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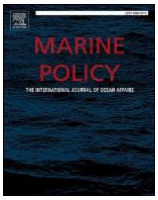

A holistic approach to manta ray conservation in the Papuan Bird's Head Seascape: Resounding success, ongoing challenges☆

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ABSTRACT

Despite a precipitous decline in global populations of sharks and rays over the past fifty years due to overfishing, and increasing concerns over the conservation status of manta and devil rays worldwide, manta ray populations in Raja Ampat in the Papuan Bird's Head Seascape of Indonesia are seemingly thriving. Reef manta rays (*Mobula alfredi*) in particular are abundant and have higher rates of pregnancy than have been recorded elsewhere in the Indo-Pacific, and have demonstrated a significant population increase over the past decade of monitoring. Here we document two decades' of conservation efforts in the Bird's Head Seascape (BHS) which, when considered in their entirety, represent an organically-developed, holistic approach to manta ray conservation that has demonstrated compelling evidence of success despite ongoing challenges. We provide detailed insights on the adaptive, continuously evolving approach used for manta ray conservation in the BHS in order that this approach might inform similar efforts towards elasmobranch conservation in other areas of the developing tropics.

1. Introduction

Global populations of sharks and rays, caught both in targeted fisheries and as bycatch, are in steep decline [1], with approximately one-third of all shark and ray species now considered threatened with extinction [2]. Manta and devil rays in the genus *Mobula* are no exception [3]. Numerous studies have revealed sharp declines in their local populations, from Mozambique [4,5] to Sri Lanka [6], and from the Philippines [7] to the Eastern Tropical Pacific [8]. Mobulids are frequently caught as bycatch in net and longline fisheries in particular [8], and since at least the 1990s have been targeted for their gill rakers, which are sold as a non-traditional "medicine" in southern China and other parts of southeast Asia [9]. As a result of this fisheries pressure and their slow growth and low fecundity [10], reef manta rays (*M. alfredi*) are now listed as Vulnerable on the IUCN Red List [11], while oceanic manta rays (*M. birostris*) have recently been listed as Endangered [5].

Indonesia is representative of the global plight of elasmobranchs, and for over three decades it has led the world in fisheries landings of sharks

☆ The authors dedicate this paper to the memory of our departed colleague, Pak Dharmadi, who played a pivotal role in the movement to protect manta rays in Indonesia.

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and rays [12,13]. Mobulids are frequently recorded as bycatch in Indonesia [14], while targeted harpoon fisheries are well known from the Savu Sea region and have seen steep declines in landings and even local extirpations over the past decade [15]. In Raja Ampat in the Papuan Bird's Head Seascape (BHS) in eastern Indonesia (Fig. 1), there is no historical evidence of systematic exploitation of mobulids by local fisheries [16], though there are anecdotal reports of sporadic targeting of manta ray aggregations in northern Raja Ampat in the early 2000s by shark fishers from Sulawesi [17]. Local community members also report that manta rays were observed as bycatch when fishing boats from Sulawesi and Maluku using large drift nets occasionally operated in Raja Ampat in the 1990s and early 2000s (Mambrasar, pers. obs.).

Despite this occasional mortality from fisheries two decades ago, manta ray populations in Raja Ampat are now fully protected and appear to be thriving [18]. Oceanic manta rays (*Mobula birostris*) in the Raja Ampat archipelago are both relatively abundant (588 individuals recorded over six years) and are estimated to have high survival rates [16]. The reef manta ray (*M. alfredi*) population in Raja Ampat is the largest reported from Indonesia (1375 individuals recorded over 15 years), with evidence of an unusually high rate of pregnancies compared to other populations across the Indo-Pacific and at least four active nursery habitats [18]. Additionally, a mark-recapture analysis of sightings data from 1052 individual Raja Ampat reef manta rays from 2009 to 2019 revealed significant annual increases in estimated population size in both the Dampier Strait and South East Misool MPAs [19]. By comparison, the well-studied reef manta ray population in Mozambique, which has been targeted in subsistence fisheries [20] showed a decreasing trend in apparent survival over 15 years (2003–2018), suggesting high mortality linked to continuing pressure from targeted fisheries and insufficient conservation efforts to protect the population [4,21].

We posit that the comparatively optimistic outlook for manta rays in Raja Ampat is most likely a result of two decades of intensive conservation efforts in the BHS [22,23] by a dedicated stakeholder coalition comprised of local and national government agencies, traditional communities, local universities and local and international non-governmental organizations (NGOs) [24]. These efforts have not only protected the manta rays of Raja Ampat, but have moreover leveraged national level protection for manta rays [25] and other elas- mobranchs [26,27] while inspiring other regencies (the secondary level of local government administration in Indonesia, one step below the level of province), including West Manggarai [28] and Berau [29], to similarly protect manta rays in their waters.

In this paper we document the progressive development of a holistic approach to manta ray conservation in Raja Ampat, providing insights on the strategies used, in order that they might inform similar efforts towards elasmobranch conservation in other parts of Indonesia and across the developing tropics. We also highlight ongoing challenges that are currently being addressed to ensure that manta rays and other elasmobranch populations not only continue to grow in Raja Ampat but also begin to show signs of recovery in other regions of the BHS.

2. 2001–2011: a decade of MPA development in the BHS

While the traditional communities of West Papua have long practiced *sasi* – a traditional resource management technique utilizing

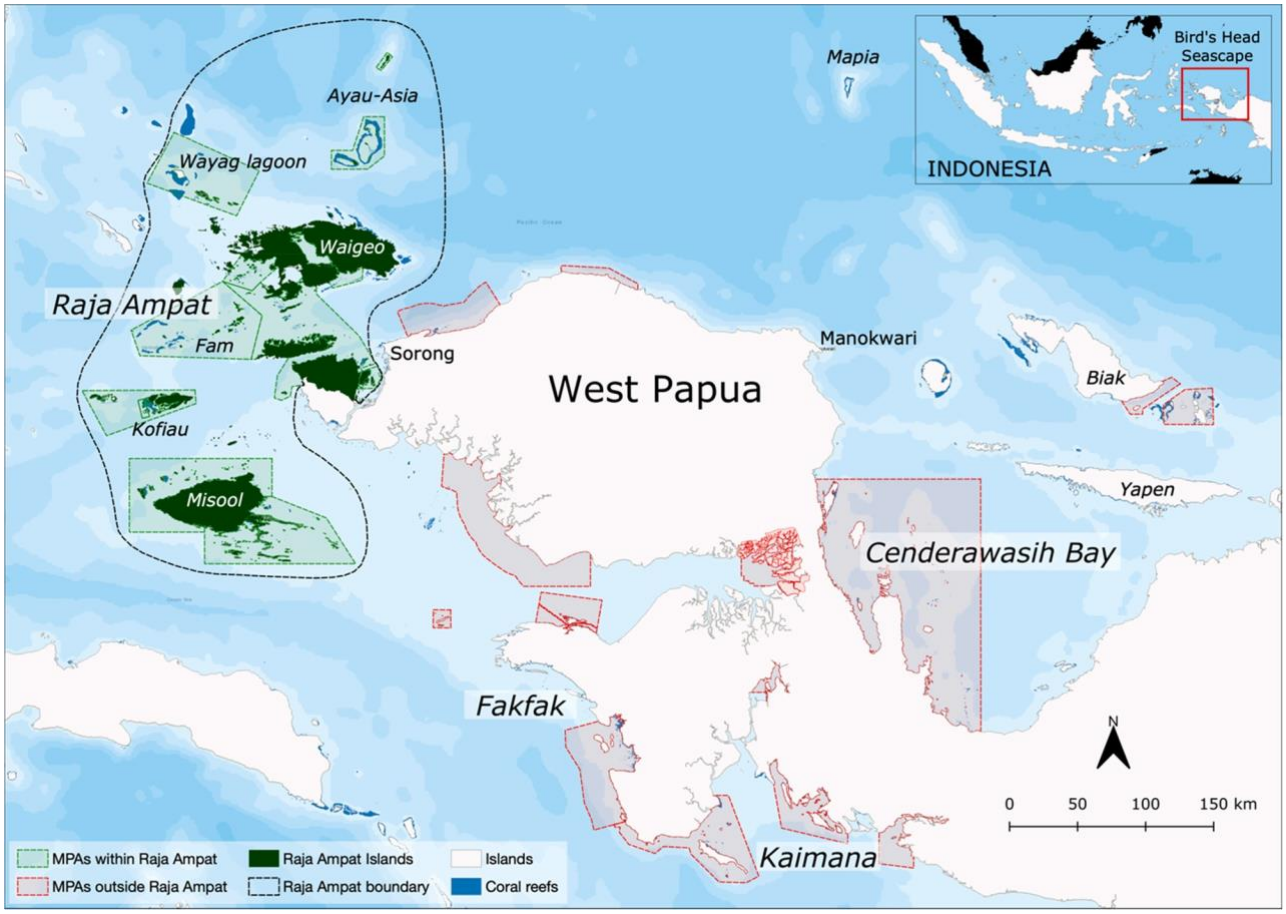

Fig. 1. The Bird's Head Seascape in West Papua, Indonesia, with key coastal regencies and large islands labeled and the network of 26 individual marine protected areas (MPAs) denoted by polygons (green for those within Raja Ampat Regency, and red for those outside Raja Ampat Regency). The approximate boundary of Raja Ampat's administrative boundary is demarcated by a dashed line.

spatio-temporal prohibitions on collection of certain marine species (usually invertebrates) as a means of allowing these exploited populations to recover [30], "formal" (legislated) marine conservation in the BHS only began in the late 20th century with the designation of the 60,000 ha Raja Ampat Marine Wildlife Sanctuary in 1993 (see timeline in Fig. 2). Soon thereafter, a marine rapid ecological assessment (MRAP) conducted by the Indonesian Institute of Sciences, University of Cenderawasih, and Conservation International (CI) in 2001 [31] brought the world's attention to the Raja Ampat archipelago's superlative marine biodiversity. Results from a series of follow-on surveys throughout the BHS sponsored by CI and The Nature Conservancy (TNC) cemented the BHS' reputation as the global epicenter of coral reef biodiversity

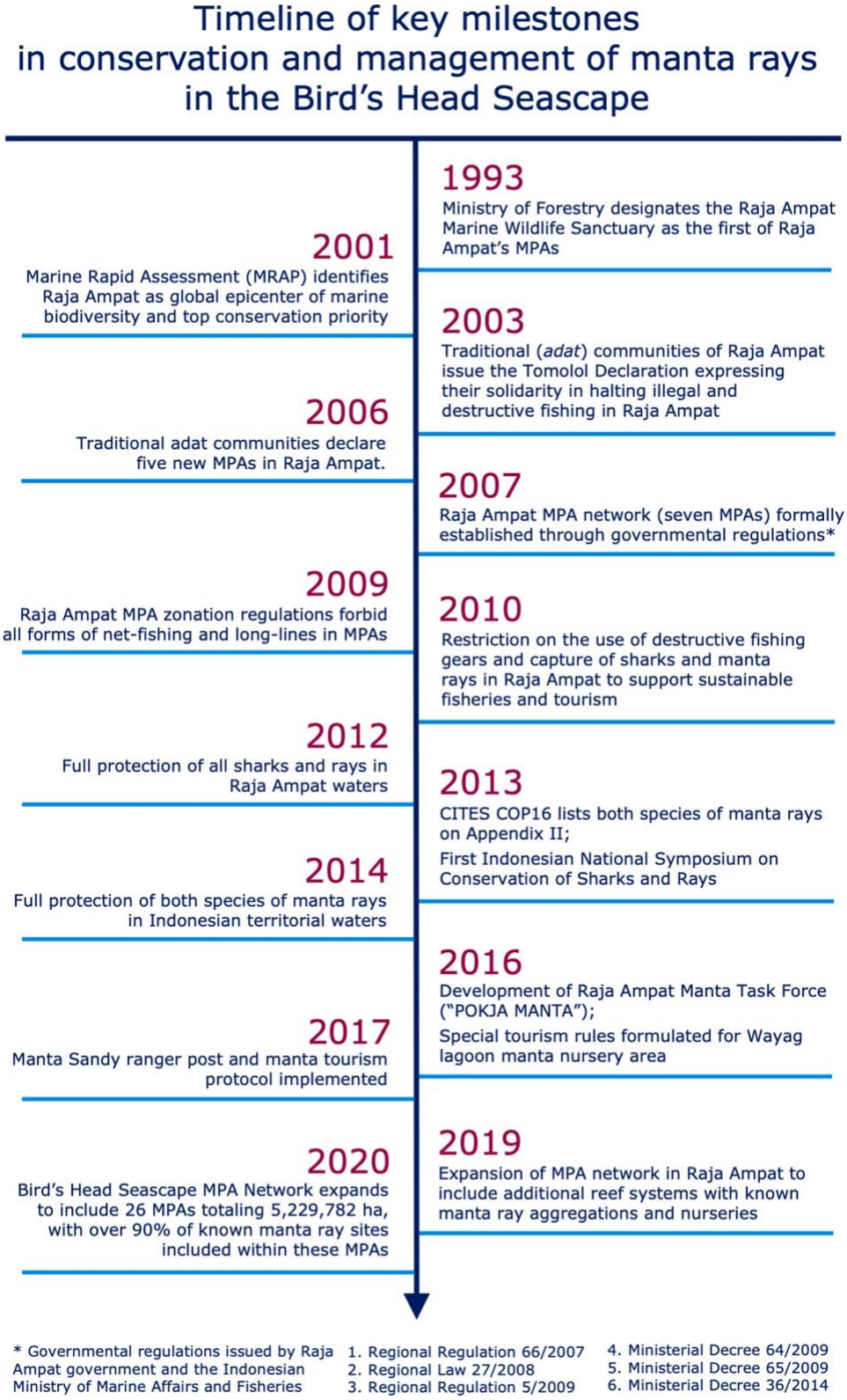

Fig. 2. Timeline of key milestones in conservation and management of manta rays in the Bird's Head Seascape, Indonesia.

[32]. Ongoing research has shown the BHS is home to over 600 species of hard coral [33], 14 species of cetacean [34,35], 1876 species of reef fish [36,37], and both species of manta rays [18], making it Indonesia's top priority region for marine biodiversity conservation [38,39].

The designation of Raja Ampat as a new regency in West Papua in 2003 provided an opportunity for its nascent government to craft a development plan that featured a strong focus on conservation and sustainability. To further guide this governmental vision, the traditional *adat* communities of Raja Ampat set forth the Tomolol Declaration in December 2003, calling for an end to the rampant illegal and destructive fishing practices being conducted by outside fishing boats in the regency's waters and demanding the government prioritize sustainable marine resource management to guarantee food security for local communities. Environmental NGOs (led by CI and TNC) and the State University of Papua worked closely with the Raja Ampat government and local communities to help realize this vision, which centered upon the development of a network of MPAs, collaboratively managed by the regency government and local communities, and designed to both protect marine biodiversity and ensure food security by serving as a focal point for sustainable fisheries and marine tourism development [22].

MPAs were chosen as the initial primary conservation intervention by the Raja Ampat government, as they have long been proven to be an effective tool to protect benthic communities and increase the abundance and biomass of coral reef fish species both within and outside their boundaries [40]. They have also been shown to promote the recovery of large mobile species (e.g., reef sharks), especially in large MPAs [41,42]. With this in mind, Indonesia's Ministry of Marine Affairs and Fisheries (MMAF) has for the past two decades prioritized the establishment of a representative national network of MPAs, and has moreover targeted protecting 10% of its marine area (32.5 million ha) as part of its commitment to the Convention on Biological Diversity's (CBD) Aichi Target 11 [43].

In 2006, traditional *adat* leaders declared five new MPAs in Raja Ampat, including the Kawe, Dampier Strait, Mayalibit Bay, Kofiau-Boo Islands, and South East Misool MPAs. In 2007, the Ayau-Asia MPA was similarly declared, after which the full network of seven MPAs in Raja Ampat was then legally gazetted by the Raja Ampat government [44–48] under new national legislation by the Indonesian Ministry of Marine Affairs and Fisheries [49,50] that encouraged decentralized, local ownership and management of MPAs. Similar efforts were initiated in other regencies in the BHS, and by 2011 a network of 12 MPAs covering nearly 3.6 million hectares was established and under active co-management by local communities and the government [22]. At the time, ten of these were managed by the Regency governments of Raja Ampat and Kaimana, but in 2014 a new national law [51] transferred the authority for managing these local MPAs to the provincial level. As a result, at the present time, 19 of the 26 MPAs in the BHS MPA network are managed collaboratively between the West Papua provincial government and local stakeholders, while the remaining seven are national level MPAs managed by the MMAF or the Ministry of Environment and Forestry.

Each of the MPAs in the Raja Ampat network is actively enforced by its own joint patrol team comprised of rangers recruited from local communities and either police or fisheries officers, generally targeting at least 3 patrols per week [22,23]. The patrol system is sustainably financed via the Raja Ampat MPA environmental services fee levied upon all domestic and international visitors, and is one of the primary reasons that the Raja Ampat MPA network fulfills nearly all of the criteria (except for having boundaries demarcated by buoys) for a blue rating ("managed optimally") in MMAF's E-KKP3K MPA Management Effectiveness Assessment [52].

Importantly, the siting of MPAs within Raja Ampat (and the broader BHS) was based upon a combination of traditional ecological knowledge and community marine tenure and socioeconomic considerations, combined with the results of a series of scientific studies investigating the ecology, oceanography and genetic connectivity of the BHS [53,54]. While manta rays were not a specific focus of research or conservation prior to 2011, local communities and tourism operators both considered them an important tourism asset in Raja Ampat, and known manta aggregation sites were explicitly included in MPAs [22]. Moreover, a participatory zonation planning process resulted in all forms of net fishing and long-lining being banned in Raja Ampat MPAs [55]. While these fishing gears were banned by local communities for sustainability reasons, this move was undoubtedly highly beneficial to Raja Ampat's manta ray populations. As mentioned previously, though manta rays were never consistently targeted by fisheries in Raja Ampat, the area was heavily fished for sharks [42], with manta rays regularly caught as bycatch in shark gillnets and longlines [17,56] and sometimes even used as bait on shark long-lines (Mambrasar, pers. comm).

3. An increasing focus on manta rays

By 2011, Raja Ampat's coral reefs were under active local management, with illegal and destructive fishing practices largely under control and marine tourism rapidly becoming the primary economic engine for Raja Ampat [22]. As the coalition of conservation stakeholders in Raja Ampat began to focus on fine-tuning conservation efforts, four separate but synergistic developments combined to greatly advance manta ray conservation, not only in Raja Ampat but nationally. First, a targeted campaign by Misool EcoResort, WildAid and Shark Savers convinced the Regent of Raja Ampat to announce his intention to make Raja Ampat a shark and ray sanctuary [57] to increase tourism to the region. With the help of the CI and TNC Raja Ampat programs, this initiative was brought to the Raja Ampat parliament and leveraged into a Regency Law [58] in 2012, strictly protecting all sharks and rays in Raja Ampat waters – the first of its kind in southeast Asia.

Also in 2011, the Indonesian Manta Project (and its related initiative, the Misool Manta Project, both affiliates of the Manta Trust) began collecting photo-identification images of Raja Ampat's reef and oceanic manta rays and launched a collaboration with CI, TNC and the Raja Ampat MPA Management Authority to investigate the natural history of manta rays in the region. These partners also worked with the Raja Ampat Tourism Department and local marine tourism operators to encourage the implementation of a code of conduct for divers and snorkelers interacting with manta rays.

In 2013, two final developments of particular importance in the same timeframe included the publication of an analysis of the global economic impact of manta ray watching tourism, which revealed Indonesia to be the second most valuable manta tourism industry in the world (worth over US$15 million annually) [59], and the historic decision at the CITES CoP16 conference to list both species of manta ray (and six species of shark) on CITES Appendix II [60].

Buoyed by the successful campaign for the Raja Ampat shark and ray sanctuary, the BHS conservation coalition supported MMAF in hosting the first National Symposium on Shark and Ray Conservation in 2013, primarily as a vehicle to highlight the conservation vision of the Raja Ampat government and to encourage other regencies to also protect their elasmobranchs. The symposium was attended by about 80 participants and presided over by the Minister of Marine Affairs and Fisheries. At a pre-symposium press briefing, the Minister voiced concern about the implications of the recent CITES shark and ray listings, noting that while Indonesia was obliged as a signatory to CITES to uphold these new protections, there were sure to be negative economic impacts upon coastal fishing communities deriving incomes from elasmobranch fisheries.

When the coalition later presented the results of the manta tourism economic study, explained as a "mantanomics" argument that a single manta ray was worth less than $500 dead for its gill plates but over $1M alive as a tourism asset (Fig. 3), the Minister commented that having such a strong economic argument provided clear justification for conservation action for manta rays. In his closing comments to the symposium, he instructed his Marine Conservation Directorate to convene a

Fig. 3. "Mantanomics" poster produced in 2013 as part of a strategy to convince the Indonesian Minister of Marine Affairs and Fisheries of the strong economic argument in favor of protecting manta rays as valuable tourism assets.

high-level shark and manta ray conservation working group to formulate and justify national level legislation to protect manta rays and to consider similar protections for the other CITES-listed sharks, particularly if there were economic justifications for doing so [61].

This working group met regularly for the second half of 2013, producing the academic justification document for the proposed legislation and then drafting the manta protection regulation for consideration by the Minister. Importantly, the initiative was championed on social media by Indonesian television celebrity Riyanni Djangkaru and her "Save Sharks Indonesia" campaign [62]. In early 2014, the Minister signed a Regulation [25] fully protecting both species of manta rays in Indonesian territorial waters [12], thus creating the world's largest manta ray sanctuary at nearly 6,000,000 km^2 [62].

Over the course of two years, the world's largest shark and ray fishing nation had rapidly adopted and championed robust elasmobranch conservation initiatives. Importantly, whale sharks (*Rhincodon typus*) were also given full protected status [26] based also upon their tourism value, and other fisheries regulations quickly followed, providing varying levels of protection to thresher (*Alopias* spp.) and oceanic whitetip (*Carcharhinus longimanus*) sharks [12]. Indonesia's transition to a country with a significant elasmobranch conservation focus had begun, underscored by steadily increasing participation in the three successive national Symposiums on Sharks and Rays in 2015 (124 participants), 2018 (235 participants) and 2021 (776 online participants). Importantly, the 2015 symposium resulted in the signing of Indonesia's first National Plan of Action on Manta Ray Conservation for the period 2016–2020 [63].

4. A new threat: tourism

Throughout this period of increasing manta ray protection, marine tourism grew rapidly in Raja Ampat, from a total of about 300 guests visiting the region via one resort and one liveaboard dive vessel in 2001 [64], to 28,952 guests accommodated by 11 resorts, over 50 homestays and more than 70 dive liveaboards in 2018 – with a nearly 3000% increase in visitor arrivals between 2007 and 2018 [23]. Raja Ampat's manta rays had become a top attraction, and overcrowding and disturbance by divers at popular manta "cleaning stations" was a common concern voiced by both scientists and tourism operators [65]. Reef manta rays routinely aggregate at specific coral colonies to be "cleaned" of their ectoparasites by a variety of reef fishes including the cleaner wrasse *Labroides dimidiatus*; these cleaning stations also provide opportunities for courtship and other social interactions between manta rays [66]. Importantly, while manta cleaning stations are often targeted by divers due to the reliability of manta sightings, the presence of large numbers of divers, as well as aggressive behaviors by divers such as approaching too closely to cleaning manta rays, has been shown conclusively to cause disruption to manta ray behavior and often results in manta rays leaving and avoiding cleaning stations, which may decrease individual fitness [67].

In response to this new threat, in 2016 the Raja Ampat Tourism Department and MPA Management Authority jointly launched a Raja Ampat Manta Task Force (the "POKJA Manta") comprised of representatives from communities, government, the tourism sector, NGOs and several manta ray researchers. The Task Force initially focused its efforts on implementing special management of the "Manta Sandy" dive site, an important manta ray cleaning station which at times had up to 9 boats and 50 divers crowding the site at once and clearly affecting the behavior of the manta rays [68]. In 2017, the Task Force built a ranger station at the dive site and hired and trained the "Manta Cadre", a group of young manta conservationists from nearby villages that began strictly limiting the numbers of divers and snorkelers allowed on the site at a given time and enforcing the code of conduct for appropriate manta interactions [69,70]. Later, as ongoing surveys revealed the presence of manta nursery areas in Wayag Lagoon and other reef systems, the Task Force worked to formulate special rules to prevent disturbances to juvenile manta rays in the nurseries, including limiting boat speeds in these sensitive areas [18]. While the impacts of these management interventions have not been quantified, dive operators in 2019 reported general satisfaction with the new regulations and an increase in the numbers of manta rays visiting the Manta Sandy cleaning station (Kasmidi, pers. obs.).

5. Further considerations and ongoing challenges

Over the past decade, communities around the BHS have continued to call for more MPAs, with the BHS MPA network now comprising 26 MPAs covering 5,229,782 ha [71]. Importantly, of the 127 sites in the BHS where regular manta ray sightings have been recorded, 91% (n = 115) of them are distributed within 13 of the BHS MPAs [18]. Moreover, 68 of the 70 known manta ray cleaning and feeding aggregation sites and all four of the known manta nursery areas (Wayag lagoon, Ayau Besar lagoon, Hol Gam lagoon, and the Fam islands) are within MPAs [18]. In a previous study, we have shown that all four

nurseries fulfill the three criteria of elasmobranch nurseries proposed by Heupel et al. [72], with (1) Young-of-the-Year (YoY) and juvenile reef manta rays (defined as individuals $\leqslant$ 2.0 m DW (disc width) and $\leqslant$ 2.4 m DW, respectively) more commonly encountered in the nursery areas than elsewhere in the BHS, (2) YoY and juvenile *M. alfredi* shown to remain in the nursery area for extended periods of up to 1.7 years; and (3) the nursery areas used repeatedly by YoY and juvenile *M. alfredi* across periods of 3–14 years [18].

Although both species of manta ray are capable of long distance movements in excess of 1000 km [73,74], a range of studies have shown that populations of both species across the Indo-Pacific demonstrate strong patterns of site fidelity [74,75], and some authors have shown that even short distances of 20–50 km across deep water can serve as a barrier to reef manta ray movements in particular [76,77]. Previous movement studies in Raja Ampat have similarly shown that both *M. alfredi* and *M. birostris* show strong site fidelity to the region [16,18,65,74]. While data on oceanic manta home ranges is lacking, the home range size of reef manta rays has been estimated as ranging from 64 to 2457 km^2 [78]. With Raja Ampat MPAs ranging in size from 50 to 3573 km^2 (and BHS MPAs up to 14,535 km^2) they are considered appropriately-sized for reef manta ray conservation [18].

Nonetheless, both reef and oceanic manta rays have been shown to occasionally move southwards from Raja Ampat into the Seram Sea and the waters of Fakfak and Kaimana regencies, and manta rays have been recorded from four of the 17 BHS MPAs outside of Raja Ampat Regency [16,18]. However, extensive surveys in these areas have confirmed that manta ray populations in these areas are much smaller than in Raja Ampat [18]. Unfortunately, net fishing (including with set and drifting gill nets and large net traps) is still practiced in much of the BHS, and given the frequency of manta ray bycatch recorded in net fisheries globally [6,8], it is likely the low numbers of manta rays found outside Raja Ampat is a direct consequence of these nets. Moreover, while targeted manta ray fisheries in the BHS are not generally known, there is one report of local communities opportunistically harpooning manta rays in southern Yapen Island in the eastern BHS [63].

With this in mind, the BHS conservation coalition is in ongoing discussions with the Kaimana and Fakfak regency governments and the West Papua provincial government to urge the implementation of net bans and possibly a province-wide shark and ray sanctuary in an attempt to expand protections for manta rays throughout the BHS in order to promote population recovery. Fortunately, the West Papua government has declared itself Indonesia's first "Conservation Province", and the provincial law which provides the substance of this declaration [79] includes strong justification for further protection for economically-important elasmobranchs. As with most conservation work globally, the COVID-19 pandemic has unfortunately slowed these efforts, but as the pandemic eases and tourism begins to recover in the BHS, we anticipate renewed interest in elasmobranch conservation, particularly in those regencies with strong "elasmotourism" potential.

Continued monitoring of manta ray populations in Raja Ampat and the broader BHS will be required to investigate the efficacy of the management and conservation measures described herein, and is considered a priority by both governmental agencies (ranging from the Raja Ampat and Cenderawasih Bay MPA Management Authorities to the West Papua provincial government and MMAF's National MPA Management Authority in Kupang) and NGOs such as Conservation International and Thrive Conservation. Given the vast region to cover and the challenges in monitoring marine megafauna, tourists and tourism operators in the BHS will be called upon to continue assisting with the monitoring the manta ray populations through citizen science [18]. The Raja Ampat MPA Management Authority in particular is currently developing an integrated system to improve the contribution of citizen science to manta ray monitoring, and also continues to collaborate with NGOs and Universities to actively survey and monitor Raja Ampat's manta ray populations. Moreover, the Authority has now requested the Raja Ampat Manta Task Force to develop additional manta tourism regulations for eight additional dive sites with manta ray cleaning stations.

6. Conclusion

Science-based management, well-enforced MPAs, and protection of aggregation sites and critical habitats (*e.g.*, nursery areas) are each considered important to ensure the recovery of elasmobranch populations [80]. The adoption of each of these components in a holistic approach to manta ray conservation and management by Raja Ampat government agencies has allowed manta populations in the archipelago to thrive. Importantly, this approach was not carefully formulated in an *a priori* fashion; rather, it developed organically. Beginning with the designation of an extensive network of MPAs managed collaboratively by local communities and government and supported by NGOs, academia and the private tourism sector, the initiative added fisheries gear restrictions, a shark and ray sanctuary, a national manta awareness campaign, national protection legislation and multistakeholder tourism management components as it developed. It made use of a carefully-worded "mantanomics" argument in favor of manta conservation over fisheries exploitation, and it worked with Indonesian media celebrities to utilize the power of social media to garner public support and influence policymakers. As this manta conservation initiative gained momentum in Raja Ampat, it influenced other elasmobranch protections [26] and eventually leveraged other regencies in Indonesia (including West Manggarai and Berau) to follow suit in protecting their manta rays [28,29]. It launched the first National Symposium on Conservation of Sharks and Rays, which has grown into a triennial event with continuously increasing numbers of Indonesian elasmobranch conservationists and scientists participating. It has thus provided an important "ray of hope" for the future of not only manta rays but all elasmobranchs in the world's largest archipelagic nation.

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CRediT authorship contribution statement

Edy Setyawan: Conceptualization, Writing – original draft, Writing – review & editing. **Mark Erdmann:** Conceptualization, Writing – original draft, Writing – review & editing. **Nikka Gunadharma:** Writing – review & editing. **Tiene Gunawan:** Writing – review & editing. **Abdi Hasan:** Writing – review & editing. **Muhamad Izuan:** Writing – review & editing. **Meidiarti Kasmidi:** Writing – review & editing. **Yusdi Lamatenggo:** Writing – review & editing. **Sarah Lewis:** Writing – review & editing. **Nugraha Maulana:** Writing – review & editing. **Ronald Mambrasar:** Writing – review & editing. **Meity Mongdong:** Writing – review & editing. **Alberth Nebore:** Writing – review & editing. **Mochamad Iqbal Herwata Putra:** Writing – review & editing. **Abraham Sianipar:** Writing – review & editing. **Kristian Thebu:** Writing – review & editing. **Syafri Tuharea:** Writing – review & editing. **Rochelle Constantine:** Conceptualization, Writing – original draft, Writing – review & editing.

Declaration of interest statement

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

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