it is not surprising that they were considered only moderately effective. However, in some cases, existing MPAs may require only minor modifications to enhance to proportion of time sharks and rays receive protection. In these contexts, information obtained from tracking studies could be combined with participatory processes to modify MPA boundaries and/or zoning so that core use areas are protected while ensuring that any negative social impacts of these modifications are mitigated.

While Shark Sanctuaries and large-scale MPAs may provide better protection across species home ranges, their large size poses significant monitoring and enforcement challenges, and insufficient enforcement may enable further overexploitation (Davidson, 2012; Dulvy, 2013). Given the limited resources and capacity for enforcement in many developing countries—in many cases where shark and ray conservation is most needed (Bräutigam et al., 2015)—smaller MPAs encompassing key habitat areas may be a more feasible option in these contexts. In developed country contexts where natural resource governance is often top-down and where resources and capacity for enforcement is greater, large MPAs may be a more feasible strategy. Overall, comments by participants support the notion that (a) there is room to improve the effectiveness of MPAs for sharks and rays, and (b) MPAs are not a panacea, but represent one of many tools in the toolbox. This is well illustrated by one participants' comment: "Sometimes MPAs are seen as the panacea and the answer to shark and ray conservation questions… They definitely can play a part to varying degrees in effective shark and ray conservation. But to just use MPAs "as the answer, problem solved" can lead to more problems because once managers and the public think the problem has been solved, the focus shifts away from tackling the problem further… It's not to say [MPAs] will never be important or part of the solution, it's just that they need to be considered as a part of a suite of tools" (Respondent #11). Indeed, the potential effectiveness of MPAs could be enhanced by complementing spatial protections with gear restrictions and other fisheries management measures to reduce fishing-induced mortality beyond MPA boundaries.

4.2 | Factors perceived to influence the success of shark and ray-focused MPAs

The factors perceived to influence the success of shark MPAs—and the emphasis on both social (i.e., support/buy-in) and biophysical aspects—reflect the broader literature on MPA success (e.g., Edgar et al., 2014). Moreover, as seen in our results, some studies have emphasized the importance of social over biophysical drivers of success. For example, a recent case study review identified six key themes consistently cited as contributing to MPA success/failure (Rossiter & Levine, 2014): (a) *level of community engagement*, including stakeholder involvement and participation in decision-making (e.g., Agardy et al., 2003; Fox et al., 2012), which aims to address stakeholder needs and reduce conflict (Agardy et al., 2003; Heck, Dearden, & McDonald, 2012); (b) *socioeconomic characteristics*, including the level of resource dependence, cultural values, distribution of benefits and alternative livelihood options (Fox et al., 2012; Gjertsen, 2005; Pomeroy, Watson, Parks, & Cid, 2005); (c) *ecological factors*, including species mobility and scientific understanding of an area's ecology, impacts and threats (Friedlander et al., 2003; Lester et al., 2009); (d) *MPA design*, which includes—in addition to ecological factors—sustainable funding sources and long-term monitoring

of outcomes (Christie & White, 2007; Lester et al., 2009); (e) *governance*, including effective management policies and MPA governing institutions (e.g., governments, NGOs, community groups) that are supportive and linked at multiple scales (e.g., Pomeroy & Berkes, 1997; Taylor, Baine, Killmer, & Howard, 2013); and (f) *enforcement*, with clear penalties and appropriate sanctions (Cinner et al., 2012; Mascia, Claus, & Naidoo, 2010).

While most of the themes discussed by Rossiter and Levine (2014) featured in our study, one theme—socioeconomic characteristics—was largely absent from discussions regarding the factors that influence the success of MPAs for sharks and rays. Given the high economic value of sharks, socioeconomic characteristics are likely to be a particularly important contributor to the success of MPAs for these species. Indeed, the existence of a lucrative market for shark products (Clarke & Dent, 2015), in addition to the use of meat as a source of protein, distinguishes sharks from many other species often targeted for protection by MPAs (Dulvy et al., 2017). Consideration of socioeconomic characteristics and local context, including the level of resource dependence and alternative livelihood options, is therefore crucial to ensure that MPAs do not negatively impact local communities (Clua & Pascal, 2014).

4.3 | Desired outcomes of shark and ray-focused MPAs

The consistent and strong emphasis on population outcomes suggests that our study may have captured the prevailing view that for sharks and rays, MPA effectiveness is currently based on the achievement of population outcomes. This result is not surprising given that MPAs are often evaluated by examining spatial or temporal population trends of species targeted for protection. However, population outcomes—specifically, increased abundance—may not always be an appropriate or achievable outcome for MPAs established for particular species or in certain contexts. The life history characteristics of many sharks and rays (low fecundity, late age at maturity, etc.) are such that population recovery rates will be slow, especially where populations are already severely depleted (Simpfendorfer, 2000). It may therefore be inappropriate to evaluate effectiveness based on whether or not abundance increases following MPA establishment, especially given the short time periods over which effectiveness is often evaluated. Additionally, increases in population size may not be achievable in places where threat levels to sharks have always been relatively low—for example, due to low historic catches (e.g., French Polynesia) that have minimally affected population size. As such, and especially over the short term, maintaining populations or even slowing their decline may be a more realistic, achievable outcome of shark and ray-focused MPAs.

Using population outcomes as a measure of the effectiveness of spatial protections may not be a useful way of evaluating their impact—that is, the difference they make to conservation outcomes. Comparisons of population trends before and after MPA establishment are not possible if baseline population data are lacking, as is the case for most Shark Sanctuaries (Ward-Paige & Worm, 2017). Even when baseline data are available, before–after comparisons can be confounded by other factors that change over time (Ferraro & Pressey, 2015). Separating out natural changes, those caused by large-scale exogenous forces (e.g., climate change), and those caused locally through human activities, represents a major challenge to measuring the ecological impact of MPAs. Similarly, spatial evaluations of MPA effectiveness can be confounded by factors relating to where and when the MPA was established (Ferraro & Pressey, 2015). For example, while some studies have shown that marine reserves harbour higher biomass and density of sharks than comparable fished areas (Bond et al., 2012), this may be driven by natural differences in abundance, habitat quality, or may even reflect differences in the rate of population decline as opposed to population stability or growth within the reserve (Lester et al., 2009). In the case of large-scale MPAs and Shark Sanctuaries, spatial evaluations using this kind of with–without comparison are simply not possible. In spite of these challenges, reliable evaluations of the biological "success" of an MPA require baseline data on populations, which is currently lacking for most shark and ray-focused MPAs (but see Ward-Paige & Worm, 2017).

The greater overall emphasis placed on biological outcomes versus social outcomes suggests that biological outcomes—more specifically, population outcomes—are the current focus of conservation efforts for sharks and rays. This focus on biological outcomes is consistent with the thinking that has dominated the protected area literature over the last several decades. Conservation has historically been the primary mandate of protected areas, with biological outcomes (e.g., protection of biological diversity, recovery of populations) serving as the major rationale for the creation of both marine and terrestrial protected areas (Brandon, Redford, & Sanderson, 1998; Murray, 2003). Indeed, a review of research on terrestrial protected area success found that the majority of studies focused almost exclusively on protection of biological diversity (Brechin, Murray, & Mogelgaard, 2010). However, other goals are inherent in the discussion of conflicts between people and protected areas (e.g., Brechin, Fortwangler, Wilshusen, & West, 2003; Murray, 2005).

While social factors were recognized as paramount to MPA success, biological outcomes were prioritized over social outcomes. This disconnect between inputs (success factors) and outputs (outcomes) may indicate a lack of understanding regarding what motivates local communities to support shark and ray conservation. Research on the human dimensions of MPAs has shown that the ecological effectiveness of MPAs is linked to compliance, successful alternative income projects and a high level of community participation in decision-making (Pollnac, Crawford, & Gorospe, 2001; Pollnac et al., 2010). A greater focus on achieving social outcomes (e.g., livelihoods benefits, reduced conflict, increased participation) may thus help drive local support and compliance, especially given that illegal shark fishing often occurs in developing countries where fishers have few livelihood options and are thus financially motivated to target sharks (Carr et al., 2013). Further, as mentioned by a number of participants in this study, MPAs generally carry multiple objectives and are thus unlikely to be established for the sole purpose of protecting sharks

and rays. For this reason, focusing on biological outcomes (i.e., increased abundance), particularly in resource-dependent communities, is unlikely to garner support for shark and ray conservation efforts. While regular MPAs have traditionally garnered local support by linking protection to fisheries benefits (e.g., due to the spillover effect) (Russ & Alcala, 1996; Russ, Alcala, Maypa, Calumpong, & White, 2004), local communities may not perceive to benefit from increased shark and ray abundance if (a) sharks and rays are not considered an important source of food or income; (b) legislation protecting sharks from finning already exists, or (c) sharks and rays are already protected under international conventions. We believe that in these contexts, a stronger focus on achieving social outcomes (e.g., increased income, well-being and food security) can help garner local MPA support, thus enhancing the potential for MPAs to improve biological outcomes through increased compliance.

Social considerations are important to the long-term success of MPAs (Christie, 2004) and, when overlooked, can lead to unintended consequences. In discussing "lessons learned" through involvement with a specific MPA, participants highlighted a number of elements that were not considered during MPA design and implementation. For example, two participants commented on a lack of consideration for the potential impact of an expanding tourism industry. Another participant commented on the growing tension between stakeholder groups in one Shark Sanctuary due to insufficient consideration of how to manage the non-extractive use of sharks for tourism. Another participant mentioned that equity issues within one MPA had created conflict due to a failure to consider the way that benefits were spread. These comments highlight the need to embed social considerations within MPA planning and emphasize the importance of considering how people may affect—and be affected by—MPAs over both the short and the long term.

4.4 | Ongoing challenges, future directions

Maximizing outcomes for shark and ray-focused MPAs requires understanding where and when spatial protections can provide the greatest benefits. Systematic conservation planning is one approach commonly used to select locations for marine reserves (e.g., Beger et al., 2015) and may be useful to guide the design and placement of future shark and ray-focused MPAs. Species-level information (e.g., distributions, movement patterns, habitat use) could be incorporated with socioeconomic data (e.g., coastal population density, distance to markets) to prioritize areas for protection based on the objectives of the MPA and the likelihood for long-term success (Cinner et al., 2018; Dickman, Hinks, Macdonald, Burnham, & Macdonald, 2015; Dulvy et al., 2017). Spatial prioritization could also help identify multi-objective "hotspots"—areas with high potential conservation benefits—for example, where (a) the highest number of species ranges overlaps, or (b) the highest number of endangered endemics occurs. Such hotspots have previously been used to identify priority countries with the greatest number of imperilled endemic sharks and rays and determine by how much the current global MPA network would need to be expanded in order to avert their extinction (Davidson & Dulvy, 2017). This type of approach could allow multilateral and international initiatives to maximize "return on investment" by prioritizing funding to regions where MPAs can achieve the greatest benefits for multiple objectives concurrently (Halpern et al., 2013; White, Halpern, & Kappel, 2012) .

Information on movement patterns is necessary to define the appropriate scale at which populations should be assessed and managed (Espinoza, Ledee, Simpfendorfer, Tobin, & Heupel, 2015). This information can be incorporated into MPA design to ensure that the placement and scale of spatial protections are relevant to the species targeted for protection. While an increasing number of studies use electronic tagging for monitoring shark movement (e.g., Brodie et al., 2018; Speed et al., 2010), the study of movement remains challenging. As mentioned by participants in our study, the lack of available data and the relatively poor understanding of many species remain major challenges to the effective design of MPAs for sharks and rays. Moreover, the ability of spatial protections to protect and, where necessary, rebuild shark and ray populations may be complicated by the catch of animals that travel outside, as well as illegal catch of those within, MPA boundaries (Carr et al., 2013; Davidson, 2012). As such, spatial protections will be most effective when complemented with strategies to promote compliance within MPA boundaries and manage fishing-induced mortality beyond MPA boundaries.

Maximizing outcomes for shark and ray-focused MPAs requires identifying, understanding and disentangling the social dimensions of success. While the broader MPA literature has made significant advances in this area (see Rossiter & Levine, 2014), research to date on the effectiveness of spatial protections for sharks and rays has focused almost exclusively on biological and biophysical aspects of success (Garla, Chapman, Wetherbee, & Shivji, 2006; Graham et al., 2016; Oh et al., 2017; Yates, Tobin, Heupel, & Simpfendorfer, 2016). Future studies could examine the social factors that contribute to successful outcomes in shark and ray-focused MPAs, and explore how each factor links to specific outcomes. Additionally, future studies could examine the link between subjective and objective measures of success by comparing local perceptions of success to ecological evaluations of shark and ray-focused MPAs. Finally, future perceptions research exploring the views around using MPAs for sharks and rays could examine whether and how perceptions relate to participants' level and type of experience (i.e., advocacy, policy, management, research, etc.), as well as the size, governance context and development context of MPAs in which participant experience is primarily based.

Evaluating the success of a shark and ray-focused MPA, as with any MPA, requires effective monitoring that begins during the initial stages of the MPA planning process. While objective indicators (e.g., shark abundance, tourism activity, participation, household income, livelihood diversity) are commonly used to evaluate success because they show tangible changes (and are often sought by funders and policymakers), subjective indicators (e.g., local support, attitudes towards the MPA, perceived equity, satisfaction and well-being) should also be incorporated because local attitudes will ultimately influence compliance, participation and social sustainability (Woodhouse et al., 2015). Processes

such as legitimacy, linked to compliance (e.g., Tyler, 2010), could be monitored through collection of quantitative and qualitative information on stakeholder perceptions, attitudes and experiences relating to the MPA and its management. Locally relevant evaluations conducted with stakeholder participation can be used to determine whether shark and ray-focused MPAs have achieved their intended outcomes.

5 | CONCLUSION

By capturing and critically evaluating the perspectives of a varied group of stakeholders including scientists, MPA managers, fisheries experts, conservation practitioners, advocates and policy experts, this study provides insight into current thinking and priorities relating to the use of spatial protections for shark and ray conservation. Our findings reveal that (a) while MPAs (both shark and ray-focused and regular) are considered somewhat effective for sharks and rays, they are generally viewed to be insufficient in isolation; (b) social factors are recognized as paramount to success; however, the current focus is on biological outcomes; and (c) there is consensus that achieving population outcomes is the primary biological goal of using MPAs for sharks and rays, however, this goal may not always be realistic or measurable. The apparent disconnect in emphasis between inputs (success factors) and outputs (outcomes) may indicate a lack of understanding regarding what motivates local communities to support shark and ray conservation. While population outcomes are undoubtedly the primary biological goal of shark and ray conservation efforts, we believe that an equally strong focus on achieving social goals (e.g., buy-in, livelihood benefits, compliance) can help enhance the potential for MPAs to achieve biological goals. Effective MPA design for sharks and rays, as for any mobile species, requires not only information on movement and habitat use of species targeted for protection; it requires understanding the socioeconomic context and conditions including the capacity for enforcement, level of resource dependence and alternative livelihood options. Future studies should examine the links between success factors and outcomes in shark and ray-focused MPAs and explore how local perceptions of social and biological success relate to objective measures of success (e.g., shark abundance). In highlighting the unique challenges of using MPAs for shark and ray conservation, we hope that the insights gained and lessons learned from this study can provide guidance to future planning and help improve the effectiveness of efforts to conserve and manage these species.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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SUPPORTING INFORMATION

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

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