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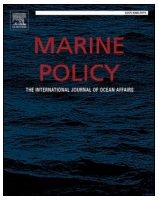

The rapid expansion of Indonesia's marine protected area requires improvement in management effectiveness

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ABSTRACT

Indonesia's marine ecosystems are among the most diverse in the world, supporting extensive critical habitats with strong connections to coastal communities. To keep pace with increasing pressures on the environment, conservation efforts need to be strengthened and expanded. The Government of Indonesia has committed to protecting marine ecosystems through establishing 32.5 million ha of marine protected areas (MPAs), with 20 million ha effectively managed, by 2030. Therefore, collating data on the status and progress of marine conservation efforts nationally is important to show the extent to which this target is being reached. Here we provide an overview of the status and trends of spatial coverage and management effectiveness of MPAs in Indonesia. As of 2020, Indonesia had made good progress in reaching its target – with 23.9 million ha MPA established and some —albeit slow— increases in MPA management effectiveness. Moving forward, we recommend that marine protection efforts in Indonesia need to balance MPAs expansion with improvement in effectiveness. Improvement of management effectiveness will require significant efforts, including improving institutional coordination, ensuring adequate human and financial resources, and strengthened monitoring, evaluation, and learning to inform adaptive management. Future MPA expansion should focus on addressing specific gaps in the existing network, such as increasing coastal habitat representation, and connectivity, or increasing recognition of a diversity of governance approaches (e.g., by communities or private entities). Progress over recent decades, however, suggests Indonesia is making progress on its marine protection goals and is well placed to meet potential future targets.

1. Introduction

Indonesia sits within the heart of global marine biodiversity, containing an estimated 16 % of the world's coral reefs [1], over 5 % of seagrass beds [2], and 20 % of mangrove forests [3]. These ecosystems support over 2000 reef fish species [4], 500 scleractinian coral species [5], and the highest mangrove diversity in the world, with 202 species [6,7]. Due to high biodiversity and the extent of coastal habitats,

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Indonesia is a global priority for conservation [8]. In addition, many Indonesian coastal communities rely on these productive marine ecosystems for their primary sources of nutrition, livelihoods, coastal protection, and culture [9]. However, anthropogenic pressures such as overfishing, destructive fishing, sedimentation, and climate change threaten coastal habitats and have resulted in the loss of approximately USD 2.6 billion of ecosystem services over 20 years [10]. These threats directly impact the food security of approximately 60 million people that depend on the coastal ecosystems as a primary food source, with the poorest and most vulnerable local communities suffering the most [1, 11–13]. Protecting Indonesia's coastal ecosystems and ensuring their continued ecosystem service provision to communities requires effective and equitable management tailored to local social-ecological conditions.

Indonesia has been protecting its coastal ecosystem for centuries through customary and formalized conservation. Customary conservation, widely known as *adat,* consists of incorporating customary beliefs and local knowledge into the management and regulation of marine resources. *Adat* has a wide range of practices, including periodic fisheries closures for species (e.g., *Sasi*), marine protection by fishers elected through the customary system (e.g., *Panglima laôt*), and customary closed areas managed by the customary law community (e.g., *Sarano Wali*) [14,15]. Formal state conservation practices in Indonesia pre-date Indonesia's independence in 1945 [16,17]. The 1945 Constitution of the Republic Indonesia Article 33(4) states "*The land, the water and the natural resources within shall be under the powers of the State and shall be used to the greatest benefit of the people.*'' This means that natural resources are managed by the Government of Indonesia (GoI) and must be governed for the benefit of Indonesian citizens [16,17]. To meet this requirement, the GoI has adopted Marine Protected Areas (MPAs) as a large-scale management tool to protect marine biodiversity and promote sustainable use, and in 2008, *adat* was formally acknowledged within MPAs [18].

The GoI defines MPAs as "spatially defined, marine, coastal or small island areas that are protected and managed by a zoning system to achieve sustainable management of fisheries resources and environmental outcomes'' (PP RI No. 60/2007) [19]. MPAs in Indonesia are managed under two national authorities: (i) the Ministry of Marine Affairs and Fisheries (MMAF)—with dual objectives of biodiversity conservation and sustainable fisheries, and (ii) the Ministry of Environment and Forestry (MoEF)—with greater focus on protecting biodiversity. Both ministries and provincial governments take a multiple-use approach to MPAs, using zonation systems to allow or prohibit different activities across an MPA.

To increase marine protection, Indonesia has made a series of ambitious commitments around MPA extent, critical habitat protection, and MPA management effectiveness (Table 1). The current national target is to establish 32.5 million ha of MPAs by 2030 [20], contributing towards global agreements such as the Convention on Biological Diversity's Aichi Target 11 and the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI) (Table 1). These targets are also complemented by the implementation of a series of coastal protection policies and tools, such as provincial marine zoning plans (*Rencana Zonasi Wilayah Pesisir dan Pulau Pulau Kecil;* RZWP3K), regional fisheries management areas (*Wilayah Pengelolaan Perikanan*; WPP), and ecosystem-based approaches to fisheries management (EAFM).

In recent decades there has been increasing efforts to measure the status and progress of MPA management effectiveness [30] to inform progress and adaptive management of protected areas, as well as provide a proxy as to how management is contributing towards conservation outcomes. Conducting regular management effectiveness assessments for MPAs is challenging because of the human and financial resources required [31,32]. Indonesia conducts assessments for most MPAs, both under MMAF and MoEF, every two to three years and annually for MMAF's 35 nationally-determined priority MPAs [33]. The assessments are led by both ministries in collaboration with related stakeholders.

Table 1
Key national and international MPA targets, actions, and commitments implemented/ratified by Indonesia (see also Table S1 for more detailed information and references).

Year Announced	Statement/Target	Agency	Scale
1945	The Indonesian government is required by constitution to manage natural resources for the benefit of Indonesian citizens (Article 33, UUD RI 1945) [17]	Government of Indonesia (GoI)	National
1999	The Ministry of Marine Exploration was established, which later became the Ministry of Marine Affairs and Fisheries (MMAF) [20]	GoI	National
2006	10 million ha of MPAs by 2010 [21]	Ministry of Marine Affairs and Fisheries (MMAF)	National
2009	20 % of each major marine and coastal habitat type within 'no-take replenishment zone' [22]	Coral Triangle Initiative (CTI)	Regional
2010	At least 10 % of coastal and marine areas are protected within well-connected protected areas that are effectively managed by 2020 [23]	United Nations Convention on Biological Diversity Aichi Target 11/ Government of Indonesia ratification	Regional
2015	Establish 20 million ha by 2019 [24]	MMAF	National
2015	Improve MPA management effectiveness by reaching a minimum of 70 % in Management Effectiveness Tracker Tool (METT) assessments by 2019 [25]	Ministry of Environment and Forestry (MoEF)	National
2016	At least 30 % of each marine habitat are protected [26]	International Union for Conservation of Nature (IUCN) World Conservation Congress	Regional
2019	Establish 32.5 million ha of MPAs by 2030 [27]	Ministry of National Development/ MMAF	National
2019	At least 10 % of Indonesian waters are protected and managed effectively [28]	GoI	National
2020	Improve MPA management effectiveness by 10 % by 2030 [29]	MMAF	National

As Indonesia continues to expand and strengthen its MPAs, decision-makers need the best available information to track progress towards national goals. However, much of this information is piecemeal and has not been compiled at the national level. This study provides an initial first step to provide an overview of the progress in MPA establishment and effectiveness in Indonesia. Specifically, this study documents: (i) the history of, and national trends in, Indonesia's MPA coverage, (ii) the current status of MPAs and extent to which coastal habitats are protected, and (iii) progress in management effectiveness in MPAs across Indonesia. We then use these results to provide recommendations to inform future MPA planning in Indonesia.

2. Methods

2.1. MPA and coastal habitat extent

The data used to analyze the extent of coastal habitat protection within Indonesian MPAs consist of all outer boundaries of legally-defined MMAF and MoEF MPAs and MoEF legally-defined terrestrial

protected areas that contain marine habitats—i.e., any ocean areas and mangrove forests (webgis.menlhk.go.id). The data was derived from 300 protected area shapefiles, sourced from MoEF and MMAF (Jakarta, January 2020). Coastal habitat extent data was sourced from existing datasets for coral reefs [34], seagrass beds (Geospatial Information Bureau, [35]), and mangrove forests (2016 layer from Bunting et al. [3]). Coral reef and mangrove forest layers represent global mapping efforts using remote sensing image analysis, while seagrass bed maps represent national mapping using remote sensing combined with in-situ field records.

Spatial data was analyzed at the provincial level using ESRI software ArcMap 10.7.1 [36]. First, we buffered the area based on the provincial boundaries (12 nautical miles (nm) offshore from the provincial coastline (UU No. 23/2014) [37]). Then, the MPA outer boundaries were overlaid to identify MPA extent within provincial waters. We continued by intersecting the coastal habitat layers with the provincial boundaries and MPA outer boundaries to identify the percentage of coastal habitat within MPAs for each province. MPA zonation plans were reviewed for all available legally-defined MPAs. In total, we analyzed zonation plans from 30 of 33 zoned MMAF MPAs and nine of the 17 zoned MoEF MPAs because of inaccessibility of spatial zonation data (Table S2). Zone types were classified into two groups: (i) "non-extractive zones" and (ii) "extractive zones". We overlaid coastal habitat layers with zonation boundaries to identify the percentage of protected coastal habitat within each group.

2.2. MPA management effectiveness

Over recent years, Indonesia has used two key tools to measure MPA management effectiveness [38]: (i) the Management Effectiveness of Aquatic, Coasts, and Small Island Conservation Areas (*Efektivitas Pengelolaan Kawasan Konservasi Perairan, Pesisir dan Pulau-Pulau Kecil*; E-KKP3K) used for MPAs under MMAF authority [39], and (ii) the Management Effectiveness Tracking Tool (METT) used for MPAs under MoEF authority [40]. In this study, we used the result of both assessment tools between the year 2013 and 2019. E-KKP3K evaluations are available for 122 out of 166 MMAF MPAs. The most recent E-KKP3K evaluation for each MPA was used to provide an overview of the national status of MMAF MPA management effectiveness. Changes in MMAF MPA management effectiveness were evaluated through trends in annual E-KKP3K assessments between 2013 and 2019 for 35 nationally identified priority MPAs, consisting of 10 nationally governed MPAs and 25 provincially governed MPAs (Table S3). Data was sourced from the MMAF website (http://kkji.kp3k.kkp.go.id; January 2020). Meanwhile, MoEF evaluated 18 MPAs in 2015 and 26 MPAs in 2017 out of a total of 30 MPAs. Both 2015 and 2017 METT data were used to illustrate current

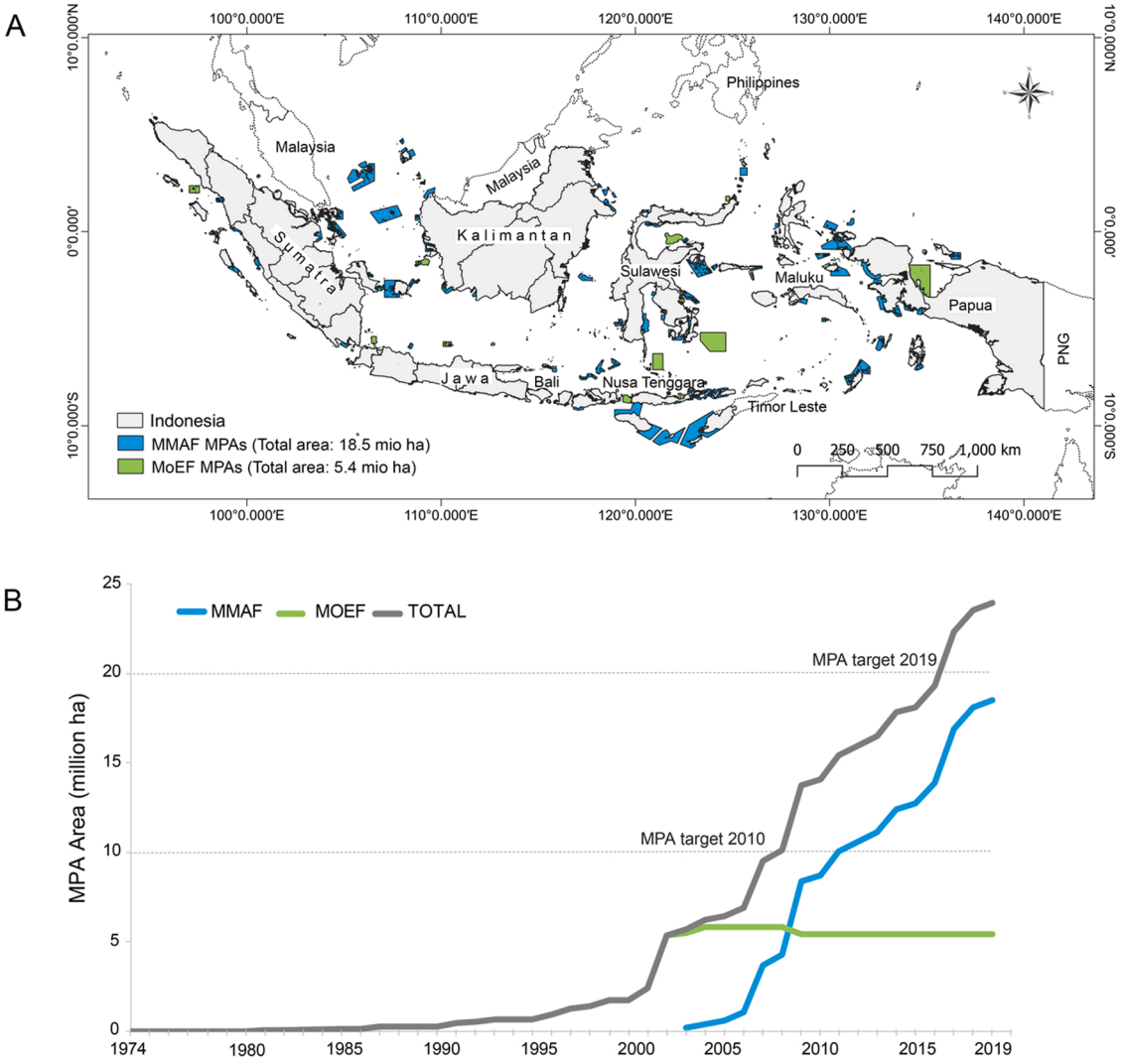

Fig. 1. (A) Map of the distribution of the 300 analyzed MPAs in Indonesia and (B) Change in MPA extent by year for the 300 MPA managed by MMAF (blue) and MoEF (green). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

status and trends in MoEF MPA management effectiveness, while 2019 data are not publicly available. Data was sourced from the MoEF METT website (http://mett.ksdae.menlhk.go.id; January 2020).

3. Results and discussion

3.1. Status and trends in MPA coverage

3.1.1. MPA and coastal habitat extent

As of January 2020, 7.3 % of Indonesian waters were contained within a network of 300 protected areas (Fig. 1A). In total, MPAs and terrestrial protected areas that incorporate coastal ecosystems covered 23.9 million ha of marine areas across 34 provinces. These protected areas consisted of 196 legally-designated MPAs (166 under MMAF and 30 under MoEF) and 104 protected areas under MoEF management designated under terrestrial protected area legal instruments but incorporating marine ecosystems. The majority of Indonesian MPAs are in nearshore areas—with 75 % of MPA extent within 12 nm of coastlines. MPAs are more heavily concentrated in eastern Indonesia (especially Nusa Tenggara Timur, Sulawesi Tenggara and Papua Barat Provinces; Table S4). Our results suggest Indonesia met the MPA area national target set in 2015 (20 million ha by 2020), but (as of January 2020) fell slightly short of the revised 2019 target (25.4 million ha by 2020; Table 1; Fig. 1B; Table S1).

Trends in MPA coverage through time demonstrate the motivating forces of national MPA targets and reflect the long and varied history of MPAs in Indonesia driven by changes in ministry involvement and priorities. The establishment of MPAs in Indonesia dates back to 1974, when the first legally-defined protected area incorporating marine ecosystems—Suaka Margasatwa (Wildlife Reserve) Pulau Baun, Maluku Province—was created. This included mangrove forests and was established using terrestrial protected area legal instruments under MoEF authority. The first legally-defined MPA in Indonesia was Taman Laut Banda, Maluku Province, which was established in 1977, also by MoEF. MoEF continued establishing protected areas that also covered coastal ecosystems during the 1980 s, and by the mid-1990 s, Indonesia had designated 24 formal MPAs encompassing 2.4 million ha [41]. Most of these MPAs focused primarily on coral reefs, with lower coverage of seagrass beds and mangrove forests [41]. The new designation of MoEF MPAs continued until the early 2000 s when the four largest marine national parks were created (Fig. 1B), Kepulauan Seribu (107,489 ha), Taka Bonerate (530,765 ha), Wakatobi (1390,000 ha), and Teluk Cendrawasih (1453,500 ha). By 2004, MoEF stopped initiating new MPAs and focused efforts on managing the existing MPAs under its control.

In 1999, the GoI established the Ministry of Marine Exploration, which later became MMAF. A primary focus of MMAF is to reduce the threats to marine resources through the development of MPAs, therefore MMAF assumed responsibility for new MPA designation from MoEF in the early 2000 s. The first MMAF MPA was Kawasan Konservasi Perairan Daerah (KKPD/Provincial MPA) Pesisir Selatan, Sumatra Barat Province, initiated in 2003. MMAF continued to establish new MPAs—with a target set in 2006 of 10 million ha of MPAs by 2010 (Table 1) [21]. In 2009 there was a transfer of management of eight MPAs from MoEF to MMAF, representing 0.7 million ha (Fig. 1B; [42]). By the end of 2010, Indonesia had established 180 MPAs covering 14.1 million ha (Fig. 1B), comprising 53 MPAs managed under MMAF, 30 MPAs under MoEF, and 97 terrestrially-designated MoEF protected areas that incorporate marine ecosystems.

Initially MPAs that were established were relatively small, with the average size of new MPAs increasing until about 2010. In the 1970 s, the average of newly designated MPA was 1800 ha, which increased to 46,000 ha in the 1980 s. In the build-up to achieving the national target of establishing 10 million ha of MPAs by 2010 (Table 1), average MPA size increased to 345,700 ha (Fig. 1B). This rapid increase in average MPA size was influenced by the designation of Laut Sawu MPA, which covers more than 3.3 million ha, during that period. Over the past decade (2010–2019), however, the average new designated MPA size decreased to 83,000 ha per MPA due to most MPAs being initiated by district or provincial governments (15 out of 18 MPAs) that have limitations on their jurisdiction. For example, MPAs initiated by the district government cannot span to other districts, meanwhile MPAs with an area that covers more than one district within the same province are under the provincial government's authority, but it cannot extend further to another province [43].

Challenges remain for the recognition of marine ecosystems within the 104 MoEF 'terrestrial' protected areas. These protected areas were designated using terrestrial protected area legal instruments (see [44] for legal instrument review) and are currently excluded from the GoI's national and international reporting towards MPA targets. Yet, these 'unrecognized' protected areas extend from land to offshore, protecting coral reefs (e.g. Bali Barat National Park) or mangrove forests (e.g. Sembilang National Park). Several of these MoEF 'terrestrial' protected areas contain extensive ocean areas and are managed as multi-use MPAs. For example, 72 % (124,275 ha) of Komodo National Park are ocean areas zoned for no take or sustainable fisheries. Our results presented here, therefore, are higher than previous MPA-specific protection estimates reported for Indonesia, given that we include all marine ecosystems under legally-recognized protected areas. The combination of a focus on legal status and separate reporting systems have likely led to this disconnect in marine protection reporting between MMAF and MoEF. Moving forward, it is important to develop a more holistic approach to define how protected areas are counted towards marine protection targets, acknowledging the significant marine areas that are currently under active management in MoEF protected areas.

3.1.2. Coastal habitat protection

Across Indonesia, 43 % (876,800 ha) of coral reefs, 37 % (48,300 ha) of seagrass beds, and 25 % (672,900 ha) of mangrove forests are included within protected areas (Fig. 2A). Therefore, while Indonesia has incorporated a substantial proportion of coral reefs and seagrass beds within MPAs, mangrove forests are currently the least protected. However, more than 17 provinces (17 provinces for coral reefs, 28 provinces for seagrass beds, and 25 provinces for mangrove forests) fall short of the IUCN World Conservation Congress 2016 to protect at least 30 % of each coastal marine habitat (Fig. 1A; Table 1; Table S4). These critical habitats play a vital role in supporting marine biodiversity and economically important fisheries commodities for coastal communities. Mangrove forests protect coastal areas by reducing wave exposure and also act as a buffer against land-based impacts, capturing sediment and protecting coral reefs and seagrass beds from smothering [7]. While seagrass protection in Indonesia appears to be over 30 %, this should be interpreted with caution. Seagrass beds in Indonesia have not been fully mapped because most of the areas are unsurveyed [45]. Much of the survey effort biased towards MPAs and adjacent areas, likely inflating the protected seagrass estimates.

Across Indonesia, 7 % of coral reefs, 7 % of seagrass beds, and < 1 % of mangrove forests are within non-extractive zones of MPAs (Fig. 2A). Our results show Indonesia has not yet met the regional Coral Triangle Initiative (CTI) target of at least 20 % of each major marine and coastal habitat in strictly protected "no-take replenishment zones" (Table 1). Central and eastern Indonesia had the highest coverage of coral reefs and seagrass beds within non-extractive zones, while the majority of provinces in western Indonesia included less than 1 % of these habitats within non-extractive zones (Fig. 2B; Table S4). Conversely, the proportion of mangrove forests included within non-extractive zones in western Indonesia was higher than in central or eastern Indonesia, though mangrove extent is much greater in central and eastern Indonesia than western Indonesia (Fig. 2B; Table S4). However, Susanto et al. [15], argued that designating 20 % protection of each major marine and coastal habitat may potentially decrease fisheries production due to less area that can be used as fishing ground.

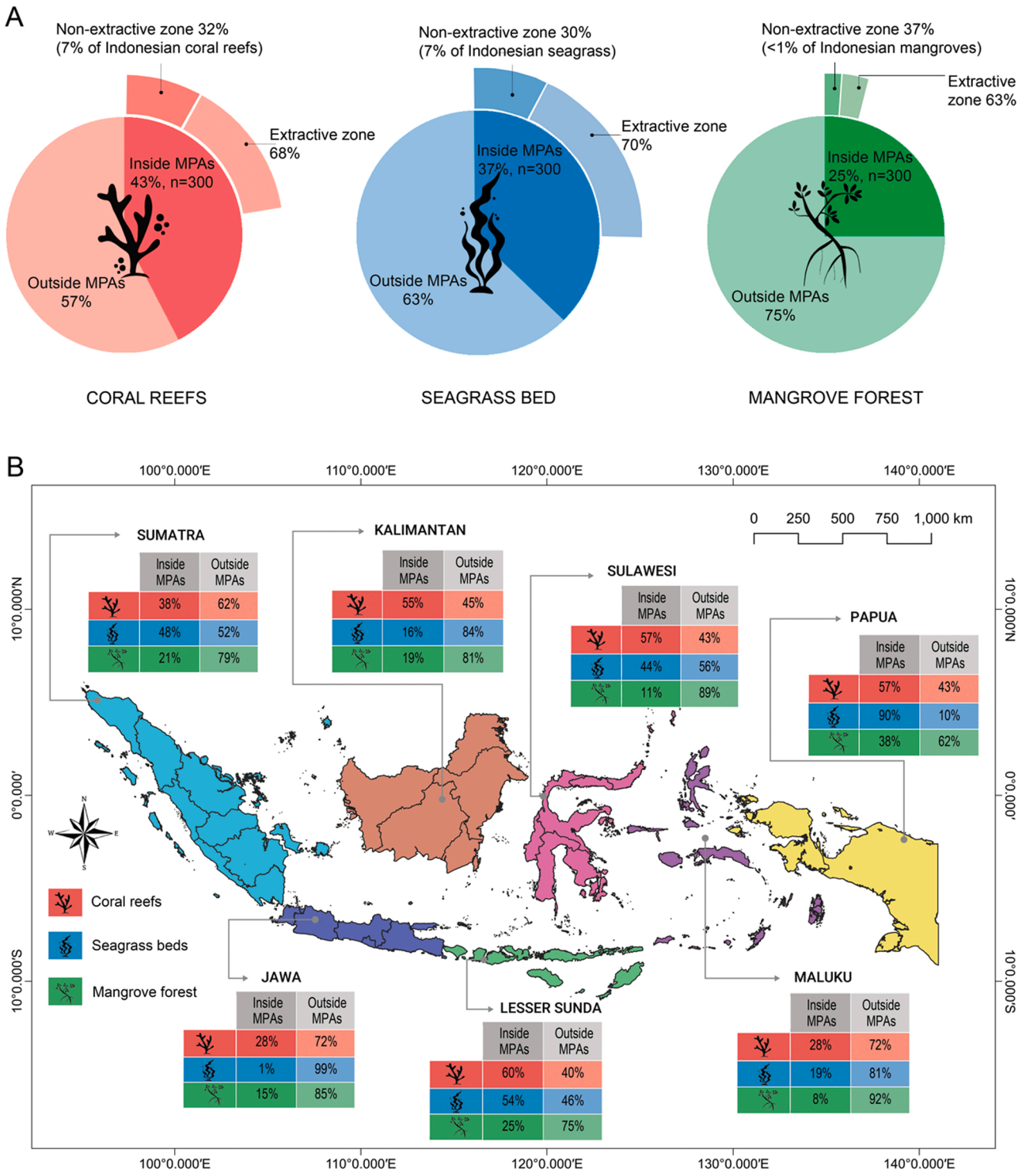

Fig. 2. (A) Protection level of national coastal marine habitats within MPAs in Indonesia. Percentages based on comparisons to total coastal habitat extent within provincial waters (see Table S4 for more detailed information), n = number of MPAs. (B) Coastal marine habitat protection included within MPAs by big island.

3.2. Progress of MPA management effectiveness in Indonesia

3.2.1. Trends in MPA stage of establishment and management effectiveness

As of January 2020, of the 122 E-KKP3K–assessed MPAs, no MPA had yet reached the 'managed optimally' (Blue level) or 'self-reliant' (Gold level). Most of them were still in the 'initiated' level (70 MPAs), 28 MPAs were in the 'established' level, and 24 were in the 'minimally managed' level (Fig. 3A; Table S5; Table S6). MPAs under 'initiated' level are in the earliest stages of establishment and are working to develop management plans and management units, and identify the formal outer MPA boundary together with related stakeholders. Once all initiation steps have been achieved, the MPA receives formal recognition as 'initiated' in a governor decree or MMAF ministerial decree, and vessels larger than 10 GT are excluded from the MPAs boundary for any fishing activity (though in some cases transit through the MPA is allowed except the Core Zone). However, there is limited enforcement at this stage [40]. MPA management authorities then work to build management capacity and conduct several rounds of consultations with stakeholders resulting

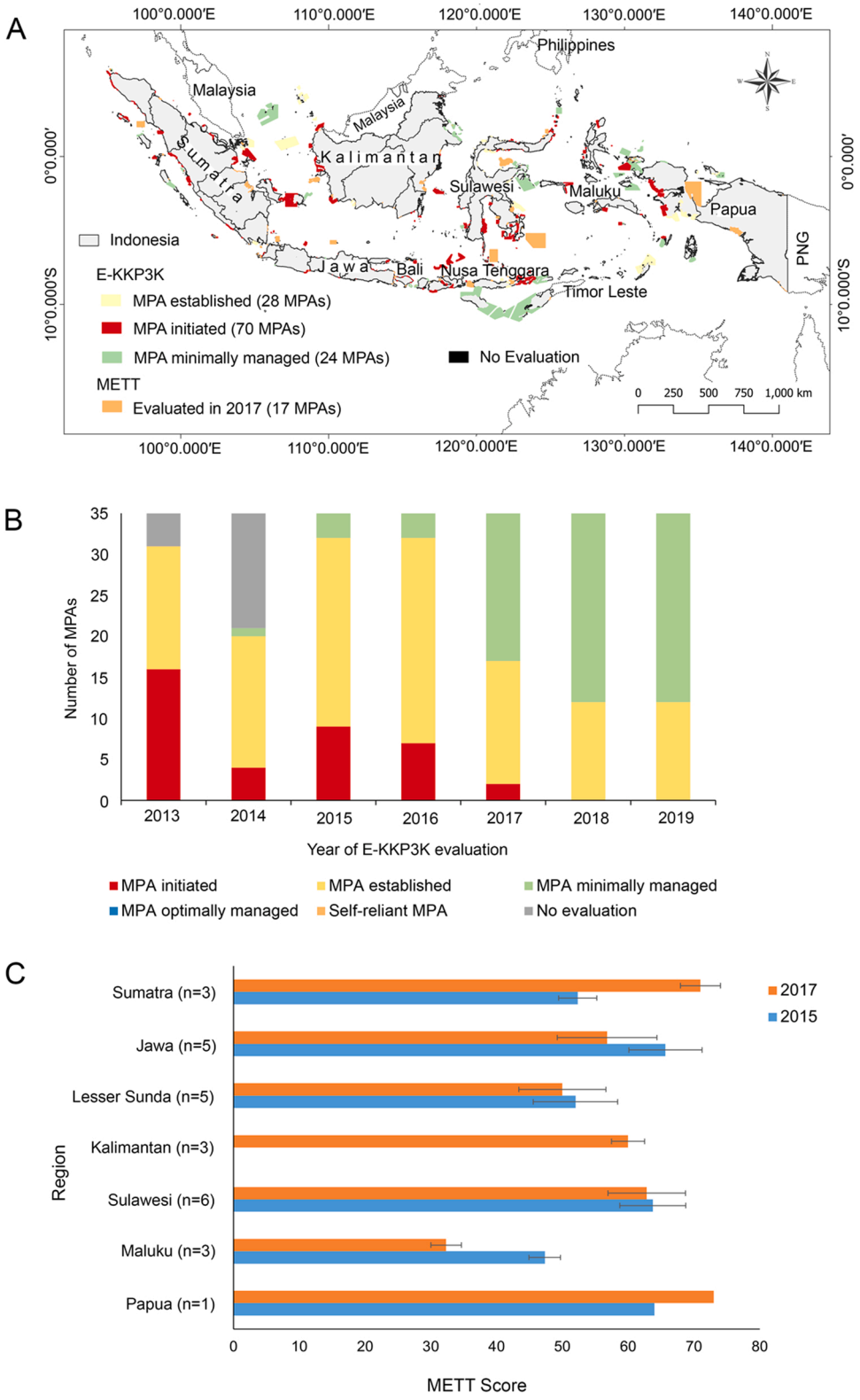

Fig. 3. (A) Map of Indonesian MPAs based on management effectiveness and proportion of protected areas coverage (see also Table S6 for more detailed information). (B) E-KKP3K trends of 35 priority MPA for 2013–2019. (C) METT trends for 2015–2017. METT scores are based on 26 (out of 30) MoEF recognized MPAs with available data.

in a zonation plan. These are required for the MPA to be formally 'established' through ministerial decree from MMAF, i.e., when the rules and regulations of the zonation plan come into force (Fig. S1;[46]).

Trends in management effectiveness across MMAF MPAs, based on the 35 nationally identified priority MPAs, indicate that they are generally increasing—though the majority of MMAF MPAs in Indonesia are not yet under active management. Annual assessments showed steady improvements between 2013 and 2019, from no 'minimally

managed' MPAs in 2013–23 in 2019 (Fig. 3B). It took an average of 3.1 years ± 2.5 SE (n = 18 MPAs) from 'initiated' level to become 'established' level and an average of 6.2 years ± 2.5 SE (n = 24 MPAs) to reach the 'managed minimally' level. However, these time estimates should be treated with caution, as the 35 MPAs are not representative of all MPAs in Indonesia. These MPAs are likely to have higher progress rates than typical MPAs in Indonesia, due to the increase in efforts and resources provided by the government and active support from non-government organizations (NGOs) [38].

Meanwhile, mean MoEF METT scores showed no significant changes between 2015 (57.12 ± 2.99 %; n = 17 MPAs) and 2017 (56.69 ± 3.32 %; n = 26 MPAs) (Fig. 3A; Fig. 3C). Leverington et al. [47] categorized METT scores < 33 % as 'clearly inadequate' management; 33–66% as 'basic management', and > 66 % as 'sound management'. Thus, based on those categories, the average of MoEF MPAs management effectiveness falls under the 'basic management' category. In 2015, MoEF set a target for its MPAs to achieve a METT score of ≥ 70 % by 2019 (Table 1). Across the 26 MoEF MPAs with data available in 2017, three scored < 33 %, 13 scored between 33 % and 66%, and 10 MPAs scored > 66 %. Nine out of the 10 MPAs with score > 66% have reached the 2019 target of ≥ 70 % METT score.

3.2.2. Improving MPA management effectiveness

Our results indicate that there has been slow progress in improving MPA management effectiveness and Indonesia still has a long path ahead to achieve effective management across all MPAs. However, substantial progress has been found in MPAs that have been established for longer periods of time and have sufficient resources (e.g., funding and technical support). To accelerate the improvement of MPA management effectiveness, the GoI has implemented several strategies. These strategies include (i) provincial consolidation in management capacity, (ii) increased institutional coordination, (iii) staff capacity building, and (iv) priority MPAs for targeted improvements. Governance structures for MPAs in Indonesia have changed in 2014, shifting to a more consolidated structure which transferred authority from district to provincial government (UU No.23/2014) [37], and impacting management effectiveness [48]. Provincial consolidation in management capacity has the potential to support better functioning management units and thus enhancing MPA management effectiveness long-term [49–51]. This includes increased opportunities for knowledge sharing and learning between MPAs, reduced impact of staff turnover within MPA management offices (management offices are now larger institutions that can build up 'institutional knowledge'), and more formalized pathways for capacity building efforts. However, there is some concern that this consolidation moves decision-making geographically and politically away from staff 'on the ground' in MPAs—potentially reducing local awareness of staff and their ability to respond adaptively and rapidly to changing local context, and creates another challenge regarding jurisdictional arrangements [52]. However, currently it is unclear on how this situation will impact management effectiveness of MPAs moving forward. Given these institutions' arrangements changed in 2014, it would be expected that any gains in management effectiveness should now start to become apparent.

Efforts to increase institutional coordination to improve MPA management effectiveness take several forms. MMAF MPAs can either be managed by the relevant provincial government fisheries office or under direct national management of MMAF (via a local MPA management office that answers to MMAF in Jakarta). MoEF MPAs are managed directly by MoEF with on ground management implemented by the Technical Implementation Unit that reports directly to MoEF [50]. This management system creates redundancies between authorities, resources, and policy, negatively influencing MPA management effectiveness [18]. Provincial consolidation of MMAF MPA management offices has already improved coordination across management of different MPAs within a province and with managers of regional fisheries management areas (*Wilayah Pengelolaan Perikanan*). Marine Affairs and Fisheries Provincial Offices (*Dinas Kelautan dan Perikanan Provinsi*) may also form Technical Implementation Units (*Unit Pelaksana Teknis;* UPT) to improve coordinated MPA management. Further strengthening of coordination and work plans between technical implementation units, provincial government, different MMAF departments (e.g. regional fisheries, marine spatial planning), MoEF, and other relevant inter-sectoral ministries (such as Ministry of Tourism, Ministry of National Development Planning) are important to improve management effectiveness of MPAs [53,54].

There are increasingly formalized programs for MPA management staff capacity building across Indonesia. In recent years, several new MPA 'learning centers' have been established. These are partnerships between provincial governments, NGOs, and regional universities that provide professional training to MPA managers and formal MPA management qualifications. Learning centers supported by WWF-Indonesia and Coral Triangle Center in partnership with MMAF have been established in Sulawesi Tenggara (Akademi Komunitas Kelautan dan Perikanan), Nusa Tenggara Timur (Artha Wacana Kupang Christian University), and Maluku (Sekolah Tinggi Perikanan Hatta-Syahrir). Additionally, MMAF implements a staff rotation scheme aimed at building staff capacity through gaining knowledge and experiences from changing roles or geographical locations staff are based in.

To accelerate MPA management effectiveness, MMAF has identified 35 priority MPAs for focused improvements (Fig. 3C). Most of these MPAs have the support of NGOs working with MPA management staff, and are spread across Indonesia. The 35 priority MPAs have annual management effectiveness assessments to support rapid identification and responses to management gaps. This approach allows these 35 MPAs to act as demonstration sites, where MPA management staff and MPA learning centers can learn or teach best practices for MPA management. MPA management staff can then take the skills learned from these priority MPAs to other MPAs in their province—allowing rapid diffusion and scaling of management capacity.

3.3. A path forward to support MPA progress in Indonesia

Indonesia has made substantial progress in area-based components of the national MPA target of 23.4 million ha by 2020 and under international targets (e.g., Aichi Target 11; Table 1; Table S1). While the next round of targets is still being debated, there is a strong global push behind a new global target of 30 % ocean protection by 2030, building on momentum from the International Union for the Conservation of Nature (IUCN) World Conservation Congress resolution in 2016 (Table 1; Table S1). Progress over recent decades suggests Indonesia is well placed to meet area components of future targets. However, despite the rapid expansion of MPAs that contribute towards area targets, Indonesia has not yet realized its full potential in achieving the qualitative aspects of MPA targets. Indonesia's national MPA estate is currently not fully representative or fully effective. Moving forward, increased focus on the non-area components of national and international targets will be key for Indonesia to achieve the desired 'sustainable management of fisheries resources and environmental outcomes' (PP RI No. 60/2007) [19] from the national MPA network.

3.3.1. Balancing MPA outcomes with extent

While both MPA expansion and improvement of management effectiveness are important for Indonesia to reach its national MPA targets, a greater focus needs to be given to the latter. This includes progressing the stage of establishment of already initiated MPAs that are not yet delivering desired outcomes. Reaching the higher levels of management effectiveness criteria (e.g. 'managed minimally', 'optimally managed', or 'self reliant' based on E-KKP3K or reaching a METT score more than 70 %) are associated with active management, higher staff capacity, and sustainable finance. The large number of MPAs at early stages of establishment limits the expected outcomes from the current MPA network and hinders some MPA targets. For example, the

shortfall in the CTI regional targets is largely due to the lack of zonation within MPAs (only 30 % of MPAs are zoned). Therefore, the pathway to achieve a higher level of protection targets requires focus on achieving 'MPA established' status, the completion and implementation of zonation plans for the 70 % MPAs currently unzoned, and improvements in their management effectiveness.

Evaluation results are more valuable if they combine both management effectiveness and outcome (ecological and social) assessments [55,56]. Both E-KKP3K and METT provide information on management activities, processes, and perceived outcomes, but provide limited information on measured ecological and social outcomes of the MPA. Increased MPA management effectiveness is generally expected to increase MPA effectiveness [55] — i.e., good management is normally a prerequisite for an MPA to deliver desired outcomes. Therefore, while management effectiveness assessments can be a good proxy for MPA effectiveness, monitoring of social and ecological outcomes provide a better understanding of progress towards achieving MPAs goals to inform adaptive management, as well as provide more opportunities for learning about conditions that lead to success or failure. For example, through regular social and ecological monitoring, effectively managed MPAs can be demonstrated to improve the economic condition of local communities through enhanced fisheries catch rates [57,58]. This is due to fish spillover effects – with individual fish and fish larvae moving from the no-take zone to surrounding areas [57,59]. Benefits that local communities experience are important for influencing support for protecting marine resources, leading to more compliance with MPA regulations [30,57]. Evaluation of management effectiveness can also be enhanced by involving other local stakeholders, such as resource users and community groups, to give their perspectives of the performance of the management authority [60]. This reduces biases associated with self-reporting (e.g., MPA managers perceiving better management unit performance than other stakeholders [60]), and reduces subjectivity in the assessment result [61,62]. This approach can also benefit the MPA by promoting compliance, communication, and strengthened relationships with the local communities, which in turn helps build effective and equitable management [63].

Where future MPA expansion is required, it should be focused on increasing representativeness and connectivity of coastal habitat protection. Currently, Indonesia's MPA network is not fully representative—neither geographically nor for coastal ecosystem inclusion. Protection of coastal habitats is highly variable between provinces, with higher protection in central and eastern Indonesia, where a relatively small number of very large MPAs make substantial contributions. In contrast, protection in western Indonesia is lower and should be a target for future protection efforts. In terms of ecosystem representation, future protection should focus on expanding mangrove forest protection. Given that the majority of MPAs in Indonesia are established to support sustainable fisheries, this should provide impetus for protecting mangrove forests as key nursery habitats for many fisheries species [64]. Incomplete maps of seagrass beds in Indonesia means our protection assessment is likely to be an overestimate. Compiling standardized remote sensed seagrass maps for Indonesia is a knowledge gap that needs to be addressed.

3.3.2. Challenges and opportunities for monitoring, evaluation, and learning

MPAs need regular and timely monitoring, evaluation, and learning to inform adaptive management [62]. Often assessment results collected in the field have to be formally verified by the central government before they are allowed to be discussed openly by MPA management authorities and shared with partners (e.g., NGOs, key community stakeholders). This can add up to extensive delays between data collection and release. Different policies on data accessibility between MMAF and MoEF also limit efforts to track MPA progress through time. Reductions in the processing time for official verification of evaluation documents and commitments to share data openly and transparently would be beneficial in identifying where weaknesses are—allowing them to be addressed rapidly before management and credibility are eroded. NGOs, working in partnership with MMAF, have produced several dashboard reports to track the status and trends in MPA management effectiveness and outcomes (e.g., [65,66]). These reports can holistically inform provincial government decision-makers and partners on key indicators from MPAs to help influence resource allocation and priorities. In addition, there are several case study approaches using impact evaluation to identify the causal effects of MPAs (e.g., [67,68]). These monitoring, evaluation, and learning approaches should be built upon to inform adaptive management.

Standardization and consistency of MPA management effectiveness tools would also aid greater national and regional tracking. This is especially important since MPAs in Indonesia are managed under two ministries (MMAF and MoEF) that use different approaches to management, staff training, and assessment tools for management effectiveness. The newly adopted *Efektivitas Pengelolaan Kawasan Konservasi* (EVIKA) tool by MMAF to replace E-KKP3K offers greater promise of standardization as it follows a framework similar to the METT used by MoEF. However, adopting a new tool to track MPA management effectiveness raises concerns that data collected going forward will not be comparable with existing management effectiveness trends assessed from 2013 to 2019 using E-KKP3K—potentially limiting insights and slowing adaptive management. Additionally, the newly launched MPA Guide provides a set of standardized criteria and language that can be used to track the stage of establishment of an MPA—including assessing whether an MPA is actively managed [69]. While not directly an MPA management effectiveness assessment, this standardized framework can help with assessing and tracking management levels of different MPAs in an internationally recognized and standardized way. Much of the information required to complete an assessment against the MPA Guide is already collected by existing E-KKP3K or METT tools, and so this approach does not require additional data collection—only processing already collected assessment data in new ways (e.g., [70]).

3.3.3. Improving institutional coordination

There are many other government initiatives affecting coastal marine conservation in addition to MPAs. These initiatives include ecosystem-focused protection targets through national/provincial laws, broader regional fisheries management objectives, and also province-specific declarations. Yet these other initiatives are rarely coordinated with MPA planning and management, reducing opportunities for synergistic impact.

Marine ecosystem protection could be better coordinated with other marine management strategies such as Fisheries Management Areas (FMA; *Wilayah Pengelolaan Perikanan*). FMAs are management units under development by MMAF to manage fisheries activities of medium and large fishing vessels from the shoreline towards the offshore ocean areas. FMAs have the potential to support biodiversity conservation and sustainable fisheries, as they regulate fishing effort through quotas and gear restrictions. MPAs are spread throughout the FMAs—meaning that decisions made in either MPA or FMA management may have impacts on the outcomes of the other. Recent studies show that MPAs contributed towards the increase in Indonesia's total fish biomass and reef fish trophic structure [65,71]. However, there is little understanding of the contribution of MPAs to reef fisheries within FMAs in Indonesia [50].

Another example of potential institutional coordination could lead to better conservation outcomes is mangrove forests protection. While many MPAs in Indonesia are designated to protect mangroves, in part to reach specific protected area targets for mangroves under the CTI Regional Plan of Action, there are additional initiatives at all levels of government focused on mangroves. For example, at the national level the Indonesian National Mangrove Action plan [72], jointly implemented by MoEF and MMAF, sets national targets to protect and restore Indonesian mangrove forests. Indonesia's President set ambitious new mangrove restoration targets in 2020 for the Peatlands and Mangrove

Restoration Agency (*Badan Restorasi Gambut dan Mangrove*/BRGM) to achieve mangrove rehabilitation of 600,000 ha by 2024 [73]. These national initiatives for mangrove protection and restoration are not directly targeted at protected areas, but also consider regency and provincial mangrove protection laws and restoration in any suitable area regardless of protected area status. These nationally-implemented activities are coordinated by different directorates (and so different groups of staff) at MMAF and MoEF to those responsible for MPA management. This means despite many MPAs including specific zones for habitat restoration and intentionally protecting mangroves, this work currently has limited coordination with national mangrove efforts. Additionally, at the provincial and local level there are other mangrove-specific activities. For example, the governors of Papua and West Papua provinces signed the Manokwari Declaration on October 10th, 2018, which commits the provinces to protect 70 % of their forest cover including mangroves [73]. Therefore, there is great potential for better alignment and coordination mechanisms between these initiatives and MPA management authorities for both coordinated planning and implementation of mangrove conservation initiatives.

3.3.4. Improving equitable MPA governance

MPA implementation requires equitable involvement of all stakeholders from the initiation of the MPA to the establishment process and monitoring and evaluation, which also builds effective and active management. Involving communities in the MPA design process and ensuring it incorporates their needs can lead to greater compliance and reduce potential conflict between and among stakeholders [15,32,74–77]. Therefore, MPA rules and regulations need to be adaptable based on changing local context. At present, all legally recognized MPAs in Indonesia require governance by either MMAF or MoEF [44]. While there are opportunities for co-management, these are currently broadly instructive (where mechanisms are in place for dialogue with stakeholders but tends to be government informing users of decisions they will make) or consultative (mechanisms exist for the government to consult with users but decisions are taken by the government) [78]. Moving forward, there is great potential to improve state-governed MPA outcomes by adopting cooperative co-management—where government and users cooperate as equal partners in decision-making [15,78]. Broadened approaches to co-management can increase the equitability of MPAs by helping them rapidly respond and tailor to changing local contexts.

While we focus on state-governed MPAs, there is increased interest in other governance approaches to MPAs that meet the IUCN MPA definition (IUCN WCPA 2018). These other approaches already exist within Indonesia – such as governance by local communities or the private sector, but are currently unrecognized by the Government of Indonesia as MPAs. These different governance models may be more appropriate to ensure that MPA implementation and decision-making take account of local peoples' needs, build on existing customary management within areas, and are sustainably financed. Recognition of other governance types—where appropriate—could play an important role in further enhancing biodiversity protection in Indonesia.

Other Effective Area-Based Conservation Measures (OECMs) could potentially lead to official recognition of other forms of governance and their contribution towards Indonesian marine conservation [79,80]. OECMs are areas that do not usually have biodiversity conservation as a primary objective but nevertheless play a major role in supporting long-term biodiversity conservation. Many Indonesian communities have a rich history of implementing natural resource management systems free from formalized government recognition that meet the definition of OECMs. Where these customary managed areas are located within formal MPAs they are often recognized as distinct zones under community management, and so contribute to marine protection as MPAs. However, many of these customary governance systems for marine resources occur outside of formal MPAs [80]. Locally Managed Marine Areas (LMMAs) can also be considered as OECMs as they are managed by local communities to promote sustainable fisheries, including in some cases designating areas as fisheries no-take zones [81]. Many other area-based management types also have the potential to be recognized as OECMs in Indonesia. For example, dive sites outside of MPAs that attract high levels of tourism and so generate income for local communities are often protected from fisheries and other harmful activities (e.g., Tulamben, Bali), or religious sites, or military sites. When sustainably managed, these areas can contribute to biodiversity conservation in the long term [15].

4. Conclusion

By tracking the expansion and effectiveness of MPAs, Indonesia is well-positioned to make informed decisions as to where to increase efforts to improve MPA outcomes. MPAs in Indonesia have expanded rapidly over the last decade; though increasing focus on the qualitative components of national and international MPA targets will lead to greater biodiversity protection and benefits. In addition, significant efforts are still required to manage these MPAs effectively. Positively, the GoI is committed to addressing this issue. This study recommends balancing between MPA expansion and management effectiveness improvement. MPA expansions should focus more on the representativeness and connectedness between coastal habitats in terms of the spatial distribution of MPAs and coastal habitats inclusion (i.e., more mangrove forests protection). Meanwhile, improving management effectiveness will require a greater focus on formulating and implementing zonation plans, strengthening and improving the monitoring and evaluation system, ensuring smooth conversion of data from E-KKP3K to EVIKA, improving coordination and communication between government institutions, expanding collaboration with related stakeholders, and recognizing OECM to contribute towards Indonesian marine conservation.

CRediT authorship contribution statement

Amkieltiela: Conceptualization, Methodology, Formal analysis, Data interpretation, Writing – original draft, Revision. **Christian N. Handayani**: Conceptualization, Methodology, Formal analysis, Data interpretation, Writing – original draft, Revision. **Dominic A. Andradi-Brown**: Conceptualization, Data Interpretation, Writing – original draft, Writing – review & editing, Supervision. **Estradivari**: Formal analysis, Writing – review & editing. **Gabby N. Ahmadia**: Conceptualization, Writing – review & editing, Supervision. **Amanda K. Ford**: Data interpretation, Writing – review & editing. **Maria Beger**: Data interpretation, Writing – review & editing. **Amehr Hakim**: Data interpretation, Writing – review & editing. **Dominic K. Muenzel**: Data interpretation, Writing – review & editing. **Eleanor Carter**: Data interpretation, Writing – review & editing. **Firdaus Agung**: Data interpretation, Writing – review & editing. **Laura Veverka**: Data interpretation, Writing – review & editing. **Mohamad Iqbal**: Data interpretation, Writing – review & editing. **Muhammad E. Lazuardi**: Data interpretation, Writing – review & editing. **Muhammad N. Fauzi**: Data interpretation, Writing – review & editing. **Sylvie N. Tranter**: Data interpretation, Writing – review & editing. All authors contributed to the article and approved the submitted version.

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Appendix A. Supporting information

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