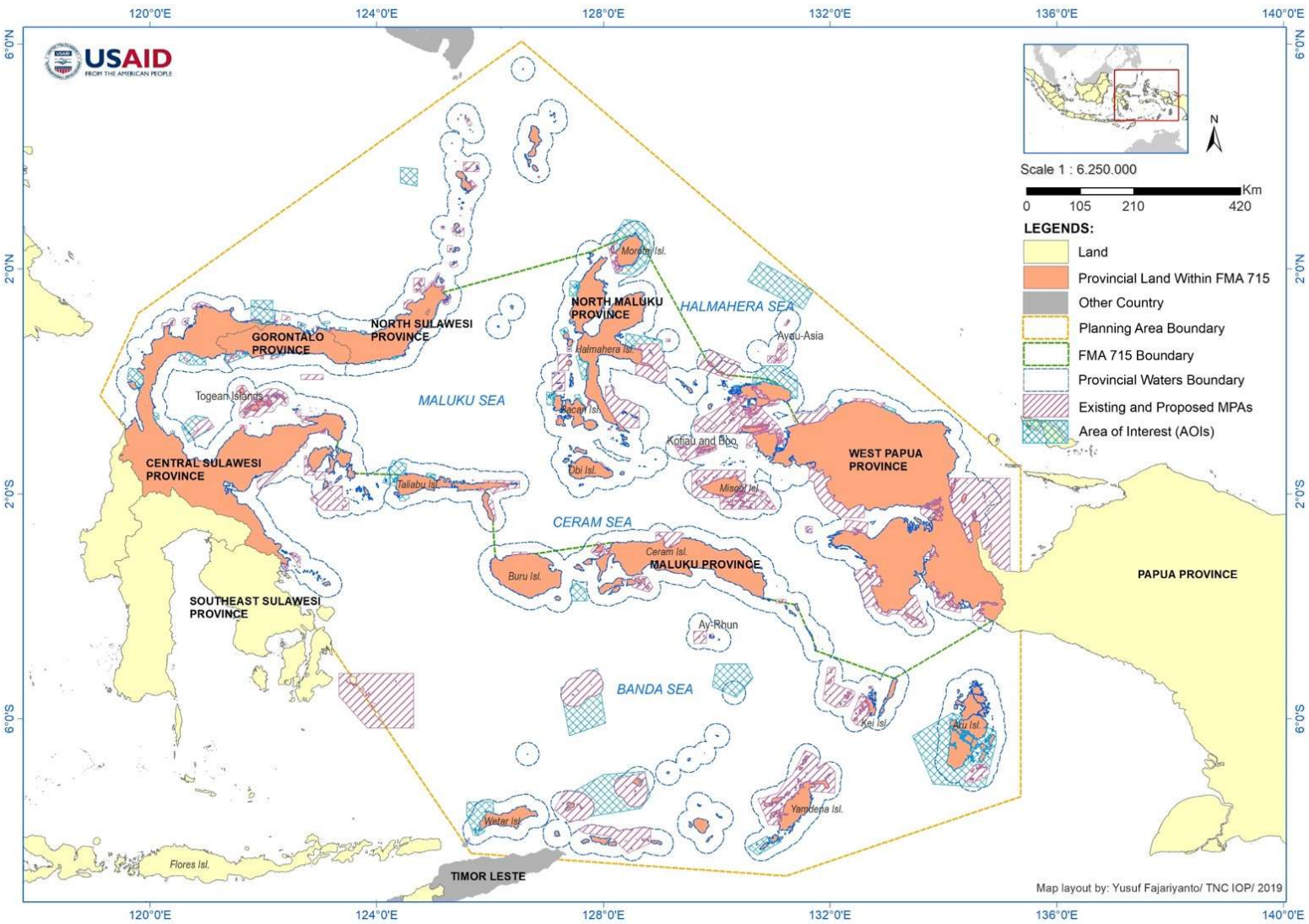




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DESIGNING A NETWORK OF MARINE PROTECTED AREAS FOR FISHERIES MANAGEMENT AREA 715 AND SIX ASSOCIATED PROVINCES IN INDONESIA



USAID SUSTAINABLE ECOSYSTEMS ADVANCED (SEA) PROJECT

Prepared by The Nature Conservancy (TNC) Indonesia Oceans Program and the Coral Triangle Centre (CTC) for the USAID Sustainable Ecosystems Advanced (SEA) Project.

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Cover Map: MPA network design for Fisheries Management Area 715 and the six associated provinces (West Papua, Maluku, North Maluku, North Sulawesi, Central Sulawesi and Gorontalo), including existing and proposed MPAs and Areas of Interest for establishing new MPAs.

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EXECUTIVE SUMMARY

The Ministry of Marine Affairs and Fisheries uses three spatial approaches to managing marine resources in Indonesia:

- Fisheries Management Areas (FMAs) were established to manage catch fisheries, mariculture and other uses at the national and regional scale, integrated with management at the provincial level.
- Marine Spatial Plans allocate spatial designations for multiple uses [such as for conservation areas (MPAs), oil and gas mining areas, shipping transportation lanes, etc.] and provides them with legal protection from other types of development.
- Marine Protected Areas (MPAs) and MPA Networks play a major and expanding role in conservation and management in Indonesia. The national government is committed to establishing 20 million hectares of effectively managed MPAs by 2020, and 30 million hectares by 2030.

Indonesia currently has no regulation or guidance regarding how to integrate these three spatial planning instruments. Although, existing and proposed MPAs must be allocated as Conservation Areas in the Marine Spatial Plans.

Fisheries Management Area 715 (FMA715) is located in eastern Indonesia, where it intersects the waters of six provinces (West Papua, Maluku, North Maluku, North Sulawesi, Central Sulawesi and Gorontalo). Each of these provinces has a Marine Spatial Plan that includes both existing and proposed MPAs.

FMA715 was selected as the focus of the USAID Sustainable Ecosystems Advanced (SEA) Project, because it comprises one of the richest fisheries areas in Indonesia, some of the highest marine biodiversity on Earth, and critical habitats for charismatic, rare, threatened and protected species (e.g., sea turtles, cetaceans, manta rays, whale sharks). These rich marine resources provide important economic and social benefits for coastal communities.

Unfortunately, many of these critically important resources, and the ecosystem services they provide, have been lost, seriously degraded or are threatened by a combination of local anthropogenic threats and global changes in climate and ocean chemistry. For example, FMA715 has nine types of commercial fisheries, seven of which are overexploited.

MPAs can be powerful tools for managing marine resources to protect biodiversity, enhance fisheries, adapt to changes in climate and ocean chemistry, support sustainable community livelihoods and traditional cultures. But only if they are well designed and effectively managed. The aim of this study is design an MPA network for FMA715 and the six associated provinces to:

- Support fisheries management and biodiversity protection in FMA715;
- Refine the MPA networks and Marine Spatial Plans for each of the six provinces that intersect with FMA715; and
- Inform the design of a national network of MPAs.

Where:

- The planning area spans 1,823 km from east to west, and encompasses an area of 1,6 million km² (161.3 million hectares), which is 49.5% of Indonesia's marine waters.

- Conservation features to protect are: shallow water habitats ($\leq 200\text{m}$: coral reefs, mangroves forests and seagrass beds); deepwater habitats ($>200\text{m}$: seamounts, canyons etc.); and critical, special and unique areas [i.e., fish spawning areas (spags), turtle nesting beaches, coelacanth distribution and walking shark distribution areas, dive sites, shipwrecks, seaworm fishing areas, important traditional areas (i.e., mystical areas) and local wisdom areas (i.e., sasi)].
- Local threats to conservation features include overfishing and destructive fishing practices, poaching, waste, mangrove logging, sedimentation, mining etc.
- Areas allocated for other uses in Marine Spatial Plans where MPAs cannot be established include military areas, transportation and fishing ports, oil and gas mining areas, underwater cable pipe lanes, sea mine areas (unexploded ordinance) and reclamation areas.

To design the MPA network, we conducted a marine gap analysis to maximize protection of the conservation features while avoiding threats and minimizing impacts on fisheries and other uses. To do this we started with the existing and proposed MPAs in the provincial Marine Spatial Plans for each province, then identified Areas of Interest to fill gaps in the MPA network using:

- The goals and design criteria provided in *A Framework for Designing Marine Protected Area and Marine Protected Area Networks in Indonesia*;
- More than 160 spatial data layers for conservation features, threats and other uses;
- Participatory expert mapping in the provinces;
- The systematic conservation planning tool Marxan; and
- Input and review by 100s of MPA practitioners and scientists from national, provincial and local governments, national and provincial universities, and NGOs.

Where Areas of Interest are potential areas for establishing new or expanded MPAs, because they comprise important biophysical, socioeconomic and/or cultural sites not currently protected within existing or proposed MPAs in the Marine Spatial Plans.

Here we provide, for the first time, a MPA network design for FMA715 and the associated six provinces (see *Front Cover*). This MPA network design, if it is implemented and managed effectively, will contribute substantially towards achieving the goals for MPAs and MPA networks in Indonesia. In particular, the MPA network is designed to:

- Increase protection of biodiversity, by increasing the level of protection of shallow water habitats, deepwater habitats, and critical, special and unique areas. In particular, it will increase the protection of important deepwater features (i.e., seamounts and canyons) currently under-represented in existing and proposed MPAs in Indonesia.
- Maintain or enhance fisheries by increasing the protection of stocks of fisheries species in MPAs, which will lead to the export of adults, juveniles and larvae to support fisheries in adjacent waters. It will also minimize impacts on commercial and subsistence fisheries, by avoiding placing MPAs in areas with high fishing intensity (as much as possible) and maintaining access to fisheries ports.
- Support community livelihoods by improving management of marine resources (habitats and populations of fisheries species), and allowing access to important areas for fishing and tourism (i.e., dive sites).
- Acknowledge and support adat, by protecting local wisdom and important traditional areas in MPAs.

The MPA network design for FMA715 and the associated six provinces includes:

- All 122 of the existing and proposed MPAs already allocated in the provincial MSPs (comprising 10.1 million hectares); and
- 44 Areas of Interest (comprising 5.3 million hectares) for establishing new MPAs in the six provinces. They were selected to increase protection of conservation features not currently protected in existing and proposed MPAs, particularly deepwater habitats (i.e., seamounts and canyons) and critical, special and unique areas (i.e., coelacanth and walking shark distribution areas, local wisdom areas etc.). If these Areas of Interest are established as new MPAs, they will increase the total area of existing and proposed MPAs in FMA715 and the six provinces from 10.1 to 15.4 million hectares. However, before they are established they need to be validated (ground-truthed to ensure they will provide the expected benefits for the MPA network), and proposals for new MPAs need to be discussed appropriately with local stakeholders.

We evaluated the MPA network design using a posthoc analysis in Marxan and the *Evaluation Tool for Marine Protected Area and Marine Protected Area Network Design in Indonesia*. The results show that the MPA network is relatively well designed to address the biophysical and socioeconomic goals and design criteria, particularly regarding:

- Representing and replicating shallow water habitats; protecting critical areas for fisheries, charismatic, endangered, threatened or protected species; incorporating connectivity; and protecting healthy areas and avoiding local threats; and
- Supporting multiple environmentally-friendly uses and livelihoods; ensuring local communities have access to resources and markets; protecting marine heritage sites, local wisdom areas and areas that have important traditional cultural value for local communities.

However:

- Some conservation features (i.e., seamounts, canyons, spags, wrecks, local wisdom or important traditional areas) could not be included in Areas of Interest because they are located in areas allocated for other uses in the Marine Spatial Plans or where there are high levels of use (i.e., marine traffic and fishing pressure).
- Some design criteria could not be applied throughout the entire planning area because we did not have the spatial data required (i.e., regarding areas with environmentally friendly uses or where stakeholders support establishing MPAs). Although, these criteria were considered when identifying Areas of Interest using participatory mapping in three of the provinces (West Papua, Maluku and North Maluku). These aspects will need to be discussed in more detail with local stakeholders when considering Areas of Interest for new or expanded MPAs or zoning MPAs in each province.
- Some design criteria could not be applied at all, because we did not have the information required (particularly regarding changes in climate and ocean chemistry).

If the MPA network design is implemented and effectively managed, it will contribute to achieving many goals including protecting biodiversity, enhancing fisheries, and supporting the livelihoods and traditional culture of coastal communities. Therefore, we recommend that the MPA network design should be:

- Integrated within the management plan for FMA715 to help protect biodiversity and improve fisheries management in this area;
- Used to develop or refine MPA networks in each of the six provinces, and integrated within their Marine Spatial Plans when they come up for review.
- Used to identify priority areas for MMAF to achieve their goal of establishing 10 million hectares of new MPAs in Indonesia by 2030.

Lessons learned include:

- How to integrate MPA network design at multiple scales in Indonesia using design guidelines developed at the national level to design MPA networks at regional and provincial scales.
- How to design MPA networks by combining both a bottom up approach using participatory mapping at local and provincial scales with a top down approach using systematic conservation planning at a regional scale (for FMA715 and the six provinces).
- There is a lot of overlap between some high priority areas for protection in MPAs (i.e., seamounts) and areas already allocated for other uses in Marine Spatial Plans and/or where there are high levels of threat. Therefore, many conservation features cannot be protected within MPAs. This issue needs to be addressed by the Government. Meanwhile, MPAs should be integrated with other approaches to manage these other uses and threats.

This the first iteration of a MPA network design for FMA715 and the associated six provinces, and one of the most detailed systematic conservation planning processes undertaken at this scale in Indonesia to date. However, there are some limitations to the design due to the limited time and resources available for the data analysis, which could be improved in future if more time and resources become available e.g., by developing and refining the spatial data layers, refining the Marxan analysis, and addressing research priorities (particularly regarding understanding more about larval dispersal and the effects of changes in climate and ocean chemistry on habitats and species).

INTRODUCTION

Indonesia comprises some of the world's most diverse tropical marine ecosystems, which are a global priority for conservation (Allen and Erdmann 2012; Veron et al. 2015). These rich marine resources provide important economic and social benefits for coastal communities, including food and revenue from capture fisheries (commercial and subsistence) and aquaculture, tourism, minerals, oil and gas, transport and shipping (Mangubhai et al. 2012; ADB 2014). Thus health, nutrition, food security, economic growth, and community welfare in Indonesia all depend upon sustainable use of marine resources.

Unfortunately, many of these critically important resources, and the ecosystem services they provide, have been lost, seriously degraded or are threatened by a combination of local anthropogenic threats (i.e., destructive or overfishing, mass tourism, coastal development and land based runoff) and global changes in climate and ocean chemistry (Burke et al. 2012, ADB 2014).

The USAID Sustainable Ecosystems Advanced (SEA) Project was established to advance sustainable fisheries management through conservation of marine biodiversity. The primary objectives of the project are to:

- Support enhanced conservation and sustainable use of marine resources by reforming fisheries management and promoting Marine Protected Areas to enhance fisheries productivity, food security, and sustainable livelihoods within the target area¹; and to
- Support strengthening the leadership role and capacity of the Ministry of Marine Affairs and Fisheries (MMAF) and local governments to promote conservation and sustainable fishing.

This will require integrating three spatial approaches to marine resource management by MMAF regarding: Fisheries Management Areas, Marine Protected Areas and Marine Spatial Plans.

Spatial Management of Marine Resources in Indonesia

Fisheries Management Areas

The Food and Agriculture Organization of the United Nations (FAO) delineates 19 fishing areas around the world, two of which occur in Indonesia: #57 (Indian Ocean, Eastern) and #71 (Pacific, Western Central). MMAF followed FAO's international standard for dividing these fishing areas into Fisheries Management Areas in Indonesia, also known as Wilayah Pengelolaan Perikanan (WPP). These Fisheries Management Areas were originally defined based on landing sites, and subsequently refined using ecology, main commodity (type of fisheries), bathymetry and other characteristics of the area².

All of Indonesia waters are divided into 11 Fisheries Management Areas declared by Permen 18/2014. This includes provincial waters (0-12nm from shore) and national waters (>12-200nm), which encompasses both deep (>200m) and shallow (≤200m) water habitats.

¹ Fisheries Management Area 715 and three focal provinces (West Papua, Maluku and North Maluku) in eastern Indonesia.

² <https://kumparan.com/saiful-umam1527864839130/mengenal-kode-angka-wilayah-pengelolaan-perikanan-di-indonesia-1rdn7hzgVrT>

These Fisheries Management Areas were established to manage catch fisheries, mariculture, conservation, research and fisheries development at the national and regional scale, integrated with management at the provincial level. Each Fisheries Management Area has a management plan, and MMAF is working towards establishing one management authority for each Fisheries Management Area.

The Fisheries Management Area management plans identify the status of each commercial fishery as either overexploited, fully exploited or moderately exploited (Figure 1), and provide recommendations for managing these fisheries at national, regional and provincial levels. For example, these recommendations are used to inform permits that can be issued by each province in the Fisheries Management Areas (where provinces have authority to issue permits for vessels up to 30 Gross Ton in size).

Marine Protected Areas and Marine Protected Area Networks

Marine Protected Areas (MPAs), particularly no-take zones (NTZs), can be powerful tools to address local threats and enhance fisheries productivity, protect biodiversity and increase ecosystem resilience to changes in climate and ocean chemistry (Green et al. 2014, 2019a). They can also enhance food security and sustainable livelihoods for communities and other stakeholders. MPA networks, collections of individual MPAs that are ecologically connected, can deliver additional benefits (e.g., by acting as mutually replenishing networks to facilitate recovery after disturbances: see review in Green et al. 2019a).

MPAs and MPA Networks play a major and expanding role in conservation and management in Indonesia. The national government is committed to establishing 20 million hectares of effectively managed MPAs by 2020, and 30 million hectares by 2030. To date, there are 177 existing national and local government MPAs (and no MPA Networks) established in Indonesia, covering an area of 22.8 million hectares (updated from MMAF 2018: <https://kkp.go.id/djprl/kkhl>). These MPAs are managed at the national level by the Ministry of Marine Affairs and Fisheries (MMAF: 5,578,816 hectares) and the Ministry of Environment and Forestry (MOEF: 4,612,869 hectares), as well as by Provincial Governments (12,594,497 hectares). MMAF is now in the process of identifying and establishing new MPAs to achieve their target of 30 million hectares in MPAs by 2030, and is interested in reviewing the design of existing MPAs. Local communities have also established Locally Managed Marine Areas (LMMAs) in many locations, particularly in eastern Indonesia.

However, MPAs and MPA networks can only achieve their objectives if they are well designed and effectively managed (Green et al. 2019b). Unfortunately, many of Indonesia's MPAs are not yet managed effectively due to a lack of staff capacity and resources to support monitoring, enforcement, administration, community engagement and sustainable tourism activities (Green et al. 2019b). More scientific advice is also required to ensure that MPAs are well designed to achieve their goals and objectives (Green et al. 2019a,b).

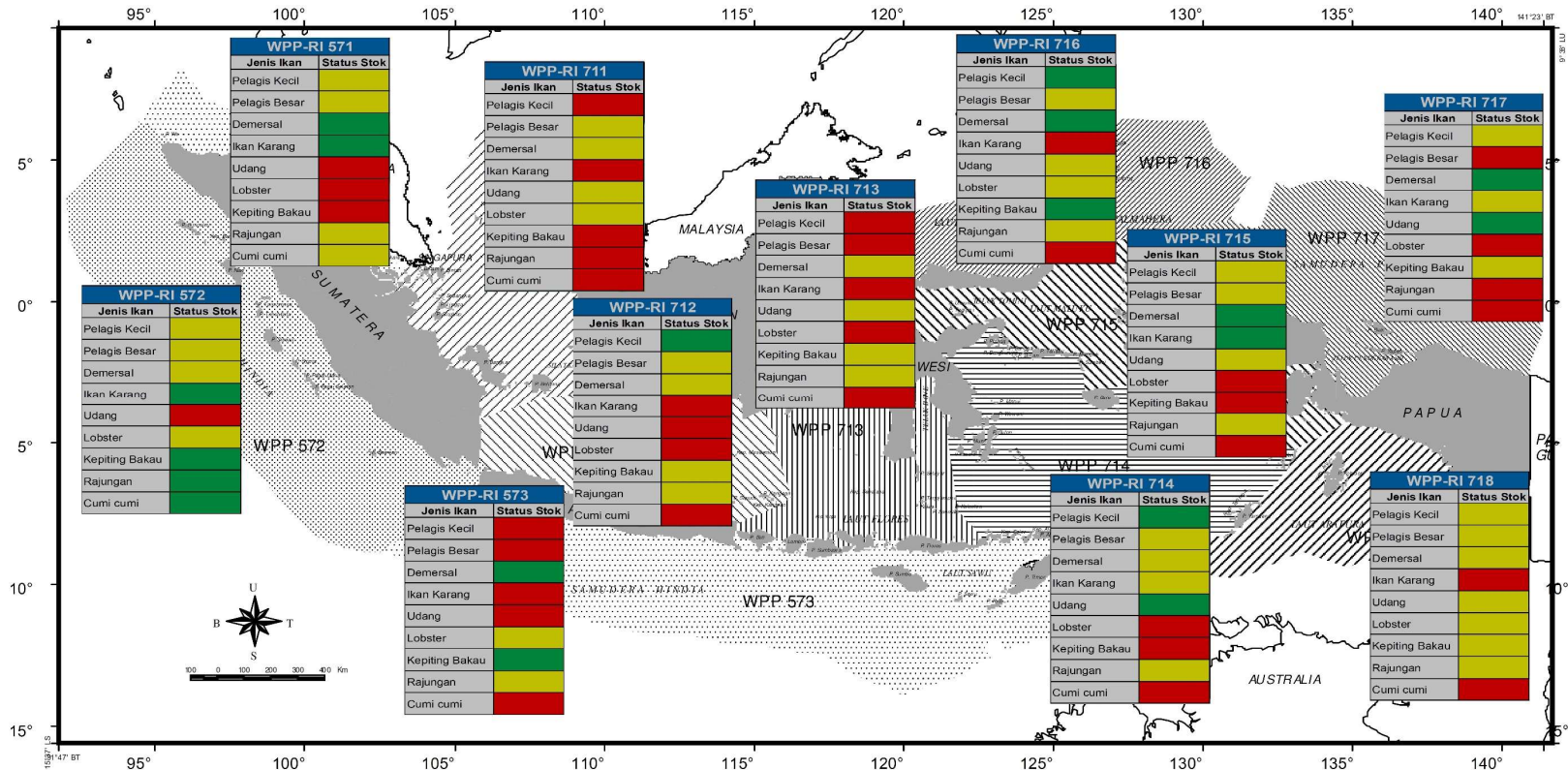


Figure 1. Fisheries resources in each Fisheries Management Area (FMA) in Indonesia are considered either overexploited (red), fully exploited (yellow) or moderately exploited (green) (Suman et al. 2016).

Recently, with technical assistance from The Nature Conservancy through the SEA Project, MMAF developed *A Framework for Designing Marine Protected Area and Marine Protected Area Networks in Indonesia* (Green et al. 2019b). This document provides a simple, easy to use logical framework (goals and objectives, design criteria and performance indicators) for managers to use to design MPAs and MPA networks in Indonesia, which takes biophysical, socioeconomic and cultural considerations into account. This framework will be provided as supplementary information to support the *Technical Guidelines of Ministerial Regulation No. 13/2014 on Establishing and Managing MPA Networks* (MMAF in prep.), and has already been used to design MPA networks for three provinces (West Papua, Maluku and North Maluku) and 14 individual MPAs in these provinces in FMA715 (see Green et al. 2019b).

Marine Spatial Plans

The National Marine Spatial Plan for Indonesia comprises three components, which are included in the national marine spatial planning database (One Map Policy):

- Provincial Marine Spatial Plans: In order to ensure protection and sustainability of marine and fisheries resources in Indonesia, each Provincial Government is required to develop a Marine Spatial Plan. These plans are for coastal waters (0-12nm from shore), which are managed by the province (except where they are areas of strategic national importance: see below).
- Area Marine Spatial Plans: These plans are developed for national waters (>12-200nm from shore), which are managed by the national government,
- Strategic National Marine Spatial Plans: These plans are for areas of strategic national importance such as outer islands near national borders or military bases. These areas may also be included in Provincial Marine Spatial Plans (see above), but they are managed by the national government.

The Marine Spatial Plans allocate spatial designations for multiple uses that have legal standing [such as for conservation areas (MPAs), traditional adat areas, general utilization areas, strategic national areas, shipping transportation lanes, etc.] and provides them with legal protection from other types of development.

The Marine Spatial Plans will be used as the basis for all planning and management decisions regarding the utilization of marine resources in Indonesia, and the government will not grant or approve permits that are incompatible with the zoning in these plans.

Integrating Fisheries Management Areas, Marine Protected Areas and Marine Spatial Plans

Indonesia currently has no regulation or guidance regarding how to integrate MMAF's three spatial planning instruments: MPAs, Marine Spatial Plans and Fisheries Management Areas.

However, both existing and proposed MPAs must be allocated as Conservation Areas in the Marine Spatial Plans. This ensures that these MPAs are supported by stakeholders, and they are allocated for conservation for 20 years (with "revisions" allowed once every 5 years). Where:

- Existing MPAs have already been established; and

- Proposed MPAs have not yet been established.

The design of MPA networks for the three focal SEA Project Provinces (West Papua, Maluku and North Maluku) demonstrates how to integrate MPA network designs and Marine Spatial Plans in Indonesia (TNC/SEA 2018a,b, 2019 a, b, c). To do this, we:

- Started with the existing and proposed MPAs in the provincial Marine Spatial Plans; and
- Identified gaps in the MPA network for each province using the goals and design criteria in *A Framework for Designing Marine Protected Area and Marine Protected Area Networks in Indonesia* (Green et al. 2019b) and participatory expert mapping.

The results are MPA network designs for each province that include the existing and proposed MPAs in the provincial Marine Spatial Plans, and Areas of Interest for establishing new MPAs (see *Existing and Proposed Marine Protected Areas, and Areas of Interest for Establishing New Marine Protected Areas*).

There is now a need to refine these provincial MPA network designs, and demonstrate how to use MPAs and Marine Spatial Plans to support fisheries management and conservation in Fisheries Management Areas since:

- MPAs can be powerful tools for conservation and enhancing fisheries in Fisheries Management Areas; and
- Marine Spatial Plans can provide an umbrella for integrating MPAs and Fisheries Management Areas, which both include spatial management areas for fisheries, mariculture, conservation and research.

Designing A Marine Protected Area Network for Fisheries Management Area 715 and Six Associated Provinces

Aim

The aim of this study is to use *A Framework for Designing Marine Protected Area and Marine Protected Area Networks in Indonesia* to design a network of MPAs to:

- Support fisheries management and biodiversity protection within FMA715 (including both national and provincial waters);
- Refine the MPA network design and Marine Spatial Plans for each of the six provinces (which include provincial waters only) that intersect with FMA715; and
- Inform the design of a national network of MPAs.

Designing a network of MPAs at this regional scale (for FMA715 and the associated six provinces combined), will allow large scale considerations to be taken into account in MPA network design including:

- Incorporating patterns of connectivity of fisheries, charismatic, rare, threatened and protected species (e.g., turtles and cetaceans) across provincial, regional (Fisheries Management Areas) and national boundaries (e.g., see Green et al. 2019a); and
- Protecting critical, special and unique areas that are important for conservation at the regional, national or international scale (i.e., critical areas for charismatic, rare, threatened and protected species: see Green et al. 2019a).

Study Area

Fisheries Management Area 715 (FMA715, also known as WPP715) was selected as the focus of the USAID SEA Project, because it comprises one of the richest fisheries areas in Indonesia and some of the highest marine biodiversity on Earth.

FMA715 is located in eastern Indonesia, and includes the waters of Tomini Bay, Maluku Sea, Halmahera Sea, Seram Sea, and Berau Bay (Permen 18/2014: Figure 2). FMA715 intersects the waters of six provinces (see Cover): West Papua, Maluku, North Maluku, North Sulawesi, Central Sulawesi and Gorontalo.

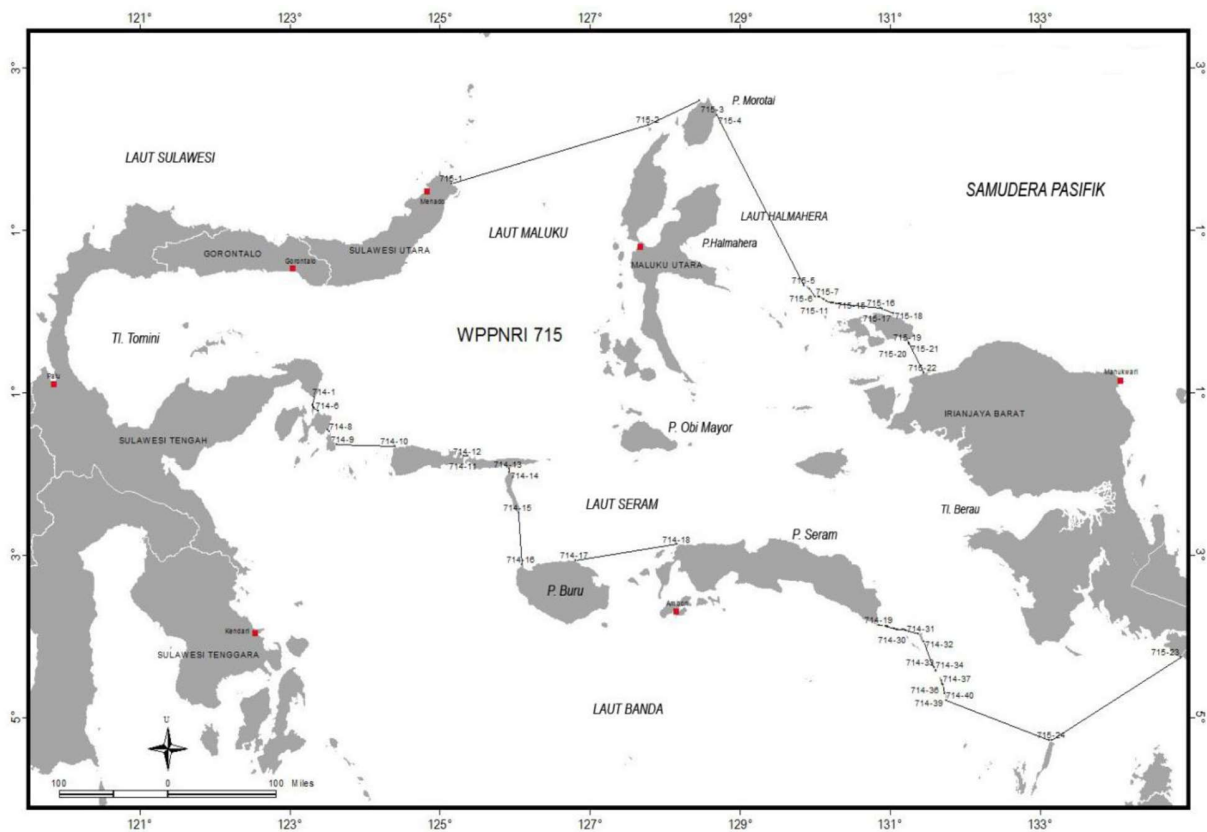


Figure 2. Fisheries Management Area 715 (FMA715, also known as WPPNRI715).

FMA715 has nine types of commercial fisheries (for demersal, coral reef, small pelagic and large pelagic fishes, squid, shrimp, lobsters, mangrove and sand crabs). Seven of these fisheries are overexploited (particularly pelagic and deepwater fisheries: Figure 1).

FMA715 is also in the heart of the Coral Triangle and comprises some of the world's most diverse tropical marine ecosystems (coral reefs, mangroves and seagrasses: Burke *et al.* 2012, Veron *et al.* 2015) as well as critical habitats for charismatic, rare, threatened and protected species (e.g., sea turtles, cetaceans, manta rays, whale sharks: Mangubhai *et al.* 2012). These rich marine resources provide critically important food and livelihoods for coastal communities (Mangubhai *et al.* 2012, ADB 2014). Unfortunately, these resources and the ecosystem services they provide are threatened by a combination of local anthropogenic impacts (including habitat loss,

overharvesting, destructive fishing, coastal development, mass tourism, mineral, oil and gas exploration and mining) and global changes in climate and ocean chemistry (Burke *et al.* 2012, Mangubhai *et al.* 2012, ADB 2014).

Indonesia comprises 12 marine ecoregions, which are areas of relatively homogeneous species composition clearly distinct from adjacent systems (Spalding *et al.* 2007, Figure 3). Species composition in each ecoregion is likely to be determined by the ecosystems present and/or a distinct suite of oceanographic or topographic features. Seven of these ecoregions occur within the study area, with two to three ecoregions occurring in each province (Table 1, see also Figure 2 and Figure 3).



Figure 3. Marine ecoregions of Indonesia.

Table 1. Marine ecoregions that occur in each of the six provinces that intersect with FMA715.

Province	# of Ecoregions	Ecoregion Names
West Papua	2	Papua and Halmahera
Maluku	3	Banda Sea, Arafura Sea and Lesser Sundas
North Maluku	2	Halmahera and Papua
North Sulawesi	2	Sulawesi Sea/Makassar Strait and NE Sulawesi/Tomini Bay
Central Sulawesi	3	Sulawesi Sea/Makassar Strait, NE Sulawesi/Tomini Bay and Banda Sea
Gorontalo	2	Sulawesi Sea/Makassar Strait and NE Sulawesi/Tomini Bay

Existing and Proposed Marine Protected Areas, and Areas of Interest for Establishing New Marine Protected Areas

Each of the six provinces whose waters intersect with FMA715 have Marine Spatial Plans that identify existing and proposed MPAs. However, since these MPAs were established or proposed independently, they were not designed to form ecological networks (e.g., see TNC/SEA 2019a). Although the latest science and best practices has been used to zone some individual MPAs (i.e., the five components of the Raja Ampat Islands Marine Tourism Park: see Grantham et al. 2013, Mangubhai et al. 2015). Furthermore, since each of these Marine Spatial Plans focus on individual provinces, they do not take regional biophysical, socioeconomic and cultural considerations into account, such as large scale patterns of connectivity of fisheries, charismatic, rare, threatened and protected species.

Recently, TNC through the SEA Project, worked with local, provincial and national stakeholders to use *A Framework for Designing Marine Protected Area and Marine Protected Area Networks in Indonesia* (Green et al. 2019b) to design MPA networks for each of the SEA Project's three focal provinces in FMA715 using participatory expert mapping (West Papua, Maluku and North Maluku: see Figure 4, Figure 5 and Figure 6). These MPA network designs include:

- Existing and proposed MPAs included in the Provincial Marine Spatial Plans; and
- Areas of Interest for establishing new MPAs.

Where Areas of Interest were identified as potential areas for establishing new or expanded MPAs, because they comprise important biophysical, socioeconomic and/or cultural sites that are not currently protected within existing or proposed MPAs in the Marine Spatial Plans, where communities are likely to support establishing new MPAs (TNC/SEA 2018 a, b). These Areas of Interest, if established as well designed and managed MPAs, will help ensure that the provincial MPA networks are designed to achieve their goals (see *Identifying Goals and Design Criteria*). However, before these Areas of Interest are established as MPAs, they need to be validated (ground-truthed to ensure they will provide the expected benefits for the MPA network) and proposals for new MPAs need to be discussed appropriately with local stakeholders.

MPA networks have not yet been designed for the other three provinces that intersect with FMA715 (North Sulawesi, Gorontalo and Central Sulawesi Provinces). However, TNC and CTC have worked with these provinces to identify (see Figure 7):

- Existing and proposed MPAs included in their provincial Marine Spatial Plan; and
- New areas identified as proposed MPAs by provincial fisheries agencies (DKP), local universities and other stakeholders (i.e., areas important for biodiversity conservation and fisheries management) that have not yet been incorporated in the provincial Marine Spatial Plans.

In this study, we refine or develop MPA network designs for each province using the best available spatial data and the systematic conservation planning tool Marxan.

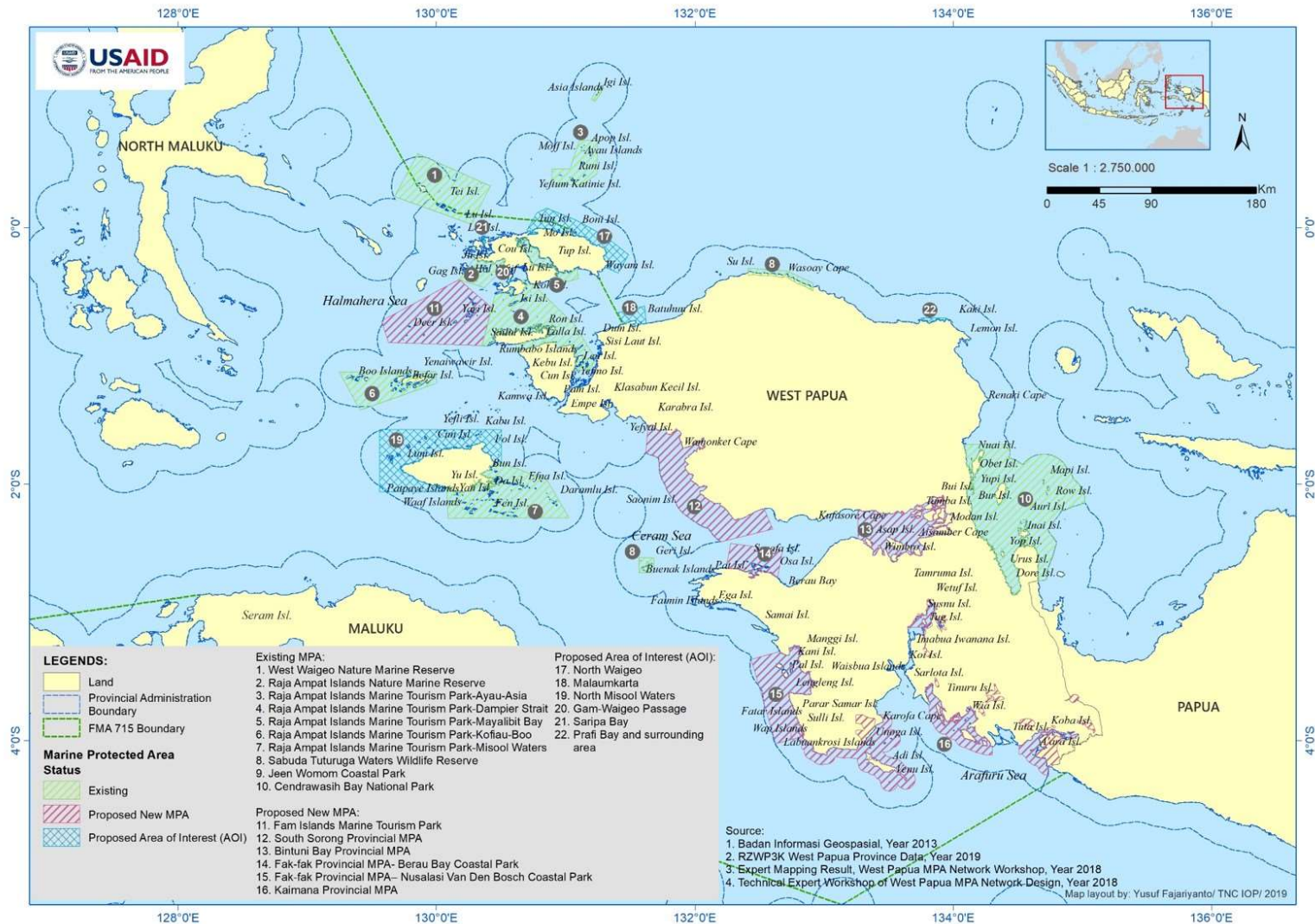


Figure 4. West Papua Province: existing and proposed MPAs in the provincial Marine Spatial Plan and Areas of Interest for establishing new MPAs identified using participatory expert mapping (TNC/SEA 2018a, 2019a).

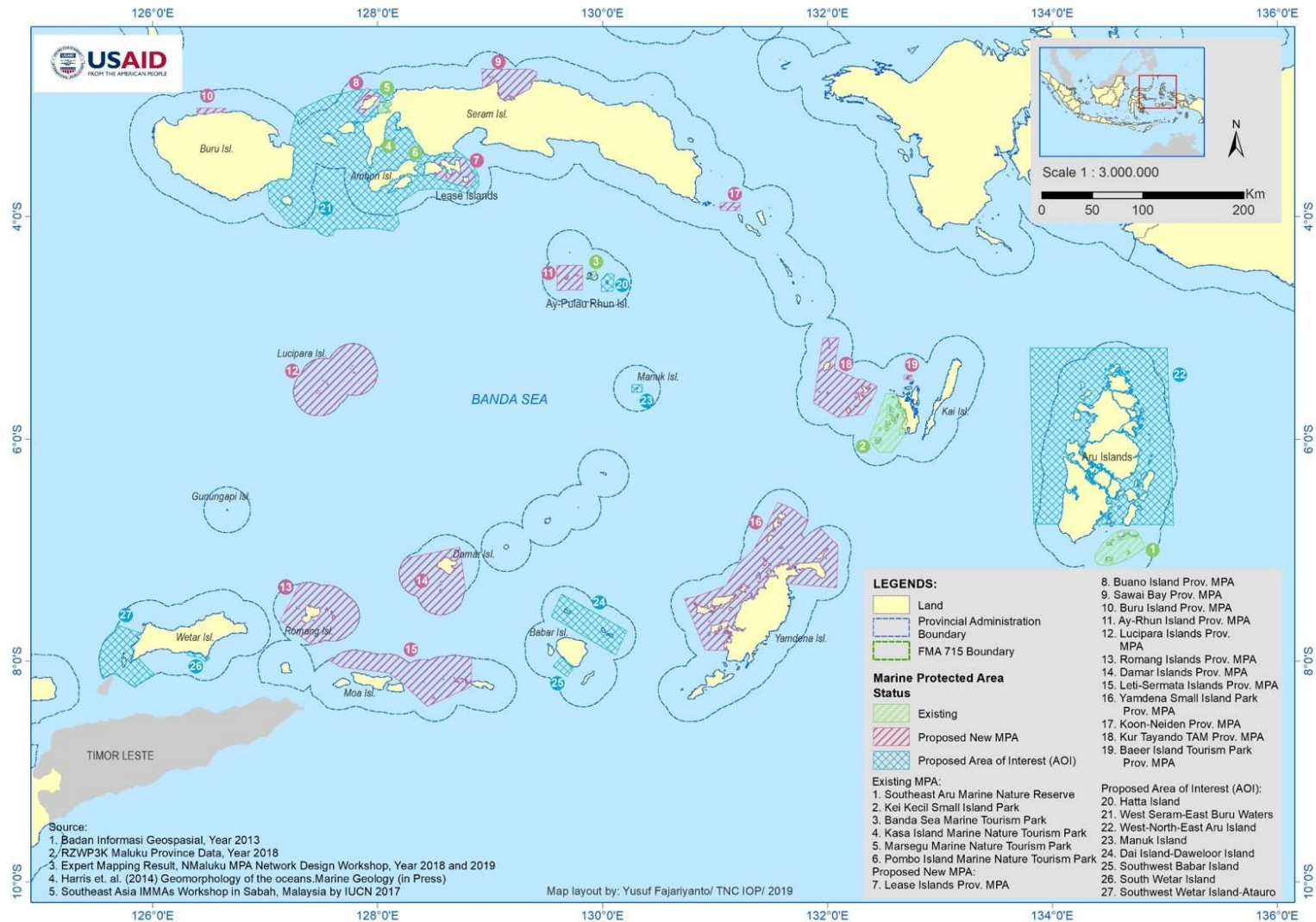


Figure 5. Maluku Province: existing and proposed MPAs in the provincial Marine Spatial Plan and Areas of Interest for establishing new MPAs identified using participatory expert mapping (TNC/SEA 2018b, 2019c).

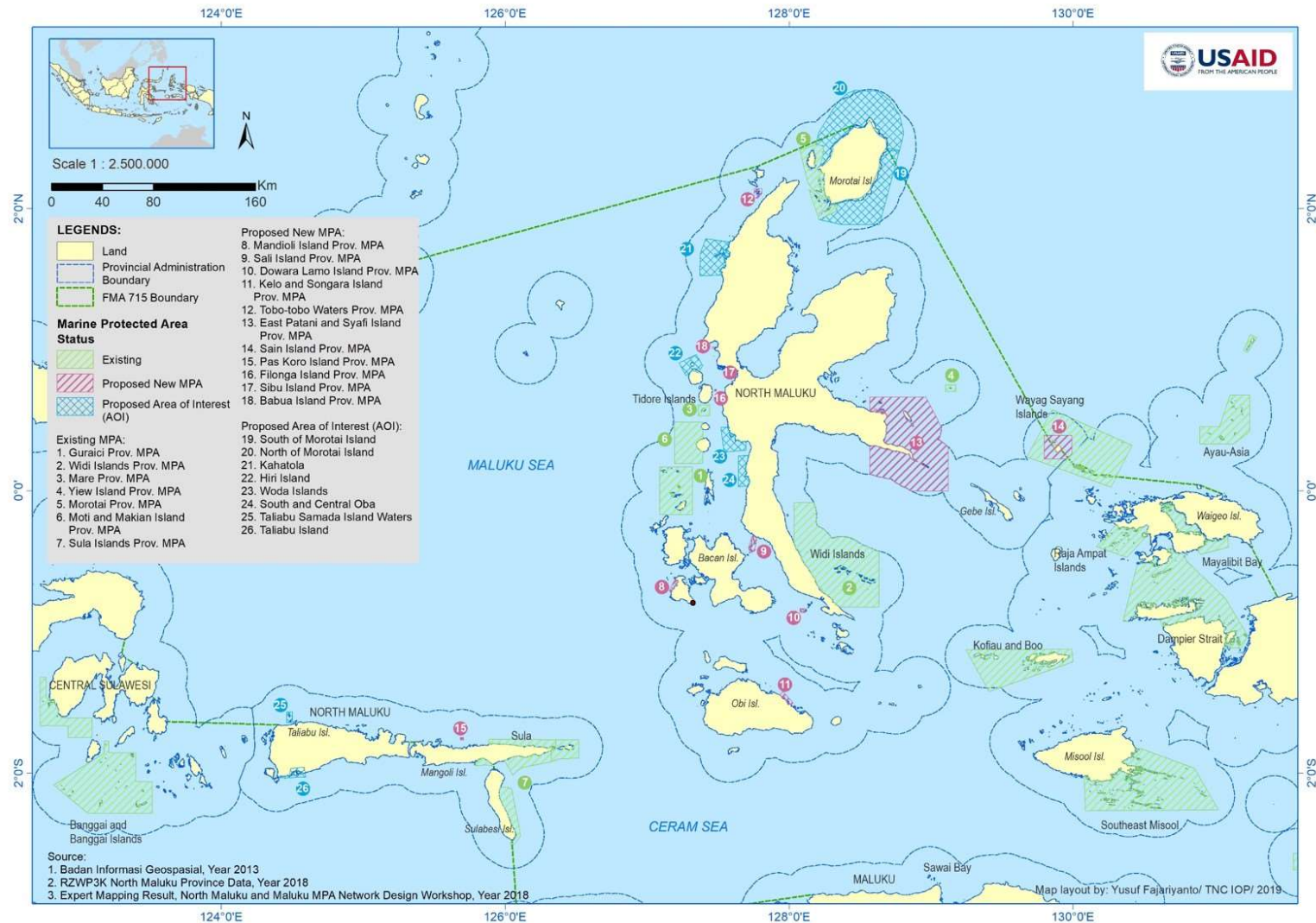


Figure 6. North Maluku Province: existing and proposed MPAs in the provincial Marine Spatial Plan and Areas of Interest for establishing new MPAs identified using participatory expert mapping (TNC/SEA 2018b, 2019b).

METHODS

We used the a five step process to design a MPA network for FMA715 and six associated provinces by:

- Identifying the goals, and the design criteria required to achieve these goals.
- Delineating the planning area and stratification units.
- Identifying the conservation features to protect, and threats and other uses to avoid.
- Compiling and processing the spatial data layers needed to apply the design criteria.
- Analyzing the data and designing an MPA network using the systematic conservation planning tool Marxan, reviewing the results at a scientific workshop, and manually refining the results.

Identifying Goals and Design Criteria

The first step in designing a MPA network for FMA715 and the six associated provinces is to clearly define the goals, and the design criteria required to achieve these goals. To do this, we used the biophysical, socioeconomic and cultural goals and design criteria provided in *A Framework for Designing Marine Protected Area and Marine Protected Area Networks in Indonesia* (Green et al. 2019b: Tables 2-4).

Table 2. Biophysical, socioeconomic and cultural goals for designing MPAs and MPA Networks in Indonesia.

Goals	
Biophysical	<i>Protect critical ecosystems, habitats, biodiversity, species, and abiotic resources.</i>
	<i>Maintain, enhance or restore productivity and biomass of coastal fisheries.</i>
	<i>Rehabilitate ecosystems, habitats and populations of focal and protected species</i>
	<i>Adapt and mitigate to changes in climate and ocean chemistry.</i>
Socioeconomic and Cultural	<i>Facilitate minimal or no conflicting use of marine resources and fisheries.</i>
	<i>Support sustainable community livelihoods based on (biotic and abiotic) marine resources.</i>
	<i>Promote active community participation and support in MPA or MPA network management (including adat by acknowledging local wisdom in planning and implementation).</i>

Table 3. Biophysical criteria for designing MPAs and MPA Networks in Indonesia.

Please note that many of these criteria are designed to consider the ecology of focal species. They include: key fisheries species (fish and invertebrates); endangered, threatened and protected species and/or migratory marine biota (sea turtles, marine birds, cetaceans, dugong and crocodiles); large charismatic marine fauna (sharks, manta rays, whale sharks or *Mola mola*); species important for maintaining ecosystem function i.e., habitat forming species (e.g., corals) or species important for reef resilience (e.g., herbivores).

Consideration	Biophysical Design Criteria
Represent Habitats	<i>Protect at least 20% of each major habitat in NTZs (e.g., each type of coral reef, mangrove forest, estuary or seagrass bed).</i>
Replicate Habitats (Spread the Risk)	<i>Protect at least three examples of each major habitat in NTZs; and Spread them out to reduce the chances they will all be affected by the same disturbance (such as major storms, mass coral bleaching events and crown-of-thorns starfish outbreaks).</i>
Protect Critical, Special and Unique Areas	<i>Protect critical areas in the life history of focal fisheries species in NTZs (e.g., spawning and nursery areas).</i>
	<i>Protect critical areas or habitats for charismatic, endangered, threatened or protected species (e.g., breeding, feeding or resting areas, or migratory corridors).</i>

Consideration	Biophysical Design Criteria
	<p>Protect special and unique natural phenomena in NTZs [e.g., areas with very high biodiversity, high endemism, unique marine communities or high productivity (e.g., unique pelagic habitats i.e., upwelling, fronts, eddies)].</p> <p>Protect areas that are important at the national, international or global scale for conservation or management of focal species (e.g., World Heritage Areas, critical habitats for globally endangered species, or critical areas for maintaining connectivity of fisheries species across national boundaries).</p>
Incorporate Connectivity: Abiotic Factors	Consider variations in oceanography (i.e., currents, tides, temperature, salinity and acidity), substrate and bathymetry that affect the spread of biological and non-biological material.
Incorporate Connectivity: Movement of Adults and Juveniles	<p>Ensure NTZs are large enough to sustain adults and juveniles of focal fisheries species within their boundaries.</p> <p>Ensure NTZs are large enough to contain all habitats used by focal species throughout their life history (e.g., for home ranges, nursery grounds and spawning areas); or</p> <p>Establish networks of NTZs close enough to allow for movements of focal species among protected habitats (e.g., through ontogenetic habitat shifts and spawning migrations).</p> <p>Include whole ecological units (such as reefs or seamounts) in NTZs. If not, chose larger versus smaller areas.</p> <p>Use compact shapes (such as squares) for NTZs, except when protecting naturally elongated habitats.</p>
Incorporate Connectivity: Larval Dispersal	<p>Establish:</p> <ul style="list-style-type: none"> • NTZs large enough to be self-sustaining for focal species; or • Networks of NTZs close enough to be connected by larval dispersal. <p>Protect spatially isolated areas in NTZs.</p> <p>Protect larval sources in permanent or seasonal NTZs or by using fisheries closures during spawning times.</p> <p>Locate more NTZs upstream relative to fished areas if there is a strong, consistent, unidirectional current.</p>
Allow Time for Recovery	<p>Establish NTZs for the long term (>20 to 40 years), preferably permanently.</p> <p>Use short term (<5 years) or periodically harvested NTZs in addition to, rather than instead of, long-term or permanent NTZs</p>
Protect Healthy Areas and Avoid Local Threats	<p>Protect areas where habitats and populations of focal species are in good condition with low levels of local threats (e.g., from overfishing, destructive fishing, coastal development, mass tourism, land-based runoff of sediments and nutrients, marine pollution, shipping, mining, oil and gas industries).</p> <p>Avoid areas where habitats and populations of focal species are in poor condition due to local threats. If this is not possible:</p> <ul style="list-style-type: none"> • Reduce threats; • Facilitate natural recovery (e.g., by protecting larval sources and species that play important functional roles in ecosystem resilience i.e., herbivores); and • Consider the costs and benefits of rehabilitating habitats and species (e.g., by restoring structures, transplanting corals, or facilitating population recovery of focal species by re-stocking or using temporary closures).
Adapt to Changes in Climate and Ocean Chemistry	<p>Protect sites that are likely to be more resilient or resistant to global environmental change (refugia) in NTZs.</p> <p>Protect ecologically important sites that are sensitive to changes in climate and ocean chemistry.</p> <p>Increase protection of species that play important functional roles in ecosystem resilience (i.e., herbivores).</p>

Consideration	Biophysical Design Criteria
	Address uncertainty by: Spreading the risk (see above); and Increasing protection of habitats, critical areas and species most vulnerable to changes in climate and ocean chemistry.

Table 4. Socioeconomic and cultural criteria for designing MPAs and MPA Networks in Indonesia.

Please note that stakeholders include local, adat and traditional communities, governments, NGOs, civil society organisations, scientific institutions and industries i.e., fisheries, tourism etc.).

Consideration	Socioeconomic and Cultural Design Criteria
Involve stakeholders in establishing MPAs and MPA Networks. (MPA establishment includes developing zoning and management plans.)	Involve all stakeholders in each step of the process of establishing MPAs and MPA Networks.
	Prioritize establishing MPAs in areas supported by stakeholders
	Consider opportunities for collaborative management among all stakeholders and implement as appropriate.
Ensure Stakeholder Compliance within MPAs.	Provide capacity building for stakeholders to help them engage more effectively in establishing MPAs and MPAs networks.
	Involve local community in compliance and enforcement [e.g., by joint patrols among government institutions and communities, and Pokmaswas (community surveillance groups)].
Support MPA management actions that maintain or increase ecosystem goods and services for local communities.	Support MPA management actions that maintain or increase ecosystem goods and services for local communities.
	Allow for multiple environmentally-friendly uses in MPAs (including sustainable fishing, tourism, aquaculture, education and research).
Support multiple, environmentally-friendly uses in MPAs.	Support environmentally-friendly livelihoods of local communities [i.e., community-based, environmentally-friendly fisheries, aquaculture and marine resource based tourism based on an areas' uniqueness (biotic and abiotic resources).]
	Protect marine heritage sites (i.e., shipwrecks and airplane wrecks) that have important, archeological-historical value, and manage them for their potential to support community based tourism.
Support community welfare (livelihoods and food supplies).	Ensure local communities have fair and equal access to, and utilization of, marine and fisheries resources.
	Maintain or improve access to resources and markets to support community economies that comply with MPA management plans.
Ensure fair and equal access and use.	Protect adat, local wisdom, traditional law, and culture that support conservation and sustainable resource management, which are still acknowledged and applied by the existing adat community or institution.
	Protect areas that have important traditional cultural value for local people/adat [including mystical (pamali) areas, and important sites for traditional medicine].
Support local wisdom and practices.	

Delimiting the Planning Area and Stratification Units

Planning Area

We defined the planning area for the MPA network design for FMA715 and six associated provinces to include (Figure 8):

- All of the national and provincial waters within FMA715;
- All of the provincial waters of the six provinces that intersect with FMA715; and
- All of the national waters between the six provinces.

The planning area spans 1,823 km from east to west (and 1,607 km from north to south), and encompasses an area of 1,613,457 km² (161,345,748 hectares) which is 49.5% of Indonesia's marine waters (3,257,483 km²: Table 5). The planning area includes both shallow ($\leq 200\text{m}$) and deep water ($>200\text{m}$) areas, including a large proportion of the shallow water habitats in Indonesia (34.9% of coral reefs, 22.7% of mangroves, and 67.3% of seagrasses).

Table 5. Percent of Indonesia's marine waters and shallow water habitats in the planning area.

	Indonesia (ha)	FMA 715 and Six Province MPA Network Planning Area	
		(ha)	Percent of National
Marine Waters	325,748,300	161,345,748	49.5%
Coral	3575236.1	1245883.8	34.9%
Mangroves	3471698.8	789415.3	22.7%
Seagrass	1776220.2	1195563.8	67.3%

Stratification Units

We divided up the planning area into stratification units that represent the range of environmental, geographic and political (provinces) variation in the planning area.

We stratified the planning area for the analysis in two ways:

- By province (see Figure 8), so the results can be used to refine or develop MPA network designs for each of the six provinces that intersect with FMA715 (see *Existing and Proposed Marine Protected Areas, and Areas of Interest for Establishing New Marine Protected Areas*).
- By ecoregion (see Figure 3) to ensure that the design criteria of habitat representation and replication will be applied to each of the shallow water habitats (coral reefs, mangroves and seagrasses) that occur in each ecoregion.

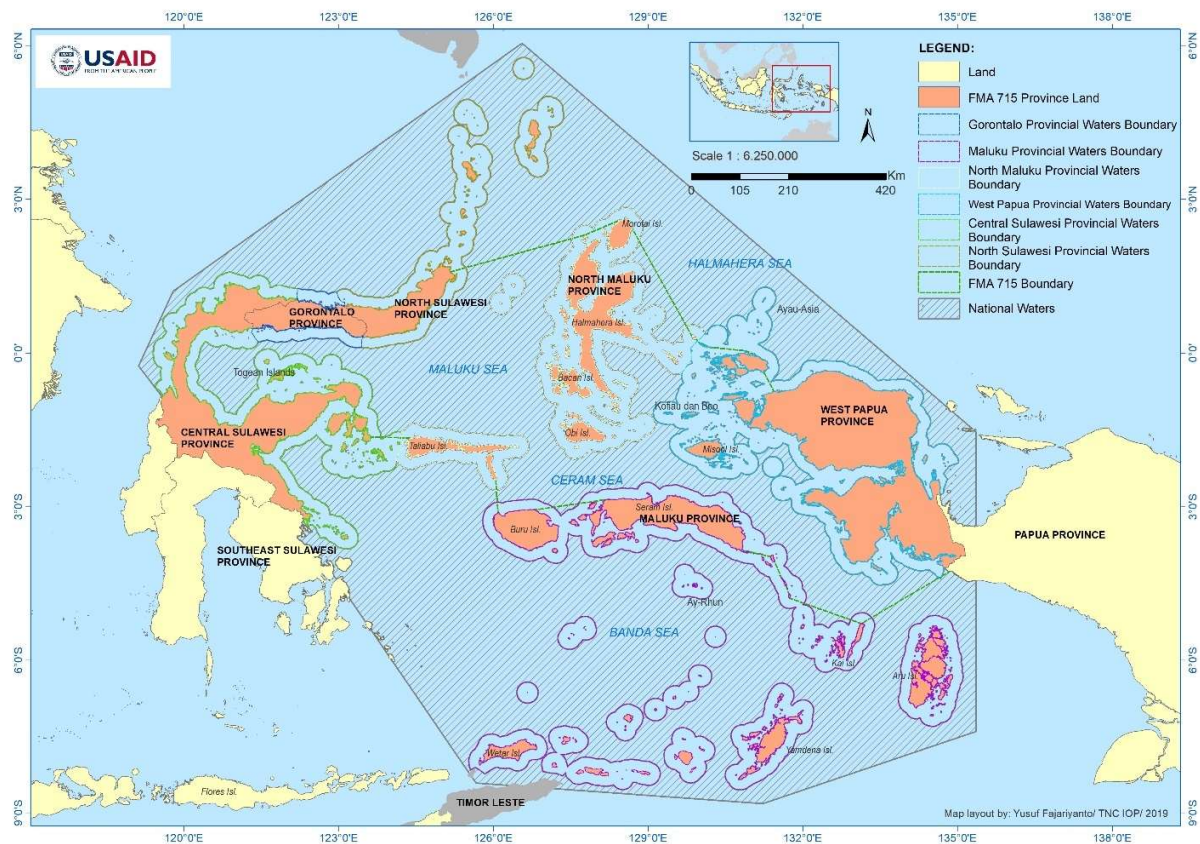


Figure 8. Planning area for designing the MPA network, which includes all national and provincial waters in FMA715, all provincial waters in the six provinces that intersect FMA715, and all of the national waters between the six provinces.

Identifying Conservation Features, Threats and Other Uses

Here we define the conservation features to protect in the MPA network design for FMA715 and the six associated provinces, threats to these conservation features, and areas allocated for other uses (where MPAs can't be established).

Conservation Features

Conservation features include:

- Shallow water habitats ($\leq 200\text{m}$): coral reefs, mangroves forests and seagrass beds.
- Deepwater habitats ($>200\text{m}$) including seamounts, canyons and other features (i.e., abyssal, basin, bridge, escarpment, hadal, ridge, shelf, sill, slope, terrace, trench and trough habitats).
- Critical, special and unique areas for focal fisheries, endangered, threatened and protected species i.e., fish spawning areas (spags), turtle nesting beaches, coelacanth distribution areas and walking shark distribution areas.

- Critical, special and unique socioeconomic and cultural areas i.e., dive sites, shipwrecks, seaworm fishing areas, important traditional areas (i.e., mystical areas) and local wisdom areas (i.e., sasi).

Threats

Threats to conservation features include overfishing and destructive fishing practices (poison, trawl and blast fishing, and reef gleaning), poaching (of turtles and their eggs), hot water from power plants, waste, mangrove logging, sedimentation, mercury pollution, algal blooms, wave abrasion and mining (for nickel, gold, iron sand, sand, and oil and gas).

Other Uses

Some areas are allocated for other uses in the Marine Spatial Plans, and MPAs cannot be established in these areas. They include military areas, transportation and fishing ports, oil and gas mining areas, underwater cable pipe lanes, sea mine areas (unexploded ordinance) and reclamation areas.

Compiling and Processing Spatial Data Layers

We compiled 170 spatial data layers (Annex I Table 9), which included data for:

- MPA status (see *Existing and Proposed Marine Protected Areas, and Areas of Interest for Establishing New Marine Protected Areas*: Figure 4, Figure 5, Figure 6 and Figure 7).
- Conservation features: shallow water habitats (Figure 9), deepwater habitats (Figure 10) and critical special and unique areas (Figure 11);
- Threats (Figure 12); and
- Other uses (Figure 14).

Each of these data layers were processed and verified i.e., by validating the accuracy of the data by comparing it with other spatial and non-spatial information for the same area (i.e., conservation features, threats and other uses).

We reviewed all of the data, and identified 58 data layers (Annex I) that could be used for the Marxan analysis because they are:

- Comprehensive (available for entire planning areas).
- Unbiased (information is not only available for certain areas).
- Reliable (see above).

We prepared each of the spatial data layers to be used in Marxan, by intersecting them with the planning area, stratification and planning units (see *Planning Area, Stratification Units and Planning Unit Layers*).

We also identified 103 other data layers that could be used manually to refine the results of the Marxan analysis to define the Areas of Interest for new MPAs later in the process (see Annex I and *Manually Refining the Results of the Second Marxan Analysis*). These data layers were reliable and unbiased, but were not available for the entire planning area (so they could not be used in Marxan).

Therefore, we used most (161) of the 170 data layers we compiled to design the MPA network (Annex I). Only nine of the data layers we compiled could not be used, because they were either biased or unreliable.

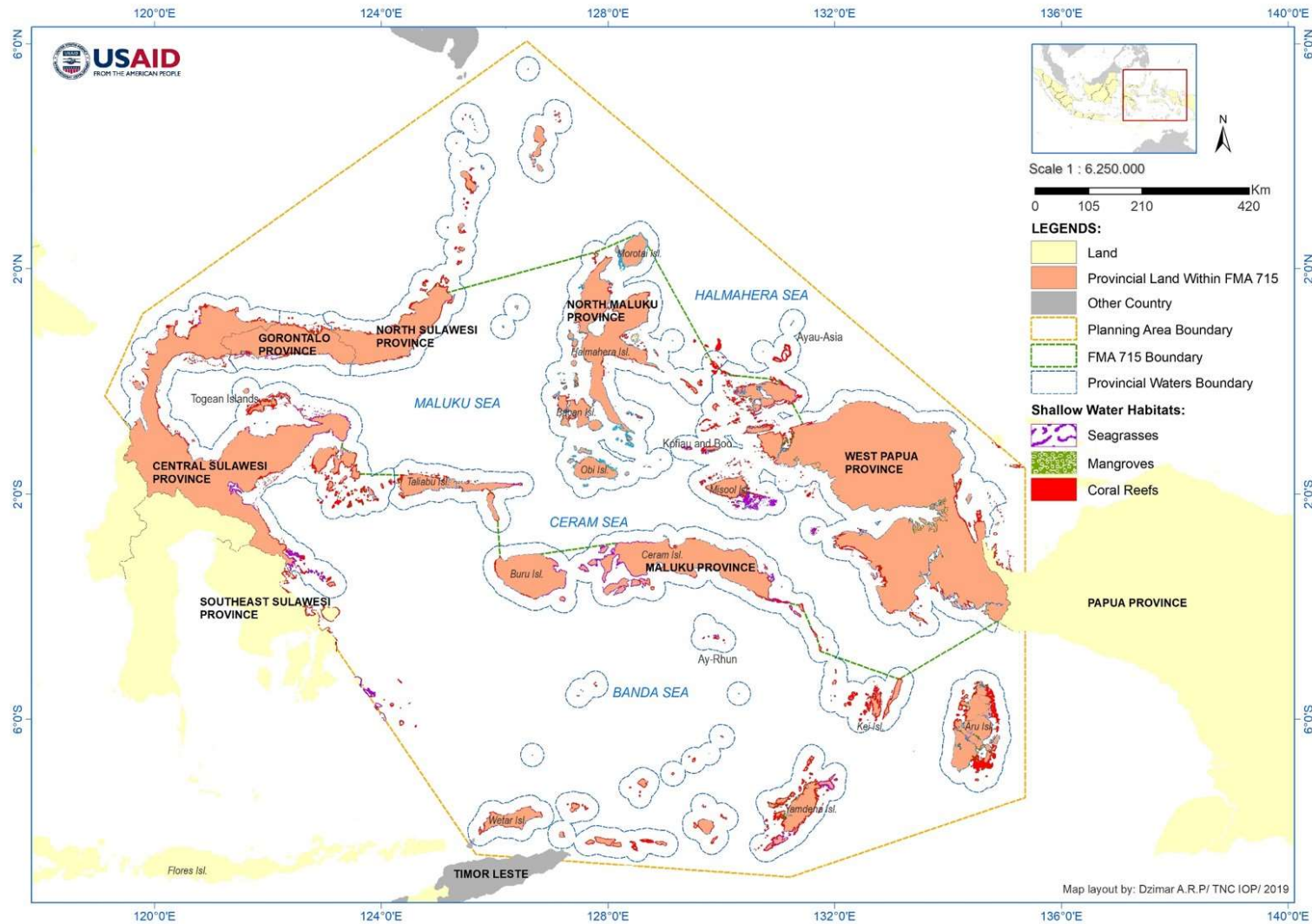


Figure 9. Conservation features: shallow water habitats used in both the 1st and 2nd Marxan analyses.

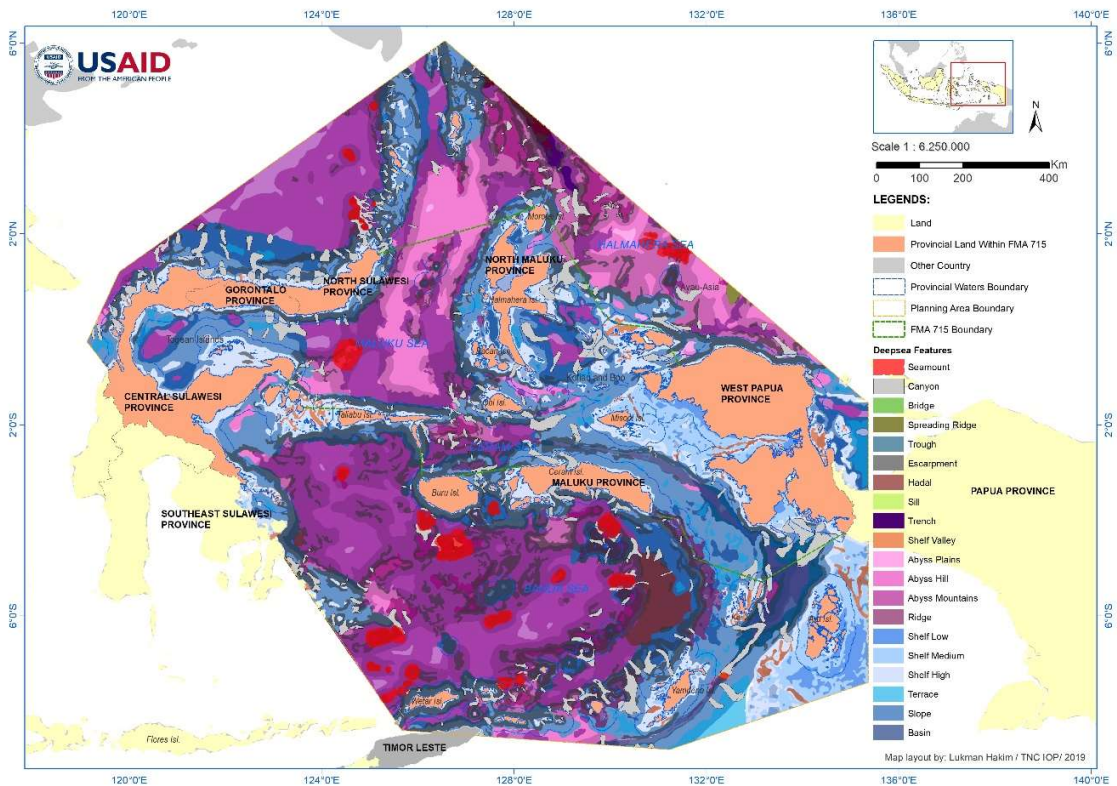
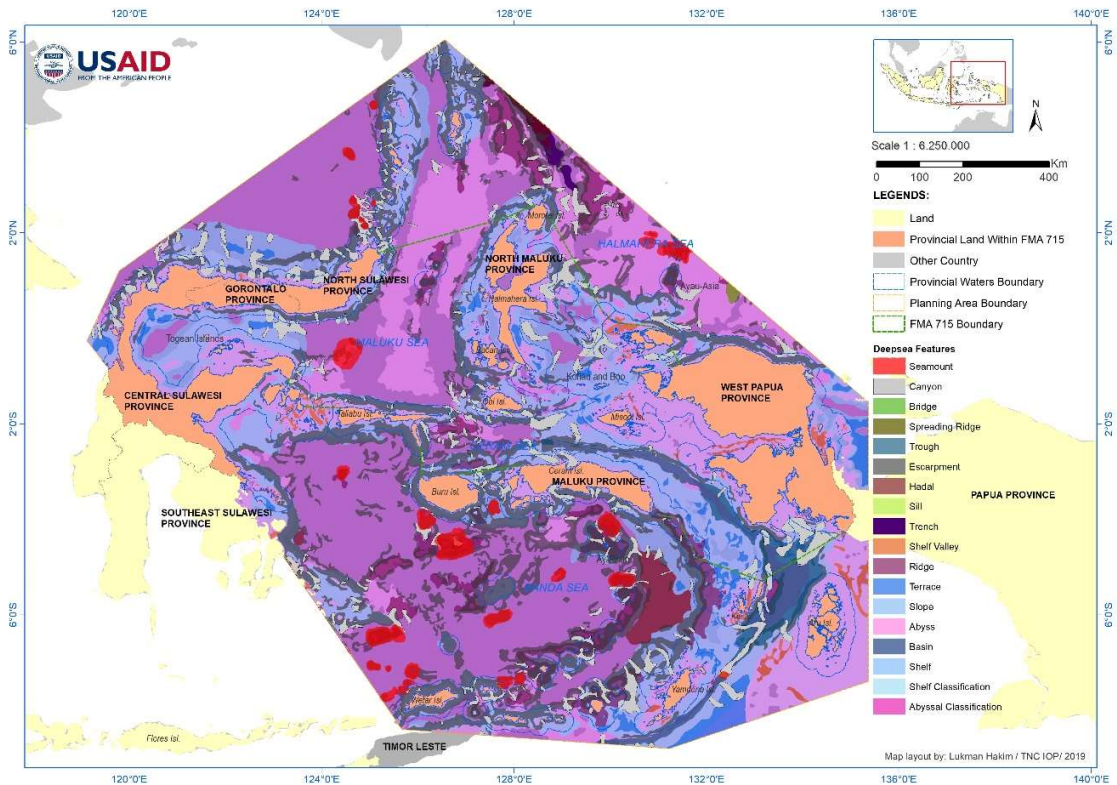


Figure 10. Conservation features: deepwater habitats used in the 1st (top) and 2nd (bottom) Marxan analyses.

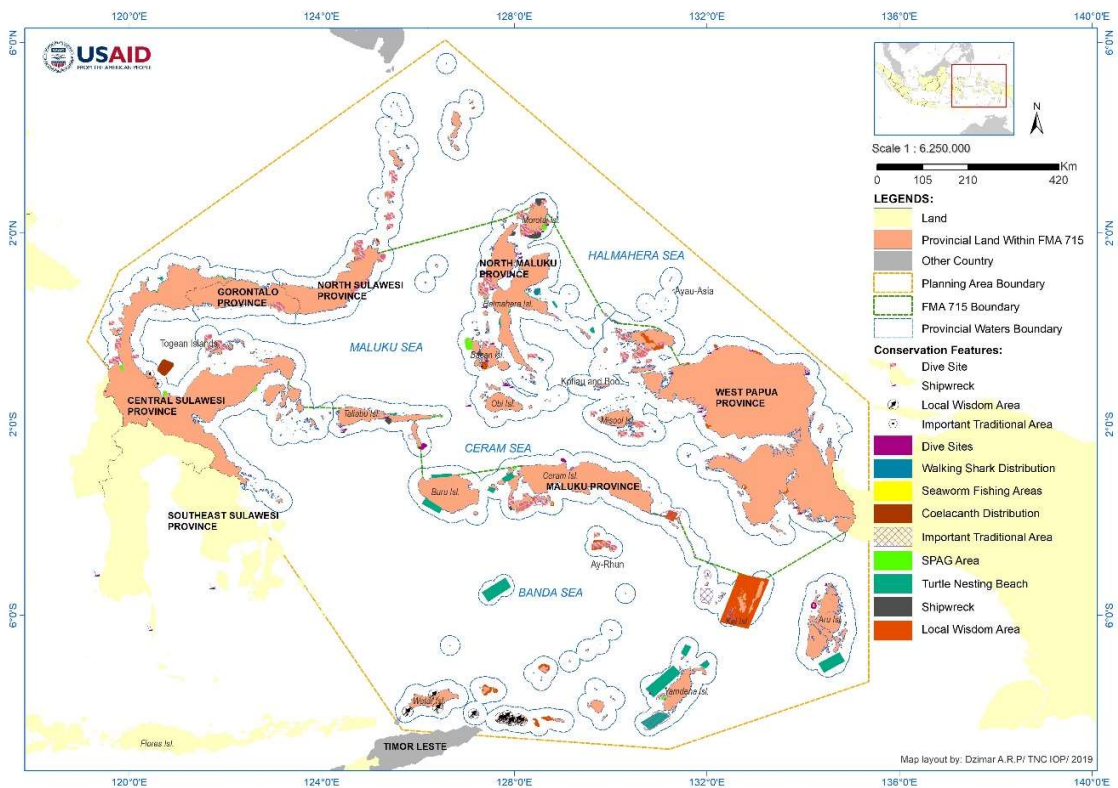
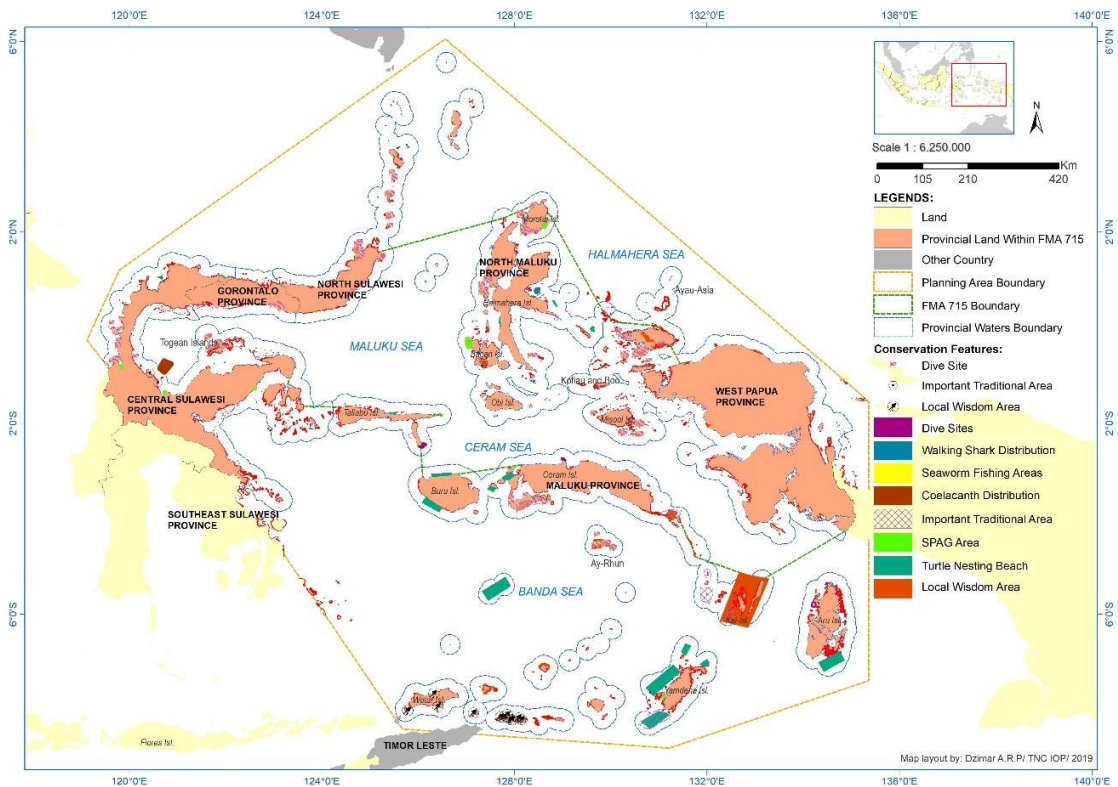


Figure 11. Conservation features: critical, special and unique areas used in the 1st (top) and 2nd (bottom) Marxan analyses.

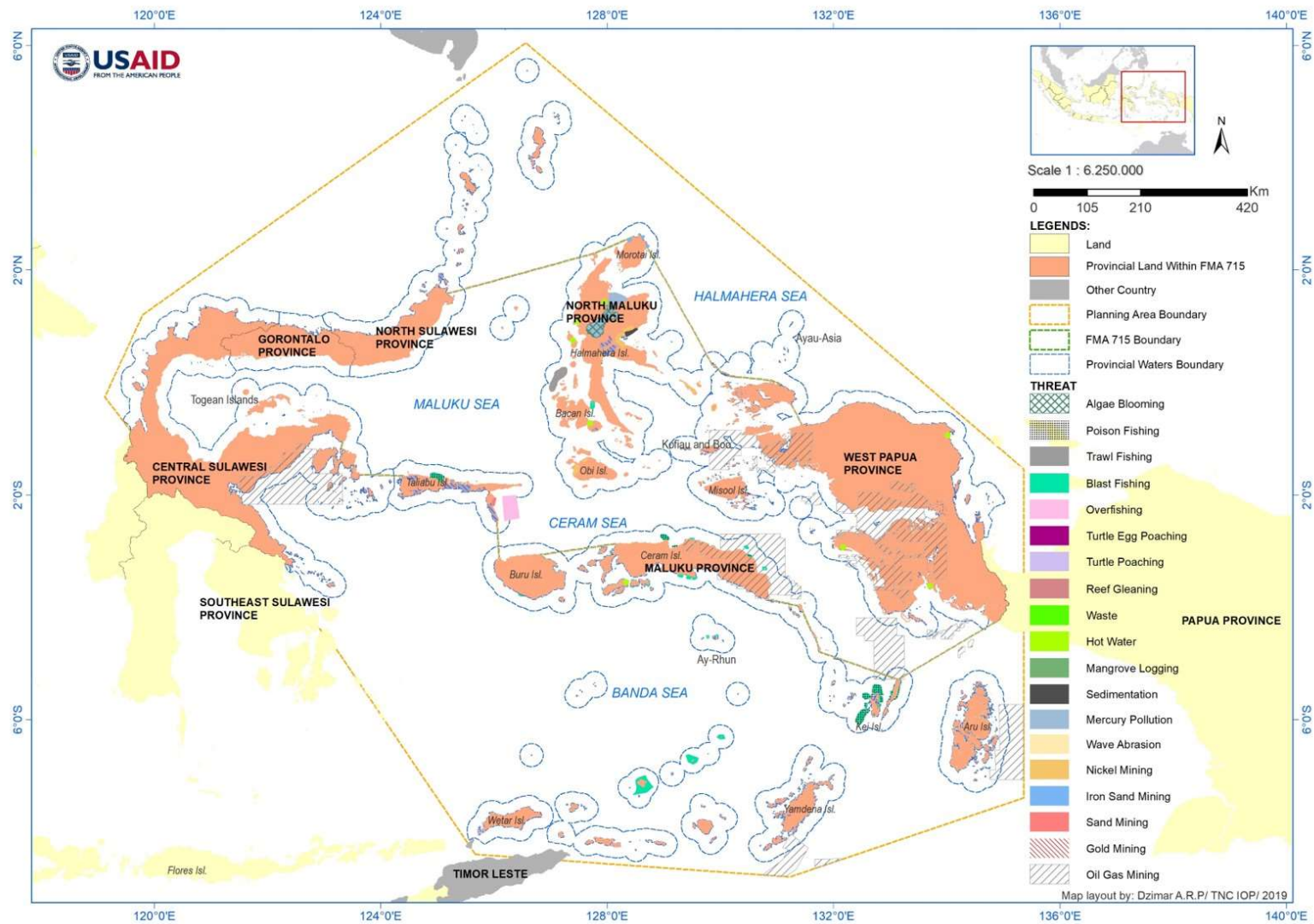


Figure 12. Threats.

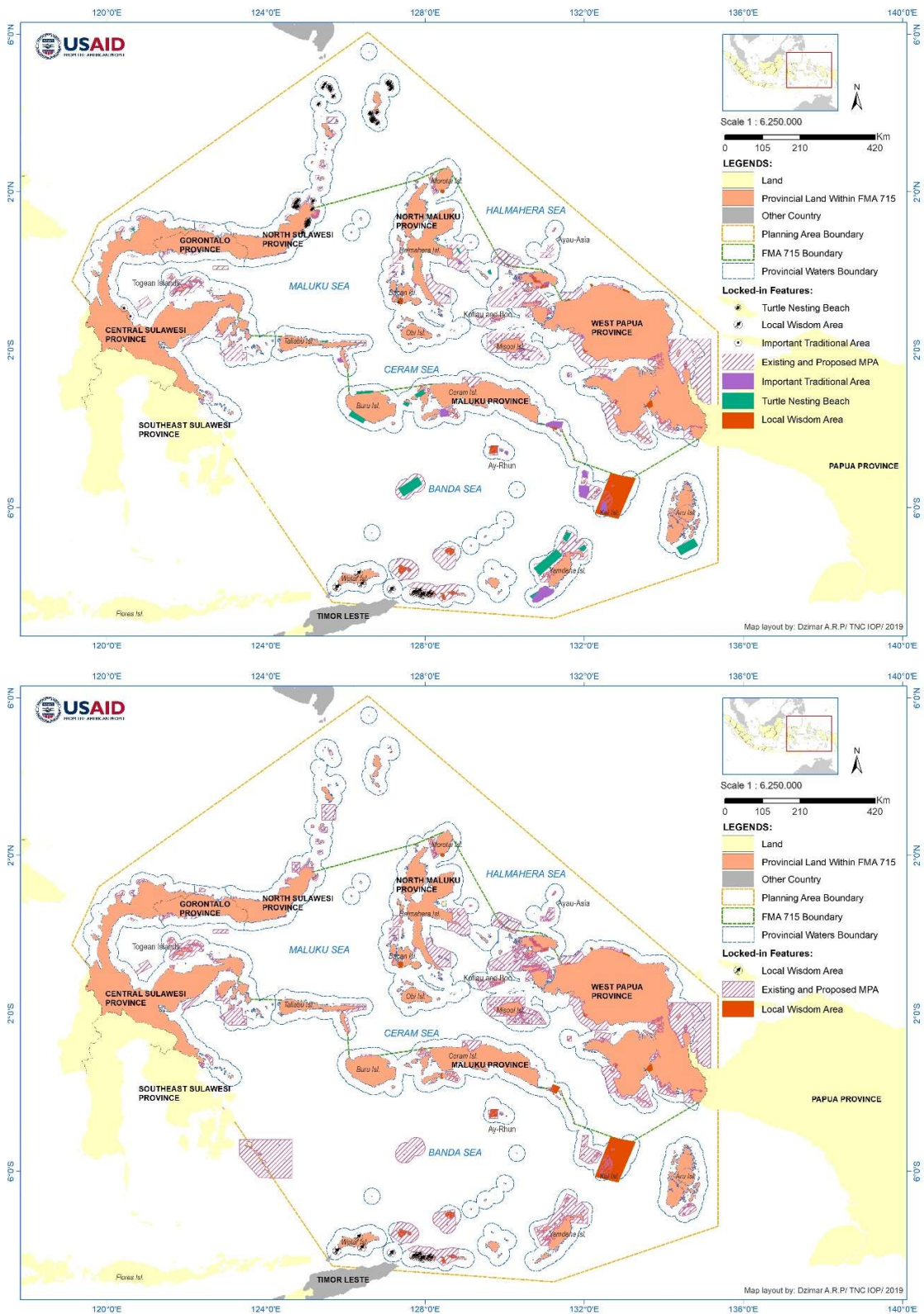


Figure 13. Locked in features used in the 1st (top) and 2nd (bottom) Marxan analyses.

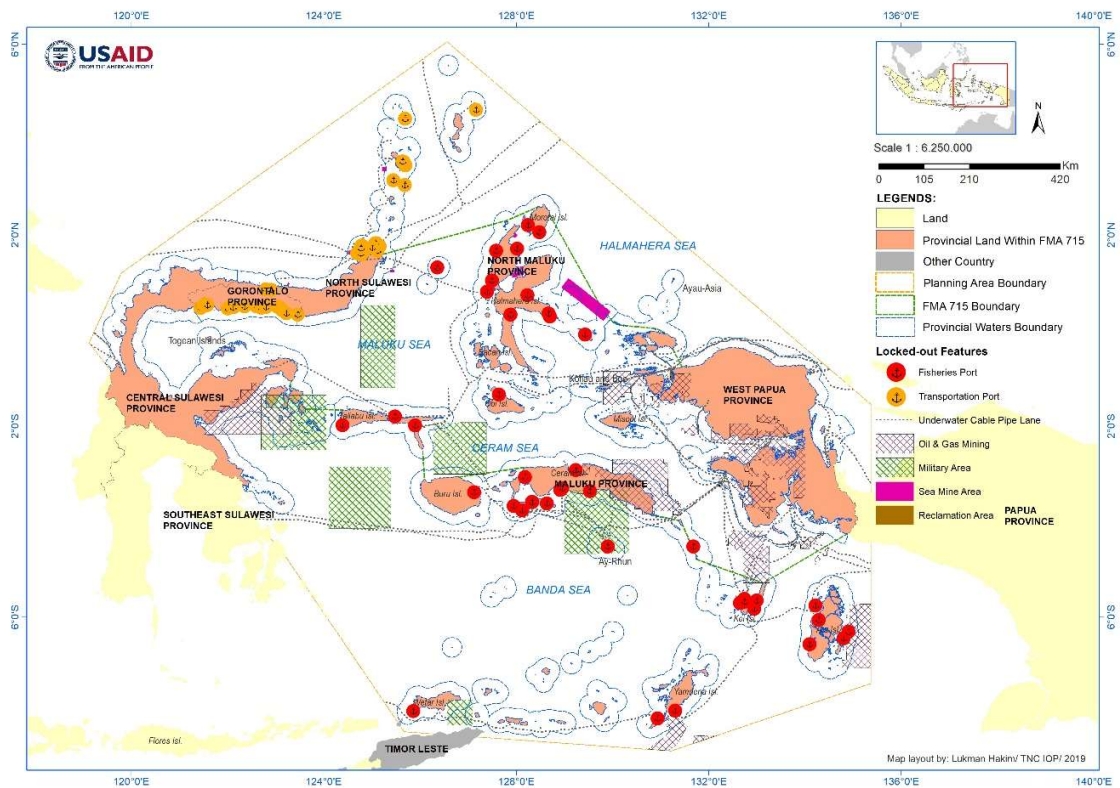
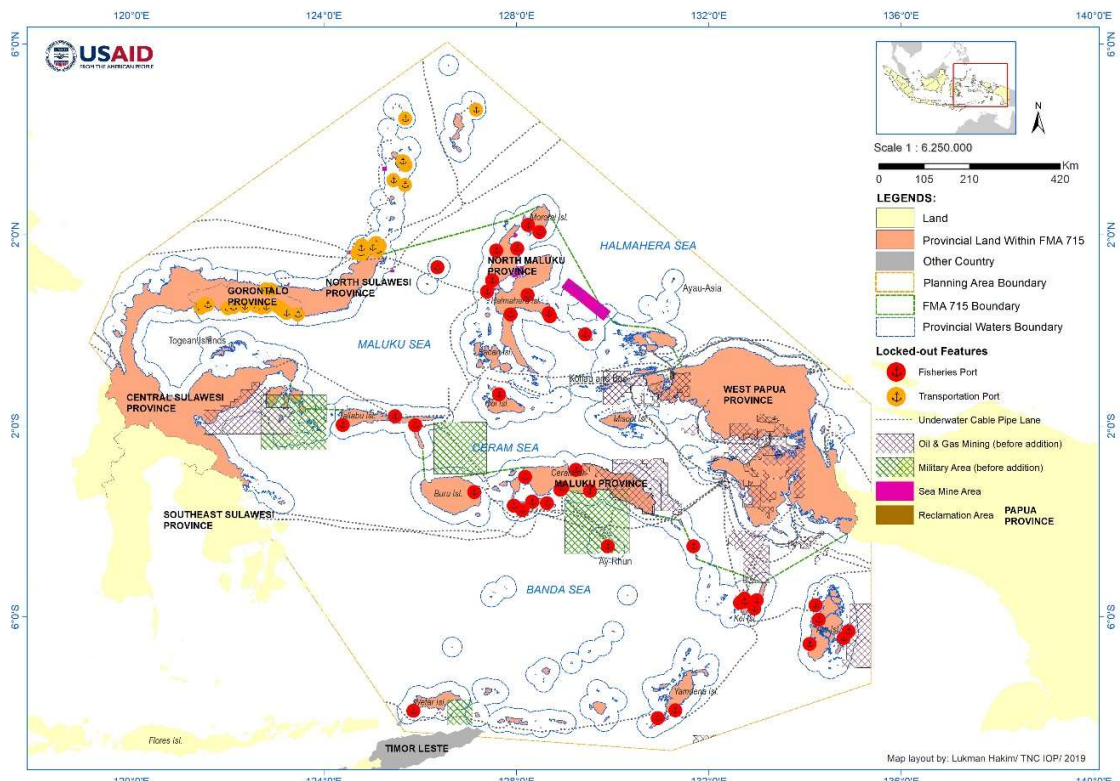


Figure 14. Locked out features (other uses allocated in Marine Spatial Plans) used in the 1st (top) and 2nd (bottom) Marxan analyses.

Designing the Marine Protected Area Network

We used Marxan to conduct a marine gap analysis to design a MPA network for FMA715 and the six associated provinces. The gap analysis takes existing and proposed MPAs into account (that are allocated in the provincial Marine Spatial Plans: see Figure 4, Figure 5, Figure 6 and Figure 7), and identifies Areas of Interest for establishing new MPAs using the design criteria to achieve the goals for MPA network design in Indonesia (see *Identifying Goals and Design Criteria*).

Marxan aims to efficiently meet targets for protecting conservation features while minimizing the impacts on utilization (fisheries, industry, etc.) (Ball et al. 2009: <http://marxan.org>), and is the most widely used systematic conservation planning tool supporting the design of MPA networks worldwide.

However, it is important to remember that Marxan is a decision support tool and not the decision maker. Therefore, we used the results of the Marxan analysis and other information to refine the MPA network design in a four step process:

1. Conducting the first Marxan analysis.
2. Reviewing the results of the first Marxan analysis with MPA practitioners and scientists from local, provincial and national governments, universities and NGOs.
3. Conducting a second, refined Marxan analysis.
4. Manually refining the results of the second Marxan analysis to develop the MPA network design. This included considering Areas of Interest previously identified using participatory expert mapping in the provinces (see *Manually Refining the Results of the Second Marxan Analysis*).

First Marxan Analysis

Shallow and Deepwater Analyses

We conducted the Marxan analysis in two steps, because we had better quality data (higher resolution with more validation) for shallow water (≤ 200 m) than deepwater (> 200 m) habitats.

First, we ran Marxan for the shallow water analysis only. Then we locked in the best solution from the shallow water analysis, and ran the shallow and deepwater analysis combined. This ensured that higher priority was given to using the better quality data in the analysis. It also prioritized protecting shallow water habitats and critical, special and unique areas, while considering connectivity between shallow and deepwater habitats.

To do this, we used different data layers and planning units for each analysis. For the shallow water analysis, we used:

- Data layers for MPA status (existing and proposed MPAs in Marine Spatial Plans), conservation features (shallow water habitats and critical, special and unique areas), and other uses (Table 6); and
- Smaller planning units for a finer scale analysis (see *Planning Unit Layers*).

For the combined shallow and deepwater analysis, we used:

- Data layers for the result (best solution) from the shallow water analysis, conservation features (deepwater habitats) and other uses (Table 7);

- Larger planning units for a coarser scale analysis (see *Planning Unit Layers*).

Planning Unit Layers

Planning units provide the individual unit of choice for selection in the analysis, and can be a variety of shapes and sizes. We used hexagons because they share a boundary with all neighbouring units.

We used two planning unit layers with hexagons of different sizes (Figure 15), based on the resolution of the data and the scale of conservation features:

- One planning unit layer consisted of 49,571 smaller hexagons (5km² in size) for shallow water habitats (≤200m deep) only. The size of these planning units reflected the finer resolution of the data for shallow water habitats, and the size of the conservation features for protection (see Table 6, Figure 9 and Figure 11).
- The other planning unit layer consisted of 67,395 larger hexagons (25km²) for both shallow and deep water (>200m deep) habitats. The size of these larger planning units reflected the coarser resolution of the spatial data available for deepwater habitats, and the larger size of many of the deepwater conservation features (see Table 7, Figure 10).

The size of these planning units also allowed us to keep the processing time for Marxan within manageable time frames.

Targets

Targets are how much of each conservation feature we aim to include in the MPA network. Marxan will aim to achieve these targets, while also minimizing the “cost” of including them in the network (see *Cost Surface*).

We set the following targets for the biophysical and socioeconomic and cultural conservation features:

- 20% of each shallow water habitat (coral reef, mangrove and seagrass) per province / ecoregion (Table 6, Figure 9).
- 10 to 100% of each deepwater habitat (100% of seamounts, 30% of canyons, and 10% of each of the other habitats: Table 7, Figure 10). Higher targets were allocated for seamounts and canyons than for other habitats, because of their importance for protecting biodiversity and as feeding areas for cetaceans and large pelagic fishes.
- 100% of critical, special and unique areas (fish spawning areas, coelacanth distribution areas and endemic walking shark distribution areas: Table 6, Figure 11).
- 50% of sea worm fishing areas and dive sites (Table 6, Figure 11).

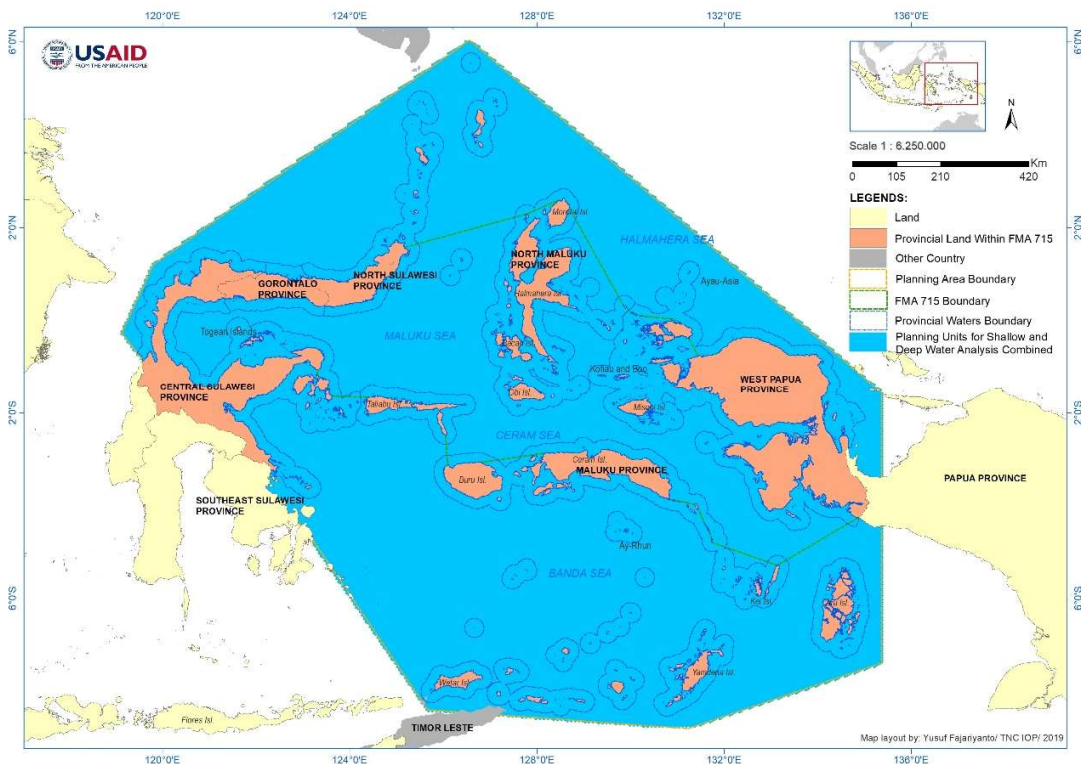
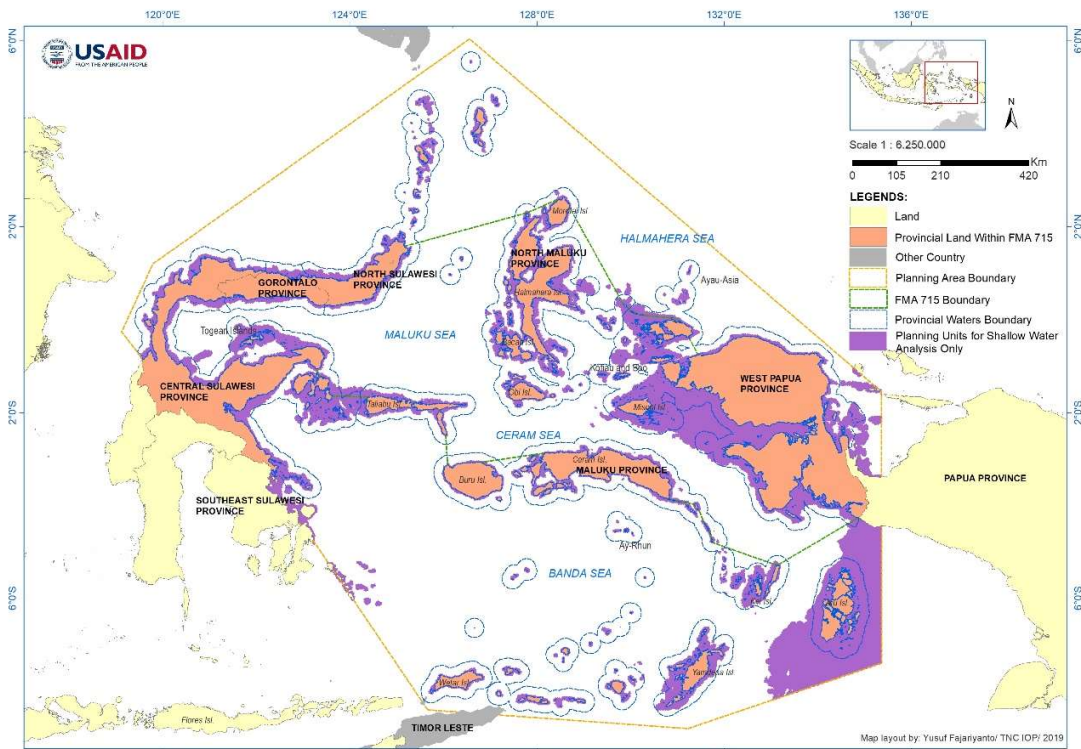


Figure 15. Planning unit layers: one planning unit layer was used for the shallow water analysis only (with smaller planning units: top) and the other was used for the combined shallow and deepwater analysis (with larger planning units: bottom).

Table 6. Spatial data layers and how they were used in the first and second Marxan analyses for the shallow water analysis only (targets for conservation features, and features locked in and locked out of the analyses).

Category	Data Layer	Targets (%), Locked In and Locked Out Features	
		(First Analysis)	(Second Analysis)
MPA status	Existing and proposed MPAs in Marine Spatial Plans	Locked in	Locked in
Conservation features: shallow water habitats (Figure 9). Stratified by province and ecoregion = 37 strata.	Coral Reefs	20%	30%
	Mangroves	20%	30%
	Seagrasses	20%	30%
Conservation features: critical, special and unique areas (Figure 11).	Fish spawning areas (SPAGs)	100%	80%
	Turtle nesting beaches	Locked in	80%
	Walking shark distribution areas	100%	80%
	Coelacanth distribution areas	100%	80%
	Seaworm fishing areas	50%	50%
	Dive sites	50%	50%
	Important traditional areas (i.e., mystical areas)	Locked in	80%
	Local wisdom areas (i.e., sasi)	Locked in	Locked in
Other Uses (Figure 14).	Shipwrecks	-	80%
	Fisheries Port	Locked out	Locked out
	Transportation Port	Locked out	Locked out
	Military areas	Locked out	Locked out
	Cable pipe lanes	Locked out	Locked out
	Reclamation areas	Locked out	Locked out
	Sea mine areas (unexploded ordinance)	Locked out	Locked out
Oil and gas mining areas	Locked out	Locked out	

Table 7. Spatial data layers and how they were used in the first and second Marxan analyses for the combined shallow and deep water analysis (targets for conservation features, features locked in and locked out of the analyses, and data used for the cost surface).

Category	Data Layer	Targets (%), Locked In and Locked Out Features, and data used for Cost Surface	
		(First Analysis)	(Second Analysis)
Result (best solution) from shallow water analysis	Best solution	Locked in	Locked in
	Abyss	10%	-

Category	Data Layer	Targets (%), Locked In and Locked Out Features, and data used for Cost Surface	
		(First Analysis)	(Second Analysis)
Conservation features: deepwater habitats (Figure 10). Stratified by ecoregion = 89 & 100 strata for first and second analysis respectively. (see GEBCO Undersea Feature Names for definitions)	Abyssal classification	10%	-
	Abyss hills	-	10%
	Abyss mountains	-	10%
	Abyss plains	-	10%
	Basin	10%	10%
	Bridge	10%	10%
	Canyon	30%	30%
	Escarpment	10%	10%
	Hadal	10%	10%
	Ridge	10%	10%
	Seamount	100%	80%
	Shelf Valley	10%	10%
	Shelf	10%	-
	Shelf Classification	10%	-
	Shelf high	-	10%
	Shelf medium	-	10%
	Shelf low	-	10%
	Sill	10%	10%
	Slope	10%	10%
	Terrace	10%	10%
Spreading ridge	10%	10%	
Trench	10%	10%	
Trough	10%	10%	
Other Uses (Figure 14)	Fisheries Port	Locked out	Locked out
	Transportation Port	Locked out	Locked out
	Military areas	Locked out	Locked out
	Cable pipe lanes	Locked out	Locked out
	Reclamation areas	Locked out	Locked out
	Sea mine areas (unexploded ordinance)	Locked out	Locked out
	Oil and gas mining areas	Locked out	Locked out
	Transportation ports (a combination of four data layers for local, national, and uncategorized ports in Annex 1)	Cost surface	Cost surface
	Fisheries ports	Cost surface	Cost surface
	Fishing grounds (a combination of all 12 data layers for fishing grounds in Annex 1)	Cost surface	Cost surface

Locked In and Locked Out Features

Some areas should be included in the MPA network design, because they are important to achieve the goals (Table 2). These areas were locked in for the analyses (see Table 6, Table 7 and Figure 13), which means that Marxan should select these as priority areas to include in the MPA network design. They included:

- Existing and proposed MPAs in the provincial Marine Spatial Plans, because they have already been allocated for that purpose.
- Areas important for cultural reasons (local wisdom areas and important traditional areas).
- Areas important for conservation of rare, threatened and protected species (turtle nesting areas).

In contrast, some areas are allocated for other uses in the Marine Spatial Plans [i.e., transportation and fisheries ports, underwater cable pipe lanes, military areas, oil and gas mining areas, sea mine areas (unexploded ordinance) and reclamation areas]. MPAs cannot be established in those areas. Therefore, they were locked out in the analysis (see Table 6, Table 7 and Figure 14). This means, that Marxan will not select these areas for inclusion in the MPA network.

Where areas are included in both locked in and locked out areas, Marxan will not select locked out areas for inclusion in the MPA network.

Cost Surface

"Costs" are values assigned to planning units to help minimize the impact of the MPA network on the utilization of marine resources (e.g., for fisheries and other industries). Where the values reflect the "cost" of including each planning unit in the MPA network, which is not necessarily a monetary value (e.g., it may be loss of an area for fishing or other uses).

Practitioners use a variety of methods to assign costs to planning units. We used two cost surfaces to design an MPA network for FMA715 and the six associated provinces. Where costs are:

- The same for all planning units for the shallow water analysis.
- A measure of different socioeconomic costs in the planning units (to minimize impacts to fisheries and ports) for the combined shallow and deepwater analysis. To do this, we developed a cost surface as a weighted sum of impacts to fisheries and access to transportation and fishing ports (Figure 16, for more information see *Annex 2*).
-). Marxan will avoid placing MPAs in darker areas to minimize impacts on fisheries, transportation ports and fishing ports.

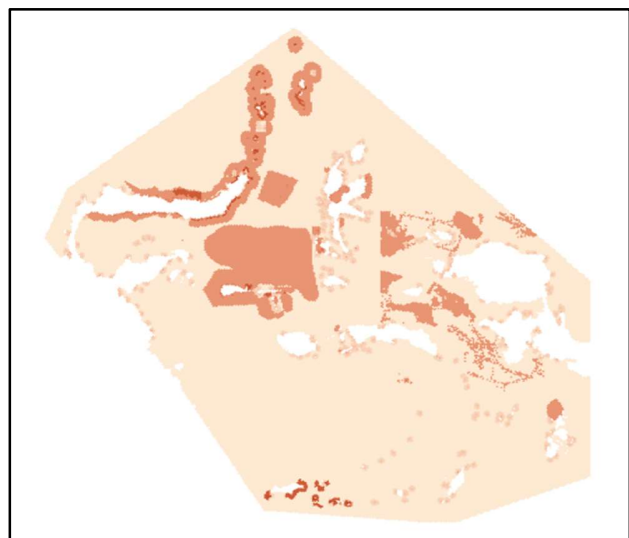


Figure 16. Weighted cost surface.

Scenarios

Scenarios are different ways of carrying out the analysis. For example, we explored several scenarios that used different data layers, planning areas, cost surfaces, locked in and locked out areas, and/or other parameters for targets and costs.

We selected a scenario that included using:

- All of the data layers, targets for conservation features, and locked in and locked out features in Table 6 and Table 7.
- The cost surfaces described above (see *Cost Surface*).

Running Marxan

We ran Marxan 100 times for the scenario described above, which produced 100 possible solutions for the MPA network design.

We set up Marxan to develop solutions that generate a compact network (with more clumping i.e., less, larger areas) and avoid fragmentation (i.e., many small areas).

Outputs

Marxan provided several outputs (for both the shallow water only and the combined shallow and deepwater analyses) that we used to design the MPA network including:

- 100 individual solutions, where each solution identifies areas that efficiently met the targets for the conservation features while minimizing costs.
- The sum solution, which shows how often each planning unit was selected in the 100 solutions (i.e., areas that were always, often, rarely or never selected).
- The best solution, which identifies areas that most efficiently meet the targets for minimal cost. This is not necessarily the ideal solution, rather it is a very good solution based on the information available.

We used the results of the Marxan analysis as follows:

- We used the best solution for the shallow water analysis only (Figure 17), and locked it in for the combined shallow and deepwater analysis; and
- We used the sum solution for the combined shallow and deepwater analysis (Figure 18) to identify priority areas for including in the MPA network (areas selected in 70-100 solutions: Figure 19).

Shallow Water Analysis

The best solution for the Marxan analysis for shallow water only is provided in Figure 17. This solution meets the targets for protection for most of the conservation features in Table 6. However, it could not meet the targets for some conservation features e.g., for sea worm fishing areas in Ambon (Figure 11) because they overlap with the port (which was locked out: Figure 14); and local wisdom areas in Kei Islands in Maluku (Figure 11) because they overlap with locked out areas for other uses (oil and gas mining areas, and underwater cable pipe lanes: Figure 14).

Combined Shallow and Deepwater Analysis

The sum solution for the combined shallow and deepwater analysis is provided in Figure 18, overlaid with the existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest identified by participatory mapping as potential areas for establishing new MPAs in the provinces (Figure 4, Figure 5, Figure 6 and Figure 7).

Some areas were not selected for inclusion in the MPA network, because they include locked out features (see *Locked In and Locked Out Features*: Figure 14) e.g., large areas in the Maluku, Ceram and Banda Seas. While others were selected in a few (<10), some (11-40), many (41-69), most or all solutions (70-100: Figure 18).

Priority areas for inclusion in the MPA network were defined as areas selected by Marxan in 70 to 100 solutions (Figure 19), because they maximized achieving conservation targets while avoiding threats and minimizing impacts on fisheries and other uses (see *Cost Surface* Figure 16, and *Locked In and Locked Out Features*).

Priority areas for inclusion in the MPA network included many areas already allocated as existing or proposed MPAs in Marine Spatial Plans (which were locked in). However, some existing or proposed MPAs were not selected by Marxan because they overlapped locked out features. For example, Banggai MPA in Central Sulawesi (Figure 7) is in an oil and gas mining area and military area (Figure 14).

Most of the Areas of Interest identified by participatory mapping in the provinces were selected as a priority for inclusion on the MPA network by Marxan (e.g., around Morotai in North Maluku). Since these Areas of Interest were not locked in for the analysis, nor were they allocated a target for inclusion in the MPA network, this provides additional support for establishing new MPAs in these areas. Although the reason they were prioritized by different processes may have been because similar information was used in both processes (e.g., the presence of spags, turtle nesting areas, shipwreck, etc.).

However in some instances, Marxan did not select Areas of Interest identified by participatory mapping in the provinces. For example, southwest Wetar Island in Maluku was identified as an Area of Interest by participatory mapping (Figure 5), because of the presence of a spag, turtle nesting beaches and an important cetacean migratory corridor. However, Marxan did not select this area (Figure 19), because of the presence of an underwater cable and port (locked out features: Figure 14) even though the underwater cable was > 4 km offshore. Instead, Marxan selected an area northwest of Wetar Island because of the presence of many deepwater habitats in this area (seamounts and canyons).

Marxan also identified new Areas of Interest for MPAs required to:

- Achieve targets for protecting both shallow and deepwater habitats, particularly high priority deepwater habitats for protection such as seamounts and canyons e.g., the largest seamount in the region in the middle of the Maluku Sea; and
- Achieve targets for protecting critical, special and unique areas (e.g., a coelacanth distribution area in Tomini Bay, Central Sulawesi; and a shipwreck in Miossu and Su Island, West Papua).

This emphasizes the importance of using the results from both the participatory mapping and Marxan analysis to refine the Areas of Interest for new MPAs when finalizing the MPA network design for FMA715 and the associated six provinces (see *Manually Refining the Results of the Second Marxan Analysis*).

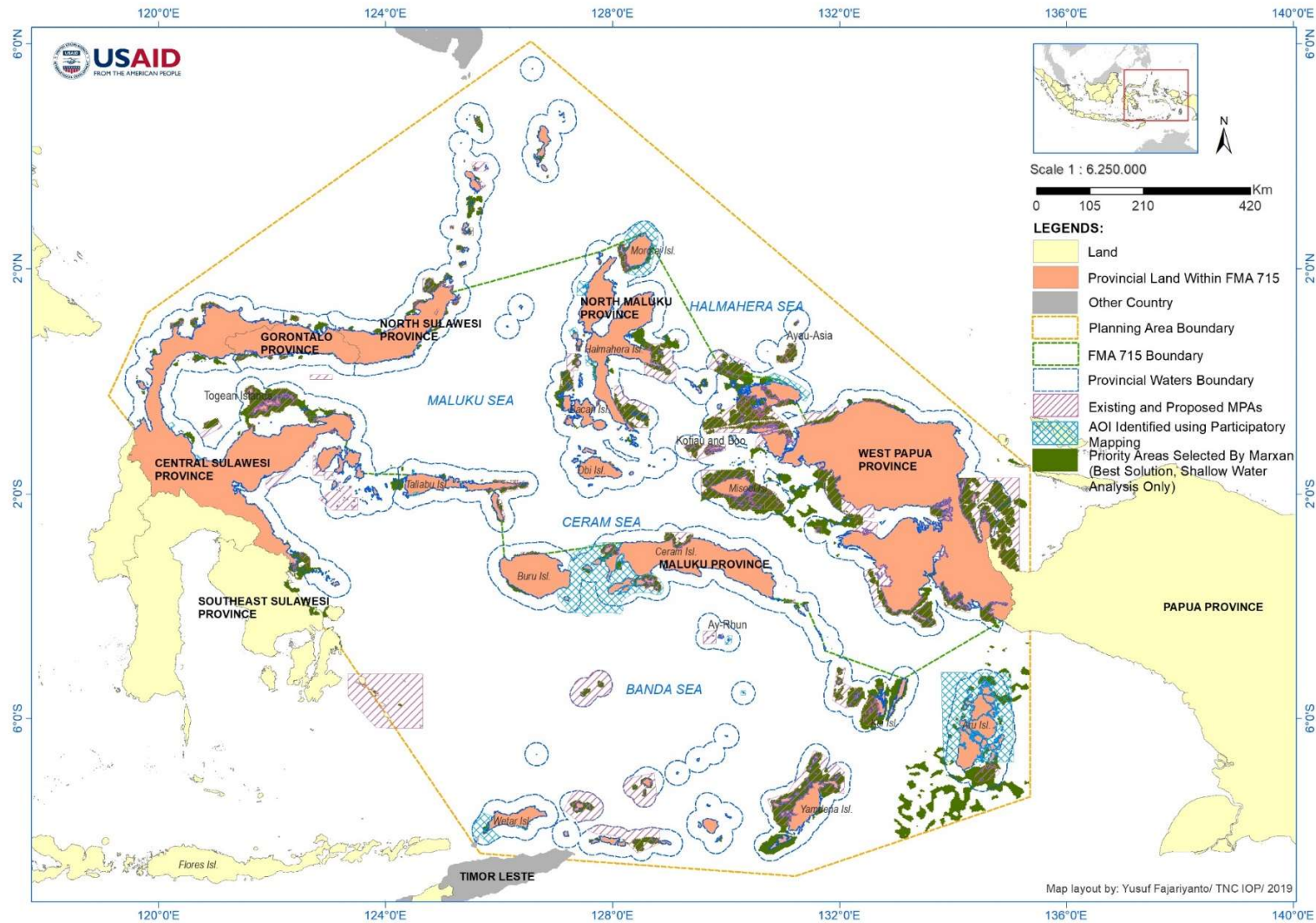


Figure 17. Best solution for the shallow water analysis from the first Marxan analysis, overlaid with existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs identified by participatory mapping in the provinces. Where the dark green areas were selected as priority areas for inclusion in the MPA network by Marxan.

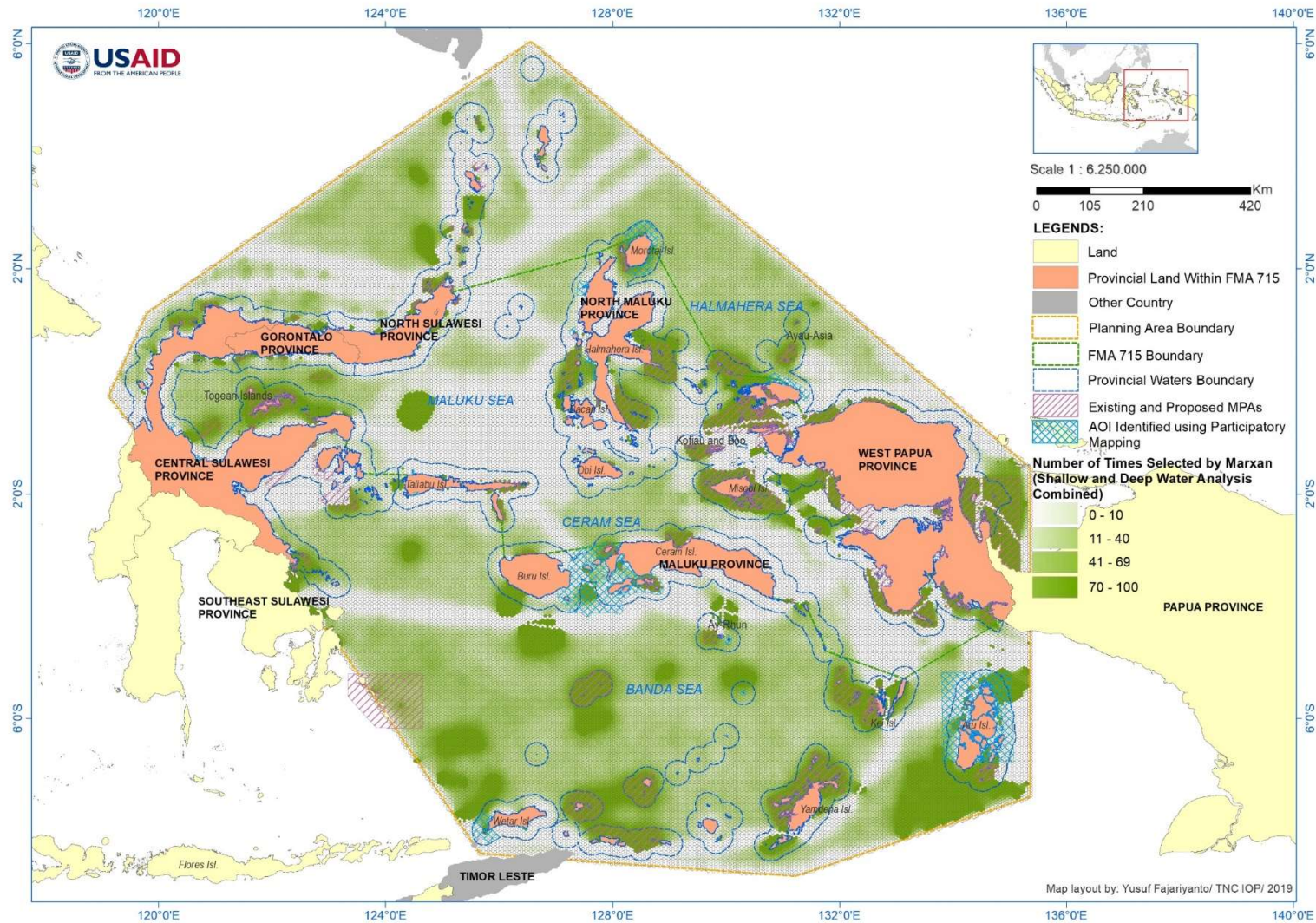


Figure 18. Sum solution for the combined shallow and deepwater analysis from the first Marxan analysis, overlaid with existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs identified by participatory mapping in the provinces. Where different shades of green show how many times each planning unit was selected by Marxan.

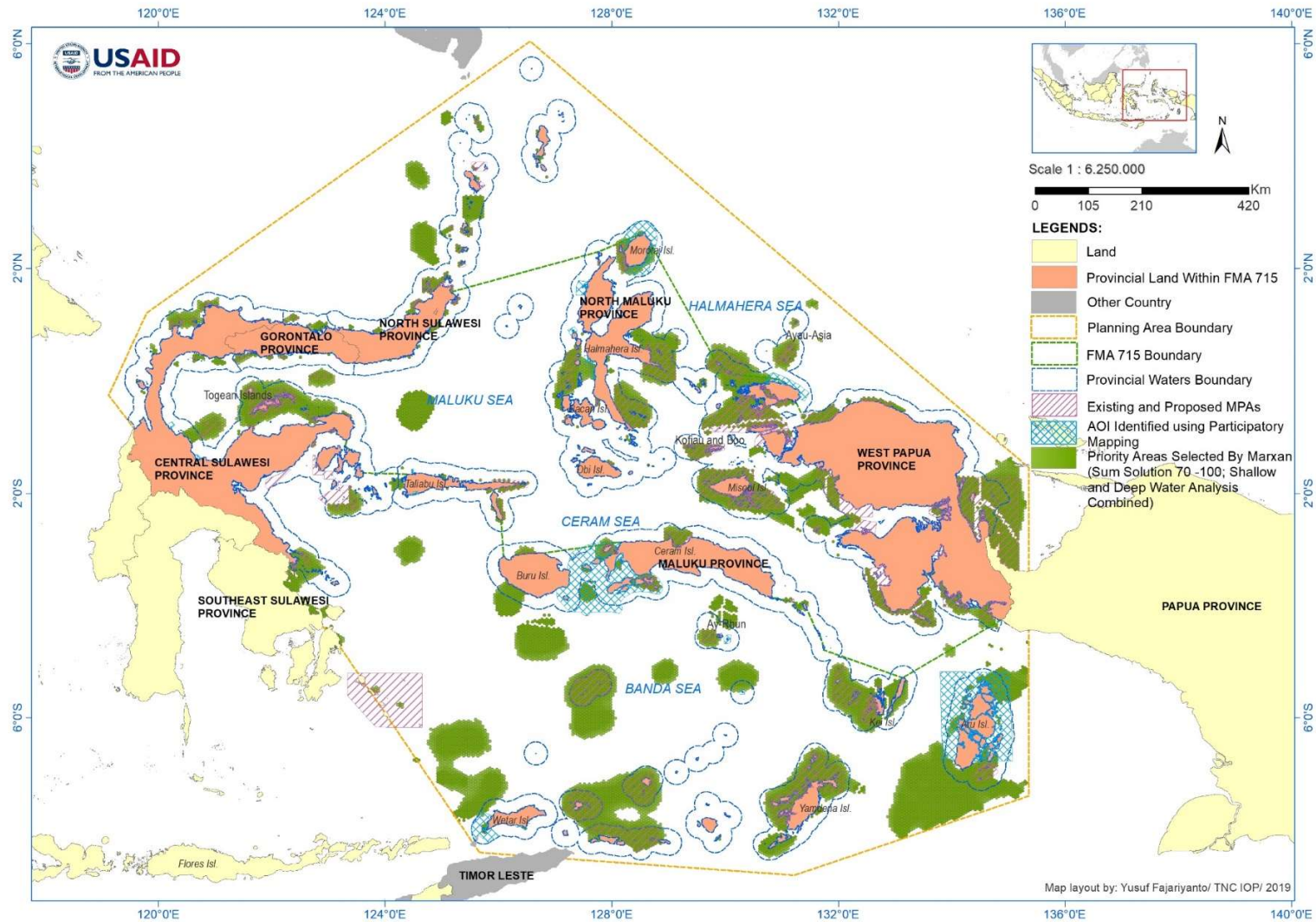


Figure 19. Priority areas for inclusion in the MPA network selected by the first Marxan analysis (in 70-100 solutions) for the combined shallow and deepwater analysis, overlaid with the existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs identified by participatory mapping in the provinces.

Scientific Workshop to Review the Results of the First Marxan Analysis

From 6-7th August 2019, we held a workshop at MMAF in Jakarta to review the outputs of the first Marxan analysis with 62 MPA practitioners and scientists from 28 institutions including:

- Eight representatives from the national government including MMAF (KKHL, PRL, BKKPN Kupang, Loka PSPL Sorong, BRSDMKP, LRSDKP, Pusat Riset Kelautan KKP/BROL and P2O LIPI);
- Ten representatives from each of the six provincial governments, except Maluku;
- Eight scientists from a national university (IPB) and universities in each of the six provinces.
- Thirteen representatives from NGOs (TNC, WWF, WCS, RARE and Flora and Fauna International and Burung Indonesia);
- Eight representatives of the USAID SEA project.

This included scientists and practitioners with expertise in the:

- Biophysical characteristics of the planning area including shallow and deepwater habitats, critical, special and unique areas for fisheries species (i.e., coral reef species), charismatic, endangered, threatened or protected species (i.e., marine mammals, seabirds, turtles and endemic reef fishes), oceanography and connectivity; and
- Socioeconomic and cultural characteristics of the planning area including the economic value of marine resources, fisheries, community livelihoods, local wisdom and marine archeology (shipwrecks).

To do this, we described:

- The background for this project (see *Introduction*).
- The goals and design criteria for the analysis (see *Identifying Goals and Design Criteria*).
- The data layers we used (Table 6 and Table 7), and how we did the Marxan analysis (see *First Marxan Analysis*).
- The results of the Marxan analysis (see *First Marxan Analysis*).

We then used the priority areas selected for inclusion in the MPA network by Marxan (Figure 19) for review and input by participants to assess how well we had addressed the MPA network goals and design criteria.

We conducted the review in two ways:

- By theme for: habitats; critical, special and unique areas (for fisheries, charismatic, endangered, threatened and protected species); fisheries; large scale processes (oceanography, larval connectivity, climate change etc.) and socioeconomic and cultural considerations.
- By geography (for all of FMA715 and each of the six provinces).

Input from the workshop participants included the need to:

- Increase the target for representation of shallow water habitats from 20% to 30% to be consistent with the target set for highly protected MPAs and other effective areas by the World Conservation Congress 2016³.

³ <https://mpanews.openchannels.org/news/mpa-news/iucn-members-approve-30-2030-goal-mpas-%E2%80%94-most-ambitious-target-so-far-mpa-coverage>

- Check the MPA data layer (for North Sulawesi).
- Consider new Areas of Interest (e.g., to protect cetaceans, dugong and seabirds).
- Check/refine some existing data layers for biophysical conservation features (e.g., for seagrasses, spags and turtle nesting beaches), socioeconomic and cultural conservation features (e.g., for shipwrecks and local wisdom areas) and threats (e.g., for oil and gas concessions and military areas).
- Find and use more information regarding habitat condition (e.g., for mangroves), currents (e.g., the Indonesian Monsoon Flow), socioeconomic and cultural considerations, threats and other uses (i.e., the location of FADs and the density of fishing boats).

More details are provided in the workshop report (TNC/SEA 2019d) and Annex 3 (Table 10).

Where possible, we used this information to refine the Marxan analysis as described below and in Annex 3 (Table 10).

Second Marxan Analysis

Refining the Analysis

We conducted a second Marxan analysis. This analysis was similar to the *First Marxan Analysis* except we made some refinements based on the input received from the Scientific Expert Review Workshop (see above, Table 6 and Table 7) regarding:

- Increasing the target for shallow water habitat representation in the scenario from 20% to 30%; and
- Refining and adding data layers for MPA status (Annex 4), conservation features, threats and other uses.

We also made some refinements to improve the analysis including (see Table 6 and Table 7):

- Lowering the target for protecting some conservation features from 100% (or locked in) to 80% to provide more flexibility for the analysis (for spags, turtle nesting beaches, seamounts, important traditional areas, coelacanth distribution and walking shark distribution areas).
- Using a refined data layer for abyss and shelf deepwater habitats, which increased the number of deepwater habitat features from 18 to 20 (Table 7, Figure 10).
- Using a refined shipwreck data layer in the second analysis (Table 6, Figure 11), with a target of 80%.

Outputs

The results of the second Marxan analysis are provided in Figure 20, Figure 21 and Figure 22. The results are generally similar to those in the first analysis, with many of the same priority areas for inclusion in the MPA network identified in both analyses (see *Outputs, First Marxan Analysis*: Figure 17, Figure 18 and Figure 19). However, some refinements were apparent in the second analysis. For example:

- While many of the same priority areas were selected in both the first (Figure 19) and second (Figure 22) analysis, priority areas selected were often larger in the results of the 2nd analysis (e.g., around Misool Island in West Papua and the Togeian Islands in Central Sulawesi). This is because the target for shallow water habitats was increased from 20% to 30%, and six of the Areas of Interest now include shipwrecks (e.g., South Taliabu in North Maluku: see Figure 28).

- A few areas selected as priorities in the 1st analysis (e.g., a seamount between Southeast Sulawesi and Buru Island in Maluku Province; an area south of Banggai Island MPA in Central Sulawesi Province; and areas near Leti Island and Ay-Rhun Island MPA in Maluku Province: Figure 19), were not selected as priorities in the 2nd analysis (Figure 22). This is because new information regarding military areas (PP No 68 Year 2014) was added to the locked out features (Figure 14) that overlapped these areas.
- A new priority area was identified in the 2nd analysis north of Ayau-Asia MPA in West Papua (Figure 22), possibly because of the need to include more deepwater habitats in areas in the MPA network not already allocated for other uses (Figure 14).

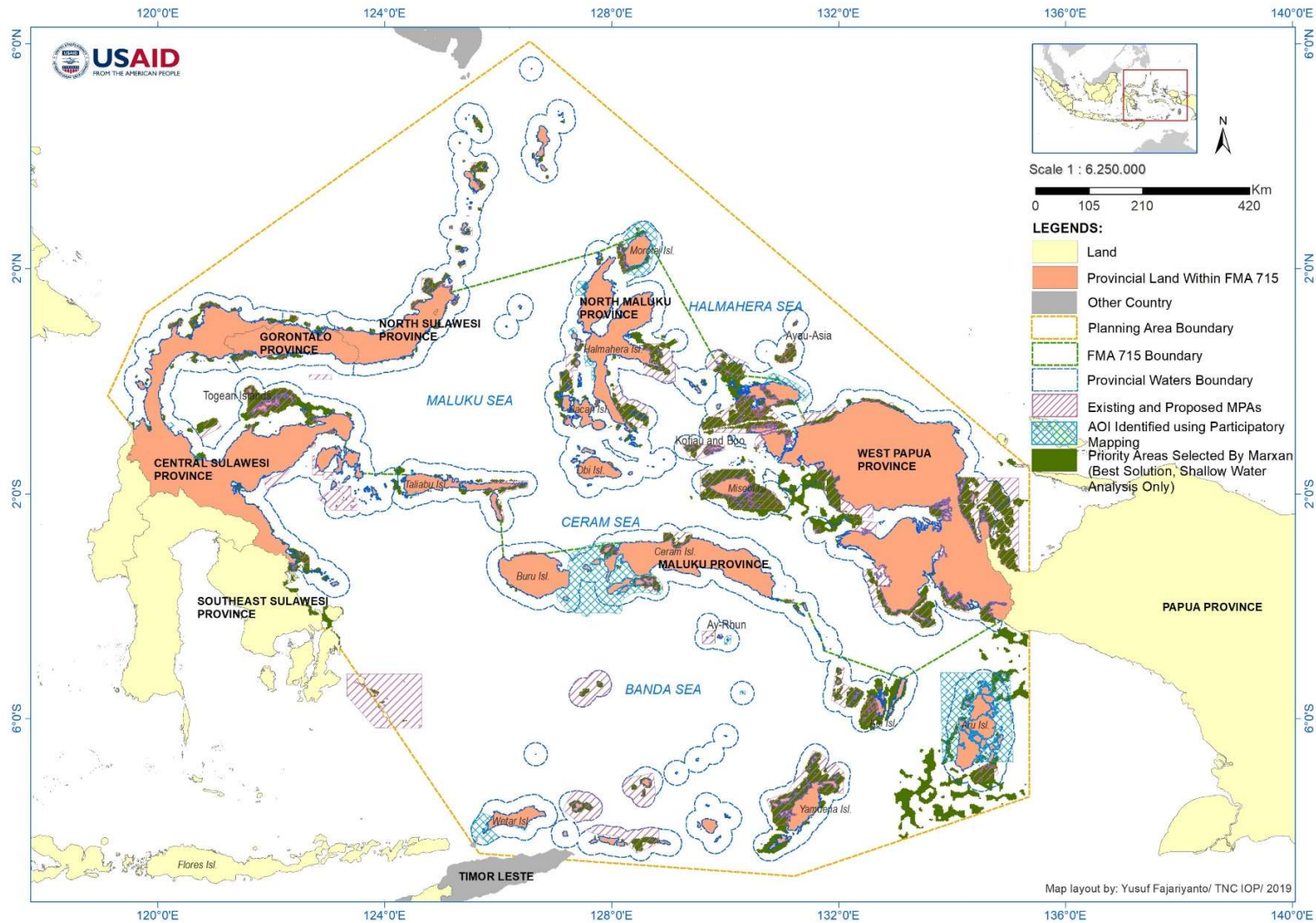


Figure 20. Best solution for the shallow water analysis from the second Marxan analysis, overlaid with existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs identified by participatory mapping in the provinces. Where the dark green areas were selected as priority areas for inclusion in the MPA network by Marxan.

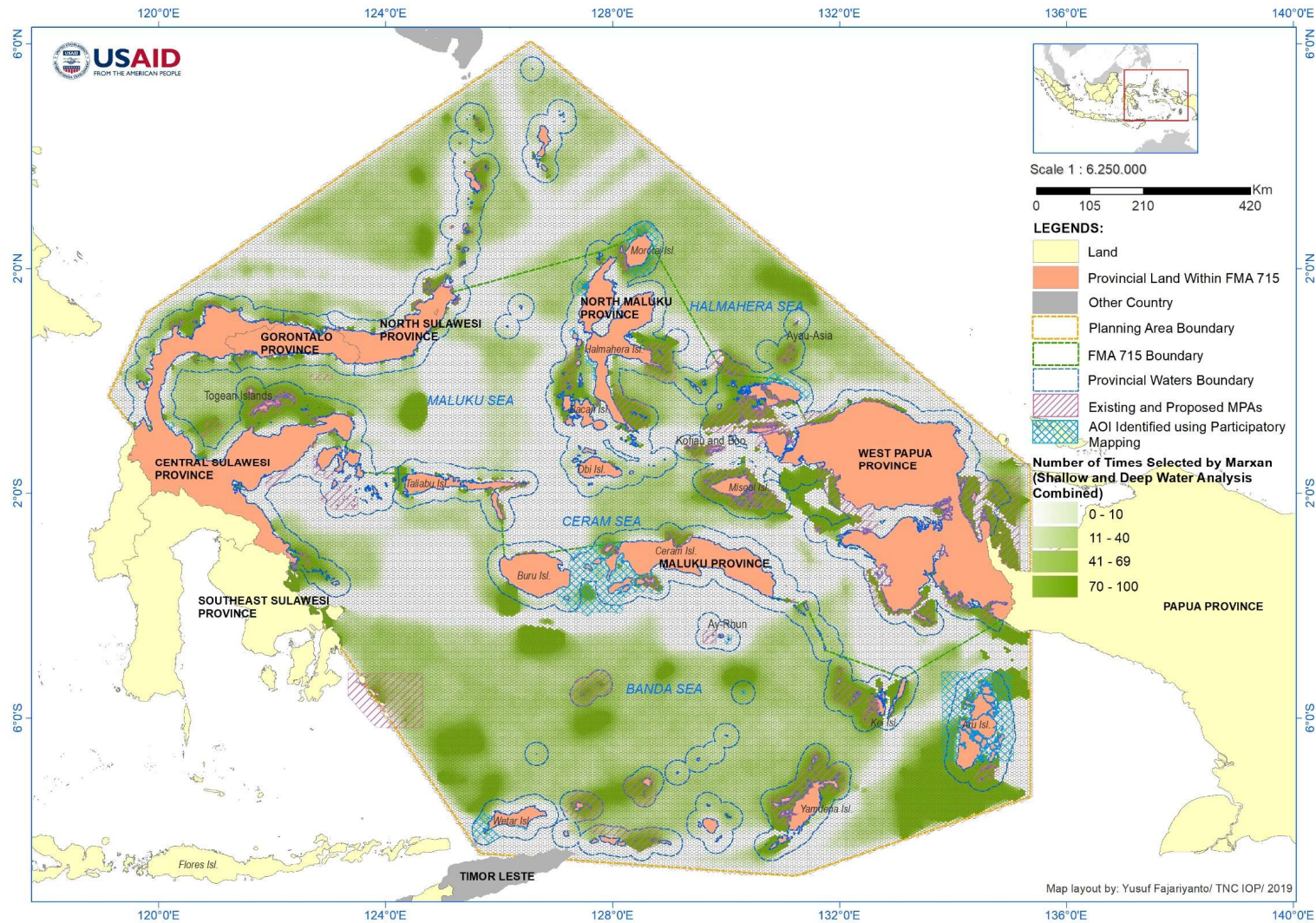


Figure 21. Sum solution for the combined shallow and deepwater analysis from the second Marxan analysis, overlaid with existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs identified by participatory mapping in the provinces. Where different shades of green show how many times each planning unit was selected by Marxan.

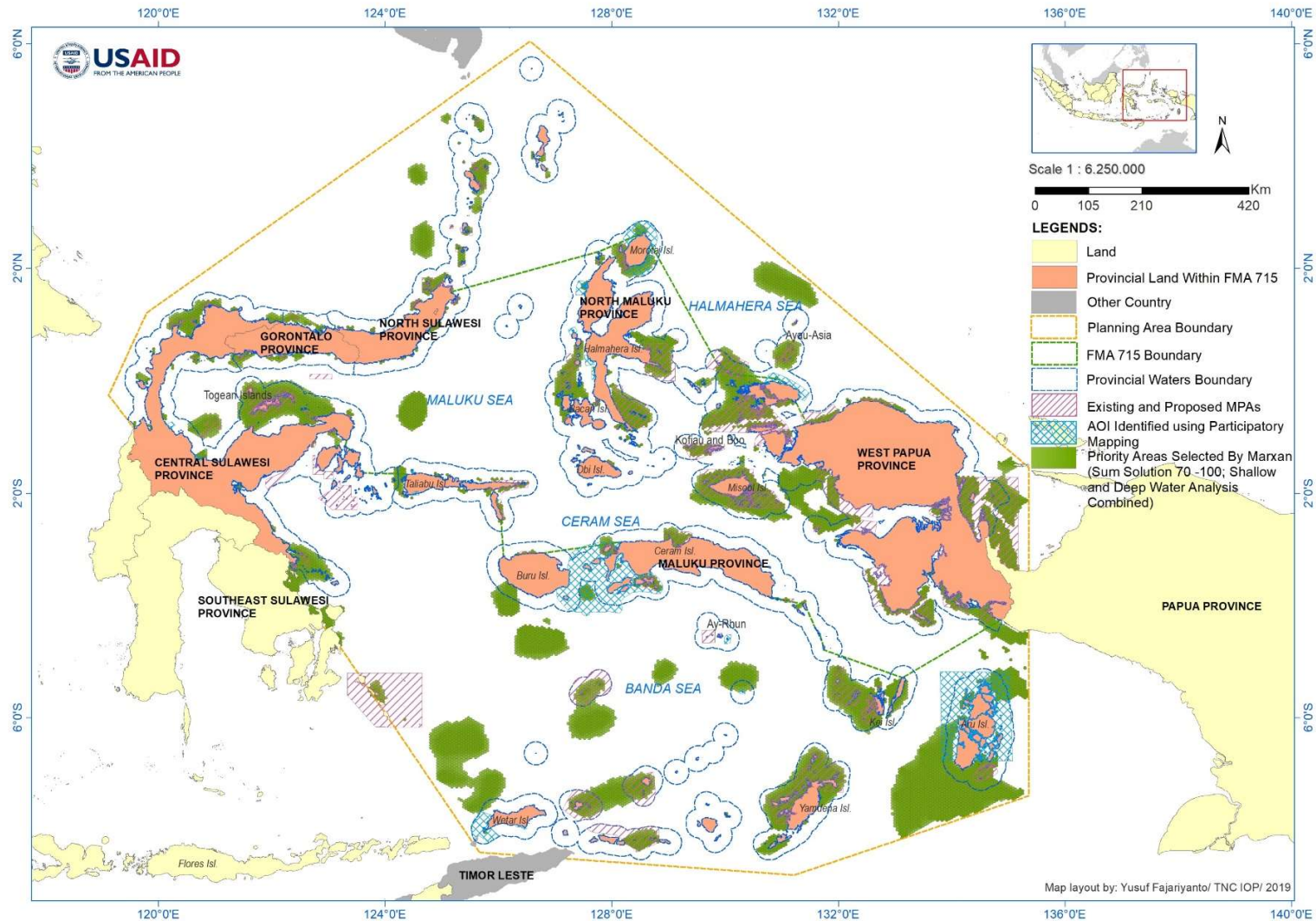


Figure 22. Priority areas for inclusion in the MPA network design selected by the second Marxan analysis (in 70 to 100 solutions) for the combined shallow and deepwater analysis, overlaid with existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs identified by participatory mapping in the provinces.

Manually Refining the Results of the Second Marxan Analysis

We refined the results of the second Marxan analysis to develop a MPA network design for FMA715 and the six associated provinces, which included:

- All existing and proposed MPAs in the Marine Spatial Plans; and
- Areas of Interest for establishing new MPAs or expanding existing MPAs.

To do this, we used the priority areas selected by the second Marxan analysis outside of existing and proposed MPAs (Figure 22), and refined these manually to identify Areas of Interest for establishing new or expanding existing MPAs using other data layers that were not included in the Marxan analysis (see Annex 1) as follows:

- We included Areas of Interest identified as priorities by both the second Marxan analysis (Figure 22) and participatory expert mapping in the provinces (see *Existing and Proposed Marine Protected Areas, and Areas of Interest for Establishing New Marine Protected Areas*). For example, Prafi Bay in West Papua was identified as an Area of Interest by both Marxan and participatory mapping (Figure 4), because it has a turtle nesting beach. Participatory mapping also identified this as an Area of Interest because it is a migratory corridor for turtles and has a coral reef, where there are low levels of threat and no incompatible uses.
- We did not include some priority areas selected by Marxan as Areas of Interest, because manual checking of data layers not included in the analysis showed that these areas were not good choices for MPAs because of the intensity of marine traffic (Figure 23), fishing intensity (Figure 24) and/or local threats (Figure 12). For example: two deepwater areas identified as priorities by Marxan south of Buru Island in Maluku (Figure 22) were not included as Areas of Interest (Figure 25) because of the intensity of marine traffic and fishing in these areas; while the shallow area identified as a priority by Marxan in northwest Buli Bay in East Halmahera was not included as an Area of Interest because of ports, nickel mining and sedimentation in the area (Figure 14).
- We added some Areas of Interest identified by participatory expert mapping that Marxan did not select. For example, we included southwest Wetar Island in Maluku (Figure 25) which is an Area of Interest identified by participatory mapping (Figure 5) because of the presence of a spag, turtle nesting beaches and an important cetacean migratory corridor. However, Marxan did not select this area, because the presence of locked out features (a port and an underwater cable > 4 km offshore: Figure 14). We included southwest Wetar as an Area of Interest because we believe that these conservation features can still be protected in areas adjacent to the cable and the port.
- We added two Areas of Interest where there were important conservation features not identified as priority areas by either Marxan or the participatory mapping. These areas were identified in some of the data layers we used to manually evaluate the design. For example, we added Lito Bongkil Area of Interest (Figure 29) because it has an offshore submerged coral reef, whale sharks frequent the area, and there appears to be low shipping activities and fisheries pressure. Adding this Area of Interest helped achieve the target for coral reef protection in both Gorontalo and North Sulawesi provinces, because the submerged coral reef is on the boundary of these two provinces.

We also conducted a posthoc analysis using Marxan to determine if we had achieved our targets for protecting each conservation feature in the MPA network. We used the results of this analysis to refine the Areas of Interest until we achieved our targets as far as possible (see *Considering Large Scale Patterns of Connectivity and Conservation Priorities Posthoc Analysis* below).

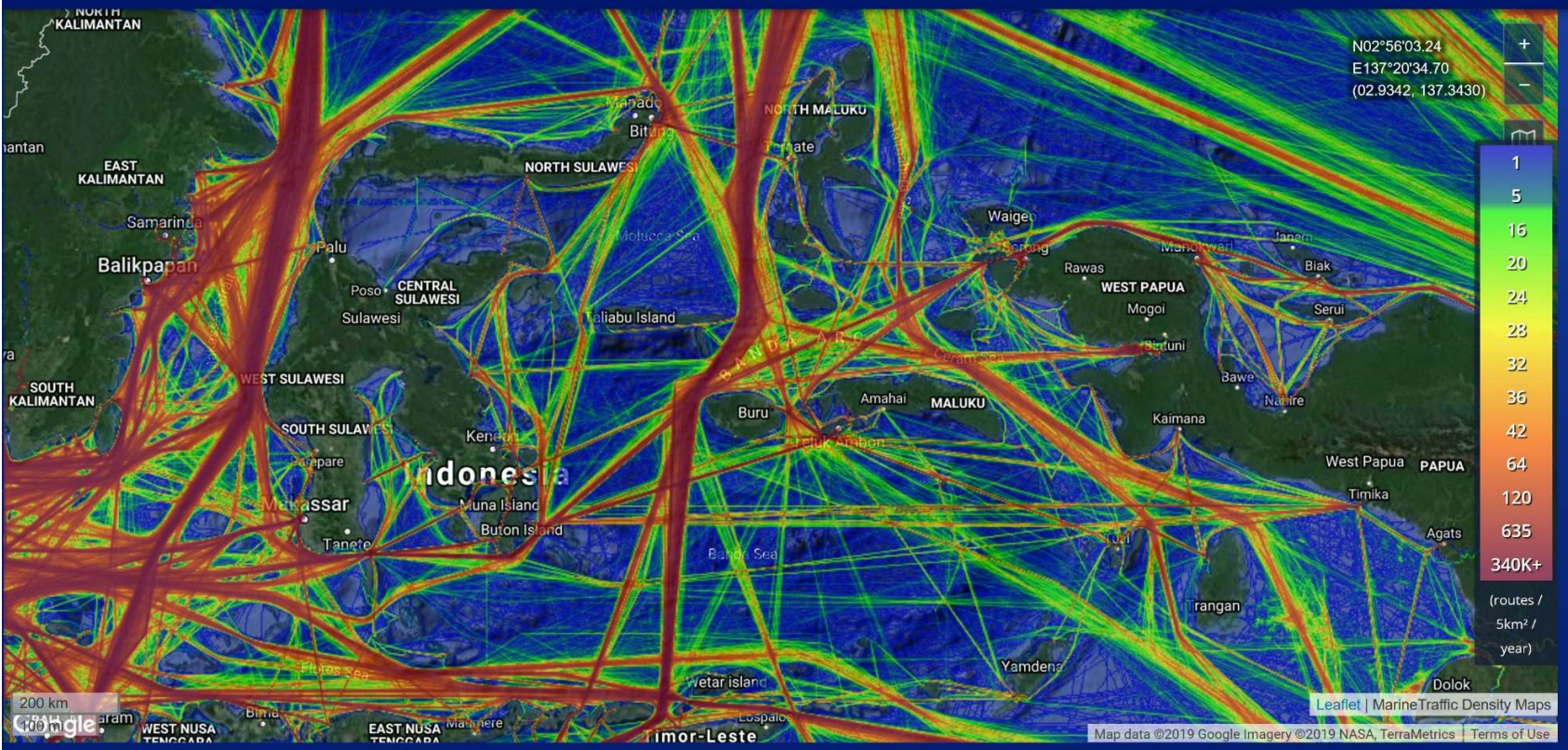


Figure 23. Density of marine traffic in eastern Indonesian waters in 2017 (Source: www.marinetraffic.com).

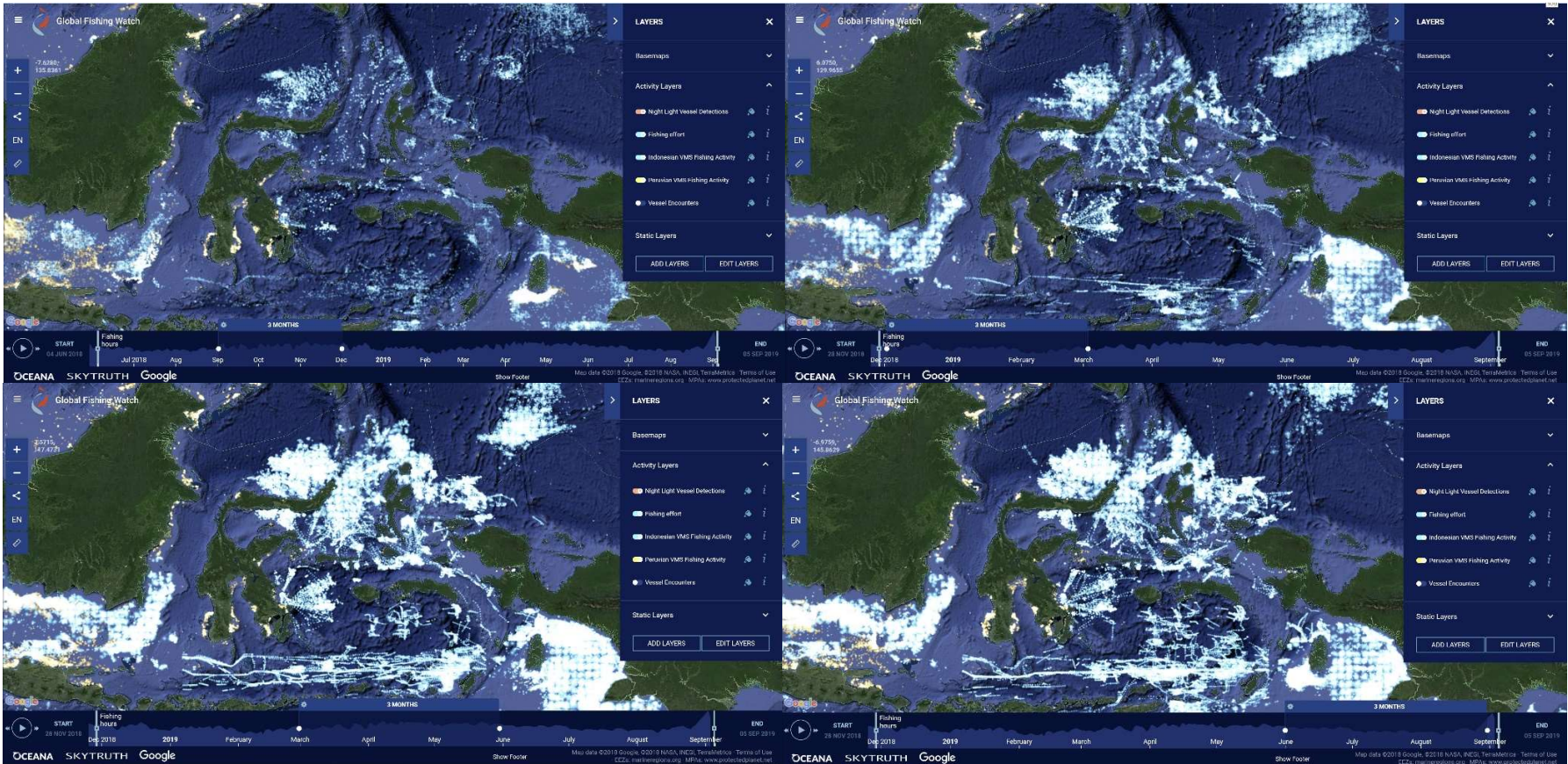


Figure 24. Intensity of commercial and subsistence fishing (based on vessel monitoring systems and night lights) in different seasons: the southeast monsoon (June to August: bottom right), the northeast monsoon (December to February: top right) and transition periods in between (left). (Source: <https://globalfishingwatch.org/initiatives/indonesia-vms/>).

RESULTS

Marine Protected Area Network Designs

Fisheries Management Area 715 and the Six Associated Provinces

The result was the first iteration of a MPA network design for FMA715 and the six associated provinces (Figure 25) that includes:

- All 122 of the existing and proposed MPAs already allocated in the provincial Marine Spatial Plans (comprising 10.1 million hectares); and
- 44 Areas of Interest for establishing new MPAs in the six provinces (comprising 5.3 million hectares).

For details of each existing and proposed MPA and Area of Interest, see *Annex 4* (Table 11 and Table 12).

These Areas of Interest were selected as potential areas for establishing new MPAs, because they comprise important biophysical, socioeconomic and/or cultural sites that are not currently protected within existing or proposed MPAs in the provincial Marine Spatial Plans. They include:

- 16 Areas of Interest for establishing new MPAs previously identified by participatory mapping in West Papua, Maluku and North Maluku Provinces;
- 1 new Area of Interest (Botubarani) previously identified as a proposed MPA by provincial fisheries agencies (DKP) and local universities in Gorontalo Province; and
- 27 new Areas of Interest not previously identified.

If these Areas of Interest were established as new MPAs, they would increase the total area of existing and proposed MPAs in FMA715 and the six provinces from 10.1 to 15.4 million hectares (Table 8).

Table 8. Area of existing and proposed MPAs in the provincial Marine Spatial Plans (hectares), and Areas of Interest for establishing new or expanded MPAs for the MPA network design for FMA715 and six associated provinces. For more detail see Annex 4.

Province	Existing and Proposed MPAs (ha)	Areas of Interest (ha)
West Papua	4,831,002	866,534
North Maluku	1,043,033	847,621
Maluku	2,942,193	2,922,080
Central Sulawesi	972,764	478,446
Gorontalo	82,752	72,069
North Sulawesi	246,570	149,727
Total	10,118,314	5,336,477

Each Province

West Papua Province

The MPA network design for West Papua Province () includes:

- All 22 of the existing and proposed MPAs already allocated in the provincial MSPs (comprising 4.8 million hectares); and
- 7 Areas of Interest (comprising 0.8 million hectares) for establishing new MPAs in West Papua Province.

If these Areas of Interest were established as new MPAs, they would increase the total area of existing and proposed MPAs in West Papua Province from 4.8 to 5.6 million hectares.

Maluku Province

The MPA network design for Maluku Province (Figure 27) includes:

- All 19 of the existing and proposed MPAs already allocated in the provincial MSPs (comprising 2.9 million hectares); and
- 7 Areas of Interest (comprising 2.9 million hectares) for establishing new MPAs in Maluku Province.

If these Areas of Interest were established as new MPAs, they would increase the total area of existing and proposed MPAs in Maluku Province from 2.9 to 5.8 million hectares.

North Maluku Province

The MPA network design for North Maluku Province (Figure 28) includes:

- All 17 of the existing and proposed MPAs already allocated in the provincial MSPs (comprising 1.0 million hectares); and
- 11 Areas of Interest (comprising 0.8 million hectares) for establishing new MPAs in North Maluku Province.

If these Areas of Interest were established as new MPAs, they would increase the total area of existing and proposed MPAs in North Maluku Province from 1.0 to 1.8 million hectares.

North Sulawesi Province

The MPA network design for North Sulawesi Province (Figure 29) includes:

- All 29 of the existing and proposed MPAs already allocated in the provincial MSPs (comprising 0.24 million hectares); and
- 9 Areas of Interest (comprising 0.14 million hectares) for establishing new MPAs in North Sulawesi Province.

If these Areas of Interest were established as new MPAs, they would increase the total area of existing and proposed MPAs in North Sulawesi Province from 0.24 to 0.39 million hectares.

Gorontalo Province

The MPA network design for Gorontalo Province (Figure 30) includes:

- All 16 of the existing and proposed MPAs already allocated in the provincial MSPs (comprising 0.08 million hectares); and
- 5 Areas of Interest (comprising 0.07 million hectares) for establishing new MPAs in Gorontalo Province.

If these Areas of Interest were established as new MPAs, they would increase the total area of existing and proposed MPAs in Gorontalo Province from 0.08 to 0.15 million hectares.

Central Sulawesi Province

MPA network design for Central Sulawesi Province (Figure 31) includes:

- All 16 of the existing and proposed MPAs already allocated in the provincial MSPs (comprising 0.97 million hectares); and
- 5 Areas of Interest (comprising 0.47 million hectares) for establishing new MPAs in Central Sulawesi Province.

If these Areas of Interest were established as new MPAs, they would increase the total area of existing and proposed MPAs in Central Sulawesi Province from 0.97 to 1.45 million hectares.

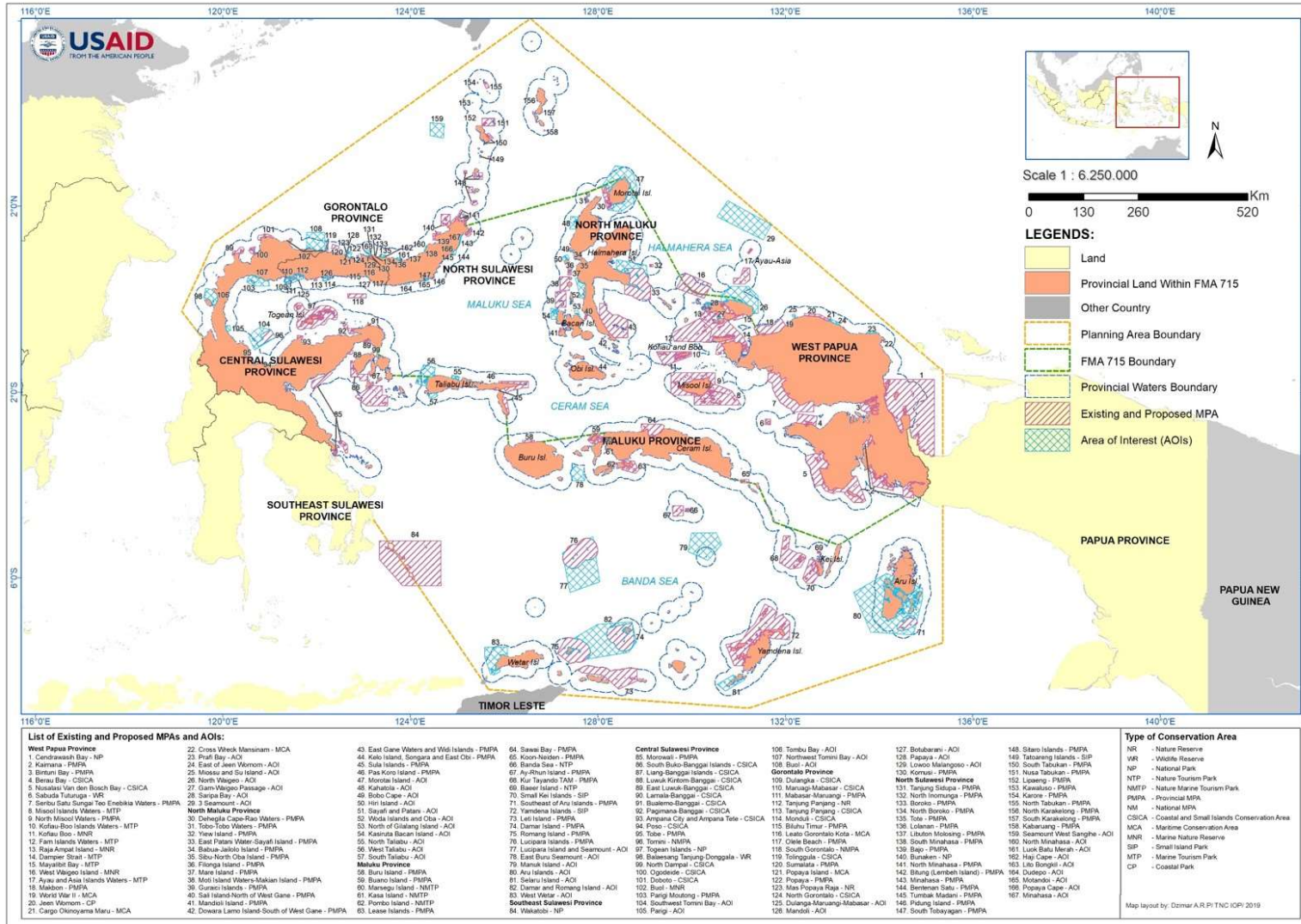


Figure 25. MPA Network Design for FMA715 and six associated provinces, consisting of the existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs.

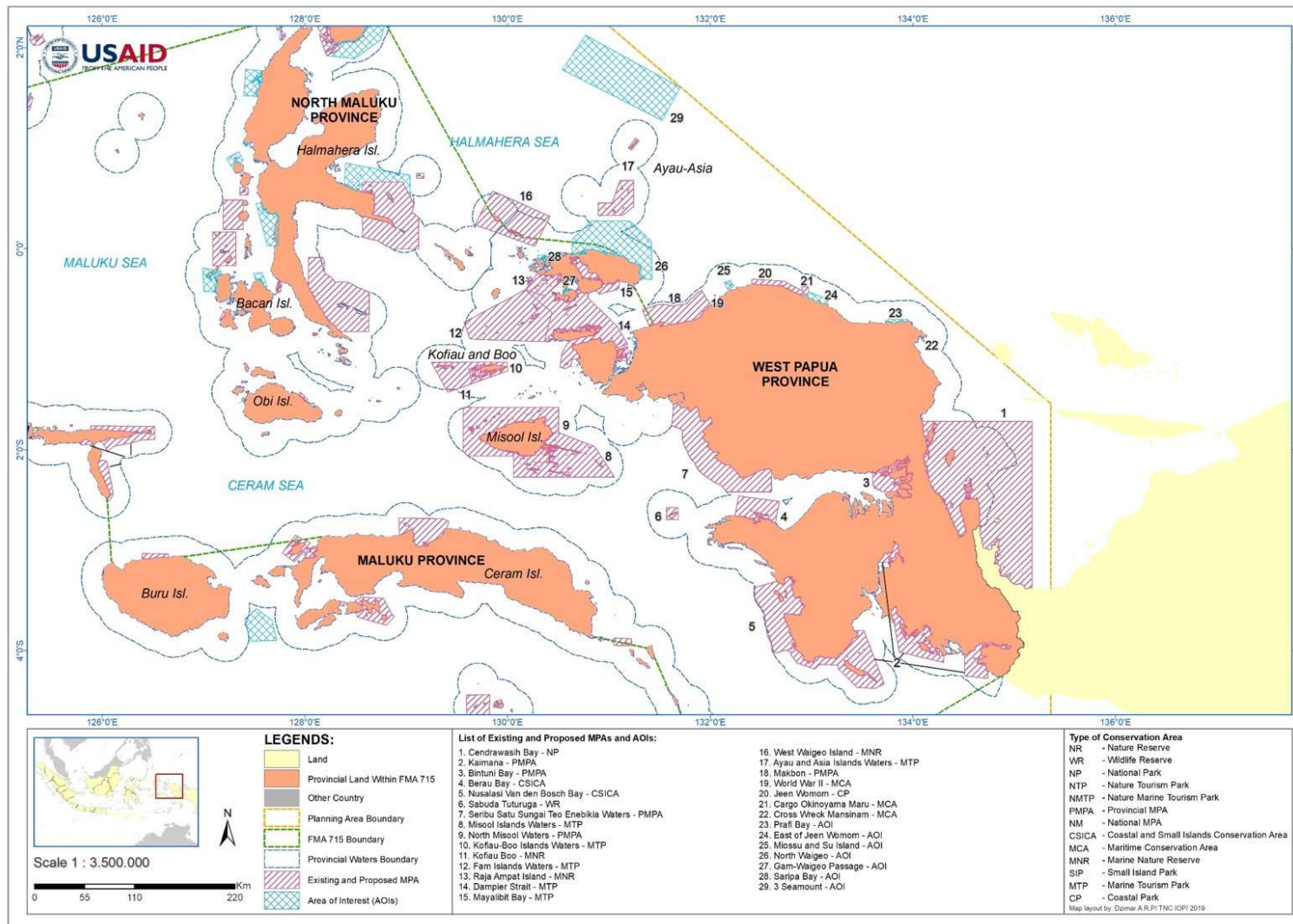


Figure 26. MPA Network Design for West Papua Province, consisting of the existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs

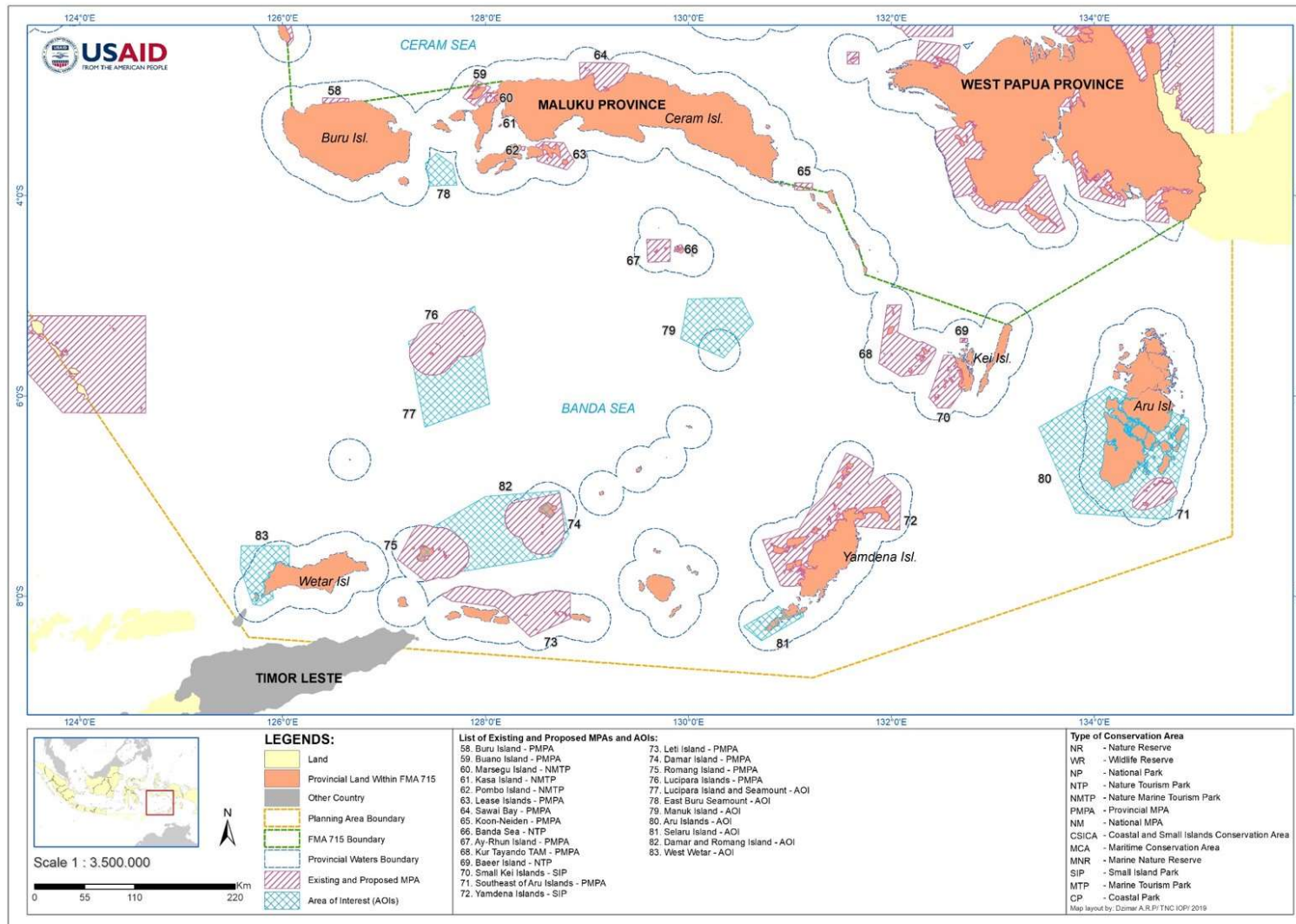


Figure 27. MPA Network Design for Maluku Province, consisting of the existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs.

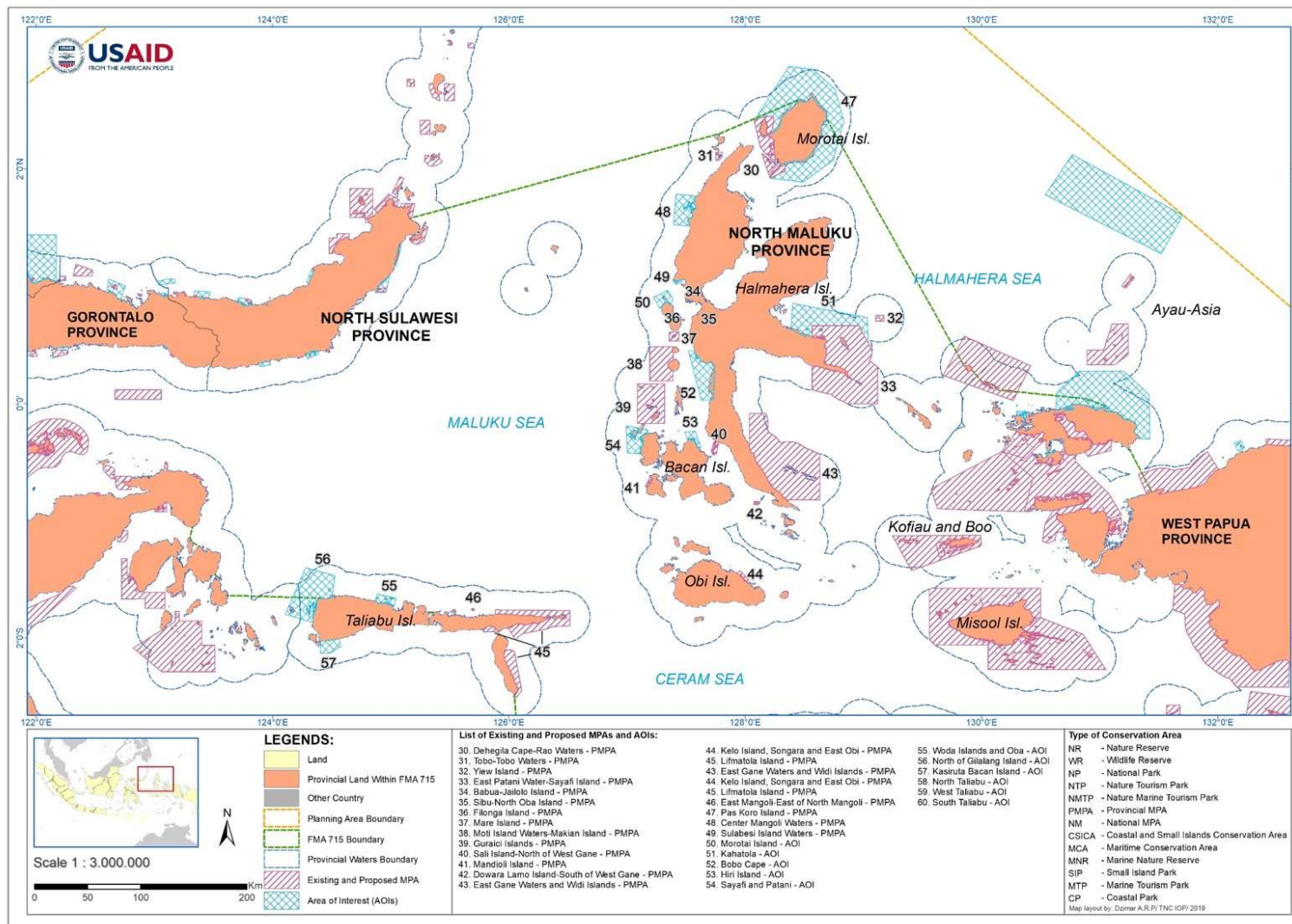


Figure 28. MPA Network Design for North Maluku Province, consisting of the existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs.

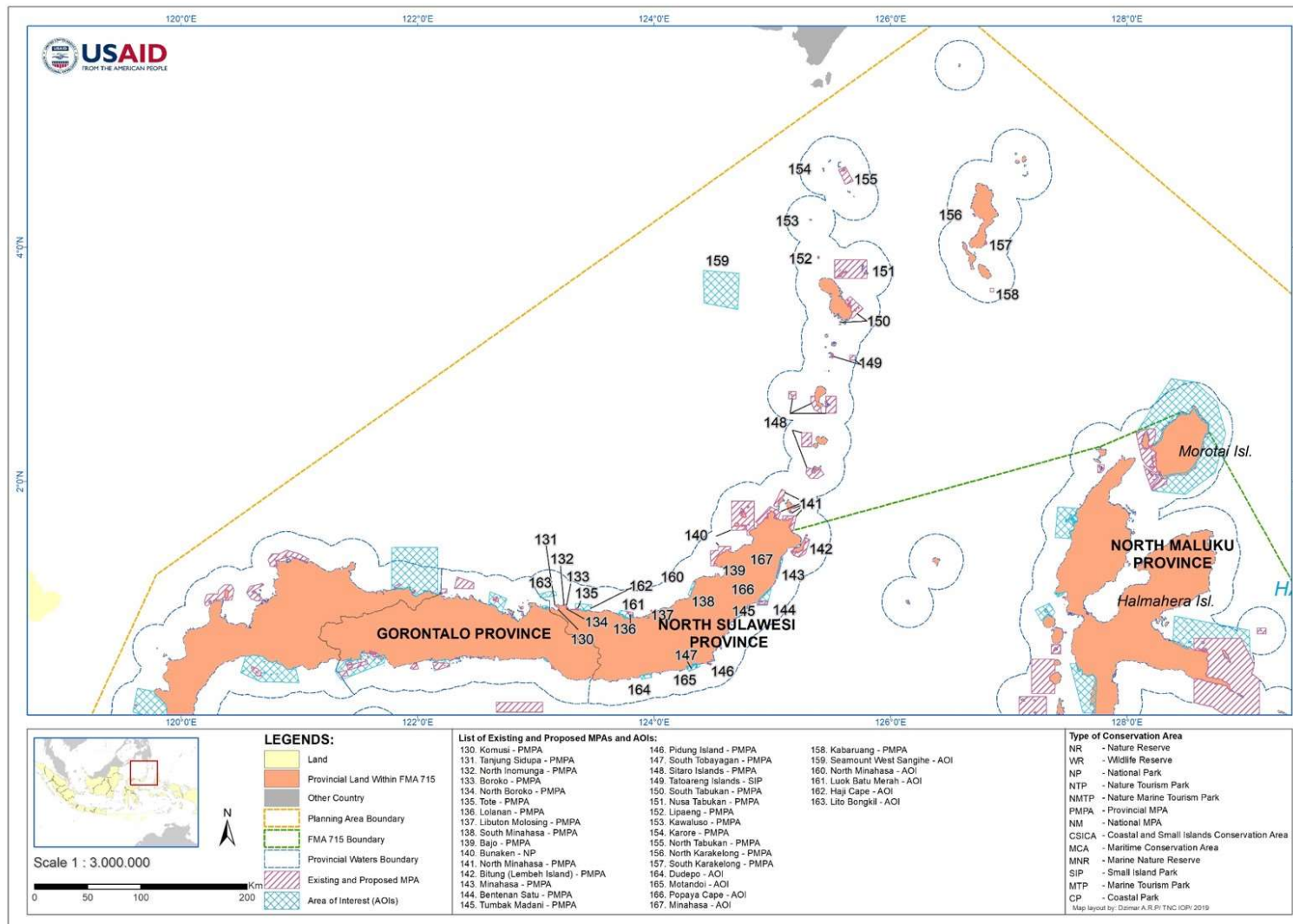


Figure 29. MPA Network Design for North Sulawesi Province, consisting of the existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs.

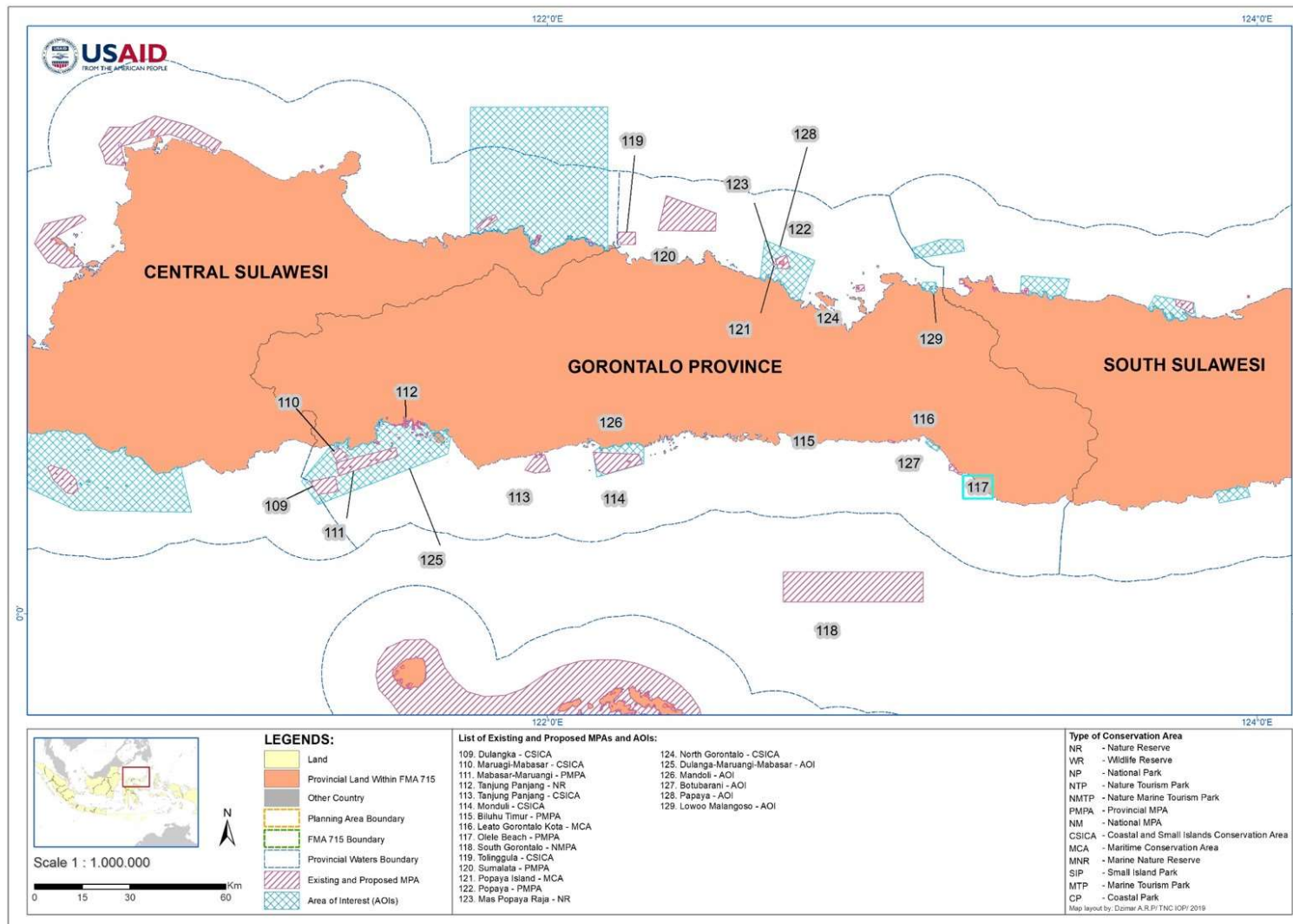


Figure 30. MPA Network Design for Gorontalo Province, consisting of the existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs.

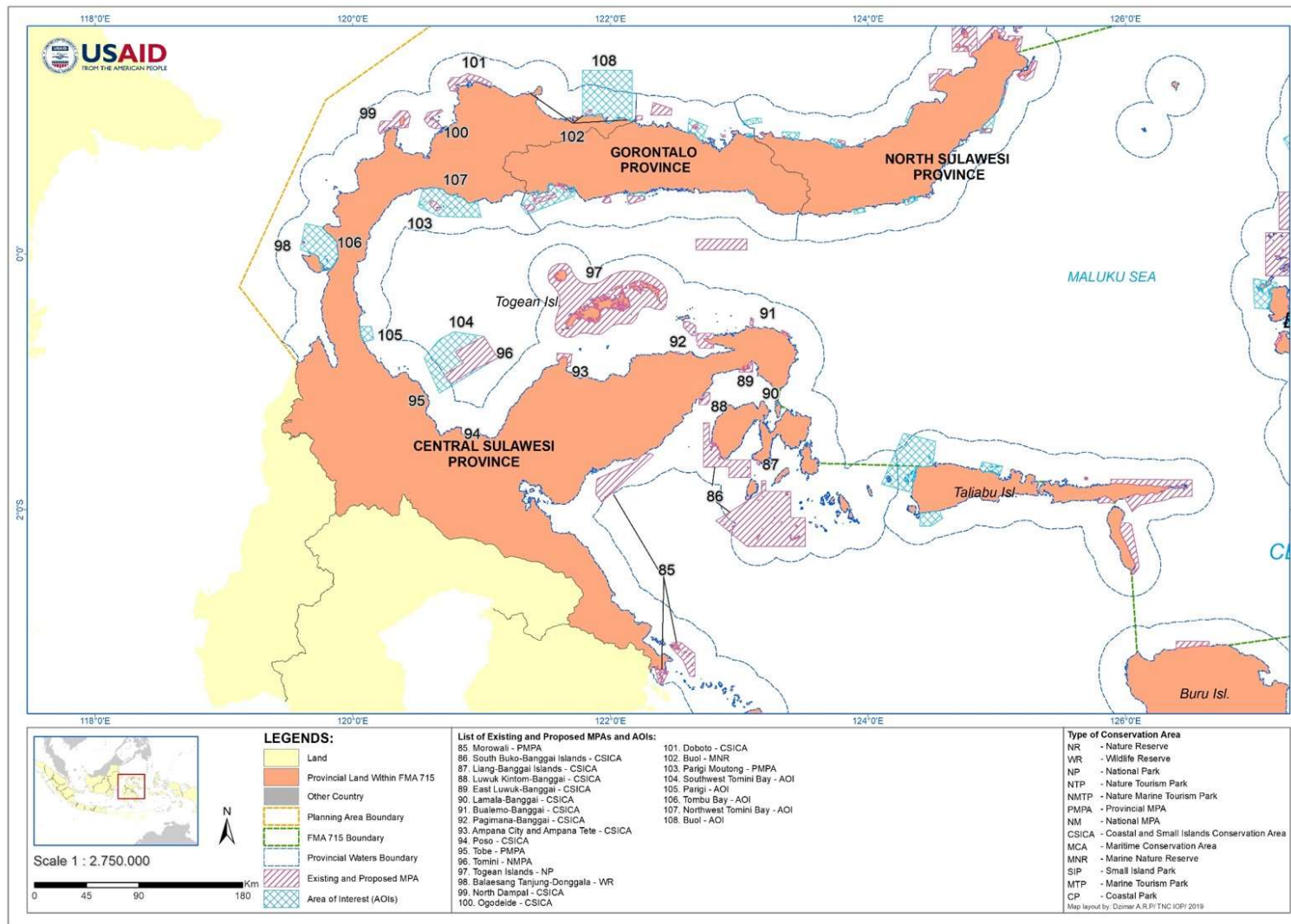


Figure 31. MPA Network Design for Central Sulawesi Province, consisting of the existing and proposed MPAs in the provincial Marine Spatial Plans and Areas of Interest for establishing new MPAs.

Considering Large Scale Patterns of Connectivity and Conservation Priorities Posthoc Analysis Using Marxan

We conducted a post hoc analysis in Marxan to determine if we achieved our targets for the conservation features in the MPA network design (Figure 25).

Shallow Water Habitats

We set a target of 30% protection for each of three shallow water habitats: coral reefs, mangroves and seagrasses (Table 6, Figure 9). More than 30% of each of these habitats is already included in existing or proposed MPAs throughout the entire planning area (Figure 32). This is because a high percentage of each of these habitats is already included in existing or proposed MPAs in some provinces, particularly in West Papua (Figure 33). However, this target has not yet been achieved for all or some of these habitats in other provinces (i.e., in Gorontalo and North Maluku: Figure 33).

Therefore, where possible, we added Areas of Interest to the MPA network design to protect at least 30% of each of these three habitats in each province (Figure 33). This led to an increase in the total % of these habitats included in the MPA network design throughout the planning area ranging from 42% for seagrasses, to 49% for mangroves and 56% for coral reefs. However, this varies with 38% to 72% of coral reefs, 23% to 59% of mangroves and 33% to 95% of seagrasses included in the MPA network design in different provinces (Figure 33).

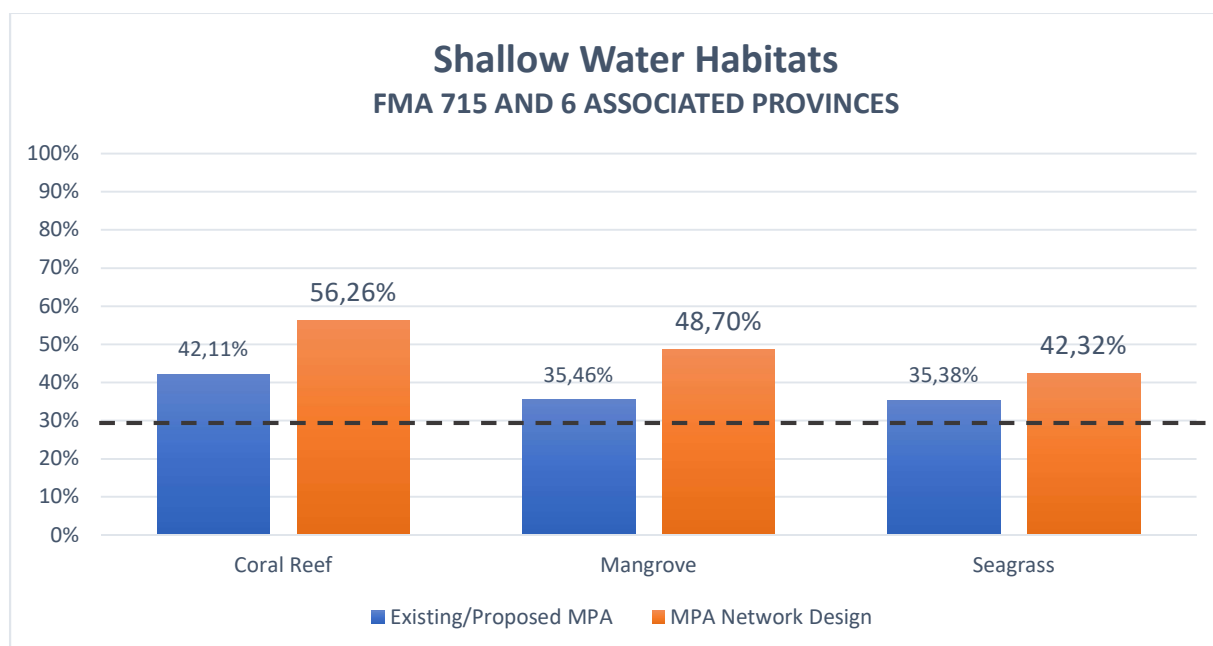


Figure 32. Percentage of each shallow water habitat in existing or proposed MPAs and the MPA network design (which includes existing and proposed MPAs, and Areas of Interest for establishing new MPAs) throughout the planning area. Where the target for protection in MPAs is at least 30% for each habitat type.

It is important to note that while this level of habitat protection may seem high, these calculations are for habitats protected in all zones in existing or proposed MPAs and Areas of Interest.

However, the biophysical design criteria recommends that at least 20% of these habitats should be protected in NTZs (see Table 3). We could not do post hoc accounting to determine how much of each of these habitats is included in NTZs, because many MPAs have not yet been zoned or the spatial data for existing or proposed zoning plans for MPAs is not available. However, the percentage of NTZs in MPAs in this region is generally low. For example, the percentage of NTZs in the Banda Sea Marine Tourism Park is 7% (including for both core and non-extractive utilization zones), compared to 92% for the sustainable fisheries zone. Therefore, the MPA network is still a long way from achieving this design criteria. This will need to be taken into account when zoning individual MPAs (i.e., each MPA should aim to protect at least 20% of each habitat type in NTZs: Green et al. 2019a).

The relatively high level of protection of each shallow habitat in the MPA network design will also add a buffer for the effects of changes in climate and ocean chemistry on these habitats (see Green et al. 2019a).

Deep Water Habitats

We set targets for protecting deepwater habitats in the MPA network at 80% for seamounts, 30% for canyons and 10% for the other habitats (see Table 7).

The level of protection of most of these habitats in existing or proposed MPAs is currently low (<5-10%) throughout the planning area, with only 1% of seamounts and 4% of canyons included in existing or proposed MPAs (Figure 34). The exception is shelf and sill habitats, which range from 12 to 41% protection in existing and proposed MPAs.

The MPA network is designed to provide a higher level of protection for most of the 20 deepwater habitats, with seven habitats exceeding their target of 10% of each habitat included in the MPA network design (Figure 34). However, we have not achieved our targets for protecting the other habitats because they overlap with other uses. For example, only 31% of seamounts (Figure 10) could be included in the MPA network design (Figure 25), which is much less than our target of protecting 80% of this habitat. This is because most seamounts are located in areas where MPAs cannot be established because they are located in areas allocated for other uses in the Marine Spatial Plans (i.e., military areas: Figure 14) or in areas with high intensity of marine traffic or fishing (Figure 23 and Figure 24). Similarly, we were only able to include 8% of canyons in the MPA network design, because they overlap with areas allocated for other uses or high intensity areas for marine traffic and fishing.

Critical, Special and Unique Areas

We set targets for protecting critical, special and unique areas in the MPA network (Table 6) of:

- 80% for fish spawning areas, turtle nesting beaches, coelacanth distribution and walking shark distribution areas, important traditional areas and shipwrecks; and
- 50% of sea worms fishing areas and dive sites.

We also locked in local wisdom areas, aiming to include 100% of these areas in the MPA network.

Some of these features are already protected in existing and proposed MPAs throughout the planning area, including 13% of spags, 36% of turtle nesting beaches, 24% of coelacanth distribution areas, 27% of shipwrecks, 43% of dive sites, 28% of local wisdom areas and 36% of important

traditional areas (Figure 35). Although this is less than the target set for protecting each of these features. Furthermore, some features are not currently protected in existing and proposed MPAs (seaworm fishing areas and walking shark distribution: Figure 35).

Therefore, we increased the level of protection of all of these features in the MPA network design as far as possible, which would achieve the targets of protecting 80% of coelacanth distribution and walking shark distribution areas and 50% of dive sites throughout the entire planning area (Figure 35).

However, while the % of each of the other features protected would be increased in the MPA network design throughout the planning area, we could not meet the targets for most features because they overlap with other uses allocated in the Marine Spatial Plan. For example most of the sea worm fishing areas in Ambon (Figure 11) could not be included in the MPA network design because they overlap with the port (which was locked out: Figure 14). Similarly, some local wisdom areas (e.g., in Kei Island in Maluku: Figure 11), spags and turtle nesting beaches could not be included in the MPA network because they overlap with areas allocated for other uses (i.e., ports, military areas, oil and gas mining or underwater cables: Figure 14).

There was also a lot of variation among provinces regarding how well critical, special and unique areas are protected in existing and proposed MPAs and the MPA network design (Figure 36). For example:

- West Papua already has a high level of protection for most of these features in existing and proposed MPAs (e.g., for walking shark distribution, dive sites and spags). Therefore, the level of protection of these features was not significantly improved by the MPA network design.
- North Maluku is already protecting some features in existing and proposed MPAs (i.e., turtle nesting beaches) but not others (i.e., walking shark distribution and local wisdom areas). The MPA network design would increase the protection of most of these features, and would achieve the targets set for at least two of these (for walking shark distribution areas and turtle nesting beaches).
- Maluku is already protecting some features in existing and proposed MPAs (e.g., spags), and the % protected would be increased in the MPA network design. Although none of the targets for these features would be achieved.
- Gorontalo and Central Sulawesi are already protecting some of these features in existing and proposed MPAs (e.g., turtle nesting areas and dive sites). Although the % of these features protected would be higher in the MPA network design, which would allow for more of the targets to be achieved (e.g., for turtle nesting beaches).
- North Sulawesi is already achieving the target for protecting shipwrecks in existing and proposed MPAs, but not for the other features (which was not substantially improved by the MPA network design).

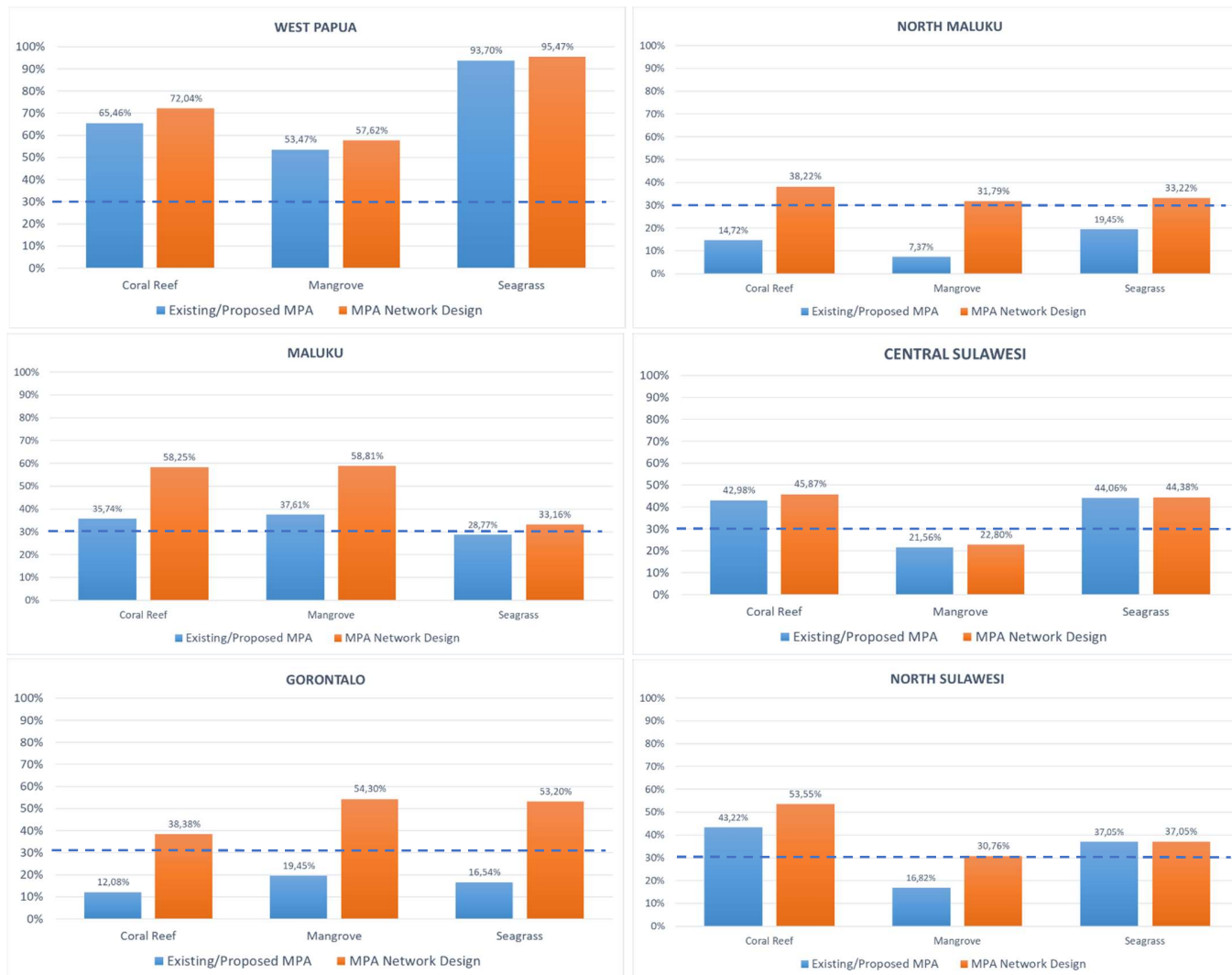


Figure 33. Percentage of each shallow water habitat in existing and proposed MPAs and the MPA network design (which includes existing and proposed MPAs, and Areas of Interest for establishing new MPAs) in each province. Where the target for protection in MPAs is at least 30% of each habitat in MPAs in each province.

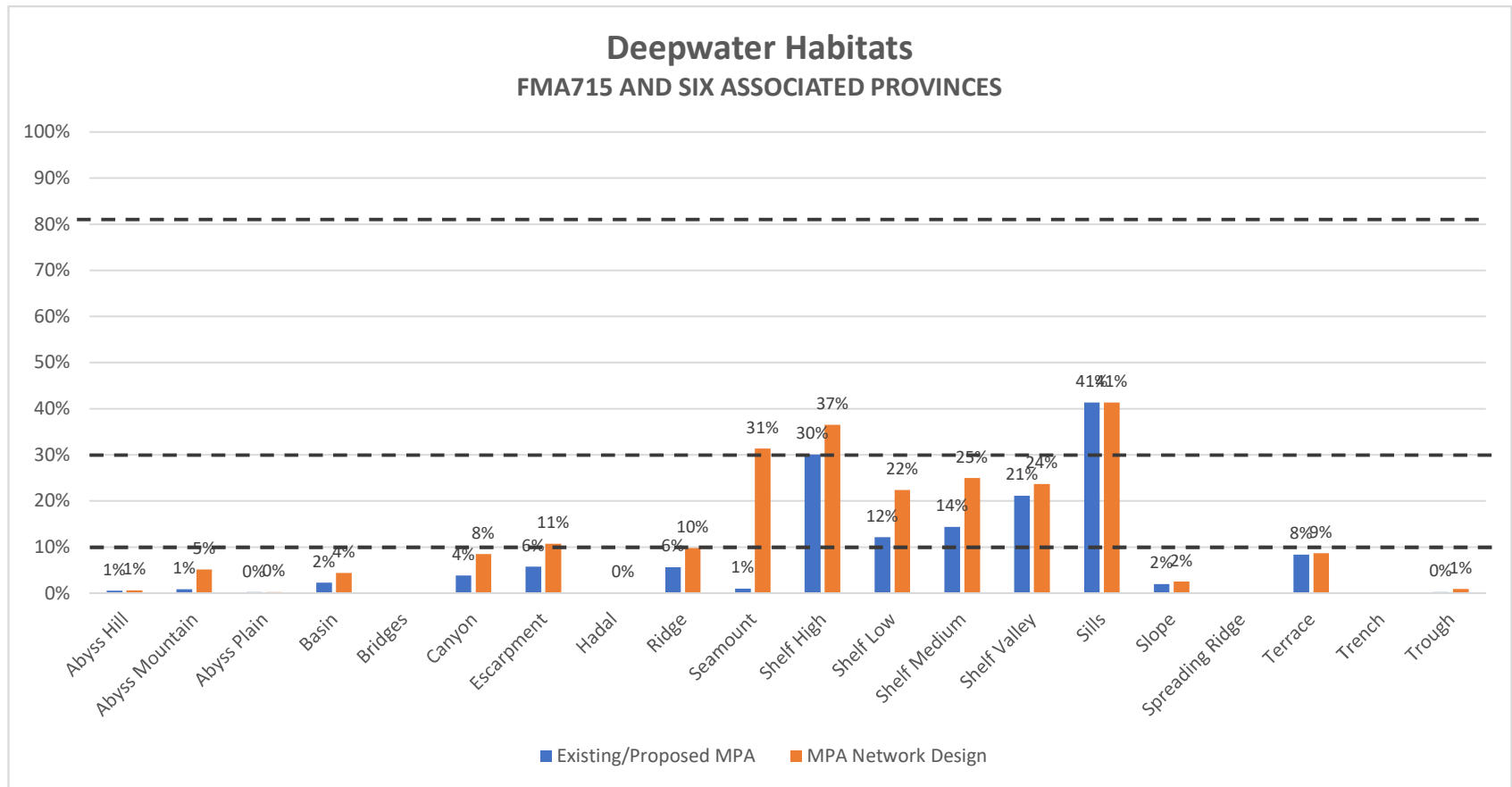


Figure 34. Percentage of each deepwater habitat in existing or proposed MPAs and the MPA network design (which includes existing and proposed MPAs, and Areas of Interest for establishing new MPAs) throughout the planning area. Where the target for protection in MPAs is 80% for seamounts, 30% for canyons and 10% for the other habitats.

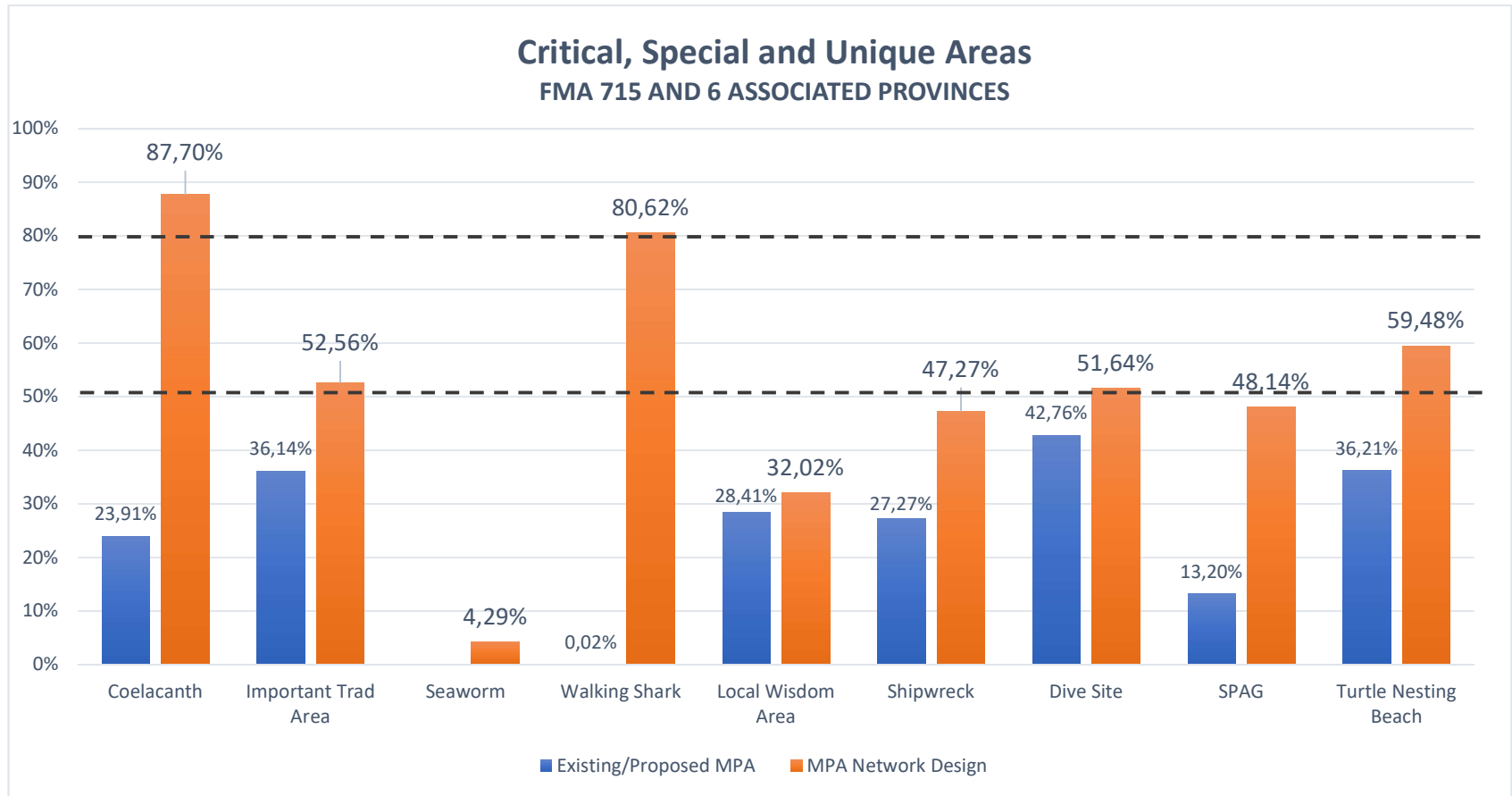


Figure 35. Percentage of each critical, special and unique area in existing or proposed MPAs and the MPA network design (which includes existing and proposed MPAs, and Areas of Interest for establishing new MPAs) throughout the entire planning area. Where the target for protection in MPAs is 80% for each feature, except for seaworm fishing areas and dive sites (which are each 50%) and local wisdom areas (which were locked in).

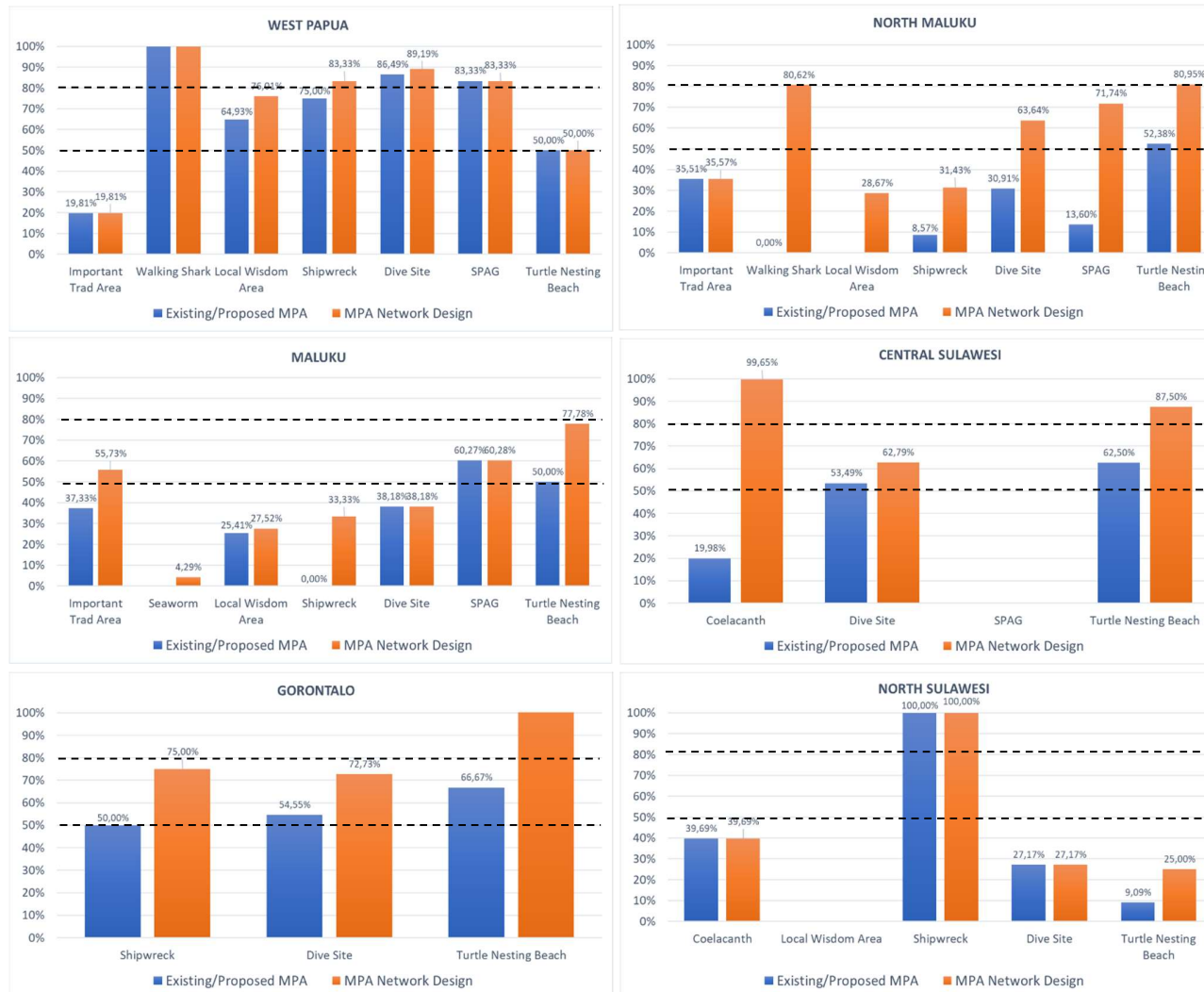


Figure 36. Percentage of each critical, special and unique area in existing and proposed MPAs and the MPA network design (which includes existing and proposed MPAs, and Areas of Interest for establishing new MPAs) in each province. Where the target for protection in MPAs is 80% for each feature, except for seaworm fishing areas and dive sites (which are each 50%) and local wisdom areas (which were locked in) in each province.

Using the Evaluation Tool for Marine Protected Area Network Design in Indonesia

We used the *Evaluation Tool for Marine Protected Area and Marine Protected Area Network Design in Indonesia* (see Green et al. 2019b,c) to evaluate the MPA network design for FMA715 and the six associated provinces (Figure 25). The results show that the MPA network is relatively well designed to address the biophysical and socioeconomic design criteria, with an overall score of 76% (see Annex 5).

Most design criteria are addressed well by the MPA network design because we had the information required for the analysis (see Annex 1, Table 6 and Table 7), and the conservation targets were in areas not allocated for other uses in Marine Spatial Plans. Particularly regarding designing the MPA network to:

- Represent and replicate shallow water habitats; protect critical areas for fisheries, charismatic, endangered, threatened or protected species; incorporate connectivity; allow time for recovery; and protect healthy areas and avoid local threats; and
- Support multiple environmentally-friendly uses and livelihoods; ensure local communities have access to resources and markets; protect marine heritage sites; and protect local wisdom and areas that have important traditional cultural value for local communities.

However, some conservation targets (i.e., seamounts, canyons, spags, wrecks, local wisdom or important traditional areas) could not be included in the MPA network design because they are located in areas allocated for other uses in the Marine Spatial Plans (e.g., military areas, shipping lanes, ports, underwater cables, oil and gas mining) or in areas with high levels of use (i.e., marine traffic and fishing pressure: see *Considering Large Scale Patterns of Connectivity and Conservation Priorities Posthoc Analysis Using Marxan*).

Furthermore, some criteria could not be applied in the MPA network design throughout the entire planning area because we did not have the spatial data required (i.e., regarding protecting special and unique natural phenomena; protecting sites that are likely to be more resilient or resistant to global environmental change (refugia); areas with environmentally friendly uses or where stakeholders support establishing MPAs). Although, some of these criteria were considered when identifying Areas of Interest using participatory expert mapping in three of the provinces (West Papua, Maluku and North Maluku: see *Existing and Proposed Marine Protected Areas, and Areas of Interest for Establishing New Marine Protected Areas*), and subsequently incorporated when *Manually Refining the Results of the Second Marxan Analysis*. These criteria will need to be addressed in more detail with local stakeholders when considering Areas of Interest for new or expanded MPAs or zoning MPAs in future.

Some design criteria could not be applied in the design at all, because we did not have the information required (particularly regarding the need to adapt to changes in climate and ocean chemistry). Research priorities for improving the MPA network design are provided below (see *Recommendations for Improving the Design*).

Considering Large Scale Patterns of Connectivity and Conservation Priorities

We evaluated the extent to which large scale considerations were addressed in the MPA network design for FMA715 and the six associated provinces. We found that the MPA network is designed to:

- Address connectivity of focal fisheries species through larval dispersal and movement patterns of adults and juveniles. For example, we examined the size and spacing of MPAs and Areas of Interest to determine if they comply with the size and spacing recommendations to incorporate connectivity of coral reef fishes and invertebrates in MPA network design in Indonesia (Green et al. 2019a). We found that the MPA network design appears to accommodate connectivity patterns of many species, since most MPAs and Areas of Interest are either large enough to be self-sustaining (e.g., Cenderawasih National Park in West Papua) or close enough to form mutually replenishing networks (e.g., the MPAs in north Gorontalo: Figure 37). However, a more rigorous scientific analysis is required to confirm it this is the case.
- Protect migratory corridors for some cetaceans, dolphins, dugong and sea turtles (Figure 38), which are important at the provincial, trans-provincial and trans-national scales. For example, the MPA network is designed to protect important migratory corridors for the Pygmy Blue Whale in three Areas of Interest (East Buru Seamount, Damar & Romang Island and Manuk Island) and one existing MPA (Lucipara Islands Provincial MPA) in Maluku Province (Figure 27), which connect to other important migratory corridors for this species protected in the Savu Sea Marine National Park and Pantar Strait MPA in East Nusa Tenggara, and West Australian Waters.
- Protect critical, special and unique areas important for conservation at the regional, national or international scale. For example, it protects sea turtle nesting beaches (i.e., the leatherback turtle nesting beach in Kei Kecil MPA, and the olive ridley and leatherback turtle nesting beach in Jeen Womom MPA). Jeen Womom also known as one of the largest remaining western Pacific leatherback turtle nesting beaches and Kei Kecil known as one of the major feeding grounds for leatherback turtles (*Dermochelys coriacea*) in the Pacific Ocean. Study using satellite telemetry of leatherback turtles nesting in the North Coast of West Papua (Jeen Womom) identifies that the migration route of those endangered species reaches to Kei Kecil (Benson et.al., 2011). The seasonal abundance of brown large jellyfish (sea nettles) around the islands has attracted this world's largest sea turtle to find food.

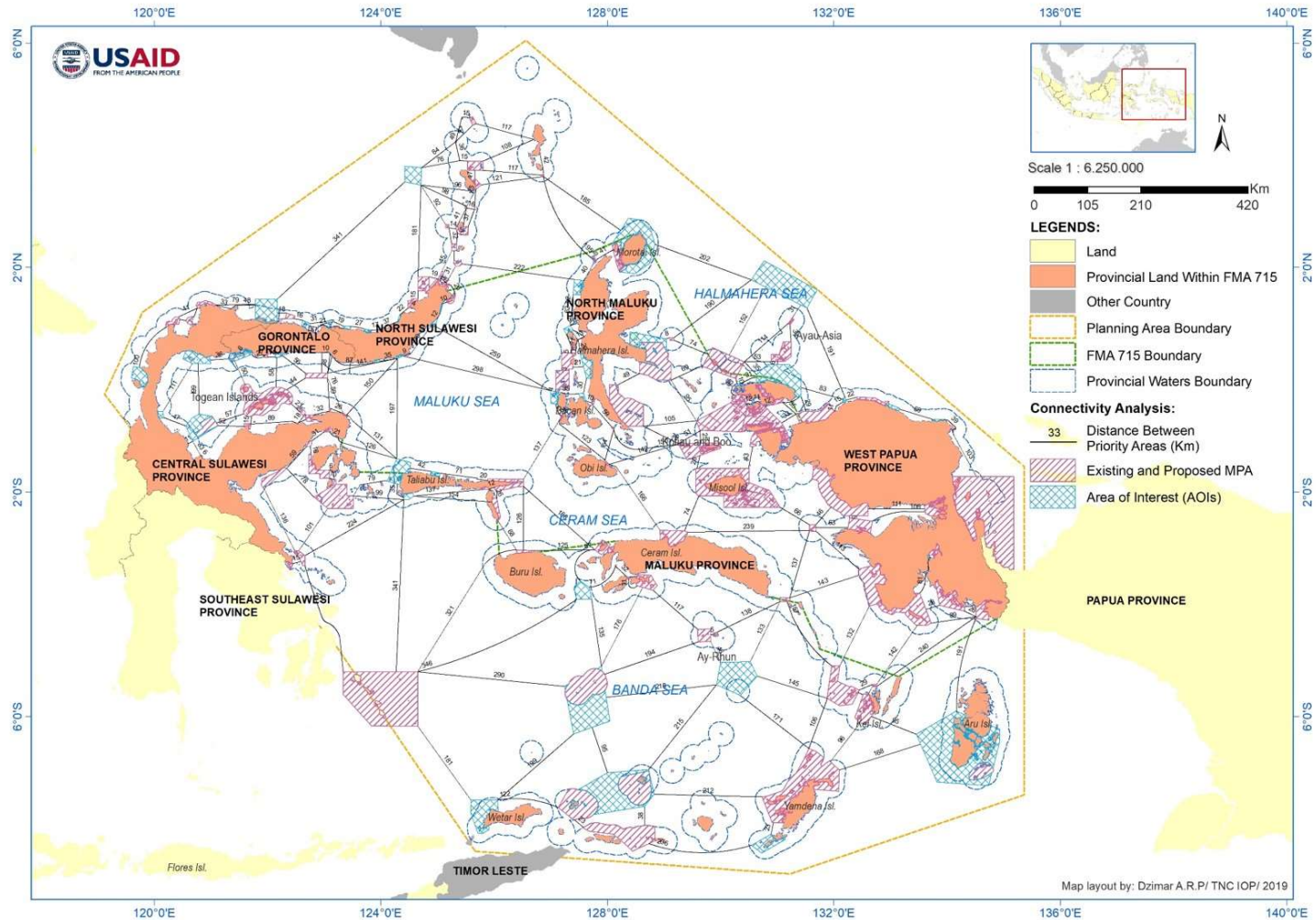


Figure 37. Size and spacing of existing and proposed MPAs and Areas of Interest in the MPA network design for FMA715 and the six associated provinces.

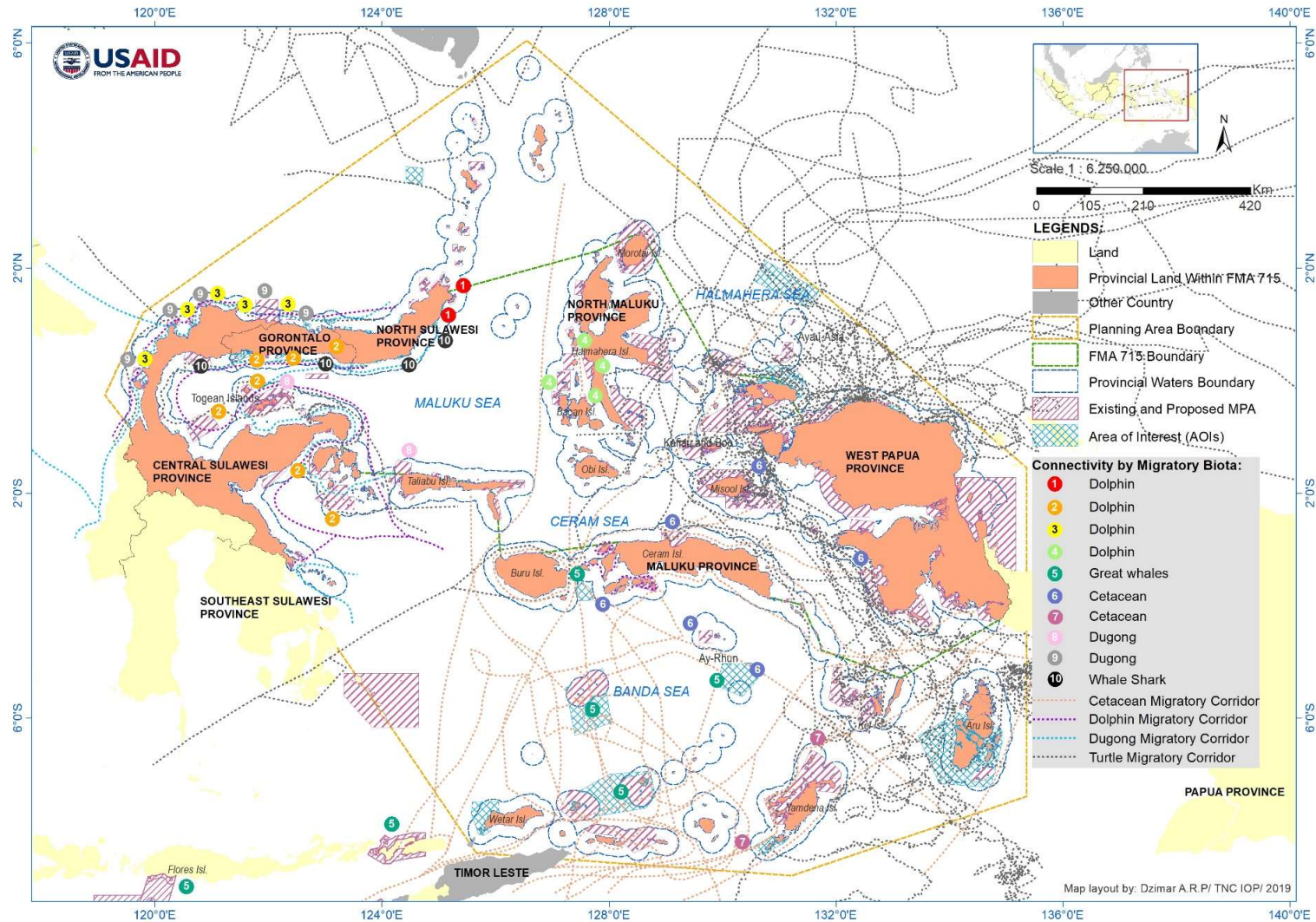


Figure 38. Migratory corridors for rare, threatened and protected species (cetaceans, dolphins and turtle) from satellite tracking overlaid with the MPA network design for FMA715 and the six associated provinces (including existing and proposed MPAs in Marine Spatial Plans, and Areas of Interest for new or expanded MPAs).

DISCUSSION

Marine Protected Area Network Design for Fisheries Management Area 715 and Six Associated Provinces

Here we provide, for the first time, a MPA network design for FMA715 and the associated six provinces (Figure 25). This MPA network design, if it is implemented and managed effectively, will contribute substantially towards achieving the goals for MPAs and MPA networks in Indonesia (Table 2). In particular, the MPA network is designed to:

- Increase protection of biodiversity, by increasing the level of protection of shallow water habitats (coral reefs, mangroves and seagrasses), deepwater habitats, and critical, special and unique areas (i.e., fish spawning areas, turtle nesting beaches, shipwrecks, etc.).
- Maintain or enhance fisheries by increasing the protection of stocks of fisheries species in MPAs, particularly if at least 20% of each habitat is protected in no-take zones (Green et al. 2019). This will lead to the export of adults, juveniles and larvae to support fisheries in adjacent waters. The MPA network design will also minimize impacts on commercial and subsistence fisheries, by avoiding placing MPAs in areas with high fishing intensity and maintaining access to fisheries ports.
- Support community livelihoods by improving management of marine resources (habitats and populations of focal species) and allowing access to important areas for fishing and tourism (i.e., dive sites).
- Acknowledge and support adat, by protecting local wisdom and important traditional areas in MPAs.

The MPA network includes all 122 of the existing and proposed MPAs in the provincial Marine Spatial Plans, and 44 Areas of Interest for establishing new or expanded MPAs. Many of these Areas of Interest are designed to increase protection of some important deepwater habitats (i.e., seamounts and canyons) and critical, special and unique areas (i.e., coelacanth and walking shark distribution areas) currently under-represented in existing and proposed MPAs in Indonesia. However, before the Areas of Interest are established as new MPAs, some may need to be validated (ground-truthed to ensure they will provide the expected benefits for the MPA network), and proposals for new MPAs will need to be discussed appropriately with local stakeholders.

It is also important to note that this is a MPA network design, which should be used to identify potential areas for establishing new or expanded MPAs that will still need to be zoned. However, the best available science shows that NTZs provide the greatest ecological benefits for enhancing fisheries productivity, protecting biodiversity, and supporting the ecosystem goods and services marine resources provide for coastal communities (see review in Green et al. 2019a). Therefore, the biophysical and socioeconomic and cultural design criteria used to design the MPA network (Table 3 and Table 4) should also be used to design individual MPAs. For example, the biophysical design criteria recommend that at least 20% of each major habitat should be protected within NTZs. These design criteria can also be applied to other types of zones, although they are likely to be less effective in achieving these objectives.

Integrating Marine Protected Area Network Design from Local to National Scales in Indonesia

In this process we have demonstrated how to integrate MPA network design at multiple scales in Indonesia by using design guidelines developed at the national level to design an MPA network at both regional and provincial scales.

We have also demonstrated how to use an integrated approach to design MPA networks that combines both:

- A bottom up approach to designing MPA networks using participatory mapping at local and provincial scales (see *Existing and Proposed Marine Protected Areas, and Areas of Interest for Establishing New Marine Protected Areas*); and
- A top down approach to designing an MPA network at a regional scale (FMA715 and six provinces) using the systematic conservation planning tool Marxan.

Furthermore, since our MPA network design is based on the most detailed spatial analysis of biophysical and socioeconomic data across ~49.5% of Indonesia's waters to date (with input from 100s of MPA practitioners and scientists at local, provincial and national scales), the results of our study can also be used to identify priority areas for new MPAs to achieve MMAF's goal of establishing 10 million hectares of new MPAs in Indonesia by 2030.

If useful, this approach could provide a model for refining the national MPA network design in other areas of Indonesia.

Integrating Marine Protected Areas, Marine Spatial Plans and Fisheries Management Areas, in Indonesia

If the MPA network design is implemented and effectively managed, it will contribute to achieving many goals including protecting biodiversity, enhancing fisheries, and supporting the livelihoods and traditional culture of coastal communities (see Table 2).

Therefore, we recommend that the MPA network design should be:

- Integrated within the management plan for FMA715 to help protect biodiversity and improve fisheries management in this area;
- Used to develop or refine MPA networks for each of the six provinces (see *Existing and Proposed Marine Protected Areas, and Areas of Interest for Establishing New Marine Protected Areas*); and
- Integrated within marine spatial plans at both the provincial and national scale when they come up for review (see *Marine Spatial Plans*).

Addressing Conflicting Use Among Marine Protected Areas and Other Uses

The MPA network design for FMA715 and the six provinces also highlights the issue of conflicting use of areas, since there is a lot of overlap between some high priority areas for protection and other uses or threats. For example, seamounts are frequently located in areas allocated for other uses or where there are busy shipping lanes or high fishing intensity. Where possible, we included these conservation features in the MPA network design where these uses were lower than in

surrounding areas. However, that was not always possible and many important conservation features remain unprotected particularly in deepwater.

Meanwhile, some existing and proposed MPAs are already located in areas allocated for other uses in the Marine Spatial Plans e.g., Banggai MPA in Central Sulawesi (Figure 7) is in an oil and gas mining area and military area (Figure 14). We are not proposing that existing or proposed MPAs be removed. However, this demonstrates the need for MPAs to be integrated with other approaches to manage other uses and threats.

These results demonstrate that there is still an issue of conflicting use between MPAs and other uses that needs to be addressed by the Government. Some useful lessons may be learned from other countries regarding how to address this issue. For example, the Great Barrier Reef Marine Park in Australia accommodates many uses (e.g., shipping etc.) through a variety of zones.

Recommendations for Improving the Design

This is the first iteration of the MPA network design for FMA715 and the associated six provinces, and one of the most detailed systematic conservation planning processes undertaken at this scale in Indonesia to date. However, there are some limitations to the design due to limited time and resources available for the data analysis, which could be improved in future.

If more time and resources become available, the MPA network design could be improved by:

- Conducting a more detailed classification of coastal habitats (i.e., coral reefs, mangrove forests and seagrass beds), and using this to apply the design criteria regarding habitat representation and replication (see Green et al. 2019a).
- Identifying and mapping special and unique natural phenomena for protection.
- Conducting a spatial analysis to identify refugia (i.e., mangrove and turtle nesting beaches that have room to move as sea levels rise, and coral reefs likely to be more resilient to rising sea water temperatures) to apply the design criteria regarding adaption to climate change.
- Refining the cost surface to incorporate local threats and the intensity of conflicting uses considered manually in the design process.

Once this has been completed, the analysis could be repeated and refined.

In the long term, research priorities for improving the spatial data required to improve the MPA network design may include (see Green et al. 2019b):

- Modelling or mapping connectivity (particularly regarding larval dispersal); and
- Understanding the potential effects of changes in climate and ocean chemistry on the ecology of focal species and the associated changes in communities, ecosystem function and dynamics.

When this information becomes available, the MPA network design should be reviewed and refined as necessary.

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Annex I. Spatial Data Layers

Table 9. Biophysical, socioeconomic and cultural spatial data layers compiled for FMA715 and the six associated provinces, their coverage and how they were used to design the MPA network.

Where coverage provides the spatial extent of the data including: for all of the planning area (all area) or for one or more of the provinces (NM: North Maluku, M: Maluku, WP: West Papua, NS: North Sulawesi, CS: Central Sulawesi, G: Gorontalo).

No	Aspect	Category	Feature Category	Coverage	How Used
1	BIOPHYSICAL	MPA Status	Existing and Proposed MPAs in Marine Spatial Plans	All area	Marxan shallow water analysis only
2			Areas of Interest for new MPAs identified in the provinces	All area	Manually
3		Conservation Features: Shallow Water Habitats	Coral Reef Distribution	All area	Marxan shallow water analysis only
4			Mangrove Distribution	All area	Marxan shallow water analysis only
5			Seagrass Distribution	All area	Marxan shallow water analysis only
6			Mangrove Distribution by Species	CS	Not used
7			Coral Reef Condition (very good, good, moderate, poor)	All area	Manually
8			Mangrove Condition (good, moderate, poor)	All area	Manually
9			Seagrass Condition (very good, good, moderate, poor)	All area	Manually
10			Mangrove Density	All area	Not used
11			Seagrass Density	All area	Not used
12			Seagrass and Algae Distribution	NS	Not used
13			Seagrass and Algae Condition	NS	Not used
14			Unique Area	M, WP	Manually
15		Conservation Features: Critical, Special, and Unique Species and/or Areas	Coelacanth Distribution	NS	Marxan shallow water analysis only
16			Sea Worm Fishing Areas	M	Marxan shallow water analysis only
17			Turtle Nesting Beaches	NS, G, M, NM	Marxan shallow water analysis only
18			Walking Shark Distribution	NM	Marxan shallow water analysis only
19			Fish Spawning Areas (SPAGs)	WP, M, NM	Marxan shallow water analysis only
20			Algae Distribution	NS	Not used
21			Algae Condition	NS	Not used
22			Bamboo Coral Condition	CS	Manually
23			Bat Distribution	M	Not used

No	Aspect	Category	Feature Category	Coverage	How Used
24			Big Eye Trevally Distribution	G	Manually
25			Bumphead Parrotfish Distribution	NM	Manually
26			Canary Crab Distribution	NM	Manually
27			Crocodile Distribution	NM	Manually
28			Dolphin Distribution	G, NS, M	Manually
29			Dolphin Migratory Corridor	CS, NS, G	Manually
30			Dolphin Resting Ground	NM	Manually
31			Dugong Distribution	WP, NS, M, NM	Manually
32			Dugong Migratory Corridor	NS, CS, G	Manually
33			Eel Migratory Corridor	NS, CS, G	Manually
34			Giant Clam Distribution	M, NM	Manually
35			Giant Squid Distribution	NM	Manually
36			Anchovy Fish Distribution	WP	Manually
37			Flying Fish Distribution	WP	Manually
38			Grouper Fish Distribution	WP	Manually
39			Lobster Distribution	WP	Manually
40			Maleo (megapode) Nesting Ground	M, G	Manually
41			Manta Ray Distribution	NM, G	Manually
42			<i>Mola mola</i> Distribution	G	Manually
43			Napoleon Wrasse Distribution	G, NS	Manually
44			Seabird Distribution	M	Manually
45			Seabird Resting Ground	M	Manually
46			Seabird Nesting Ground	NM	Manually
47			Marine Important Bird and Biodiversity Areas (IBAs)	M	Manually
48			Shark Distribution	WP, M, NM, G	Manually
49			Shrimp Distribution	M	Manually
50			Tuna Feeding Ground	M	Manually
51			Tuna Distribution	G	Manually
52			Tuna Migratory Corridor	NS, G, NM, CS	Manually

No	Aspect	Category	Feature Category	Coverage	How Used
53			Turtle Feeding Ground	NS, NM, M	Manually
54			Turtle Migratory Corridor	CS, WP, G, M, NS	Manually
55			Whale Distribution	G, M, NM	Manually
56			Whale Distribution Orca	NM	Manually
57			Whale Migratory Corridor	G	Manually
58			IUCN Important Marine Mammal Area	M	Manually
59			Whaleshark Distribution	All area	Manually
60			Whaleshark Migratory Corridor	CS, G,	Manually
61			Rehabilitation Area Coral Reef	NM	Manually
62			Fish Abundance (very good, good, moderate, poor)	M	Manually
63			Fish Biomass Good	M	Manually
64			Biota Migratory Corridor	NM, M, NS	Manually
65			Cetacea Migratory Corridor	WP	Manually
66		Conservation Features: Deep Water Habitats	Canyon	All area	Marxan combined shallow and deepwater analysis
67			Seamount	All area	Marxan combined shallow and deepwater analysis
68			Abyss	All area	Marxan combined shallow and deepwater analysis
69			Abyssal Classification	All area	Marxan combined shallow and deepwater analysis
70			Abyss Hills	All area	Marxan combined shallow and deepwater analysis
71			Abyss Mountains	All area	Marxan combined shallow and deepwater analysis
72			Abyss Plains	All area	Marxan combined shallow and deepwater analysis
73			Basin	All area	Marxan combined shallow and deepwater analysis
74			Bridge	All area	Marxan combined shallow and deepwater analysis
75			Escarpment	All area	Marxan combined shallow and deepwater analysis

No	Aspect	Category	Feature Category	Coverage	How Used
76			Hadal	All area	Marxan combined shallow and deepwater analysis
77			Ridge	All area	Marxan combined shallow and deepwater analysis
78			Shelf Valley	All area	Marxan combined shallow and deepwater analysis
79			Shelf	All area	Marxan combined shallow and deepwater analysis
80			Shelf Classification	All area	Marxan combined shallow and deepwater analysis
81			Shelf High	All area	Marxan combined shallow and deepwater analysis
82			Shelf Medium	All area	Marxan combined shallow and deepwater analysis
83			Shelf Low	All area	Marxan combined shallow and deepwater analysis
84			Sill	All area	Marxan combined shallow and deepwater analysis
85			Slope	All area	Marxan combined shallow and deepwater analysis
86			Spreading Ridge	All area	Marxan combined shallow and deepwater analysis
87			Terrace	All area	Marxan combined shallow and deepwater analysis
88			Trench	All area	Marxan combined shallow and deepwater analysis
89			Trough	All area	Marxan combined shallow and deepwater analysis
90	SOCIOECONOMIC & CULTURAL	Conservation Features: Critical, Special, and Unique Areas	Important Traditional Area (i.e., mystical areas)	WP, CS, NM, M	Marxan shallow water analysis only
91			Local Wisdom Area (i.e., sasi)	WP, NM, M	Marxan shallow water analysis only
92			Shipwrecks	M, NM, NS, G, WP	Marxan shallow water analysis only
93			Dive Site	All area	Marxan shallow water analysis only
94		Other Uses and Threats	Cable Pipe Lane	All area	Marxan both shallow water analysis & combined shallow and deepwater analysis

No	Aspect	Category	Feature Category	Coverage	How Used
95			Military Area	WP, CS, NS, M, G, NM	Marxan both shallow water analysis & combined shallow and deepwater analysis
96			Reclamation Area	NM, WP	Marxan both shallow water analysis & combined shallow and deepwater analysis
97			Sea Mine Area (unexploded ordinance)	NM, WP, M, NS	Marxan both shallow water analysis & combined shallow and deepwater analysis
98			Threat Mining Oil Gas	WP, M	Marxan both shallow water analysis & combined shallow and deepwater analysis
99			Fishing Ground Skipjack Tuna	NM	Marxan combined shallow and deepwater analysis
100			Fishing Ground Tuna	NM	Marxan combined shallow and deepwater analysis
101			Fishing Ground SMI Pelagic	NM	Marxan combined shallow and deepwater analysis
102			Fishing Ground Pelagic	NM, G, M, WP, NS	Marxan combined shallow and deepwater analysis
103			Fishing Ground Anchovy	NM	Marxan combined shallow and deepwater analysis
104			Fishing Ground Bait Fish	NM	Marxan combined shallow and deepwater analysis
105			Fishing Ground Halfbeaks	NM	Marxan combined shallow and deepwater analysis
106			Fishing Ground Demersal	G, M, NM, NS	Marxan combined shallow and deepwater analysis
107			Fishing Ground Coral Reef Fish	NM	Marxan combined shallow and deepwater analysis
108			Fishing Ground Largesnout Goby	G	Marxan combined shallow and deepwater analysis
109			Fishing Ground Shrimp	NM	Marxan combined shallow and deepwater analysis
110			Fishing Ground Traditional	NM, CS, WP, M, G, CS	Marxan combined shallow and deepwater analysis

No	Aspect	Category	Feature Category	Coverage	How Used
111			Port (uncategorized)	WP, CS, NS, M, G	Marxan combined shallow and deepwater analysis
112			Port Local	NM	Marxan combined shallow and deepwater analysis
113			Port National	NM	Marxan combined shallow and deepwater analysis
114			Fisheries Port	WP, CS, NS, M, G	Marxan combined shallow and deepwater analysis
115			Aquaculture Brackish Water	G	Manually
116			Aquaculture Clam	G	Manually
117			Aquaculture Crab	WP	Manually
118			Aquaculture Grouper	WP	Manually
119			Aquaculture Milkfish	WP	Manually
120			Aquaculture Pearl	WP, NM, M, G	Manually
121			Aquaculture Sea Cucumber	WP	Manually
122			Aquaculture Seaweed	All area	Manually
123			Aquaculture Shrimp	NM	Manually
124			Aquaculture Tuna	G	Manually
125			Aquaculture Pond	NS, CS	Manually
126			Aquaculture Floating Cage	All area	Manually
127			Aquaculture	NM, WP, NS, G	Manually
128			Fish Aggregating Device (FAD)	NS, G, NM, WP, M	Manually
129			Fish Landing Site	NS, G, CS	Manually
130			Fishing Boat Shelter	NM	Manually
131			Fishermen Village	G	Manually
132			Lift Net	NM, G, CS	Manually
133			Military Post	WP, CS, G	Manually
134			Shipping Lane ALKI (International)	NM, CS, NS, M, G	Manually
135			Shipping Lane National	All area	Manually
136			Shipping Lane Regional	All area	Manually

No	Aspect	Category	Feature Category	Coverage	How Used
137			Shipping Lane Local	G, NM, NS, CS, M	Manually
138			Shipping Lane Special (e.g., military or oil)	NS	Manually
139			Shipping Lane Other	G	Manually
140			Shipping Lane (uncategorized)	M	Manually
141			Threat Algae Blooming	NM	Manually
142			Threat Blast Fishing	NM, M	Manually
143			Threat Fish Poison	NM, M	Manually
144			Threat Overfishing	NM	Manually
145			Threat Trawl	NM	Manually
146			Threat Mangrove Logging	M	Manually
147			Threat Reef Gleaning	M	Manually
148			Threat Turtle Poaching	M	Manually
149			Threat Turtle Egg Poaching	M	Manually
150			Threat Iron Sand Factory	NM	Manually
151			Threat Mining Gold	NM	Manually
152			Threat Mining Iron Sand	NM	Manually
153			Threat Mining Nickel	NM	Manually
154			Threat Mining Sand	NM, G, M	Manually
155			Threat Mining Mineral	WP	Manually
156			Threat Mining (uncategorized)	G, NS, NM	Manually
157			Threat Sedimentation	NM	Manually
158			Threat Pollution Mercury	NM	Manually
159			Threat Waste	M	Manually
160			Threat Wave Abrasion (high, medium, low)	M	Manually
161			Threat Hot Water	NM, M, WP	Manually
162			Tourism (uncategorized)	M, NM	Not used
163			Tourism Beach Recreation	All area	Manually
164			Tourism Snorkelling	NM, NS, M	Manually
165			Tourism Beach Sport	G, WP, M	Manually

No	Aspect	Category	Feature Category	Coverage	How Used
166			Tourism Surfing	NM, M	Manually
167			Tourism Sport Fishing	NM	Manually
168			Tourism History	NM	Manually
169			Tourism Culture	WP, G	Manually
170			Tourism Mangrove	WP	Manually

Annex 2. Creating a Cost Surface

We created a cost surface as a weighted sum of impacts to fisheries and access to transportation and fishing ports (see Figure 39) as follows:

Ports Surface: We merged all fishing ports and transportation ports and created centroids for the polygons for each, and calculated the distance of each planning unit to ports using “Near analysis” [Dist_near] and geodesic. We then calculated $(1/\text{neardistance})$ [Inverse_ne] and multiplied it by *100000) to get the following layer [Dist100].

Fisheries Surface: We intersected all data layers for fishing grounds with polygons [Anchovy, Baitfish, Demersal, Halfbeak, Pelagic, Shrimp, and Traditional], then summed them [Sum_Fish].

Weighted cost: We then added them together use the following equation
 $\text{Cost} = ((\text{Sum_Fish} * 1000) * 0.8) + (0.2 * \text{Dist_100})$.

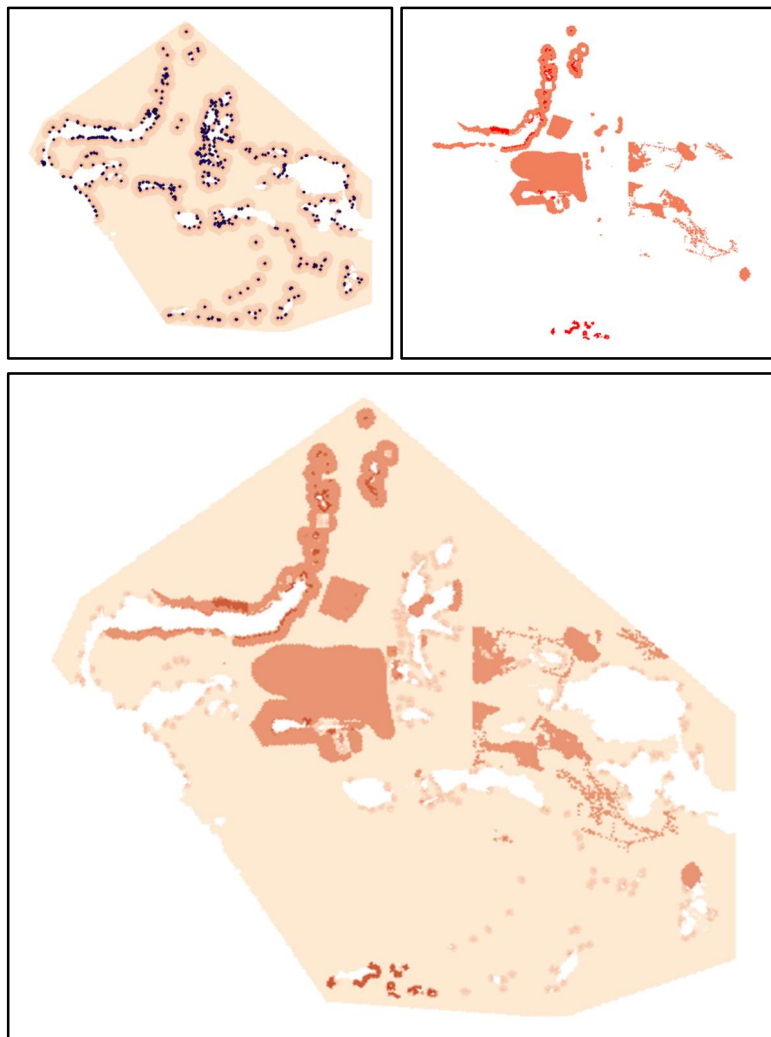


Figure 39. Ports surface (top left) and fisheries surface (top right) used to create a weighted cost surface (bottom).

Annex 3. Input Received at Scientific Expert Workshop

Table 10. Summary of input received on the results of the first Marxan analysis presented at the scientific expert review workshop, and how we used these comments to refine the design.

Input Received	How We Used This Input To Refine the Design
Increase the target for habitat representation in the scenario from 20% to 30% to be consistent with the IUCN target of 30% of each habitat to be set aside in highly protected MPAs and other effective areas by 2030 (World Conservation Congress 2016) ⁴ .	We changed the scenario from 20 to 30% habitat representation for shallow water habitats.
Most habitats are covered in the MPA network design (i.e., seagrasses, mangroves and coral reefs). However, some areas known to be in good condition were not selected, possibly because these areas of habitat are small or patchily distributed.	No changes were made because the relevant information is not available.
Should consider not only the Arlindo (Indonesian Through Flow), but also the Armondo (Indonesian Monsoon Flow), since the seasonal variability of Armondo will affect larval dispersal as the current direction changes every season. This information is available from NOAA.	We checked the NOAA website and they have not analyzed the long term data required to address this in our analysis.
Too few types of data were used in the Marxan analysis. For example, need more socioeconomic and cultural data.	We used the best available spatial data layers for the Marxan analysis. Some other information (e.g., socioeconomic and cultural considerations) were considered manually in other steps in the process (e.g., when Areas of Interest were identified using participatory mapping in the provinces).
Need to check the MPA data layer. Some existing and proposed MPAs in the Marine Spatial Plan for North Sulawesi seem to be missing.	We rechecked the Marine Spatial Plan and got the latest spatial information from the province, which required adding and removing some existing and proposed MPAs from the data file.
<p>The data layers for some biophysical conservation targets need to be checked/refined. For example:</p> <ul style="list-style-type: none"> • Need to check seagrass distribution in North Sulawesi. • Need to add some spags and turtle nesting beaches to the data layers. • Need to consider other information regarding potential Areas of Interest to include to protect cetaceans, dugong and seabirds. e.g., Gunung Api Island should be proposed as an MPA, since the island is important for endemic seabirds and the adjacent waters important for melon headed whales. 	<ul style="list-style-type: none"> • We added seagrass data from North Sulawesi's Marine Spatial Plan. • We added some spags and turtle nesting beaches to the data layers. • Where possible we validated the information with other data, and confirmed if these areas should be included as AOIs or if they were already selected as Areas of Interest due to other criteria i.e., habitat representation. For example, we checked the seabird data from Fauna and Flora International, and while Gunung Api Island is a nesting/roosting area for seabirds, these species are not endemic and are of least concern (therefore it was not added as an Area of Interest for seabirds).

⁴ <https://mpanews.openchannels.org/news/mpa-news/iucn-members-approve-30-2030-goal-mpas-%E2%80%94-most-ambitious-target-so-far-mpa-coverage>

Input Received	How We Used This Input To Refine the Design
<p>Some socioeconomic and cultural conservation targets need to be checked/refined.</p> <ul style="list-style-type: none"> • Need to add shipwrecks that have been identified and considered to be historically important (may still have artifacts). • Need to include Eha Laut and Sekek as local wisdom features: Eha Laut is an existing local wisdom area in Talaud Island, North Sulawesi where they are protecting marine resources by managing the harvest of crops both from marine and terrestrial areas (Mane'e is the fish harvest ceremony using sammi ropes they use after one-year of closure); and Sekek regulates the period or area of fishing. 	<p>We:</p> <ul style="list-style-type: none"> • Refined the data layer for shipwrecks, and used it in the second analysis (Figure 11, Table 6). • Identified the location of Eha Laut (which is in Kakorotan waters) and included it in the data layer for local wisdom areas. However, we were not able to identify the exact location of Sekek, so it could not be included.
<p>Some threat layers need to be checked/refined. Need to check:</p> <ul style="list-style-type: none"> • If all oil and gas concessions are included in available data e.g., Masela block. • For additional military areas in the national regulation (Peraturan Pemerintah Nomor 68/2014). 	<p>We added:</p> <ul style="list-style-type: none"> • Masela block and included it in the analysis. • More military areas from the national regulation.
<p>Some important cost data layers are missing i.e.,</p> <ul style="list-style-type: none"> • The location of FADs. • The density of fishing boats/ships. 	<ul style="list-style-type: none"> • We have the FAD data, but did not use it in the Marxan analysis because it is biased to a few locations. • We accessed the data on the density of commercial fishing boats from Global Fishing Watch (see Figure 24), and used it when <i>Manually Refining the Results of the Second Marxan Analysis</i>.

Annex 4. Details of Existing and Proposed MPAs, and Areas of Interest for New or Expanded MPAs, in the Marine Protected Area Network Design for Fisheries Management Area 715 and the Six Associated Provinces.

Here we provide two tables:

- Table 11 provides the details of each of the existing and proposed MPAs and Areas of interest in the MPA network design for FMA715 and the six associated provinces.
- Table 12 provides the recommendations and rationale for including the Areas of Interest.

Table 11. Details of each of the existing and proposed MPAs in the provincial Marine Spatial Plans, and Areas of Interest for establishing new or expanded MPAs in the MPA network design for FMA715 and the six associated provinces including: the type of MPA, it's status, the management authority and area (hectares).

Where the Type of MPA is: National Park (NP); Wildlife Reserve (WR); Nature Reserve (NR); Marine Nature Reserve (MNR); Coastal and Small Islands Conservation Area (CSICA); Small Islands Park (SIP); Coastal Park (CP); Nature Tourism Park (NTP); Nature Marine Tourism Park (NMTP); Marine Tourism Park (MTP); Maritime Conservation Area (MCA); National MPA (NM); and Provincial MPA (PMPA).

No	Province	District	Name	Type of MPA	Status	Management Authority	Hectare
1	West Papua	Wondama Bay	Cendrawasih Bay	NP	Existing	National	1,444,446
2	West Papua	FakFak	Sabuda Tutturuga	WR	Existing	National	16,101
3	West Papua	Raja Ampat	West Waigeo Island	MNR	Existing	National	267,217
4	West Papua	Raja Ampat	Raja Ampat Island	MNR	Existing	National	57,876
5	West Papua	Raja Ampat	Kofiau Boo	MNR	Existing	National	10,950
6	West Papua	Raja Ampat	Misool Islands Waters	MTP	Existing	Province	346,189
7	West Papua	Raja Ampat	Kofiau-Boo Islands Waters	MTP	Existing	Province	138,258
8	West Papua	Raja Ampat	Dampier Strait	MTP	Existing	Province	351,075
9	West Papua	Raja Ampat	Mayalibit Bay	MTP	Existing	Province	49,454
10	West Papua	Raja Ampat	Ayau and Asia Islands Waters	MTP	Existing	Province	99,340
11	West Papua	Tambrau	Jeen Womom	CP	Existing	Province	31,582
12	West Papua	Kaimana	Kaimana	PMPA	Proposed	Province	437,745
13	West Papua	FakFak	Berau Bay	CSICA	Proposed	Province	99,785

No	Province	District	Name	Type of MPA	Status	Management Authority	Hectare
14	West Papua	FakFak	Nusalasi Van den Bosch Bay	CSICA	Proposed	Province	246,920
15	West Papua	South Sorong	Seribu Satu Sungai Teo Enebikia Waters	PMPA	Proposed	Province	348,556
16	West Papua	Bintuni Bay	Bintuni Bay	PMPA	Proposed	Province	67,065
17	West Papua	Raja Ampat	North Misool Waters	PMPA	Proposed	Province	309,144
18	West Papua	Raja Ampat	Fam Islands Waters	MTP	Proposed	Province	357,282
19	West Papua	Sorong	Makbon	PMPA	Proposed	Province	147,224
20	West Papua	Tambrau	World War II	MCA	Proposed	Province	100
21	West Papua	Tambrau	Cargo Okinoyama Maru	MCA	Proposed	Province	4,640
22	West Papua	Manokwari	Cross Wreck Mansinam	MCA	Proposed	Province	53
Sub Total Existing and Proposed MPAs of West Papua Province							4,831,002
23	West Papua	Manokwari	Prafi Bay	AOI	AOI	Province	5,726
24	West Papua	Tambrau	East of Jeen Womom	AOI	AOI	Province	15,031
25	West Papua	Tambrau	Miossu and Su Island	AOI	AOI	Province	5,775
26	West Papua	Raja Ampat	North Waigeo	AOI	AOI	Province	309,844
27	West Papua	Raja Ampat	Gam-Waigeo Passage	AOI	AOI	Province	1,287
28	West Papua	Raja Ampat	Saripa Bay	AOI	AOI	Province	4,100
29	West Papua	-	3 Seamount	AOI	AOI	National	524,771
Sub Total AOIs of West Papua Province							866,534
Sub Total Existing and Proposed MPAs + AOIs of West Papua Province							5,697,536
30	North Maluku	Morotai Island	Dehegila Cape-Rao Waters	PMPA	Proposed	Province	58,132
31	North Maluku	North Halmahera	Tobo-Tobo Waters	PMPA	Proposed	Province	3,940
32	North Maluku	East Halmahera	Yiew Island	PMPA	Proposed	Province	4,309
33	North Maluku	Central and East Halmahera	East Patani Water-Sayafi Island	PMPA	Proposed	Province	343,904
34	North Maluku	West Halmahera	Babua-Jailolo Island	PMPA	Proposed	Province	212

No	Province	District	Name	Type of MPA	Status	Management Authority	Hectare
35	North Maluku	West Halmahera	Sibu-North Oba Island	PMPA	Proposed	Province	27
36	North Maluku	Tidore Islands	Filonga Island	PMPA	Proposed	Province	211
37	North Maluku	Tidore Islands	Mare Island	PMPA	Proposed	Province	7,612
38	North Maluku	Ternate City	Moti Island Waters-Makian Island	PMPA	Proposed	Province	67,299
39	North Maluku	South Halmahera	Guraici Islands	PMPA	Proposed	Province	95,069
40	North Maluku	South Halmahera	Sali Island-North of West Gane	PMPA	Proposed	Province	4,256
41	North Maluku	South Halmahera	Mandioli Island	PMPA	Proposed	Province	2,479
42	North Maluku	South Halmahera	Dowara Lamo Island-South of West Gane	PMPA	Proposed	Province	737
43	North Maluku	South Halmahera	East Gane Waters and Widi Islands	PMPA	Proposed	Province	327,867
44	North Maluku	North Halmahera	Kelo Island, Songara and East Obi	PMPA	Proposed	Province	3,602
45	North Maluku	Sula Islands	Sula Islands	PMPA	Proposed	Province	122,954
46	North Maluku	Sula Islands	Pas Koro Island	PMPA	Proposed	Province	423
Sub Total Existing and Proposed MPAs of North Maluku Province							1,043,033
47	North Maluku	Morotai Island	Morotai Island	AOI	AOI	Province	376,932
48	North Maluku	West Halmahera	Kahatola	AOI	AOI	Province	47,381
49	North Maluku	West Halmahera	Bobo Cape	AOI	AOI	Province	1,814
50	North Maluku	Ternate City	Hiri Island	AOI	AOI	Province	15,747
51	North Maluku	Central and East Halmahera	Sayafi and Patani	AOI	AOI	Province	127,856
52	North Maluku	Tidore Islands	Woda Islands and Oba	AOI	AOI	Province	68,428
53	North Maluku	South Halmahera	North of Gilalang Island	AOI	AOI	Province	9,885
54	North Maluku	South Halmahera	Kasiruta Bacan Island	AOI	AOI	Province	34,114
55	North Maluku	Taliabu Island	North Taliabu	AOI	AOI	Province	12,907
56	North Maluku	Taliabu Island	West Taliabu	AOI	AOI	Province	132,842
57	North Maluku	Taliabu Island	South Taliabu	AOI	AOI	Province	19,715

No	Province	District	Name	Type of MPA	Status	Management Authority	Hectare
Sub Total AOIs of North Maluku Province							847,621
Sub Total Existing and Proposed MPAs + AOIs of North Maluku Province							1,890,654
58	Maluku	Aru Islands	Southeast of Aru Islands	MNR	Existing	National	110,716
59	Maluku	Central Maluku	Banda Sea	NTP	Existing	National	2,542
60	Maluku	West Seram	Marsegu Island	NMTP	Existing	National	9,852
61	Maluku	West Seram	Kasa Island	NMTP	Existing	National	529
62	Maluku	Central Maluku	Pombo Island	NMTP	Existing	National	1,829
63	Maluku	Southeast Maluku	Small Kei Islands	SIP	Existing	Province	136,315
64	Maluku	Buru	Buru Island	PMPA	Proposed	Province	13,809
65	Maluku	West Seram	Buano Island	PMPA	Proposed	Province	34,097
66	Maluku	Central Maluku	Lease Islands	PMPA	Proposed	Province	67,600
67	Maluku	Central Maluku	Sawai Bay	PMPA	Proposed	Province	114,656
68	Maluku	East Seram	Koon-Neiden	PMPA	Proposed	Province	15,309
69	Maluku	Central Maluku	Ay-Rhun Island	PMPA	Proposed	Province	61,499
70	Maluku	Tual City	Kur Tayando TAM	PMPA	Proposed	Province	254,413
71	Maluku	Southeast Maluku	Baeer Island	NTP	Proposed	Province	3,186
72	Maluku	West Southeast Maluku	Yamdena Islands	SIP	Proposed	Province	711,198
73	Maluku	Southwest Maluku	Leti Island	PMPA	Proposed	Province	382,322
74	Maluku	Southwest Maluku	Damar Island	PMPA	Proposed	Province	304,907
75	Maluku	Southwest Maluku	Romang Island	PMPA	Proposed	Province	325,699
76	Maluku	-	Lucipara Islands	PMPA	Proposed	Province	391,715
Sub Total Existing and Proposed MPAs of Maluku Province							2,942,193
77	Maluku	-	Lucipara Island and Seamount	AOI	AOI	AOI	438,220
78	Maluku	-	East Buru Seamount	AOI	AOI	AOI	88,075

No	Province	District	Name	Type of MPA	Status	Management Authority	Hectare
79	Maluku	-	Manuk Island	AOI	AOI	AOI	379,858
80	Maluku	West Southeast Maluku	Aru Islands	AOI	AOI	AOI	1,108,787
81	Maluku	Southwest Maluku	Selaru Island	AOI	AOI	AOI	110,927
82	Maluku	Southwest Maluku	Damar and Romang Island	AOI	AOI	AOI	575,624
83	Maluku	Southwest Maluku	West Wetar	AOI	AOI	AOI	220,589
Sub Total AOIs of Maluku Province							2,922,080
Sub Total Existing and Proposed MPAs + AOIs of Maluku Province							5,864,273
84	Southeast Sulawesi	Wakatobi	Wakatobi	NP	Existing	National	1,355,061
Sub Total Existing MPA of Southeast Sulawesi Province							1,355,061
85	Central Sulawesi	Tojo Una-Una	Togean Islands	NP	Existing	National	346,730
86	Central Sulawesi	Buol	Buol	MNR	Existing	National	1,958
87	Central Sulawesi	-	Tomini	NMPA	Proposed	National	78,540
88	Central Sulawesi	Morowali, North Morowali and Banggai	Morowali	PMPA	Proposed	Province	99,900
89	Central Sulawesi	Banggai Laut and Banggai Kepulauan	South Buko-Banggai Islands	CSICA	Proposed	Province	331,161
90	Central Sulawesi	Banggai Laut	Liang-Banggai Islands	CSICA	Proposed	Province	657
91	Central Sulawesi	Banggai	Luwuk Kintom-Banggai	CSICA	Proposed	Province	6,702
92	Central Sulawesi	Banggai	East Luwuk-Banggai	CSICA	Proposed	Province	4,990
93	Central Sulawesi	Banggai	Lamala-Banggai	CSICA	Proposed	Province	224
94	Central Sulawesi	Banggai	Bualemo-Banggai	CSICA	Proposed	Province	3,283
95	Central Sulawesi	Banggai	Pagimana-Banggai	CSICA	Proposed	Province	25,730
96	Central Sulawesi	Tojo Una-Una	Ampana City and Ampana Tete	CSICA	Proposed	Province	7,447
97	Central Sulawesi	Poso	Poso	CSICA	Proposed	Province	73
98	Central Sulawesi	Poso	Tobe	PMPA	Proposed	Province	1

No	Province	District	Name	Type of MPA	Status	Management Authority	Hectare
99	Central Sulawesi	Donggala	Balaesang Tanjung-Donggala	WR	Proposed	Province	281
100	Central Sulawesi	Toli Toli	North Dampal	CSICA	Proposed	Province	25,117
101	Central Sulawesi	Toli Toli	Ogodeide	CSICA	Proposed	Province	13,139
102	Central Sulawesi	Toli Toli	Doboto	CSICA	Proposed	Province	22,200
103	Central Sulawesi	Parigi Moutong	Parigi Moutong	PMPA	Proposed	Province	4,631
Sub Total Existing and Proposed MPAs of Central Sulawesi Province							972,764
104	Central Sulawesi	Parigi Moutong	Southwest Tomini Bay	AOI	AOI	National	118,482
105	Central Sulawesi	Parigi Moutong	Parigi	AOI	AOI	Province	12,506
106	Central Sulawesi	Donggala	Tombu Bay	AOI	AOI	Province	80,656
107	Central Sulawesi	Parigi Moutong	Northwest Tomini Bay	AOI	AOI	Province	88,931
108	Central Sulawesi	Buol	Buol	AOI	AOI	Province	177,871
Sub Total AOIs of Central Sulawesi Province							478,446
Sub Total Existing and Proposed MPAs + AOIs of Central Sulawesi Province							1,451,210
109	Gorontalo	Pahuwato	Tanjung Panjang	NR	Existing	National	889
110	Gorontalo	North Gorontalo	Mas Popaya Raja	NR	Existing	National	154
111	Gorontalo	-	South Gorontalo	NMPA	Proposed	National	41,123
112	Gorontalo	Pahuwato	Dulangka	CSICA	Proposed	Province	3,419
113	Gorontalo	Pahuwato	Maruangi-Mabasar	CSICA	Proposed	Province	1,164
114	Gorontalo	Pahuwato	Mabasar-Marurangi	PMPA	Proposed	Province	6,875
115	Gorontalo	Pahuwato	Tanjung Panjang	CSICA	Proposed	Province	2,957
116	Gorontalo	Boalemo	Monduli	CSICA	Proposed	Province	7,385
117	Gorontalo	Gorontalo	Biluhu Timur	PMPA	Proposed	Province	105
118	Gorontalo	Gorontalo City	Leato	MCA	Proposed	Province	5
119	Gorontalo	Bone Bolango	Olele Beach	PMPA	Proposed	Province	479

No	Province	District	Name	Type MPA	of	Status	Management Authority	Hectare
120	Gorontalo	North Gorontalo	Tolinggula	CSICA		Proposed	Province	2,099
121	Gorontalo	North Gorontalo	Sumalata	PMPA		Proposed	Province	14,323
122	Gorontalo	North Gorontalo	Popaya Island	MCA		Proposed	Province	37
123	Gorontalo	North Gorontalo	Popaya	PMPA		Proposed	Province	1,268
124	Gorontalo	North Gorontalo	North Gorontalo	CSICA		Proposed	Province	470
Sub Total Existing and Proposed MPAs of Gorontalo Province								82,752
125	Gorontalo	Pahuwato	Dulanga-Marurangi-Mabasar	AOI		AOI	Province	48,705
126	Gorontalo	Boalemo	Mandoli	AOI		AOI	Province	4,600
127	Gorontalo	Gorontalo City	Botubarani	AOI		AOI	Province	785
128	Gorontalo	North Gorontalo	Papaya	AOI		AOI	Province	16,772
129	Gorontalo	North Gorontalo	Lowoo Malangoso	AOI		AOI	Province	1,207
Sub Total AOIs of Gorontalo Province								72,069
Sub Total Existing and Proposed MPAs + AOIs of Gorontalo Province								154,821
130	North Sulawesi	South Minahasa, Minahasa, Manado City, and North Minahasa	Bunaken	NP		Existing	National	70,496
131	North Sulawesi	North Bolaangmongondow	Komusi	PMPA		Proposed	Province	138
132	North Sulawesi	North Bolaangmongondow	Tanjung Sidupa	PMPA		Proposed	Province	203
133	North Sulawesi	North Bolaangmongondow	North Inomunga	PMPA		Proposed	Province	60
134	North Sulawesi	North Bolaangmongondow	Boroko	PMPA		Proposed	Province	20
135	North Sulawesi	North Bolaangmongondow	North Boroko	PMPA		Proposed	Province	108
136	North Sulawesi	North Bolaangmongondow	Tote	PMPA		Proposed	Province	270
137	North Sulawesi	Bolaang Mongondow	Lolanan	PMPA		Proposed	Province	1,504
138	North Sulawesi	Bolaang Mongondow	Libuton Molosing	PMPA		Proposed	Province	45
139	North Sulawesi	South Minahasa	South Minahasa	PMPA		Proposed	Province	216
140	North Sulawesi	South Minahasa	Bajo	PMPA		Proposed	Province	72

No	Province	District	Name	Type of MPA	Status	Management Authority	Hectare
141	North Sulawesi	North Minahasa	North Minahasa	PMPA	Proposed	Province	26,136
142	North Sulawesi	Bitung City	Bitung (Lembeh Island)	PMPA	Proposed	Province	9,635
143	North Sulawesi	Minahasa and North Minahasa	Minahasa	PMPA	Proposed	Province	623
144	North Sulawesi	Southeast Minahasa	Bentenan Satu	PMPA	Proposed	Province	2,164
145	North Sulawesi	Southeast Minahasa	Tumbak Madani	PMPA	Proposed	Province	183
146	North Sulawesi	South Bolaangmongondow	Pidung Island	PMPA	Proposed	Province	283
147	North Sulawesi	South Bolaangmongondow	South Tobayagan	PMPA	Proposed	Province	82
148	North Sulawesi	Siau Tagulandang Biaro Islands	Sitaro Islands	PMPA	Proposed	Province	51,510
149	North Sulawesi	Sangihe Islands	Tatoareng Islands	SIP	Proposed	Province	2,843
150	North Sulawesi	Sangihe Islands	South Tabukan	PMPA	Proposed	Province	14,514
151	North Sulawesi	Sangihe Islands	Nusa Tabukan	PMPA	Proposed	Province	52,633
152	North Sulawesi	Sangihe Islands	Lipaeng	PMPA	Proposed	Province	209
153	North Sulawesi	Sangihe Islands	Kawaluso	PMPA	Proposed	Province	17
154	North Sulawesi	Sangihe Islands	Karore	PMPA	Proposed	Province	37
155	North Sulawesi	Sangihe Islands	North Tabukan	PMPA	Proposed	Province	10,928
156	North Sulawesi	Talaud Islands	North Karakelong	PMPA	Proposed	Province	102
157	North Sulawesi	Talaud Islands	South Karakelong	PMPA	Proposed	Province	423
158	North Sulawesi	Talaud Islands	Kabaruang	PMPA	Proposed	Province	1,116
Sub Total Existing and Proposed MPAs of North Sulawesi Province							246,570
159	North Sulawesi	-	Seamount West Sangihe	AOI	AOI	National	106,617
160	North Sulawesi	South Minahasa	North Minahasa	AOI	AOI	Province	3,267
161	North Sulawesi	Bolaang Mongondow	Luok Batu Merah	AOI	AOI	Province	5,578
162	North Sulawesi	North Bolaangmongondow	Haji Cape	AOI	AOI	Province	7,908

No	Province	District	Name	Type of MPA	Status	Management Authority	Hectare
163	North Sulawesi	North Bolaangmongondow	Lito Bongkil	AOI	AOI	Province	6,479
164	North Sulawesi	South Bolaangmongondow	Dudepo	AOI	AOI	Province	3,577
165	North Sulawesi	South Bolaangmongondow	Motandoi	AOI	AOI	Province	4,414
166	North Sulawesi	Minahasa and Southeast Minahasa	Popaya Cape	AOI	AOI	Province	7,843
167	North Sulawesi	Minahasa and North Minahasa	Minahasa	AOI	AOI	Province	4,044
Sub Total AOIs of North Sulawesi Province							149,727
Sub Total Existing and Proposed MPAs + AOIs of North Sulawesi Province							396,297

Table 12. Areas of Interest for new or expanded MPAs in the MPA network design for FMA715 and the six associated provinces, recommendations and the rationale for why they were included in the MPA network design.

Province	No	Name	Rationale	Recommendations
West Papua	1	Prafi Bay	The area was identified as an Aol by participatory mapping because of a turtle nesting beach. This area has also been identified as a turtle migratory corridor, and coral reef. The area appears to have low level of threats and none incompatible utilization.	Propose the Aol as a new MPA.
	2	East of Jeen Womom Coastal Park	The area was identified by Marxan as a priority area because of coral reef, local wisdom area, and turtle migratory corridor. The shipwreck remains to be separated as it is already an existing MPA	Expand the existing Jeen Womom Coastal Park further east
	3	Myosu and Su Island	The area was identified as an Aol by participatory mapping when developing the 1 st draft of West Papua MPA network because it appears to have coral reef, turtle nesting beach, shipwreck, etc. However, it was subsequently dropped for the final MPA network design because there was not any compelling evidence showing this area was important to be proposed as MPA. The area was identified by Marxan as a priority area because of coral reef, mangrove, shipwreck, grouper fish distribution, turtle migratory corridor and local wisdom. Myosu Island is an outer most island.	Expand the existing Sansapor Bay Nature Reserve to include this area
	4	North Waigeo	The area was identified as an Aol by participatory mapping because of coral reef and turtle nesting beach for leatherback, hawksbill, green, and olive ridley. Marxan also identified it as a priority area for coastal habitats (e.g., coral reef, seagrass and mangrove), and deepwater habitats (e.g., canyon). The area also has turtle migratory corridor, and coelacanth distribution.	Propose the Aol as a new MPA.
	5	Saripa Bay	The area was identified as an Aol by participatory mapping and REA and as a priority area by Marxan for coastal habitats (e.g., coral reef and mangrove)	Propose the Aol as a new MPA.
	6	Gam-Waigeo Passage	The passage was identified as an Aol by participatory mapping and REA and as a priority area by Marxan for coastal habitats. Marxan also identified the surrounding as priority areas for coastal habitats (e.g., coral reef and mangrove) and dive sites.	Propose the Aol as a new MPA.
	7	Three Seamounts	The area was identified as a priority area by Marxan for deepwater habitats (e.g., seamounts). The area also has turtle and cetacean migratory corridor and appears to have high fishing pressure.	Propose the Aol as a new MPA.
North Maluku	8	Morotai Island	The area was identified as an Aol by participatory mapping because of good coral reef cover and condition, dolphin resting ground, spags, dive sites, surfing tourism site, leatherback turtle nesting beach, crocodile, whale shark, orca, airplane and	Expand the proposed Rao-Dehegila Cape MPA

Province	No	Name	Rationale	Recommendations
			shipwreck. Marxan also identified it as a priority area for coastal habitats (e.g., coral reef, seagrass, and mangrove), canyon, spags, turtle nesting beach, and local wisdom. This area also has shark distribution, cetacean and turtle migratory corridor.	
	9	Kahatola	The area was identified as an Aol by participatory mapping because high fish biodiversity, high coral reef cover, seagrass, mangrove, mystical area, high potency for tuna fisheries and tourism. Marxan identified it as a priority area for coastal habitats (e.g., coral reef and mangrove). This area appears to have threat for shark and turtle poaching, fishing ground and use as boat shelter during high waves.	Propose the Aol as a new MPA.
	10	Bobo Cape	The area was identified as a priority area by Marxan for coastal habitats (coral reef, seagrass and mangrove), and dive sites. There also dugong distribution in this area.	Propose the Aol as a new MPA.
	11	Hiri Island	The area was identified as an Aol by participatory mapping because of dugong, bumphead distribution, good coral reef cover and condition, and important traditional area as Mekah Island is sacred area for Faudu Village People. Marxan identified it as a priority area for coastal habitat (e.g., coral reef and seagrass), walking shark, turtle nesting beach, dive sites, and shipwreck. The area also has shark distribution and appears to have no threats.	Propose the Aol as an MPA.
	12	Woda Island and Oba	The area was identified as an Aol by participatory mapping because of pristine mangrove habitat (uninhabited island), seagrass, leatherback turtle nesting beach, far from settlement, high tourism potency and areas to catch life bait for huhate fisheries. Marxan identified it as a priority area for coastal habitat (e.g., coral reef, mangrove), and turtle nesting beach. There is a plan from the local government to develop as turtle tourism and floating cages aquaculture.	Merge the Aols identified in the participatory mapping since they are close. Propose the Aol as a new MPA.
	13	North of Gilalang Island	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef, seagrass and mangrove) and shipwrecks.	Propose the Aol as a new MPA.
	14	Kasiruta Bacan	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef, seagrass, and mangrove) and spags for snapper.	Propose the Aol as a new MPA.
	15	Sayafi and Patani	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef, seagrass and mangrove), deep water habitat (e.g., canyon), turtle nesting beach, walking shark, and important traditional area. This area also has turtle and tuna migratory corridor, giant clam and manta ray distribution.	Expand the proposed Sayafi and Patani MPA
	16	West Taliabu	The area was identified as an Aol by participatory mapping for good coral reef cover and condition, giant clam, white sandy beach, and high tourism potency. Marxan identified the west coast area as a priority area for the coastal habitats (e.g., coral reef and mangrove), and canyon. This area also has giant clam	Propose the Aol as a new MPA.

Province	No	Name	Rationale	Recommendations
			distribution, dugong and tuna migratory corridor. The Aol was not extended to the south to avoid ports.	
	17	South Taliabu	The area was identified as an Aol by participatory mapping for pristine mangrove, lagoon, crocodile and high tourism potency. Marxan identified it as a priority area for the coastal habitats (e.g., coral reef and mangrove) and three shipwrecks. The Aol was not extended to the west and east to avoid mining and ports, respectively. Note: need to groundtruth the lagoon	Propose the Aol as a new MPA.
	18	North Taliabu	The area was identified as a priority area by Marxan for coastal habitats. This area was considered to sustain the connectivity. There has been blast fishing in the area. Note: need to check if the blast fishing is still happening	Propose the Aol as a new MPA.
Maluku	19	East Buru Seamount	The area was identified as an Aol by participatory mapping for Important Marine Mammals Area. Marxan identified it as a priority area for the deep-water habitat (e.g., seamounts). Unlike the surrounding seamounts, one of them was not on the ALKI (international shipping lane). The area appears to have low fishing pressure and cetacean migratory corridor.	Propose the Aol as a new MPA.
	20	Lucipara	The area was identified as a priority area by Marxan for deep water habitat (e.g., seamount), coral reef and turtle nesting beach. This area also has cetacean migratory corridor, tuna distribution, and seabird nesting ground.	Expand the proposed Lucipara MPA.
	21	Manuk island	The area was identified as an Aol by participatory mapping because of good coral reef condition, hammerhead shark, seabird nesting ground, Marine IBAs, tuna breeding and feeding ground, and mystical island. Marxan identified it as a priority area for deep-water habitats (e.g., seamount and canyon). This area also has cetacean migratory corridor.	Propose the Aol as a new MPA.
	22	Aru Island	The area was identified as an Aol by participatory mapping because of spags, dugong, good coral reef condition, lobster, turtle and cetacean migratory corridor, sasi, dive site and pearl farm. Marxan identified it as a priority area for deep water habitats (e.g., canyon), coral, mangrove and turtle nesting beach. The area appears to have dugong and high fishing pressure.	Expand the existing Aru Island MPA.
	23	Selaru Island	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef, mangrove, and seagrass), turtle nesting beach, and important traditional area. This area also has turtle and cetacean migratory corridor. The Aol was not extended further north and northeast to avoid underwater cable and port, respectively. The area appears to have relatively low shipping activities.	Propose the Aol as a new MPA.

Province	No	Name	Rationale	Recommendations
	24	Damar and Romang Islands	The area was identified as a priority area by Marxan for deep water habitats (e.g., seamount and canyon), coastal habitats (e.g., mangrove, seagrass and coral reef), turtle nesting beach, and local wisdom. This area also has turtle feeding ground, cetacean migratory corridor and already includes two proposed MPAs. The area appears to have high fishing pressure in certain months.	Merge and expand the proposed MPAs
	25	West Wetar	The area was identified as an Aol by participatory mapping because of spags, turtle nesting beach, dolphin distribution and high reef fish biomass. Marxan identified it as a priority area for the coastal habitat (e.g., coral reef, seagrass and mangrove), deep water habitats (e.g., seamount and canyon), turtle nesting beach and spag. This area also has turtle feeding ground, dugong and whale distribution. The area was extended while avoiding shipping activities.	Propose the Aol as a new MPA.
Central Sulawesi	26	Southwest Tomini Bay	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef and seagrass) and coelacanth. This area also has dolphin, eel, and turtle migratory corridor. The area appears to have low fishing pressure.	Expand the proposed Southwest Tomini Bay MPA.
	27	Parigi	The area was identified as a priority area by Marxan for coastal habitat (e.g., coral reef and mangrove), and dive sites. This area also has turtle migratory corridor. The area was extended to the south while avoiding the pond.	Propose the Aol as a new MPA.
	28	Northwest Tomini Bay	The area was identified as a priority area by Marxan for coastal habitat (e.g., coral reef and mangrove).	Expand the proposed Parigi Moutong MPA.
	29	Buol	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef and mangrove), turtle nesting beach, and canyon. This area also has dugong, dolphin, whale, turtle and whaleshark migratory corridor.	Expand the proposed Buol Marine Nature Reserve.
	30	Tombu Bay	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef and mangrove), deep water habitat (e.g., canyon), turtle nesting beach, and dive sites. The area was extended while avoiding shipping lane on the west. The area has also dugong and dolphin migratory corridor and appears to have low fishing activities.	Expand the proposed Balaesang Tanjung-Donggala Wildlife Reserve.
Gorontalo	31	Botubarani	The area was identified as a priority area by the stakeholders in Gorontalo Province (DKP Province and Local Universities) for whaleshark aggregation area and whaleshark tourism and the boundary draw with avoiding port on the north side. This area also has coral reef, turtle nesting beach, dive site, shipwreck and whaleshark migratory corridor.	Propose the Aol as a new MPA.
	32	Dulanga Maruangi Mabasari	The area was identified as a priority area by Marxan for coastal habitat (e.g., coral reef, seagrass, and mangrove). This area also has whale, dolphin and turtle migratory corridor.	Merge 3 MPAs (Dulanga, Maruangi Mabasari, and Mabasari Maruangi) and expand to cover this AOI.
	33	Lowoo Malangoso	The area was identified as a priority area by Marxan for coastal habitat (e.g., coral reef and mangrove).	Propose the Aol as a new MPA.

Province	No	Name	Rationale	Recommendations
	34	Mandoli	The area was identified as a priority area by Marxan for coastal habitat (e.g., coral reef, seagrass and mangrove). This area also uses as whale and dolphin migratory corridor.	Expand the proposed Monduli Coastal and Small Island Conservation Area
	35	Papaya	The area was identified as a priority area by Marxan for coastal habitat (e.g., coral reef and mangrove), turtle nesting beach and shipwreck. This area also has whaleshark distribution.	Merge 3 MPAs (Popaya Island Maritime Conservation Area, Popaya MPA, and Mas Popaya Raja Nature Reserve) and expand to cover this AOI.
North Sulawesi	36	Lito Bongkil	The area was identified as a priority area by Marxan for coastal habitat (e.g., coral reef). This area also has whale shark distribution.	Propose the Aol as a new MPA.
	37	Motandoi	The area was identified as a priority area by Marxan for coastal habitat (e.g., coral reef and mangrove).	Expand the proposed South Tobayagan MPA
	38	Popaya Cape	The area was identified as a priority area by Marxan for coastal habitat (e.g., coral reef and mangrove). It's also has whale shark distribution. The area appears to have low shipping activities and fisheries pressure.	Merge and expand the proposed Bentenan Satu and Tumbak Madani MPA with this AOI
	39	Minahasa	The area was identified as a priority area by Marxan for coastal habitat (e.g., coral reef) and seven turtle nesting beaches. The area extended to the south and north while avoiding port and underwater cable, respectively. The area also avoids shipping lane located further offshore.	Expand the existing Minahasa MPA
	40	North Minahasa	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef and mangrove).	Expand proposed South Minahasa MPA.
	41	Luok Batu Merah	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef and mangrove). It's also has whale shark distribution.	Expand the proposed Lolanan MPA.
	42	Haji Cape	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef including the offshore submerged coral reef and mangrove). The area also has whale shark distribution and appears to have low shipping activities.	Expand the proposed Tote MPA.
	43	Dudepo	The area was identified as a priority area by Marxan for coastal habitats (e.g., coral reef and mangrove) and deep sea habitats (e.g., canyon).	Propose the Aol as a new MPA.
	44	Seamount West Sangihe	The area was identified as a priority area by Marxan for deep water habitat (e.g., seamount) while avoiding shipping lane. The area appears to have low fishing activities.	Propose the Aol as a new MPA.

Annex 5. Details of Assessment of Marine Protected Area Network Design for Fisheries Management Area 715 and the Six Associated Provinces Using Evaluation Tool.

We used the *Evaluation Tool for Marine Protected Area and Marine Protected Area Network Design in Indonesia* (see Green et al. 2019 b, c) to evaluate the MPA network design for FMA715 and the six associated provinces (Figure 25). The following tables provide a summary of the results of evaluating the design for both biophysical (Table 13) and socioeconomic and cultural criteria (Table 14).

Please note that some of the design criteria are spatial (i.e., they relate to identifying areas to include or exclude in the MPA network design), and should be addressed in the scientific design process. These are given a score from 0 to 3 using the evaluation tool, where 0 is not yet applied, 1 is partially applied, 2 is mostly applied and 3 is fully applied. Others provide general advice regarding how to work with stakeholders, which should be addressed in other steps in the MPA network management process (these are given an evaluation score of NA or not applicable in the scientific design process: see Table 14).

We used the scoring system to develop an overall evaluation score for the MPA network design, by adding up the scores for each design criteria and calculating the percentage (%) of the total maximum score achieved for the design criteria that apply to the MPA network. All design criteria were considered of equal importance in the overall evaluation score to avoid subjective decisions about the relative importance of the design criteria, which will vary in different MPAs that have different goals and objectives).

The results show that the MPA network for FMA715 and six associated provinces (Figure 25) is relatively well designed to address the biophysical and socioeconomic design criteria, with an overall score of 75.7% (72.2% and 81.5% for biophysical and socioeconomic and cultural considerations respectively).

Table 13. Evaluation of the MPA network design for FMA715 and six associated provinces: biophysical design criteria.

Consideration	Biophysical Design Criteria	Score	Rationale
<i>Represent Habitats</i>	<i>Protect at least 20% of each major habitat in NTZs (e.g., each type of coral reef, mangrove forest, estuary or seagrass bed).</i>	2	We identified, mapped, and classified habitats by ecoregions and provinces. We exceeded our targets for protecting 30% of shallow water habitats in the MPA network, with 56% of coral reefs, 49% of mangroves and 42% of seagrasses included in the MPA Network design (see <i>Considering Large Scale Patterns of Connectivity and Conservation Priorities Posthoc Analysis Using Marxan</i>). However further work is required to classify each of these habitats so we can use this to apply this principle (i.e., to protect each type of coral reef community). We were also unable to achieve our targets for protecting deepwater habitats, because they often occur in areas allocated for other uses.

Consideration	Biophysical Design Criteria	Score	Rationale
Replicate Habitats (Spread the Risk)	Protect at least three examples of each major habitat in NTZs; and Spread them out to reduce the chances they will all be affected by the same disturbance (such as major storms, mass coral bleaching events and crown-of-thorns starfish outbreaks).	3	Where possible, the MPA network is designed to protect at least three examples of each major habitat in each existing and proposed MPAs and Areas of Interest, spread out to reduce the chances of being affected by the same disturbance.
Protect Critical, Special and Unique Areas	Protect critical areas in the life history of focal fisheries species in NTZs (e.g., spawning and nursery areas).	2	The MPA network is designed to protect fish spawning aggregation as far as possible, increasing the protection of these areas from 35% in existing and proposed MPAs to 48% in the MPA network (see <i>Considering Large Scale Patterns of Connectivity and Conservation Priorities Posthoc Analysis Using Marxan</i>). However, we were unable to achieve our target of 80% protection of spags, because many occur in areas allocated for other uses. We also exceeded our target of 30% protection of nursery habitats, with 49% of mangroves and 42% of seagrasses included in the MPA network design.
	Protect critical areas or habitats for charismatic, endangered, threatened or protected species (e.g., breeding, feeding or resting areas, or migratory corridors).	2	We increased the level of protection of these habitats in the MPA network design as far as possible (given the need to consider other uses: (see <i>Considering Large Scale Patterns of Connectivity and Conservation Priorities Posthoc Analysis Using Marxan</i>). The MPA network is designed to: <ul style="list-style-type: none"> • Increase the protection of turtle nesting beaches from 36% in existing and proposed MPAs to 59% in the MPA network. Although this is still less than the 80% target we set for this feature. • Protect turtle feeding grounds (100% of known feeding grounds are already protected in existing and proposed MPAs), dolphin resting areas, and migratory corridors for turtles, dolphins, whales, dugong and whale sharks.
	Protect special and unique natural phenomena in NTZs [e.g., areas with very high biodiversity, high endemism, unique marine communities or high productivity (e.g., unique pelagic habitats i.e., upwelling, fronts, eddies)].	0	Information or spatial data are not available regarding special and unique natural phenomena throughout the planning area. This is a research priority for refining the MPA network design in future.
	Protect areas that are important at the national, international or global scale for conservation or management of focal species (e.g., World Heritage Areas, critical habitats for globally endangered species, or	2	The MPA network is designed to protect globally endangered species e.g., by protecting: the leatherback turtle nesting beach in Kei Kecil MPA; and the olive ridley turtle nesting beach in Jeen Womom MPA. The MPA network also protects seamounts and canyons, which area important habitat for Pygmy blue whale migrating from West Australia to the Banda Sea. This MPA network

Consideration	Biophysical Design Criteria	Score	Rationale
	<i>critical areas for maintaining connectivity of fisheries species across national boundaries).</i>		design increases the protection of seamounts and canyons from 1% to 31% and 4% to 8%, respectively (see <i>Considering Large Scale Patterns of Connectivity and Conservation Priorities Posthoc Analysis Using Marxan</i>). However, we could not achieve our targets of 80% protection for seamounts and 30% canyons, because they were often located in areas allocated for other uses (e.g., military area, oil and gas mining, international shipping lane) or where there is high fishing pressure and high-density shipping lanes. We recommend increasing protection for seamounts, canyons, and other deep-water habitats by integrating MPAs with other management tools. The MPA network also protects critical areas (e.g., spags for coral reef fishes: see above) for maintaining connectivity of fisheries species across national boundaries). Although this approach should be validated and refined based on connectivity studies of focal species (particularly regarding larval dispersal).
<i>Incorporate Connectivity: Abiotic Factors</i>	<i>Consider variations in oceanography (i.e., currents, tides, temperature, salinity and acidity), substrate and, bathymetry that affect the spread of biological and non-biological material.</i>	2	The MPA network considers variations in oceanography in broad terms e.g., regarding the likely influence of the Indonesia Through Flow (Arlindo) and Indonesia Monsoon Flow (Armondo) on larvae dispersal among existing and proposed MPAs and Areas of Interest. We also used the results of a larval dispersal model for coral trout and sea cucumber to manually refine Areas of Interest (Beger et al. unpubl. data). This approach should be validated and refined based on more studies of abiotic factors and larval connectivity.
<i>Incorporate Connectivity: Movement of Adults and Juveniles</i>	<i>Ensure NTZs are large enough to sustain adults and juveniles of focal fisheries species within their boundaries.</i>	3	The MPA network comprises existing and proposed MPAs and Areas of Interest of various sizes. Most are large enough to sustain adults and juveniles of many focal fisheries species (e.g., coral reef fishes: see Green et al. 2019a). To ensure that MPAs are large enough to accommodate movement patterns of focal species, we ensured that Areas of Interest are large enough and recommended increasing the size of small existing and proposed MPAs.
	<i>Ensure NTZs are large enough to contain all habitats used by focal species throughout their life history (e.g., for home ranges, nursery grounds and spawning areas); or Establish networks of NTZs close enough to allow for movements of focal species among protected habitats (e.g., through ontogenetic habitat shifts and spawning migrations).</i>	3	Where possible, the MPA network is designed to ensure that all major habitats used by focal species throughout their life histories (e.g., coral reefs mangroves and seagrasses) are protected either in individual MPAs or MPA networks.
	<i>Include whole ecological units (such as reefs or seamounts) in NTZs. If not, chose larger versus smaller areas.</i>	3	The MPA network is designed to include whole ecological units in MPAs (e.g., for coral reef, mangrove, seagrass, seamount, and canyons). Where this is not possible, we designed larger vs smaller MPAs (see above).

Consideration	Biophysical Design Criteria	Score	Rationale
	<i>Use compact shapes (such as squares) for NTZs, except when protecting naturally elongated habitats.</i>	3	All Areas of Interest are compact shapes.
<i>Incorporate Connectivity: Larval Dispersal</i>	<i>Establish:</i> <ul style="list-style-type: none"> • <i>NTZs large enough to be self-sustaining for focal species; or</i> • <i>Networks of NTZs close enough to be connected by larval dispersal.</i> 	2	Most of the existing and proposed MPAs and Areas of Interest in the MPA network design are either large enough to be self-sustaining or close enough to be connected by larval dispersal (see Figure 37). However, some are separated by hundreds of km where there are no important shallow or deep-water habitats between them, or where areas are allocated for other uses where MPAs cannot be established (e.g., military areas or oil and gas mining areas). This requires validation by modelling and mapping larval dispersal of focal species.
	<i>Protect spatially isolated areas in NTZs.</i>	3	The MPA network is currently designed to protect spatially isolated areas, such as Lucipara Islands and Manuk Island in the Banda Sea.
	<i>Protect larval sources in permanent or seasonal NTZs or by using fisheries closures during spawning times.</i>	2	MPA network is reasonably well designed to protect spags (see above).
	<i>Locate more NTZs upstream relative to fished areas if there is a strong, consistent, unidirectional current.</i>	2	The MPA network is designed to consider the influence of large scale currents on larval dispersal i.e., the Indonesia Through Flow (Arlindo) and the seasonal pattern of the Indonesia Monsoon Flow (Armondo). More studies of larval dispersal of focal species are required to refine and validate this approach.
<i>Allow Time for Recovery</i>	<i>Establish NTZs for the long term (>20 to 40 years), preferably permanently.</i>	3	Most of the MPA network is designed for permanent MPAs, since MPAs are permanent once they are established in Indonesia.
	<i>Use short term (<5 years) or periodically harvested NTZs in addition to, rather than instead of, long-term or permanent NTZs</i>	2	Where possible, the MPA network is designed to protect local wisdom areas (e.g., sasi) that can be periodically harvested, increasing protection of these areas from 28% in existing and proposed MPAs to 32% in the MPA network. However, we could not achieve our target of including all of these areas in the MPA network design, because many are in areas allocated for other uses (e.g., for underwater cables, military areas, and oil and gas mining areas).
<i>Protect Healthy Areas and Avoid Local Threats</i>	<i>Protect areas where habitats and populations of focal species are in good condition with low levels of local threats (e.g., from overfishing, destructive fishing, coastal development, mass tourism, land-based runoff of sediments and nutrients, marine pollution, shipping, mining, oil and gas industries).</i>	3	The MPA network is designed to establish new or expanded MPAs where there are low levels of threats (e.g., gold mining, nickel mining, and hot water from power plants). This approach could be refined with more spatial data regarding the condition of major habitats and populations of focal species.
	<i>Avoid areas where habitats and populations of focal species are in poor condition due to local threats. If this is not possible:</i>	3	The MPA network is designed to establish new or expanded MPAs where there are low levels of threats (e.g., gold mining, nickel mining, and hot water from power plants).

Consideration	Biophysical Design Criteria	Score	Rationale
	<ul style="list-style-type: none"> •Reduce threats; •Facilitate natural recovery (e.g., by protecting larval sources and species that play important functional roles in ecosystem resilience i.e., herbivores); and •Consider the costs and benefits of rehabilitating habitats and species (e.g., by restoring structures, transplanting corals, or facilitating population recovery of focal species by re-stocking or using temporary closures). 		The MPA network is integrated with other management approaches to reduce threats, by integrating the MPA network within existing Marine Spatial Plans for each province and FMA715.
Adapt to Changes in Climate and Ocean Chemistry	Protect sites that are likely to be more resilient or resistant to global environmental change (refugia) in NTZs.	0	We did not have spatial data required to apply this design criteria. This is a research priority for improving the MPA network design in future.
	Protect ecologically important sites that are sensitive to changes in climate and ocean chemistry.	0	We did not have spatial data required to apply this design criteria. This is a research priority for improving the MPA network design in future.
	Increase protection of species that play important functional roles in ecosystem resilience (i.e., herbivores).	2	Information or spatial data are unavailable regarding the distribution and abundance of species that play important functional roles in ecosystem resilience throughout the planning area. However, we have increased the protection of some species (i.e., herbivorous reef fishes), by increasing the % of their habitat protected in the MPA Network.
	Consider how climate and ocean change will affect the life history of focal species.	0	We did not have spatial data required to apply this design criteria. This is a research priority for improving the MPA network design in future.
	Address uncertainty by: Spreading the risk (see above); and Increasing protection of habitats, critical areas and species most vulnerable to changes in climate and ocean chemistry.	3	We have addressed uncertainty in the MPA network design by: <ul style="list-style-type: none"> •Applying the design criteria to <i>Replicate Habitats (Spread the Risk)</i> (see above). •Adding a climate change buffer to habitat protection i.e., by protecting more than the 30% target for protection of coral reefs, mangroves and seagrass habitats (see <i>Habitat Representation</i> above).

Table 14. Evaluation of the MPA network design for FMA715 and six associated provinces: socioeconomic and cultural design criteria.

Consideration	SEC Design Criteria	Score	Rationale
<i>Involve stakeholders in establishing MPAs and MPA Networks.</i> (MPA establishment includes developing zoning and management plans.)	<i>Involve all stakeholders in each step of the process of establishing MPAs and MPA Networks.</i>	2	This evaluation only relates to the scientific design process. To do this, we consulted with representatives of government (national, provincial and district), universities and NGOs working throughout the planning area. AOIs still need to be discussed with local stakeholders.
	<i>Prioritize establishing MPAs in areas supported by stakeholders</i>	2	Spatial data layers were not available regarding areas supported by stakeholders for MPAs, so they could not be included in the analysis. However, this issue was considered when AOIs were identified using participatory mapping in the provinces. AOIs still need to be discussed with local stakeholders.
	<i>Consider opportunities for collaborative management among all stakeholders and implement as appropriate.</i>	NA	Not applicable to the scientific design process. This will need to be discussed at a later stage in the management process.
	<i>Provide capacity building for stakeholders to help them engage more effectively in establishing MPAs and MPAs networks.</i>	NA	Not applicable to the scientific design process. This will need to be discussed at a later stage in the management process.
<i>Ensure Stakeholder Compliance within MPAs.</i>	<i>Involve local community in compliance and enforcement [e.g., by joint patrols among government institutions and communities, and Pokmaswas (community surveillance groups)].</i>	NA	Not applicable to the scientific design process. This will need to be discussed at a later stage in the management process.
	<i>Support MPA management actions that maintain or increase ecosystem goods and services for local communities.</i>	NA	Not applicable to the scientific design process. This will need to be discussed at a later stage in the management process.
<i>Support multiple, environmentally-friendly uses in MPAs.</i>	<i>Allow for multiple environmentally-friendly uses in MPAs (including sustainable fishing, tourism, aquaculture, education and research).</i>	3	Where possible, the MPA Network is designed to support multiple environmentally-friendly uses in MPAs. For example: <ul style="list-style-type: none"> • Protecting tourism areas in MPAs (e.g., dive sites, wrecks); and • Avoiding placing MPAs in important areas for fishing or aquaculture.
<i>Support community welfare (livelihoods and food supplies).</i>	<i>Support environmentally-friendly livelihoods of local communities [i.e., community-based, environmentally-friendly fisheries, aquaculture and marine resource based tourism based on an areas' uniqueness (biotic and abiotic resources).]</i>	3	Same as above for <i>Support multiple, environmentally-friendly uses in MPAs.</i>
	<i>Protect marine heritage sites (i.e., shipwrecks and airplane wrecks) that have important, archeological-historical value,</i>	2	The MPA network is currently designed to protect 45% of wrecks in MPAs, which is an increase from the 27% currently in existing and proposed MPAs. The target for protection was 80%, but this could not be achieved due to conflicting use of areas (i.e., by high density shipping lanes and ports).

Consideration	SEC Design Criteria	Score	Rationale
	<i>and manage them for their potential to support community based tourism.</i>		
<i>Ensure fair and equal access and use.</i>	<i>Ensure local communities have fair and equal access to, and utilization of, marine and fisheries resources.</i>	3	The MPA Network was designed to ensure communities in each province maintain access to fishing grounds as much as possible. When the MPAs are zoned, it will be important to consider this at a finer scale (i.e., each community can maintain access to the fishing grounds they use).
	<i>Maintain or improve access to resources and markets to support community economies that comply with MPA management plans.</i>	3	Where possible the MPA network is designed to: <ul style="list-style-type: none"> • Maintain access to fishing grounds (by avoiding placing MPAs in important fishing areas). • Avoid placing MPAs in areas that would limit access to markets (i.e., in shipping lanes or transportation and fishing ports).
<i>Support local wisdom and practices.</i>	<i>Protect adat, local wisdom, traditional law, and culture that support conservation and sustainable resource management, which are still acknowledged and applied by the existing adat community or institution.</i>	2	The MPA network is currently designed to protect 32% of local wisdom areas in MPAs, which is an increase from the 28% currently in existing and proposed MPAs. The target for protection was 100%, but this could not be achieved due to conflicting use of areas (i.e., underwater cable, military area, oil and gas).
	<i>Protect areas that have important traditional cultural value for local people/adat [including mystical (pamali) areas, and important sites for traditional medicine].</i>	2	The MPA network is currently designed to protect 52% of important traditional areas in MPAs, which is an increase from the 36% currently in existing and proposed MPAs. The target for protection was 80%, but this could not be achieved due to conflicting use of areas (i.e., military areas and underwater cables).